

CRITERION C: CREATING THE SOLUTION

C1(Making Plans): Construct a logical plan, which describes the efficient use of time and resources, sufficient for peers to be able to follow to create the solution

Flowchart depicting the overview of the Production Plan:



Production Plan - Gantt Chart:

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and 5. In the same order place the wires in “int1”, “int2”, “int3” and “int4” of the motor driver. To supply power to the motor driver, take a 5v pin from the esp expansion board and attach it to the 5v slot in the motor driver. Then take a ground pin from the esp and attach it to the ground slot in the motor driver. To provide additional power to the motor driver take an external 5v battery pack. Attach the positive charge of the battery pack to the second 5v slot in the motor driver and connect the negative wire from the battery pack to the ground slot in the motor driver where there is already one negatively charged wire present. To connect the ultrasound to the circuit take 4 female to female wires. Connect the wires to the D22, D21, VCC and Gnd pins on the esp and Trig, Echo, VCC and Gnd pins in the ultrasound sensor respectively. Lastly connect the SCL, SDA, VCC and Gnd pins of the gyro sensor to the D12, D13, 3.3v and Gnd in the esp respectively.										
Subtask 3.2: Verify the code and check for bugs Take the code already made in tinkercad and using a USB B to USB C cable upload the code in the esp. Make sure the battery pack is turned off at that time as turning the battery pack while uploading the code from a laptop may harm the battery of the laptop. Then using Arduino IDE upload the code to the esp. Make sure the library esp32 by espressif systems is downloaded and the esp32 dev model is selected in the board manager while a cable which only appears when the esp32 is plugged in into the laptop is selected. Then press command + u to upload the code. Unplug the laptop, connect the esp to the battery pack and see if the code is working. If not, recheck the circuit and code to fix and error. Note: If any smoke starts coming out of any part disconnect the power source instantly and dispose of the part. This happens with the battery. Try breaking the battery with your feet and dispose of it with toxic waste. If batteries short circuit they can explode causing catastrophic damage.										
Task 4: Make the component box and chassis										
Subtask 4.1 3d print all MDF for parts the sides should be 3.5 cm in length and 2 cm in width and make 3d print the chassis Use tinkercad to model 6 separate parts for the MDF box which will hold all components in it. Their top and bottom bases will be 3.5 cm in length and 2 cm in width. Two of the side walls will be 3.5cm in length and 1.5cm in length and the other 2 side walls will be 2cm in length and 1.5cm in width. These parts will be made as separate pieces in tinkercad and then attached together later. The chassis will also be made in tinkercad. The chassis will be a one piece build which will be the base of all components and sensors. The chassis will have a total length of 32cm and a width of 16cm. The chassis will have an arc in the front and back and no part will have a corner to ensure the safety of tourists on the beach. In the center of the chassis there will be a 2cm square which will pop out. This will separate the front and back tires. The depth of the mdf used in the chassis will be 3mm as the chassis has to be lightweight and portable.										
Subtask 4.2 Assemble all the parts together using a hot glue gun Using a hot glue gun attach the component box made in the above step. Turn on the hot glue gun and start gluing the base of the box. First glue all side walls to the base. Don’t attach the top wall to the box yet and the components have yet to be placed in them. Ensure no glue is left inside the box as that may take up space and the hot glue may also damage fragile components inside the box. Note: While using the hot glue gun always keep a scrap paper below the working space and if the glue falls it may damage the unprotected surface. Also don’t touch the hot glue as it can easily burn through skin.										
Task 5: Fit the electronics in the chassis										

Subtask 5.1
Fit the circuit made in task 3 into the compartment made in task 4

Take the esp32 along with the gyro sensor and place it inside the box. The fitting should be perfect as the box is designed perfectly for those dimensions. After the needed components are placed inside the box using the hot glue gun, glue the top surface of the box enclosing and securing the circuit. After this is done place the ultrasound sensor on top of the second chassis giving it the perfect view to detect obstacles. Place the battery next to the component box as well. Also add the motor driver next to the battery. Adding all components next to each other is crucial as the jumper wires aren't large enough to cover the whole chassis. Make sure all wires are fitted inside the chassis, no wires should be loose or be popping out from the side of the chassis. If this is the case the wires may get stuck in the tires, someone may trip over them, they may get damaged due to harsh weather, etc.

Subtask 5.3
See if the wiring of the product is still good and make sure it is aesthetically pleasing

Power the esp32 and ensure the robot works as it is supposed to. Check for these specific things.

All 4 motors are operating at the same speed. All sensors are working and the motors are able to respond to them on time.

Many times while putting the circuit some wires tend to get loose disrupting the whole flow of the circuit. Sometimes some sensors also aren't secured properly and may fall when the robot starts. Make sure while the chassis is moving no wire is coming out and running the aesthetic look of the chassis. Also make sure no parts move when the robot moves. If this happens when the whole robot has been assembled it becomes extremely difficult to fix this problem as the whole chassis will need to be disassembled.

Task 6: Make the front trash collector

Subtask 6.1

Cut the metal into the required shapes and sizes.

The side wall should be 10cm by 15cm, the back wall should be 7 cm by 10cm and the stainer should be 15cm by 10cm. Use metal thin metal sheets for the side and back walls. Cut these walls with a snip. The metal sheets will only be 2 mm and due to their thinness snips will be the best tool of choice. There should be one back wall cut and 2 side walls cut. The side walls should be a mirror image of each other. To make the metal strainer which will collect the trash use thin metal strainers. These metal strainers will have small holes in them to allow trash to exit but keep the sand in. These metal strainers will only be 1.5mm and can be cut by scissors.

Note: Be careful while cutting metal as it has sharp edges and can cut through skin easily.

Subtask 6.2

Stick the metal grid and the metal pieces together.

Using a hot glue gun assemble the trash picking up mechanism. To start, glue the side walls to the back wall. One by one attach the sides wall to the back wall to make them one entity. After this is done attach the metal strainer to the side and back walls. If the strainer is too big, cut off the edges and fit it perfectly. Then glue the metal strainer to the metal sheets to complete the trash picking up mechanism. Let the glue dry for 5 minutes. After this test the durability of the strainer by adding weight to all walls, especially the metal strainer and testing its durability.

Subtask 6.3

Stick the product made in 7.3 to the chassis robot

After the trash pick up mechanism is made using the hot glue gun attach the trash

picking up mechanism to the chassis. To do this place 2 cm of the trash picking up mechanism on top of the chassis and use a pencil and scale measure to make a rough measurement of the area the trash picking up mechanism will require. Apply hot glue to the marked area and place the trash picking up mechanism. While the glue is drying press the trash picking up mechanism into the chassis to secure the connection. After a few minutes gently pull off the trash picking up mechanism to test the durability of the connection.										
Task 7: Make the back roller										
Subtask 7.1 Cut the PVC pipe and metal pipes to their needed requirement Using a hacksaw cut the PVC pipe to 15cm. This is slightly less than the width of the chassis and this length allows the device to be able to flatten a decent amount of sand, however not create a weight imbalance. The diameter of the PVC pipe should be 10mm. Having a diameter this big will help later in the assembly process. After this is done, two metal pipes can cut both of them to 100 mm each. The metal pipes should be cut identical to each other. Use a snip to cut the metal pipes. Each metal pipe should be 5mm in diameter. It is important that the metal pipes are durable, however they aren't too heavy.										
Subtask 7.2 Assembling the roller and attaching it to the chassis. To assemble the back roller take two small rubber tyres with each having a diameter of 10mm and place them inside the PVC pipe. The rubber tyres should fit perfectly due to the matching diameters and no glue should be required, however if the tyres are slightly small use a hot glue gun to fill the gap and glue the tyres. After this is done using a hot glue gun attaching both metal pipes to the rubber tires placed on both sides. Place the metal pipes in the center axel of the tire, this will allow the tyre and roller to rotate even though they are glued to the metal pipes. After this is done using the hot glue gun attach both metal pipes to the chassis. Attach the left metal pipe to the left part of the chassis and right metal pipe to the right side of the chassis.										

C2 (Demonstrating Technical Skills): Demonstrate excellent technical skills when making the solution...

Excellent Technical Skills - No challenges faced

Design Aspect	Justification
Chassis Assembly 	The development of the exterior body of the automated vehicle suits the needs of the identified problem. The interiors of the vehicle have excellent utilization of space considering the mounting of sensors, actuators and wiring. The circuit is organized in a way that can be easily disassembled (for any future updates). The circuit remains intact when the vehicle is in motion. Safety of the circuit is considered by preparing an additional shield. All parts of the external body are stable providing great stability. The outer body is also able to fit and protect all sensors. We were able to assemble the outer body in the span of only 30 minutes and faced no difficulties while doing the same. We took 15 minutes to mount all 4 motors along with the wheels. An additional 15 minutes was taken to attach the top part of the chassis to the bottom part. After assembly of the body difficulty was faced for the rest of the duration while making the circuit and product.
Movement of wheel 	Securing the wheels to the motors was a basic and easy task which I was able to do easily. It took 2 minutes for my partner and I to secure all 4 wheels to the motors. After this step was done the wheels stayed secure to the motor for the period of the project and worked without any hiccups.
Aesthetics 	Painting the upper chassis was a basic task which my partner and I were able to do easily in the span of 15 minutes. To paint the chassis I used yellow spray paint. Keeping newspaper below the chassis I applied two layers of paint on the chassis. The first layer of the paint took 1 minute to apply. After which I waited for 13 minutes for the paint to dry. After this was done a second layer of paint was applied completing the coloring. After the chassis was colored no paint came off and never gave us any problems making it a very easy task.

Understanding the working of sensors:



As I have already done a course of the basic working of sensors such as ultrasound and ldr I was easily able to understand how the sensors work, the basics on how to connect them, when and where to use them. In the first class where we made the ultrasound sensor with a green and red light my group and I were easily able to make the circuit and I was able to finish the code of the circuit in under 15 minutes.

Intermediate level of Technical Skills – Some challenges faced

Design Aspect	Justification
Tinkercad model 	In our original design we were supposed to use an esp32 along with a expansion board which is connected to a H-bridge motor driver which is directly connected to 4 dc motors. The esp32 was also supposed to be connected to a gyro and ultrasound sensor, however tinkercad didn't have all these components. In tinkercad esp32 along with the h-bridge motor driver and gyro sensor were not available. This posed a challenge I didn't see coming. To improvise I had to use an arduino uno which was connected to a breadboard which then connected all 4 dc motors to the arduino. As tinkercad didn't have a gyro sensor as well I had to use a dummy sensor in place of gyro and code it according to a gyro sensor. This was tricky as I have never done this and if there is a problem in the circuit or code it wasn't evident due to the complex wiring needed to connect the motors and the dummy sensor. After watching some tutorial videos and spending 90 minutes I was able to figure out how to complete the circuit, however modeling the circuit on tinkercad posed a new challenge which I had never faced before and I learned something new
Coding 	Our code was made on C++ and although I already knew the language beforehand and was able to code the ultrasound light detection circuit done in the first class using a h-bridge motor driver and a gyro sensor were new challenges I had never experienced before. To use a h-bridge motor driver all different variables have to be given when compared to using a motor driver shield. Using a gyro sensor also forces the coder to use the map function which I had never done before. When mapping a gyro sensor a new set of variables and commands have to be used where the gyro sensor is able to detect any change in environment and communicate it with the esp32. Combining two new aspects in one code was challenging for me, if I got the motors to work the gyro sensor would not be able to communicate with them and if I got the gyro sensor to work it would not be able to communicate causing an infinite error loop. To break this error loop my partner and I decided to not use gyro sensors, gyro sensors weren't needed for our product to be successful and the code was getting too complicated with it. Even after not using the gyro sensor there were some errors in the code, however after 45 minutes of trying I was able to complete the revised code which was able to power the motors and control them properly.
Cad 	While designing the cad model for the component box and the chassis there were some challenges which my partner and I experienced, however with trial and error we were able to resolve these challenges. While designing the component box we were able to make the separate parts without any problem, however we faced challenges while making the chassis. The chassis we wanted needed to have many specifications such as having an arch on both sides, having a small separation between both tires and having small holes to be able to fit components such as motors. I had already made the chassis on fusion 360, however to 3D print the chassis I thought I needed to make it on tinkercad. I have little experience with tinkercad and so watched a lot of videos and tried to learn how to make a chassis there. I spent 70 minutes trying to make the chassis on tinkercad. After I wasn't able to make the circuit on tinkercad I came to know the circuit can be made on fusion 360 as well. However the chassis made in fusion 360 was joined with other components. So I had to separate the chassis from the other components, I have never done this and it was a minor challenge. After this I had to duplicate the file, however due to some technical error I wasn't able to do this and Miss Regina had to do this for me. Overall cad modeling was a minor challenge which I was able to resolve after some time of trying.

High level of Technical Skills – Aspects which were very challenging and took a lot of time

Design Aspect	Justification
Soldering 	Although I have soldered before due to a critical error, soldering was one of the most challenging parts about making the circuit. While soldering all wires have to be properly attached to both copper plates on top of the motor. However, I soldered the wires to the wrong parts of the motor. Due to this the motors weren't running no matter the power supplied to it. I spent 120 plus minutes trying to figure out why the motors weren't working before realizing there was an error in soldering. This caused me to rewire the whole circuit and edit the whole code to try to figure out the error in the motors. Even after the error was caught cutting the wires with a wire cutter and re-soldering the motors was a challenge. As there was already soldered metal on top of the wires and motors and some parts of the wires were burned from the hot soldering iron used early it became extremely difficult to re-soldering. After resoldering the motors I had to change the whole circuit and code as it originally was causing a lot of trouble and creating a new challenge. While re-soldering I had to do it alone as there was no one to help me at my house. This was also a challenge as the wires kept slipping from the motors and I almost burnt my finger with the hot soldering iron.

Making the physical circuit



While making the physical circuit a silly mistake was made which made making the circuit extremely difficult and time consuming. While connecting the esp32 to the motor driver the positive wire of the esp32 was accidentally connected to the negative wire of the motor driver and vice versa. When the esp32 was powered the esp32 along with the expansion board and motor driver got fried, however smoke only came out of the esp32. Considering this I thought only the esp32 got fried and was working with the same motor driver and expansion board. When I put a new esp32 in the expansion board the code wasn't uploading due to the fried expansion board. I spent more than 120 minutes trying to upload the code and fix the physical circuit. I rewired every pin and connected the wires to the jumper wire again to try to connect it. When I finally changed the fried expansion board with a new one and used a new motor driver the code uploaded however the circuit didn't work. This was because while putting the components in the chassis some wires had gotten loose and weren't providing power to the motor driver. I had to disassemble the whole chassis and fix the physical circuit.

Debugging the code and physical circuit:



Due to the critical mistakes I made while soldering and in the physical circuit I have to spend a lot of time debugging and finding errors in the code and circuit. As this was my first time using the h-bridge motor driver while coding, the variables were put wrong. This meant the motor wasn't working and even if it was, it was going in the wrong direction. To fix this there were some changes I needed to do in the physical circuit and in the code. This was a new challenge I have never faced and took me 120 minutes to complete. After this was done, finding the fried expansion board also took a lot of time. This was the first time I used an expansion board and I fried it. After frying, I spent a lot of time researching and trying to upload the code when I finally realized the board needed to be replaced. Providing power to the motor driver was also a challenge, unlike other motor drivers I have used, the h-bridge motor driver needed a minimum of 15v of power supply. Incorporating the physical circuit with that and coding according to that took more than 120 minutes to figure out and make. After enough power had been supplied to the motor driver the motors weren't working due to improper soldering. It took me an additional 60 minutes to figure out there was a problem with the soldering and fix it. Overall due to silly errors and the use of new components, making and coding the circuit was an extremely challenging task which needed a lot of time and thought to overcome.

C3 (Following the Plan): Follow the plan to create the solution, which functions as intended

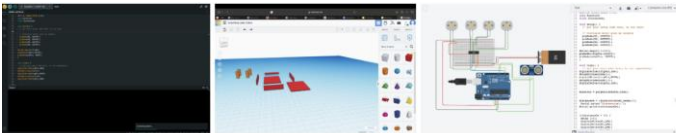
Process Logs

Date: 1/10/24

Task: Finish the tinkercad circuit and make the laser cut files

Description : Today my partner and I were able to finish the laser cut files for the compartment which will hold the sensors and also for the poles which will support the two layers of chassis and make it more stable. The tinkercad circuit which we made put us through some challenges such as the gyro sensor was not there in the database which meant that we would have to change our code also for this tinkercad model. The tinkercad circuit which we made is done but there could be some changes made which will simplify the circuit even further and it would be easier for us in the future when we are actually making the circuit.

Photos:



Challenges: In this session we faced one challenge with the tinkercad model. We made the tinkercad model right, however there was no gyro sensor in it, we had to use an arduino to connect everything and the motor driver was not there but when we sent it to get it laser cut, we realized that I put the different walls of the component way too close together which made the full thing into one big rectangle which was wrong.

Reflection: Today was a great day for us as we were able to finish all the work which we had planned for and the good part is that we got an idea of what our circuit will look like as we finished making the online circuit. This class was really important so that we can move onto the next session with an idea of what we really need to do.

Date: 3/10/24

Task: Learn how the arduino circuits are made and how the connections affect the circuit.

Description : In this task we basically learnt how the arduino circuits are made and in this class we learnt it with an ultrasonic sensor along with lights. The task was made for us to test us and see if we can manage connecting the right pins and be able to get the code to work on arduino IDE. We took a couple of tries but in the end we managed to get the circuit to work as seen in the photo's below. The light is green when nothing is near and when my hand comes near the ultrasonic sensor, the red light turns on as something is detected. We overcame the challenges by basically checking and checking our circuit again and making small tweaks every turn. This activity made me fully understand what really sensors do and how exactly they work. I understood that it is not very hard to get these sensors to work because once you understand the pins, then it becomes much easier.

Photos: 	
Challenges: There were a couple of challenges that we faced in this task which were: ➤ The pins which we connected to the sensor were wrong in the start as we messed up the connections between the GND pin and the 5V pin. ➤ The code went wrong in the middle as we messed up the digital pins which were 2,3,5 and 6.	
To do: - Make the circuit of my product - Make the code for my product	
Reflection: This day was really important for us and we were able to do a lot in this class even though we did not make our own actual product. The making of the sensor gave us a glimpse of how we need to make our circuit as well and it was fortunate for us that this class activity to get us familiar with sensors was including the ultrasound sensor which is our main sensor. Overall, this class helped us understand how our circuit should be made and exactly how it should be made as we learnt about the connections and stuff.	
Date: 7/10/24	Task: Today's task was to put all the components in the box so they are secured.
Description : Today was only a single block. The first 20 minutes of the block miss Regina was explaining to us how basic cricuts work and how we can improve them. Today was the class where we were supposed to receive our laser cut box, however due to technical difficulties, we didn't receive our box. So today we started brainstorming ideas for our final product. Using rough measurements we placed all sensors and components on the chassis to see the viability of our designs in real life. Everything seemed to fit really well and we'll start our circuit for the next class.	
Photos: 	
Challenges: There were a couple of challenges that we faced in this task which were: ➤ No MDF in school, the school had no MDF hence we had to switch to wood. Wood is not a bad material but isn't optimal. If wood gets wet it will eventually get spoiled ➤ For our cad models in B4 we had used fusion 360 where we made all measurements in mm, however to be able to 3D print our components we needed to use shaper 3d. In shaper 3d the unit of measurements was different, improper measurements held back our laser cutting ➤ No female wires and soldering iron: The school didn't have female wires which is much needed to make connections through ESP to various sensors delaying our circuit. The soldering iron was also not available, not allowing us to use our motors.	
To do: - We have to soldier our motors - Paint our Chassis - Make the circuit - Upload the code to the ESP - Remake our box - Assemble the box - Put all components and sensor in the box - Assemble the top part of the Chassis - Make the trash collecting front part - Make the sand flattening back part	
Reflection: In this class, even though we did not do any physical circuit work, we were still able to plan out our making of the circuit and plan out the placement as well. This block basically just made sure that we don't waste time in the next session by thinking what to do now because we already planned everything today.	
Date:8/10/24	Task: Make the chassis robot to connect with the motors which also have to be soldered.

Description : The main goal for today was to first solder the wires to the motor which I did as it was a dangerous task and he had some experience. All 4 of the motors were soldered because we needed to connect the wire to the motor for it to be connected to the motor driver.

While I was soldering the motors, Vedant got the lazer cut file cut for the box which will hold our sensors. After we had both we moved onto connecting the motor's to the chassis robot. Connecting the motors to the chassis was relatively easy but it still needed a lot of precision as the nuts and bolts which we used were quite small. We used the nuts and bolts which came in the chassis kit to connect all 4 motors to the chassis as seen in the photo below. We had to screw the nuts in really tight because if it is loose then it might affect the tire. It was another challenge to connect the motor to the motor driver as we had to again use the screwdriver to make space and then put the wires into the motor driver and then tighten it again. After it was all done, the motors were quite stiff and they were held in strongly which meant that we succeeded in the day's task.

Photos:



[Video of soldering](#)

Challenges:

There were a couple of challenges that we faced in this task which were:

- Soldering the motor was a challenge because it is a very dangerous item and it needed immense precision to get the perfect solder. Even a step wrong and a wrong part could have been soldered.
- We did not have enough tightening walls (the one seen on the side of the motor) for all the 4 motors which gave us quite a challenge. 2 of the motors were put perfectly but the other 2 did not have enough materials so we had to screw them in very tight so that it can get as close to the other 2 as possible.

To do:

- Paint our Chassis
- Make the circuit
- Upload the code to the ESP
- Assemble the top part of the Chassis
- Make the trash collecting front part
- Make the sand flattening back part

Reflection: In this class we were able to finish everything we wanted to so that was a big plus point. After the class, we really feel like we are at a good pace because we finished fully assembling the motors to the chassis. Apart from the couple of challenges faced, I think that we are going on a good track as we fit the motors to the motor driver as well.

Date: 10/10/24	Task: Complete the connections of the circuit
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Description : This day was probably one of the most important ones as we were finishing our connections on the circuit. The connections of the circuit is the base for any product. No matter how good the code will be, it would not work if the connections are wrong. This is why we gave this full block to work on connecting all the sensors (gyro, ultrasonic and motor driver) to the esp. We used female to male wires and female to female wires in this process. During this process my finger got slightly cut due to the sharp points on the esp. Due to this I instructed Vedant on some of the connections and he connected all the wires. We also had to solder the gyro sensor which needed a lot of focus as the gyro sensor is very small and the pins are even smaller. In the end, we both rechecked the connections several times so that we do not make a mistake like the one we made on 3rd oct with the connections.

Photos:



Challenges:

There were a couple of challenges that we faced in this task which were:

- The only challenge we faced during today's lesson was very minor and was that we had a little bit of difficulty while managing all the wires on the chassis but we were able to solve the problem easily.

To do:

- Paint our Chassis
- Upload the code to the ESP
- Assemble the top part of the Chassis
- Make the trash collecting front part
- Make the sand flattening back part

Reflection: This class really brought out the best of us because we tried our best to finish the full circuit and we were able to do that fully. This class tested us because we made a crucial change in our product today which was us switching from Arduino UNO to ESP 32 because we did not want to use a breadboard. Even though we were able to finish making the circuit, we were not able to get started on the code which was something I thought we could do but it wasn't an issue.

Date: 13/10/24	Task: Finish the code of the circuit and paint the chassis
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Description : This was an extra day on which we worked on the product at home. This extra day was needed as Vedant had to miss the whole of next week due to cricket ISSO. It was instructed to us that we could finish the product at home before he left. This was a big day as we first took the second layer of the chassis and then used yellow spray paint to paint it full yellow. We painted it once then we let it rest for a bit and then we went and painted the same layer of the chassis again so that the paint stays. After it got dried we connected the two layers using the materials in the kit which came with the chassis. Thereafter, we worked on the code for the entire circuit. The process of making the code was quite long and really tested us a lot as we had to research a lot to get through our challenges.

Photos:



[Video link of painting:](#)

Challenges:

There were a couple of challenges that we faced in this task which were:

- The code for the gyro sensor was a challenge as we both have never coded a sensor like this and we had to research a lot to find how to get the code to work
- The second challenge which we faced was on the arduino IDE application. After we made the code, we realised that because we are making this product on esp instead of arduino, we needed to add some extra code and we needed to change some settings on the application which made the ESP 32 work.

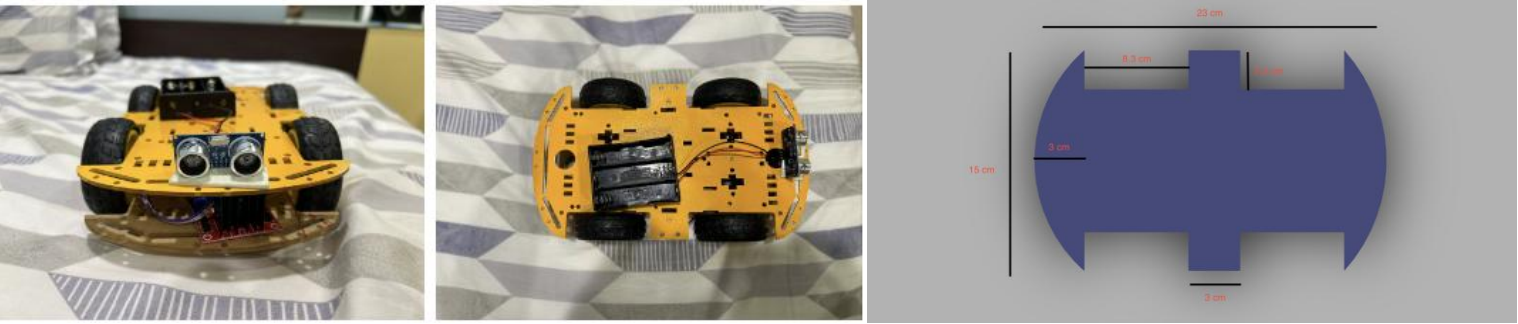
- To do:
- Make the trash collecting front part
 - Make the sand flattening back part

Reflection: This was maybe one of the most productive sessions we had in terms of work done as we worked at home for this for reasons which are already mentioned. With no one to distract us, we were able to get all the work done but still some parts of the product were yet to be finished. The challenges we faced this session were not very minor but we were able to solve them together.

Date: 15/10/24	Task: Finishing touches to the product
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Description : Today was a really important day but unfortunately Vedant was not there in this session which made things a bit harder because we get good work done when the both of us are together. There was a lot done in this class as the finishing touches were made. Due to the fact that we used a pre-made chassis, I made the cad model of the chassis which ensured that we did know how the chassis would be laser cut. This was the class where the mistakes we made were fixed like the wrong wire and stuff that like was fixed in today's class. While I was reviewing the product we realized that there were still some small mistakes which had to be fixed so that was done.

Photos:



Challenges:

There were a couple of challenges that we faced in this task which were:

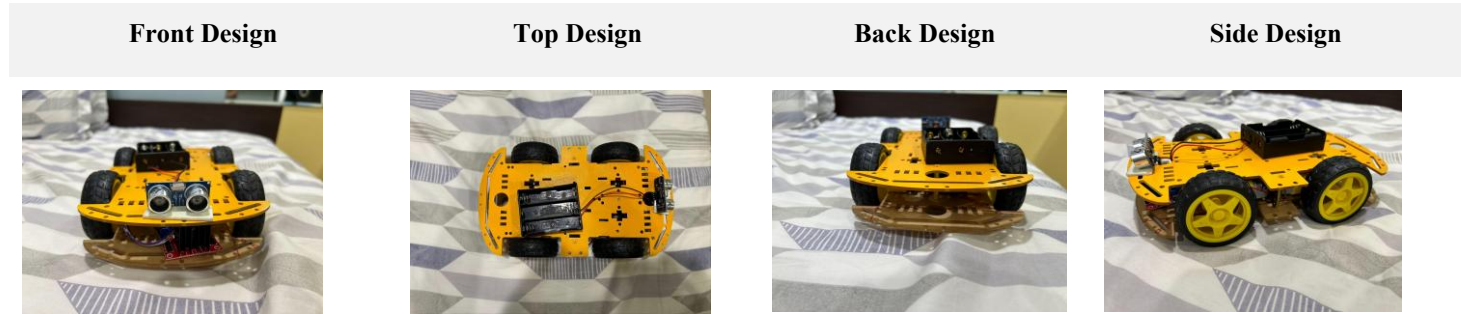
- The connection was messed up between the 5V and the GND pin
- The soldering was not proper which put us in a tough position

To do: Make sure to fix the 2 errors and challenges mentioned above

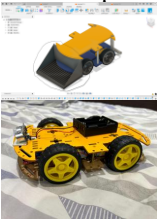
Reflection: This class really taught us a lot as we learnt the importance of rechecking our work. After today's class, we felt really confident with our product as we realized what our mistakes were and they were not at a level that we cant solve it so we knew that we can get the product to work.

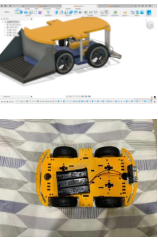
Final Product

- Link of product testing in home - [Trial Run 1](#)
- Link of product testing in school - [Trial Run 2](#)
- Photos of final product



C4 (Changes to the Solution): Fully justify changes made to the chosen design and plan when making the solution

Changes made	Initial plan	Justification for changes made
Not making the front trash collector part 	Initially we were going to make a trash collecting part in front of the robot which would pick up all the trash and complete the functionality of the robot. This part would be made out of metal and have no sensors or electronic parts inside. This trash collector would have a metal grid which would pick up all the trash and the side and back walls would make the trash stay in. It had to be 25 liters in size to be able to store a sufficient amount of trash.	We originally intended to make the trash collector as this is what our product is meant to do, but we ran out of time and decided against it. Rather than using code, we created the circuit that is required for the chassis; once that is operational, we can be certain that the trash collector will also function. We also didn't have any tools to cut and mold metal. For the product to be successful no proper exterior was required. By removing the trash collector we can also explore the product's additional use. For example the product could be used to inspect beaches by adding another sensor.
Not making the back roller 	The back roller was supposed to flatten the sand on the beach. The back roller was supposed to be made of metal. There were supposed to be two metal pipes supporting a 5 to 8 kg metal roller. This metal roller was supposed to flatten all sand behind it. This would be the second function of the product and extremely helpful to the beach overall.	The reasons for not making the back roller was similar to the one for the front trash collector. It is certain that if the circuit and basics of the product work the back roller would work. We also didn't have the materials required to make this metal roller and tools to cut and mold the metal.

Not using a gyro sensor	In the original product we were going to use a gyro sensor to keep the robot on track. While moving on sand, on uneven terrain there is a high chance the robot may deviate from its path and end up going into the ocean or cleaning the wrong area. To fix this a gyro sensor would keep the robot on track using the map function. The gyro sensor would be small and lightweight, not taking up too much space and increasing the safety and functionality of the robot.	The last change which we made was the removal of the gyro sensor at the last minute. While we were coding we realized that we only needed to get one sensor to work and we had already gotten the ultrasound sensor to work along with the motor so it was fortunate for us. It was also very complex as a gyro sensor is something which me and varish both have never even seen before.
Painting only layer of the chassis 	In our original plan we had decided to paint both the top and bottom chassis. This would be more aesthetically pleasing when compared to painting only one layer of the chassis and would blend in better with the yellow sand. If the whole robot is one color the overall feel is also much more professional and complete.	In the beginning, we had planned to paint the chassis on both layers. The first layer of the chassis was left unpainted since we had already begun connecting the motor to the chassis before painting, and we did not want any damage to the first layer's sensors. Instead, we painted the second layer which is the layer on top of the chassis using spray paint which was the original plan as well. This change did not affect the product too much as if a person is looking at our chassis, they would only see the top layer which is covered with the yellow paint. Adding more paint to the chassis may also increase the weight put on it and eventually break the chassis.
Moving the robot when obstacle is detected rather than stopping	Initially when an obstacle was detected the robot was supposed to stop. This was because many times tourists may come in the area and interpret the path of the robot. For this if the robot stops and waits for the tourists to exit it will be able to clean the beach efficiently.	After thinking about this function of the robot my partner and I decided to turn the robot and change its path slightly if an obstacle is detected. This is due to 2 main reasons. Firstly if there is a wall or an unmovable object in the way of the robot's path it will be stuck there forever. To improvise this if the robot moves it will be able to avoid getting stuck forever. Additionally if a tourist is sleeping or sitting in the way of the robot for them the move will be very inconvenient. This makes it annoying for the tourists to visit the beach when the robot is cleaning the beach. If the robot simply goes around the obstacle it will be able to tackle both these problems providing an easy and effective solution.
Changing the placement of components and not using the component box 	We originally wanted to use a component box where all components and wires will go and that will be placed in the center of the chassis. This will ensure all wires are in one place and not popping out. If the wires are popping out they are a safety hazard as they can get stuck with the motor, entangle, etc. If no wires are visible from outside it also makes the product look more aesthetically pleasing to the eye.	We realized that due to the compartment, the sensors would get too congested and maybe the wires would get bent which would affect the usability of the product for the client. Instead of having a compartment, we have assigned each sensor a particular area on the chassis like the ultrasonic sensor will be at the front, the esp along with the gyro sensor will be in the middle. The advantage of having it this way is that if somehow one of the sensors get damaged, there is space between the sensors so the other sensor won't get immediate damage whereas in a compartment everything is on top of each other. We also maneuvered our sensors into different places due to the compartment being removed. Due to there being a battery back as well, we were not able to fit all the sensors on top of layer 1 of the chassis which is why we made one sensor go on top of the 2nd layer of the chassis. This allows all sensors to be a bit more spaced out and better. We made one sensor go on top of the second layer of the chassis because we were unable to fit all the sensors on top of layer 1 due to the battery back also being present. This enables slightly better and more dispersed sensor placement.

Using esp instead of Arduino	We were going to use the Arduino uno originally as it is easier to use and the only board which the school provided. The arduino uno with the help of the breadboard was going to control the motors and the sensors.	Since an Arduino can only operate one sensor and we ran out of room on our chassis, this modification was very strategically placed. We didn't have enough room for a breadboard, which is required for an Arduino to operate two sensors, so we opted to use an ESP instead. This was much simpler because we could connect all sensors and motors directly to ESP using female to female cables. We were able to build connections much more easily thanks to this modification, although it did give us some minor difficulties when it came time to actually coding ESP.
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CRITERION D: EVALUATING

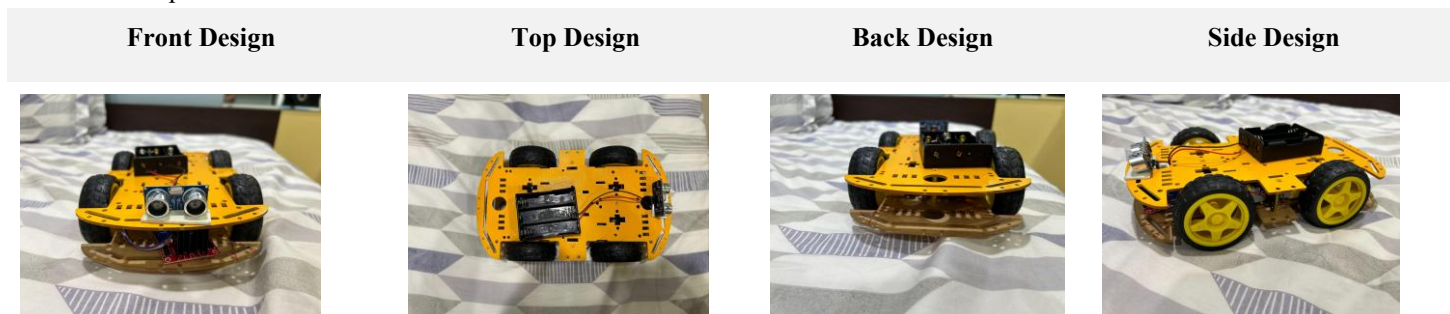
D2 (Evaluating the Solution: Critically evaluate the success of the solution against the design specification...

I wanted to have a diverse group of participants that evaluate and test the product and hence choose a cohort of target audience peers, experts, and teachers. Constructive feedback is the only way to understand the product's strengths and areas for improvement. This video and photo was shown to all respondents. All specifications from B1 were also shown to all before they rated the product. The responders had to compare the actual product to the prototype and rate the product accordingly.

Link of product testing in home - [Trial Run 1](#)

Link of product testing in school - [Trial Run 2](#)

Photos of final product



Feedback from Expert:

In this testing approach, the tester was provided access to the product drawings, Arduino Ide codes, details of hardware use and circuit design. The tester applies both top-down and bottom-up approach to critically evaluate product performance against laid-out design considerations

I asked an expert who has a degree in computer science to test my product and received the following review and rating

- “Product assembly was simple and direct. There were no unwanted / option components used in assembly
- Power supply was direct using a battery pack of 3 X 18650 X 3200mAh, connected to the Motor driver. The same power input was used to power Arduino and ensure uniform distribution to all the 4 motor that drive the wheels
- ESP32 was used enabling ease in product assembly, ability to add sensors in future and debug during design / production stage
- I will highly recommend this product to NGOs for immediate deployment”

- Overall: The tester gave a 4.5/5

Personalized Interview of Client:

Questions Asked (I asked my client to elaborate on their survey answers):

1. Is the Autonomous Vehicle Prototype easy to use without too much technical training?
2. How do you like the assembly of various components? Are the components logical places to ensure operational use and maintenance?
3. What's your favorite and least favorite aspect of this product design? Why?
4. Elaborate on the benefit provided by using this autonomous vehicle instead of picking-up the trash manually?
5. Comment on the intricacy of the design and how it caters to the targeted audience.

Answers:

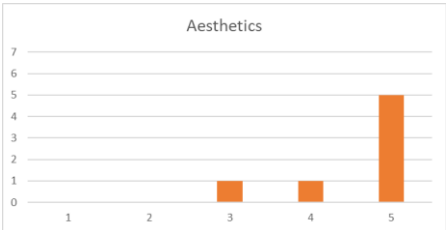
1. Due to my technical background and experience with handling machines, I was able to easily operate the autonomous vehicle without any issues. I would suggest included a simple operational handbook and making YouTube video of Dos & Don'ts for operators
2. I quite like how space has been used to fit in various components, it is not too overwhelming. There are two components which would like maintenance/operations viz (a) power input into motor driver; (b) Arduino input pin for update/change program code. These two input units were placed on either side of chassis for ease of operation
3. The best aspect of product design was compact size of vehicle, along with placement of components and seamless working of code. Components related to beach cleaning could have been incorporated and some additional sensors considered.
4. Great amount of physical labor was involved. The operator was able to use their time and energy to do more productive work like identifying source and areas of high trash volumes
5. I am very impressed by the overall design, though I understand that this could be subjective.

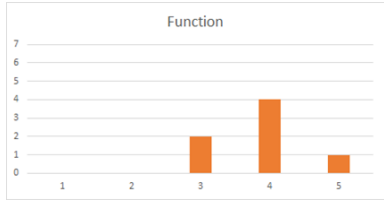
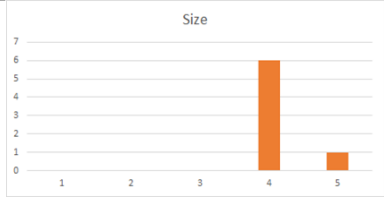
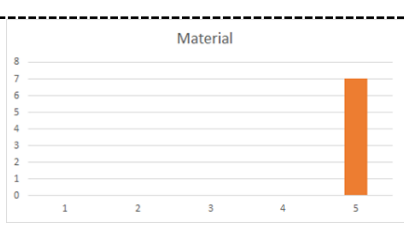
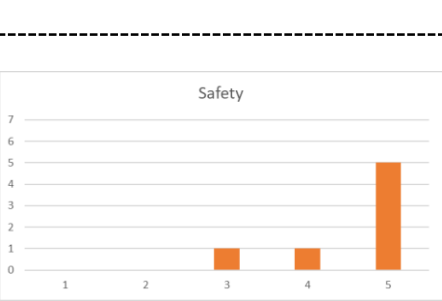
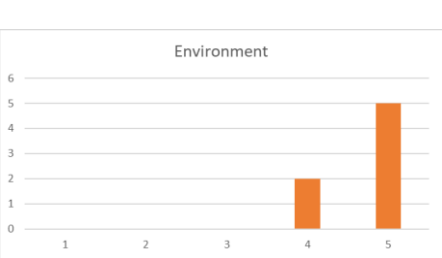
Third Party Survey

Methodology

- Survey form designed covering all design considerations
- Participants, which included target audience and peers request to rate each strand / question out of 5
- Feedback received from seven participants. To collect more unbiased data, I should have collected information from more people but wasn't able to because of time constraints.

Summary

Specification, Question	Response Summary (Graph)	Overall Response												
Aesthetics: Is the product easy to identify and not likely to be missed by beach goers? Is the product size appropriate for its use? Is the product pleasing to the eye and has the capacity to handle trash?	 <table border="1"><caption>Aesthetics Response Data</caption><thead><tr><th>Rating</th><th>Count</th></tr></thead><tbody><tr><td>1</td><td>0</td></tr><tr><td>2</td><td>0</td></tr><tr><td>3</td><td>1</td></tr><tr><td>4</td><td>1</td></tr><tr><td>5</td><td>5</td></tr></tbody></table>	Rating	Count	1	0	2	0	3	1	4	1	5	5	32/35 91% Success
Rating	Count													
1	0													
2	0													
3	1													
4	1													
5	5													
Customer: Are users excited to operate the product? Does the product achieve its objective of reducing manual labour?	 <table border="1"><caption>Customer Response Data</caption><thead><tr><th>Rating</th><th>Count</th></tr></thead><tbody><tr><td>1</td><td>0</td></tr><tr><td>2</td><td>0</td></tr><tr><td>3</td><td>0</td></tr><tr><td>4</td><td>6</td></tr><tr><td>5</td><td>1</td></tr></tbody></table>	Rating	Count	1	0	2	0	3	0	4	6	5	1	29/35 83% Success
Rating	Count													
1	0													
2	0													
3	0													
4	6													
5	1													

Function: Is the product easy to operate? Does the product have all essential features being sensors, rollers, etc.		27/35 77% Success
Size: Is the product too bulky or heavy?		29/35 83% Success
Material: How does the product feel? Does the product meet criteria of being long lasting?		35/35 100% Success
Safety: Are there loose components in the assembly? Is the product likely to be missed or run the risk of being over-run?		32/35 91% Success
Environment: Does the product meet sustainability objectives? Is the product made of sustainable material?		33/35 94% Success

Analysis of third-party survey responses

- Survey collected responses from seven participants, including peers and target audience. Despite the limited sample size, insights were gained on different criteria.
- Feedback on Function is diverse in nature where the local business community suggests that product meets all the criteria, whereas NGO's comment that more features (over and above those contemplated at product development stage) could be added. Both the Customer segment have different design priority
- Environment: Looks like participants evaluated on a standalone basis and not against design considerations. As discussed during product design stage, given product application sustainability goal is secondary
- A segment of respondents felt that product size should be bigger [missing the point that demonstrated product is prototype for school project]

Google Forms and Interview based on design specifications identified in Bi

Link of google forms from which data was collected

Category	Design Specification	Self-	Third-	Averag	Evaluation
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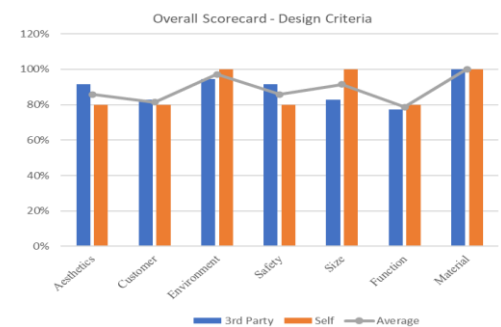
		Rating	party Rating	e	
Aesthetics	- Color which should be able to stand out. "Bright Yellow", as this color stands out - Texture of the product should be smooth - Weight of the robot should be 5 to 8 kgs - Space spread educational and general awareness about littering the beaches	4/5 (80%)	91%	86%	- The criteria got a perfect rating from both third-party and self - The product looks compact and is very pleasing, all wires are concisely packed inside the chassis and are not visible from outside packing the product - The spray paint on the top chassis looks very clean and aesthetically pleasing, this is primarily because 2 layers of paint were done on the chassis - One part where I personally feel could be improved to make the product look better is painting the bottom chassis. While the bottom chassis might not be easily visible from the top if looked from the side it is visible and is aesthetically unappealing - Additionally to attach the ultrasound a double sided tape was used which makes the product look unprofessional
Customer	- NGOs and local businesses - Minimum & Maximum age to be able to operate and handle such a device	4/5 (80%)	83%	81%	- Both the Customer segment have different design priority - NGO's looking for additional features, whereas local businesses looking for additional activities beyond beach trash clean-up
Cost	- Affordable: such that local businesses and small NGOS in their starting phases can afford - Rupee 2000 to 5000	Not Applicable for prototype	Not Applicable for prototype	Not Applicable for prototype	Not Applicable for prototype [Since the product has not been manufactured, and I lack the proper experience to confidently say my research would lead to an accurate price. Therefore, it cannot be properly evaluated]
Environment	- Clean up the environment by picking up trash. According to me as a designer and my target audience the actual materials in the product do not necessarily need to be sustainable - Long term objective rather than short term	5/5 (100%)	94%	97%	- Looks like participants evaluated on standalone basis and not against design considerations - As mentioned during product design stage, given product application I felt sustainability goal is secondary for this product - I personally feel when compared to my success criteria when looked at the design in deserves 100% as it matches all requirements - It is able to clean a lot of trash while only using 3 rechargeable batteries
Safety	- Basic safety measures which include, No loose wires, Regular safety check, Physical body check - Physical body not being in proper condition may lead to the sensors and components being damaged	4/5 (80%)	91%	86%	- The product assembly was very well done with not loose wires or components - The ultrasound sensor was also able to do its job perfectly and detect any obstacles and avoid them efficiently - However there was no gyro sensor present and according to me that is a safety hazard. With a gyro sensor the product can go off path harming tourists on the beach and not reaching optimal functionality.

Size	- Safely holds and operate its components and can hold a sufficient amount of trash - All components will be easily fitted inside the chassis of the device and also be secured	5/5 (100%)	83%	91%	- While my audience feel the device should have been able to carry more trash I personally feel it did a very good job when compared with the specifications. It was exact size of 36cm X 16cm - If a trash picking up part was build it could have easily picked up 25 liters worth of trash - Large size is not possible due to 2 reasons - Firstly this is just a prototype - Secondly I didn't have the materials or resources to scale up my project
Function	- Sensors and components interacting with each other to make the whole experience - Able to maintain a straight line and avoid humans - Flatten the beach - Space spread educational and general awareness about littering the beaches - Mobile trash can	4/5 (80%)	77%	79%	- Being a miniature / prototype space for advertisement and trash cannot be incorporated. However, the product design will ensure that there is adequate space for these features - The ultrasound sensor works perfectly and is able to avoid obstacles - However this product didn't have the trash picking mechanism and beach roller. This brings down the functionality of the product a lot as the main purpose of the product was to pick up trash and flatten the beach - No gyro sensor means the product may get stuck in unwanted areas or cleaning areas which have already been clean decreasing the functionality - The battery pack and ultrasound sensor were kept on top of the product, this meant under any harsh conditions these sensors and battery packs would stop functioning
Material	- Materials should be able handle and protect parts inside the device from harsh conditions like rain, intense heat, dust, sand and even minor storms - MDF for chassis - Rubber Wheels - Metal nuts and bolts to secure components	5/5 (100%)	100%	100%	- I was able to procure and use all the materials, except MDF chassis as planned. Materials used are sturdy, cost effective, practical, and sustainable - The wheels were made out of rubber which allowed them to work on sand efficiently and have a long lifespan while being resistant to any weather conditions

Scorecard: Overall

Product score (simple average)

- “Design Consideration Scores” average of third-party feed-back and self-evaluation
 - Third party feedback average:
 - Self-evaluation average:
- Simple average of above “Design Consideration Scores” to arrive at overall product score
- In real world weightage average is usually applied to assess success rate (weight depending on importance or criticality of design consideration as agreed between Customer and Designer)
- Overall score: **89%**



The product does have some areas to be considered from enhancing the features and tremendous scope to build further by adding additional features, it achieves the objective and effectively works through the design specification.

Strength of product	Weakness of product
● Is aesthetically pleasing ● All motors work properly ● Has a good battery life ● The ultrasound sensor works well ● The motor driver and esp are secure inside the chassis ● The materials used are of high quality and handle any condition	● Doesn't have the front trash collector ● Doesn't have the back sand roller ● Doesn't have a gyro sensor and can deviate from its path ● The product is not very sustainable ● The battery pack the ultrasound sensor are exposed to external harm ● The size of the product is not big enough ● The product could be more accessible and easy to use for customer

D3 (Future Improvements): Explain how the solution could be improved

Changes I could Make	Justification and Connection to D2	How I could change the product
Beach trash pick-up components trash pick-up tool	This is the primary product design consideration. While autonomous vehicles are the base, it should be ensured that sight is not lost on the ultimate objective of reducing beach trash with limited human intervention. This was a common request from the audience in D2. Many of the clients said they rated the functionality of the product down as the product wasn't able to complete it's main purpose and pick up trash.	This needs a lot of research, customer feedback and some trial-and-error to ensure product utility is not compromised. To increase the functionality of the product for the NGO's and local vendors to actually be able to use the device, adding the front trash picking up part is necessary. The trash collector will ensure the product is able to do it's job at it's full potential. Instead of using metal grids and sheet mesh materials like aluminum and MDF could be used to make the trash collector. This materials are more easy to use than metals and provide the safe functionally
A roller could be added at the back of the robot to give it two function and for the robot to be able to flatten the beach	While the primary use for the product will be to pick up trash from the beach, just adding a roller at the back of the product can significantly increase it's functionality and help the beach in many ways as well. Not having roller was also a main reason for which the functionality of the product was reduced. Many clients said the functionality of the product would increase if it could flatten the sand and pick up trash.	Surveys with a computer scientist and customers of this product have shown adding the roller would help the product and beach a lot. A metal or an aluminum roller could be added at the end of the product which is attached by two small metal poles. This roller would flatten the beach as it progresses to collect trash. The customers would want a function like this as having flat sand helps the beach look more aesthetics and have a stable foundation. This helps local vendors to grow their business exponentially. The roller could also be made out of heavy PVC pipes, these pipes are cheap, easy to work with and will provide the same function as metal pipes.

Function: Some element of functionality was sacrificed during the final product due to lack of time and resources	I want to create a product that is not only functional but also stylish and easy to operate. In my self evaluation in D2 and the feedback from the computer scientist in D2 more efficient batteries and chips could be used. A more effective battery pack would allow the device to run for an extended period of time increasing the functionality. Integrating Ai into the code would also allow the product to run more efficiently increasing the overall functionality.	• A customisable panel with various sensors could be provided in the vehicle. This would enable to operator to add or remove sensors depending on specific geography of beach or specific customer need • Use Lithium batteries instead of carbon batteries, as they recharge faster, can store higher quantum of energy and lighter • NPU chips should be part of design consideration. NPUs are modern add-ons that enable CPUs to handle AI workloads, as they are designed with the more specific purpose of building deep learning models and neural networks. This will increase product cost, but ensure that product if future ready
Customer: While Competing design considerations for different target segment was balanced by ensuring strong / sturdy product and reducing features / sensors	The score in this category can be improved by designing more target specific. Incorporating more features that target the interests and preferences of the control group would be the best step, since score indicates that product is not executed as per its target group. Many of my clients in C2 said that they would want a product which is easier to use and a person with no experience with robotics would also operate the robot.	It should be considered to have easy to assemble product variants based on features of the beach, where the vehicle is proposed to be deployed. In city-based beaches the considerations of the local business community like large size, safety and aesthetics would be primary considerations, whereas for smaller size tourists dominated on city beaches should be driven by sustainability and operational ease. Aesthetics can be improved by adding a body cover to the product, whereas operational flexibility would be enhancing by adding additional sensors that could detect smoke, react to sirens, etc
Environment: The product design was simplified and I decided to not add some of the optional sensors, gyro, etc to reduce energy usage	It is critical that all new product designs are made considering the future (positive & negative impact) on our environment. Climate change is a reality and products which are not environment friendly might get push back from both governmental agencies and NGOs. At the product design stage, I traded over solar panels to recharge batteries to manage my resources, time, cost, etc. The computer scientist I interviewed said the product would have a much greater impact on the environment if there were solar panels attached to the top of the robot. Adding solar panels will not only ensure the robot will be able to operate for a longer time and pick up more trash but also renewable energy will be used to power the robot	Solar panels should be installed on the top of the product, which will enable batteries to be recharged sustainably. As the product would be deployed on beaches which generally get good sunlight, panels would not have challenges on that front. The cost of silica films has reduced over the years and now films are cheaply available. However, it should be ensured that there is no compromise in product safety
Size: I made a scalable prototype by ensuring that proportion of various components (size of chassis vs motor driver vs esp) are in balanced stage	Size would primarily drive the effectiveness of the product both in terms of ability to pick-up beach trash which the product can hold before going back to the dumping yard. Balance needs to be achieved between ease of larger vehicles vis-à-vis product cost. Most of my clients wanted the size of the robot to increase. They thought doing this will allow the robot to be able to pick up my trash relating D3 to D2.	A large size chassis or autonomous vehicle axle/base should be used. While a compact product looks good on aesthetics, it could present challenges for regular maintenance and operations. The cost of product and repairs increased significantly for smaller size powerful components. Operational ease, especially as the product would be deployed in open harsh environment conditions (heat, winds, dust & sand) would get higher consideration as compared to features and aesthetics

Safety: Adding additional sensors to make the product safer	The current product only has one sensor which is the ultrasound sensor. The product can easily stray from its path, getting off track and possibly even going into the ocean. To avoid this a gyro sensor could be used. In the current product there is a power imbalance where the left motors are receiving more power than the right motors causing the product to change direction. The computer science and I both thought adding a gyro sensor will increase the safety of the product significantly. Adding a gyro sensor will allow the robot to maintain a straight line. The current product and stray from it's path interrupting the path of tourists and going into the ocean.	Along with the esp32 and ultrasound a gyro sensor could be added. This sensor will allow the product to stay on course using a mapping function to help the ultrasound to process and turn more accurately. Adding the gyro sensor will not only increase the safety of the tourists on the beach but also of the robot and environment. If the robot strays of path and goes into the ocean the robot will be destroyed and harm will be caused to the animals living in the ocean.
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The autonomous beach trash cleaning vehicle made by me has a few positive sides, but it has some potential weaknesses and limitations. I believe that by addressing these weaknesses and limitations, I can create a product that is not only functional, easy to assemble but also large, has significant operational flexibility and add an element of sustainability

Summary of changes which can be made to the product

- Adding the front trash collector to be able to pick the trash
- Adding the back roller to be able to flatten the beach while the product picks up the trash
- Adding a gyro sensor so the product stays on track
- Using lithium batteries instead of carbon based batteries to increase the duration the robot can run at one stretch
- Adding Ai chips to in increase the efficiency of the product
- Adding solar panels so the product can run without electricity for extended periods of time
- Increasing the size of the robot so it can pick up more trash at one go

Impact of the Solution on the Target Audience:

The product created is a perfect balance of using technology to solve the modern day problem of beach trash in an effective way. The autonomous vehicle design is visionary and path-breaking, with ability to have meaningful impact on my target audience i.e. NGOs and the local business community.

- Local Business Community: that operates in areas around the beaches. Their livelihood depends on the thriving eco-system of beaches with regular tourists and visitors. The Local Business Community might explore options to move away from the beaches and look for alternatives for business. This will lead of loss of employment for staff, losses of investments made by businesses, cascading impact on turnover of visitors and tourists
- Non-Government Organizations (“NGO’s): are seen leading the efforts to ensure clean beaches, as governmental agencies in cities like Mumbai have proved to be ineffective. NGO’s use their network of volunteers to improve awareness and run regular beach clean-up drives. NGOs might lose enthusiasm due to slow progress and ineffectiveness of manual process. This would severely impact the state of beaches

Evident from above score, the product has most of the critical design considerations. The product can solve the critical issue of beach trash by deploying a Technology driven solution. The product

- Uses innovative technology by building an autonomous vehicle to help existing local vendors in the area
- Connect the product with the RC as innovation is being used to help local markets.
- Have a variety of different sensors and components to achieve its goal of cleaner beaches making products related to KC

The problem of beach trash both results in (a) Reduced tourist & local visitors impacting business for local business community; and (b) Increased cost of business and social back-lash as local business community are easy targets for agencies/media targeting dirty beaches. Primary reasons for beach trash include unhealthy waste disposal strategy of local municipal authorities, industrial waste and lack of awareness among tourists & visitors. The product eliminates the need for manual labor, is safe to use and ease of operating thereby significantly improving target audiences’ quality of life.

Final product outcome provides a solution to the original design problem and also enriches overall client experience. The impact of my solution extends beyond socio-economic design consideration.

Societal Impact:

The product not only achieves laid-out design goals and addresses all critical customer needs, it also helps achieve

- *Social Impact:* The product would create impact to improve marine life, reduced time & effort of NGO in deploying man-power towards routine manual clean-up works and divert the efforts towards other issues and create a positive chain reaction by providing clean public places for masses
- *Economic Impact:* There will be tremendous economic benefit to the local business community due to clean beaches on a consistent basis achieved in a cost effective manner. Trade and the general economy would also benefit from increased tourism. The autonomous vehicle would also reduce burden on human efforts and man hours involved currently, which could be used for productive purposes.
- *Environmental Impact:* The product is non-polluting in nature and helps nature in the form of cleaner beaches. A better version of the product could be developed in future, that uses solar panels as energy input vis-à-vis current battery powered set-up

How the impact of the design is going to lead to develop a better prospect in/of the future:

The impact of the target audience is meaningful and the product provides a strong starting point to commercially develop the prototype. There are also some areas of improvement in the product, including:

- Source of power input: Solar energy should be for the product. Being a prototype and due to limitation of time, experience, and resources, this was not considered in the current design, however Solar panels should be used to recharge batteries to improve product sustainability
- Tyres usage: More research and investments could be done to customize tyres which are more effective in sands, ensure better autonomous vehicle balance and does not get stuck in sand – eg broad based tyres
- Customisation to pick-up trash: This is requiring more time, experimentation, feedback based on using different models and practical experience gained by trial-and-error
- Sensors: Higher quality sensors (leading to higher costing) and more features could be added to improve product usability.

Unique Solution: The product is unique in ways that it provides an economic easy to assemble and operate product, with capabilities to modify/upgrade the product depending on evolving technology trends and consumer needs. The product has the capability to be widely deployed and address some of the concerns raised by the target audience at assessment stage. The product has achieved the right balance between use of technology vs easy & safe to operate vs cost of operation as compared to alternate manual solutions.