Sparkyville NGTT

Technical Report

By
Veronica Bernard, Dylan Bowes, Von Whipple, and Dahlia Alotaibi

April 26th, 2024

Abstract

The team wanted to innovate an adventure for tourists and investors alike, appealing to various groups of people such as families with its spacious design and ecotourists by prioritizing sustainability in its production. Development started by interviewing a diverse group of people so that the team could outline expectations, returns, and any possible concerns in a future vehicle. By utilizing various engineering techniques such as an AHP table and a discussion matrix, the team was able to work on a prototype, the solar powered Sparkyville NGTT SUV. Boosting 6 doors, 6 seats, plenty of storage space, automatic stop feature, and a beautiful exterior, the team developed the final product on April 23, 2024.

Introduction

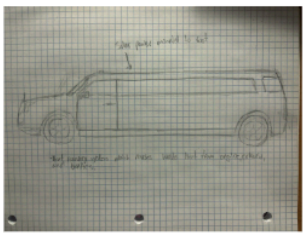
Sparkyville Resorts was in dire need of a form of transportation as noted by hotel mogul and Sparkyville owner, Melanie Waters. The hotel owner needed an innovative form of transportation which represents the spirit of Sparkyville in innovation and sustainability to catch headlines and please customers. When the team interviewed the fleet commissioner, Taylor Adams, a heavy emphasis was placed on safety for customers and workers alike. Adams requested a vehicle with an auto-stop feature but still retained a need for employees to pilot. Customers interviewed displayed a wide range of interests, families focusing on safety and storage while singular tourists had more niche requests such as an emphasis on environmentally friendly design or speed. The team identified 5 design requirements of the vehicle throughout the statements, the ability to drive around 20 miles, carry large amounts of people, feature a cutting edge design to make the news, remain within a max length of 24”, and have an auto-stop feature. The interviews conducted also allowed the team to establish 5 design criterias, safety, storage, accessibility,

comfort, and aesthetics. They were chosen due to being the most common request amongst all of the stakeholders. This was able to appeal to all audiences that were interviewed without taking away from another's requests. With this data, the team assembled an Analytical Hierarchy Process table to establish priorities in each criteria.

Criteria:	Safety	Storage	Accessibility	Comfort	Aesthetics	Total Weight %
Safety	**1**	**4**	**4**	**5**	**5**	**44.9%**
Storage	**1/4**	**1**	**2**	**4**	**3**	**24.2%**
Accessibility	**1/4**	**1/2**	**1**	**3**	**2**	**16%**
Comfort	**1/5**	**1/4**	**1/3**	**1**	**1/2**	**5.4%**
Aesthetics	**1/5**	**1/3**	**1/2**	**2**	**1**	**9.5%**

Stakeholder opinions were taken into careful consideration by the team. By understanding the importance of each interviewee's role in the development and return of the vehicle, certain criteria such as safety were prioritized. The team also weighed the importance of features by how frequently they were brought up, noting that while storage wasn't the main concern of investors, it was significant to the Sparkyville visitors and therefore should be incorporated into the final design.

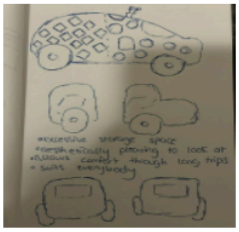
With priorities set in place, the team was now able to work on prototypes of a vehicle. The team began by working together to create a list of 100+ ideas, selected their best concepts, and then individually developed quick rough drafts to better explain their ideas.



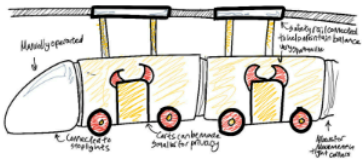
Von's Design



Dylan's Design



Dahlia's Design



Veronica's Design

After the concepts were developed, they were now able to create a decision matrix to select what the team believes to fulfill the requirements and fit the criteria importance as listed by the AHP table.

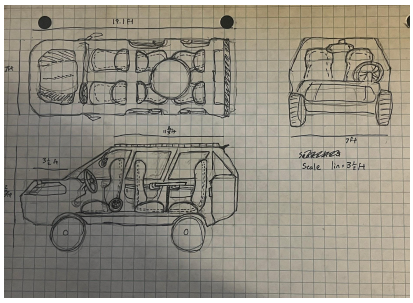
Rated 1/5	Safety	Storage	Comfort	Accessibility	Aesthetics	Total %
Dylans design	4	4	4	4	5	68.38
Vons design	5	5	5	4	3	79.12%
Veronicas design	5	5	3	5	2	78.3%
Dahlias Design	4	4	4	3	5	67.3%
Weight of criteria (%) and winning	44.9% Weight	24.2% Weight	16% Weight	5.4% Weight	9.5% Weight	Winner = Vons design

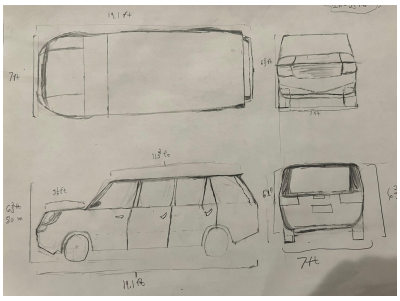
design.						

The decision matrix led to the team designing an SUV like vehicle with plenty of seats and storage capacity for guests and an auto-stop and solar powered fueling to appeal to investors. With an idea set in place, the team was able to start building a functional prototype. They started by refining out the details of the rough sketch design to incorporate as many audiences as they can. With an even bigger picture of what's needed, the team was able to sketch out a multiview drawing, configure technical parts and the build itself, mathematically plan a return on investment, and then evaluate the final product.

Design Overview

The Sparkyville NGTT took inspiration from the Land Rover Predator but with its own unique twist to satisfy its audience.





Interior *Exterior*

- *See Appendix A for a larger image*

The design upheld the requirements needed by Melanie Waters and Taylor Adams however in terms of criteria, the team had a target customer base of families, incorporating its many storage areas and seating similar to a family van. Families were the main priority, noting they make up a larger portion of the Sparkyville resort consumer base and a design focusing on singular travelers

will alienate most of the audience. Knowing what audience the team was trying to appeal to the most, the team set on adding key features to the vehicle. The exterior will include two large solar panels mounted on the top to utilize the sweltering Arizonan heat that power a compound gear ratio. The auto-stop feature will be connected to the front headlights. The vehicle's interior will have 8 seats inside and various sections for storage. Some additional features the team also added were a beautiful exterior mural to capture the Sparkyville branding and include important tourist attractions such as the A Mountain, making the vehicles work well as a form of advertisement and please investors and customers in aesthetics. The team also wanted to add an LED screen that displays text that could be used in coordinating destinations of each vehicle similar to a bus.

In the final demonstration of the vehicle, the team ran into some issues in regards to its power, switching temporarily to a battery powered motor. The Sparkyville NGTT excelled at speed however it ran into issues with tightness in its gear ratio which caused the vehicle to jam. The final product fit the criterias of storage, comfort, accessibility, and aesthetics but needed to be improved upon in the safety criteria by fixing the gear ratios.

The costs of the materials used in the vehicle's design were recorded into an Excel spreadsheet automatically calculating the total cost of $32.20, making the design $47.80 below its $80 budget

Material	Individual Price	Amount	Total Cost Each
Brass Rods	$2.50	3	$7.50
50mm Pulley	$0.50	4	$2.00
50mm Pulley Rubber Band	$0.25	4	$1.00
10 Tooth Gear Head	$0.30	1	$0.30
20 Tooth Gear Head	$0.40	2	$0.80
30 Tooth Gear Head	$0.50	2	$1.00
50 Tooth Gear Head	$0.70	1	$0.70
Rubber Grommet	$0.10	8	$0.80
Nichibo Motor	$3.00	1	$3.00
1/4"mm Ball Bearings	$1.50	2	$3.00
1/4" thick cardboard	$0.10	4	$0.40
1/8" thick plywood	$0.70	1	$0.70
RGB Sensor	$10.00	1	$10.00
TIP 120 Sensor	$1.00	1	$1.00

Overall Total
$32.20

In an official manufacturing setting with ideal materials, the team estimated that actual production will correspond to around $50 million initial investment from the bank. The borrowed funding will have an interest rate of 3% compounded annually. Annual loan payments will be at $10.92 million annually with an estimated return of $15.33 million annually, making a total net profit of $3.91 million each year or an annual return on investment of 7.82%. These were calculated using the formulas listed.

$$ROI = \frac{Net\ Profit}{Initial\ Investment} \times 100\%$$

- *See Appendix B for More Calculation Examples*

Design Trade-offs

Throughout the development of the vehicle, the team made the difficult decision to change out central parts of the design to better the functionality of the overall vehicle. The exterior was initially going to be made out of plywood, which would give it a much more clean look and cohesiveness to the overall aesthetic but in turn would potentially add unneeded weight, further stressing the gear ratio. The idea of an LED screen ended up being scrapped in exchange for more time being devoted to the auto-stop functionality which also included LED lights.

Subset Description

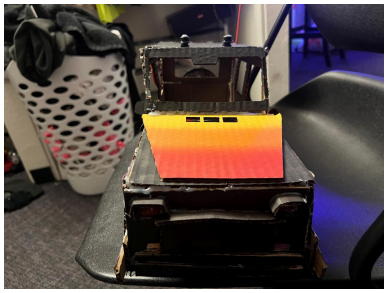
Exterior and Interior

The Sparkyville NGTT was as safe as it was aesthetically pleasing.





Side Views





Front View *Top View*

The design was hand painted by the team who had decided on a retro futuristic design. A silhouette of A mountain dawns the vehicle on one side and the Sparkyville logo on the other. The colors chosen were based on Arizona sunsets to show off the natural beauty of Sparkyville. There are 6 doors, one equipped with a handicap slope entrance for accessibility and a spacious trunk opening to allow plenty of storage space. Overall, the vehicle prototype was 18” inches long and 6” inches wide. It fit the need of holding a large quantity of people as well as providing space. However the final product had issues with running 20 feet in the demo.

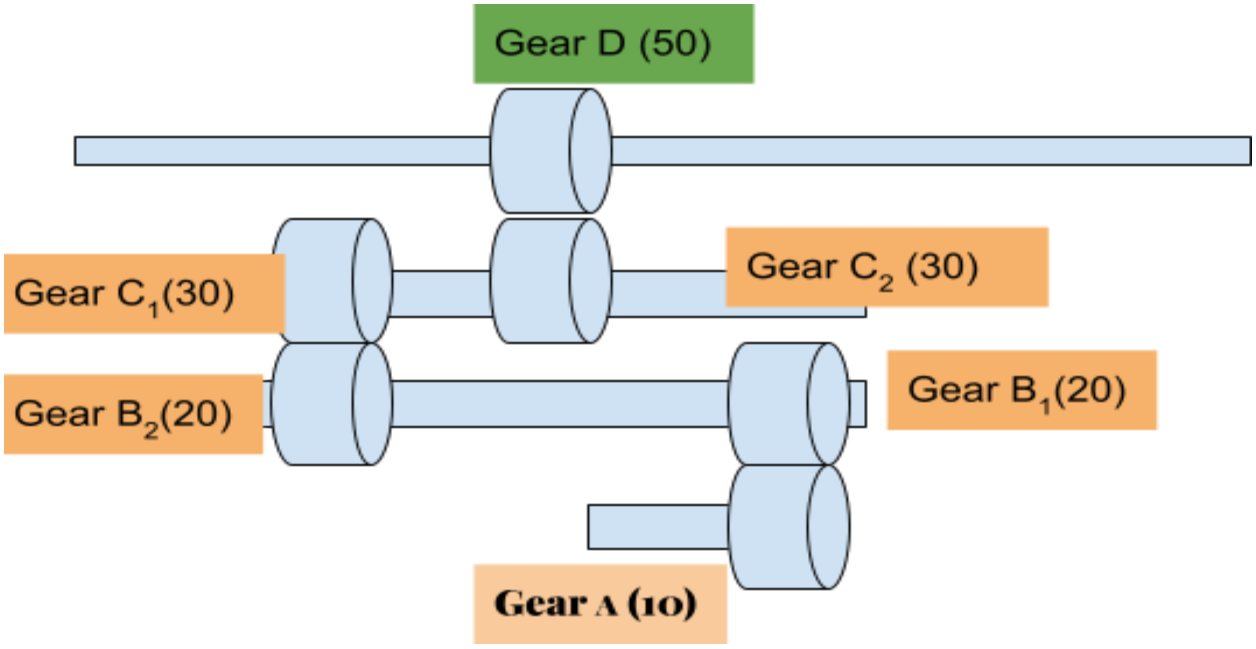
Safety was taken into careful consideration by the team. The team referenced a set of standards provided by the National Highway Traffic Safety Administration (NHTSA) and implemented the recommendations that gave previous consumer vehicles 5 star safety ratings. The team made sure

the interior was equipped with the most current technology in seatbelts, airbags, electronic stability, and driver assistance. Another focus of the team was ethicalities in terms of the environment. Many Metro area Arizonans are breathing in pollutants under 2.5 microns in diameter daily. This smog is caused 75% by nitrogen oxide emissions from vehicles (Syed, 2021). The team intends to be fully electric or solar powered. In the future, the team plans to focus on creating a negative carbon footprint by developing carbon capture systems into the Sparkyville vehicles. Human centric has been central to the prototyping process, the team focused on a family-friendly vehicle to appeal to a wider consumer base of Sparkyville tourists.

Gear Train Design

During the development and design of the vehicle, it was agreed upon by the team that, in order to get the most power from the solar panels, the car would use multiple, and therefore the car would need to be on the larger side to accommodate this. Knowing that the car would be on the larger, heavier end of the spectrum, it was decided that a 5:1 gear ratio would be ideal, utilizing the higher torque of the gear train to ensure that the car would be able to move at most weights and against most resistance.

The following diagram shows the general layout of the compound gear train, starting with gear A, a 10-tooth gear connected to the same shaft as the engine, and gear B_1, which is on the same shaft as B_2, both sharing the same amount of teeth at 20. This pattern continues until Gear C_2, a 30-tooth gear, is connected to Gear D (50 teeth), on the same shaft as the rear wheels which in turn drives power from the engine, through the gears into the wheels.

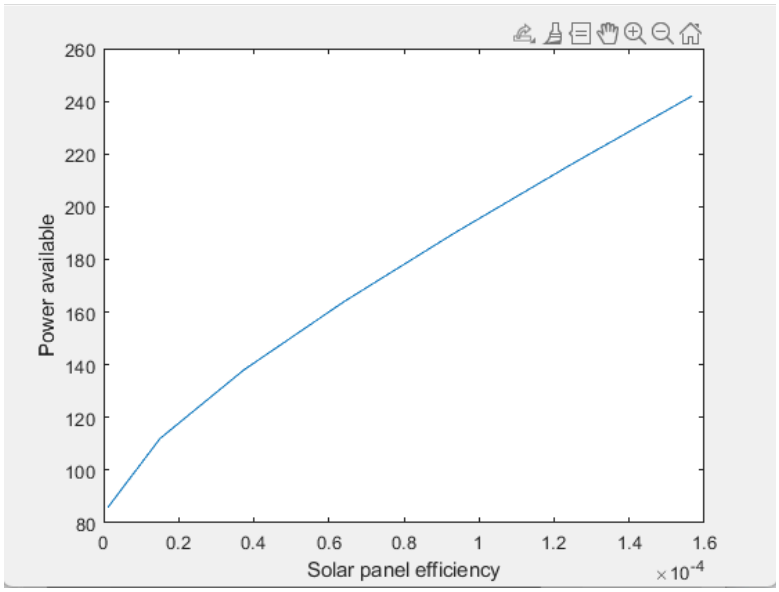


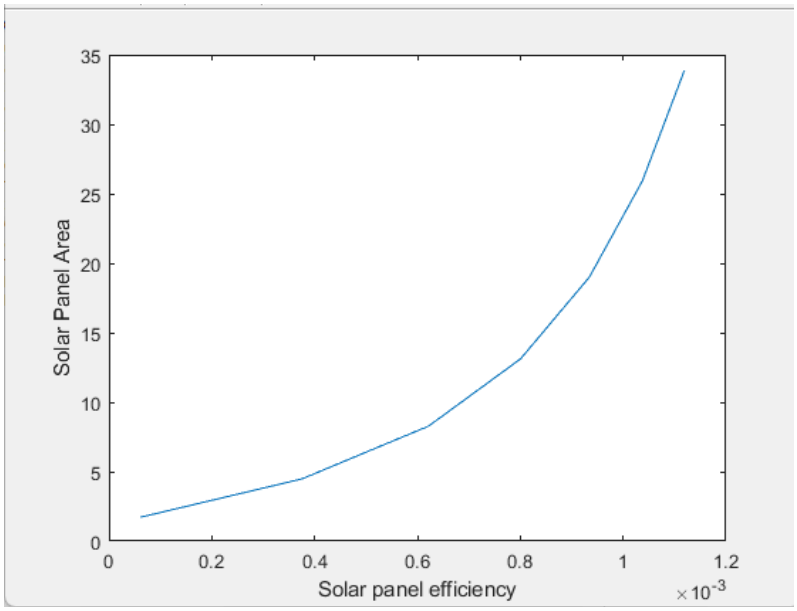
Because the gear shafts kept the same amount of teeth on the gears for shafts B and C, the calculation can go as follows.

$$\frac{20 \text{ (gear } B_1,B_2)}{10 \text{ (gear a)}} \times \frac{30 \text{ (gear } C_1,C_2)}{20 \text{ (gear } B_1,B_2)} \times \frac{50 \text{ (gear D)}}{30 \text{ (gear } C_1,C_2)} = 5.000 \text{ (Gear ratio of 5:1)}$$

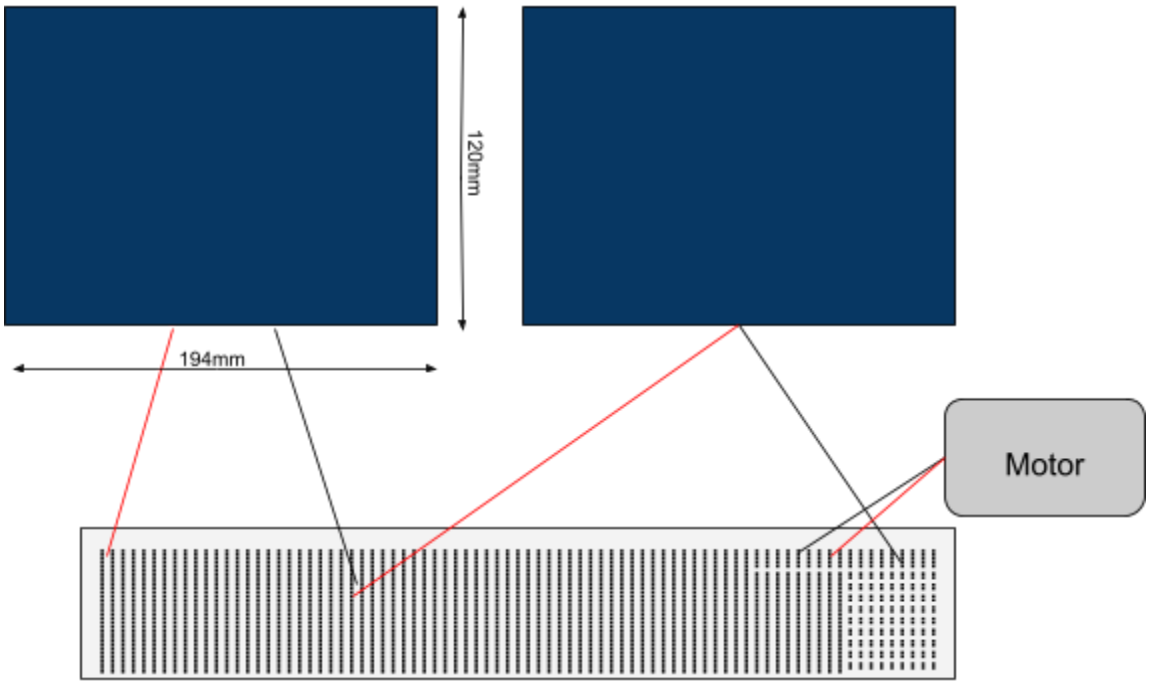
This layout grants the team the desired 5:1 gear ratio and sets the car up for success in any situation. Be it going offroad, towing, good performance when full of stakeholders (our family of four), or the ability to add more solar panels or make other modifications to the design (if the stakeholders need them) without it affecting the performance of the car or requiring an entirely new design from the ground up.

Solar Panel and Motor Configuration





- See Appendix C for MATLAB Code



Solar panel efficiency is dependent on the total solar panel surface area as demonstrated in the team's work in MATLAB generated plots. A plot was developed by collecting data of luminance in relation to the angle at which the solar panels are held in. Solar power efficiency was calculated via the formulas below.

$$Load\ Power = \frac{Voltage^2}{Resistance}$$

$$Solar\ Panel\ Efficiency = \frac{Load\ Power}{Power\ Available}$$

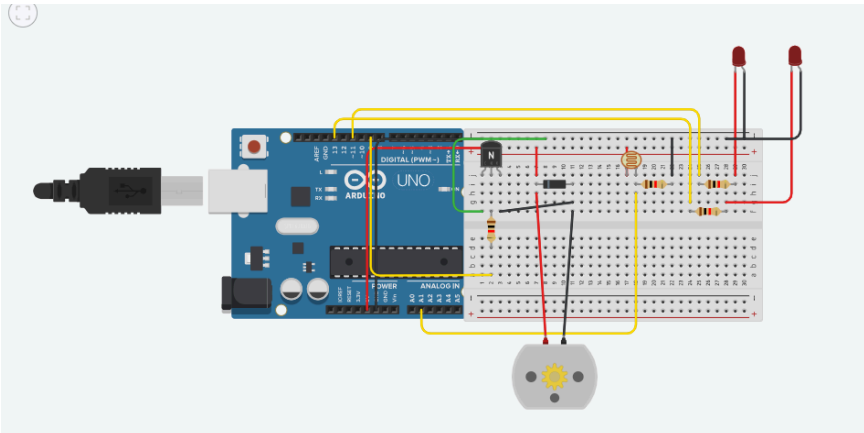
- View Appendix B for more calculations

For the circuit design, a parallel circuit was chosen to connect the solar panels to the breadboard and power the motor. This was chosen because it allows a more fail-proof and efficient circuit in comparison to a serial circuit which would depend on a singular solar panel.

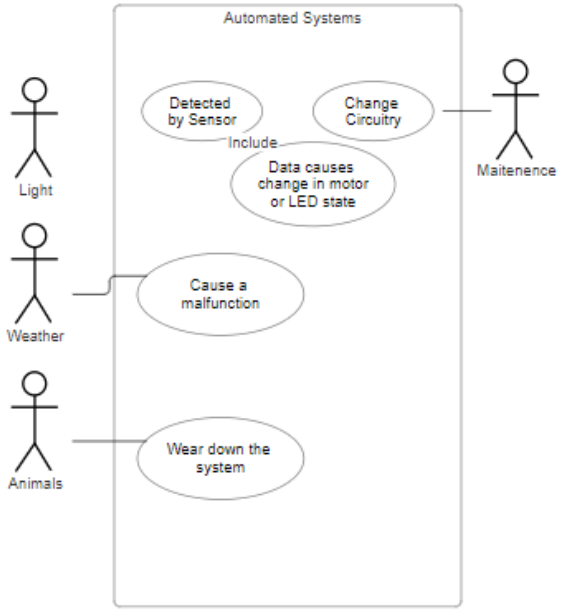
Automation

The automation used for the Sparkyville NGTT Vehicle included two features: a redlight stopping system and automatic dark enabled headlight system. The redlight feature reacts to a red light input picked up by a forward facing RGB sensor. From this data, the state of the motor (on or off) would be controlled. This translates to an automatic stoppage of the vehicle at a red light. For the darkness controlled headlights, a sensor reads the light level directly above the vehicle, and if this light level is below a certain threshold, it activates the LED headlights. This feature vastly improves safety and ease of use at night or in dark environments by illuminating the area around the vehicle.

Circuit Diagram: (note - no RGB sensor available in software, so it is excluded)

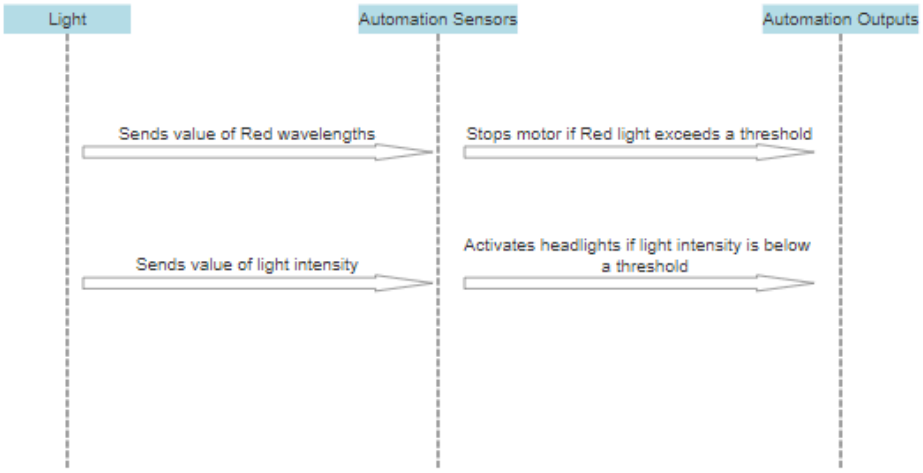


Use Case Diagram:



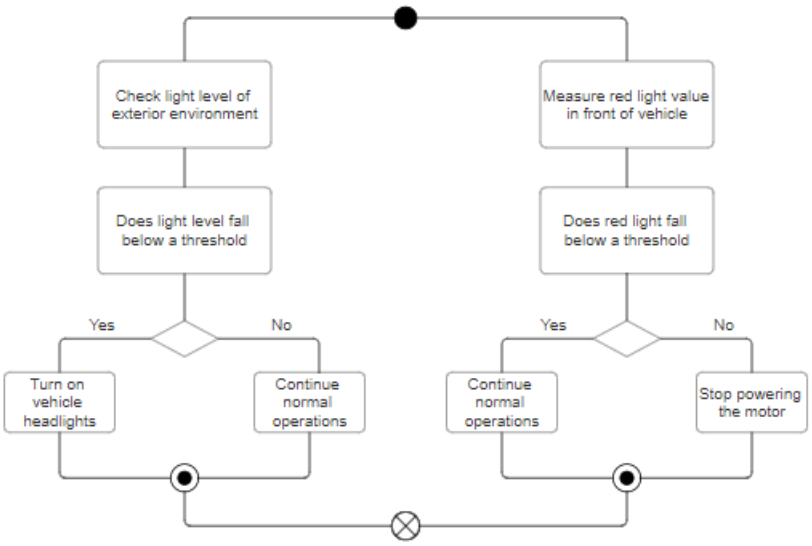
There are four actors which can interact with the automation systems. The first actor is light itself which is detected by the sensors in the system causing an output. As external light changes its characteristics, so too do the outputs of the system. The second actor is weather which includes rain, snow, wind etc. Weather can interact with the systems by affecting the physical conditions of the hardware. For example, water from rain can cause a short circuit or can render the functions of a sensor broken. Another actor would be animals who can interact with the systems physically much like weather. Animals may be able to interact with the hardware of the systems causing damage, but much more likely is water damage from urination. The final actor would be any maintenance personnel who are able to alter the hardware components of the system.

Sequence Diagram:



The sequence diagram includes three objects which interact with each other. Light is the first object which contains inherit data. This light is detected by the automation sensors and its data detected causing an output to occur. The data that is read is the value of the light intensity detected and the value of redness in the light detected. Depending on the values of this data, an output occurs in the automation features which includes a motor and lights. If the red light exceeds a given threshold value, then the motor is stopped. If the light intensity falls below a given threshold, then the LED lights are activated.

Behavioral Diagram:



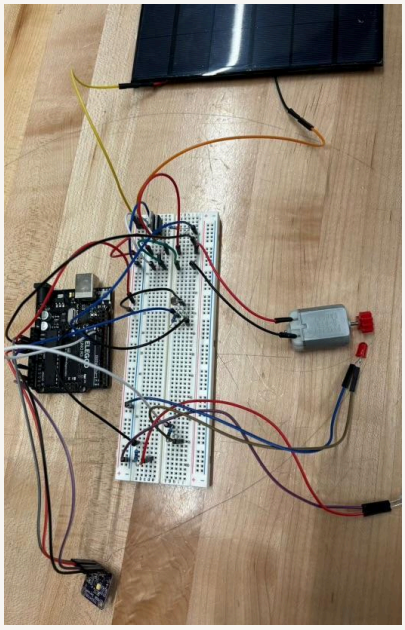
This behavioral/activity diagram illustrates the logic behind the arduino functions which interpret data and create outputs. There are two flows of activity: the first being the headlights system and the second being the red light system. The first system detects the light level of the exterior environment, then it compares that value to a given threshold value. If it is greater, then the normal operations of the light continue, in this case they remain off. If this value is lower, however, then the headlights turn on. For the second system, an RGB sensor measures the values of red, blue, and green light hitting it. Then the value of red light is compared to a given threshold value. If the red light is greater than this value, then the motor stops receiving power. If the red light is lower, then the normal operations continue which is continued power supply to the motors.

Description of Arduino System:

There are multiple sensors and output components of the arduino system. To start, there is a photoresistor which sends data into pin A1. This connects to the LED systems which receive

power from the pins 11 and 13. In more complex territory, there is an RGB sensor with multiple attachment points. The ground pin is connected to the ground pin on the arduino. The VIN pin is connected to the power line on the breadboard which is powered by the 5V pin on the arduino. The SCL is connected to the A5 pin on the arduino. The SDA pin is connected to the A4 pin on the arduino. All of this is input data which affects the motor. The motor is connected to the power line on the breadboard through a diode and it is connected to pin 9 on the arduino through a transistor and a diode.

Arduino Image:



- See Appendix D for Arduino Code

Automation Results:

The results of the automation were as follows. When directly powered by a computer, the RGB sensor would detect a red value which is read by the arduino and shown on the Serial Monitor. If this value exceeded 100 then the motor would turn off. Additionally, the photoresistor would measure the light value of the environment which was read by the arduino and shown on the

Serial Monitor. If this value fell under 4, then the LEDs would receive power and turn on. However, it was found that by changing the power source, whether that be solar or battery, the functions of the system would fail. When connected to solar panels, the LED lights and motor would stay on permanently. The sensors were reading data and so was the arduino, but the data had no effect on the outputs of the motor or the LEDS. When plugged into a battery, the motor was on and the LEDS were off naturally. The sensor worked as intended, but when the values of light level or red level triggered a response, they would both cause a deactivation in the LEDS. The motor remained on.

Design Choices:

The justification for the red light response in the vehicle was merited on safety. It was hypothesized that if the vehicle could react to a hypothetical red light or stop sign, then it would come to a stop. Being that it is fully self-driving, this is a necessary feature in obeying road laws and avoiding collisions. For the headlight system, the idea was made to mimic the function of all other vehicles. This function is that the car lights turn on when it is dark. This is because darkness reduces the field of visibility which limits reaction time and overall perception. Two characteristics vital to safe driving. Being that this car has no driver, this choice was justified in that it improves the readings of visible light cameras and sensors on the vehicle and it makes the driving experience more comfortable for customers.

Testing and Evaluation

Lessons learned while testing:

Adaptability and troubleshooting circuitry components while inputting our codes:

We experienced malfunctions with our LCD component since it was unable to display our RGB values as planned and we quickly removed the component since it also interfered

with our motors performance.

{Troubleshooting methods: testing the arduino circuit after downloading the code.}

Material compatibility: We found that the alignment of our gears was slightly off , noticing excessive glue residue on the gears, Jamming it completely, disrupting It's functionality.

{Troubleshooting methods: adding our solar panels in a parallel circuit with our gear design in direct contact with sunlight.}

Conclusion

In conclusion, the vehicle design brings elements from luxury SUVs and VIP transport coupled with the robustness and reliability of an offroading SUV. In total, the design comes out to be a luxury vehicle that has the potential to drive on all roads and in any conditions while simultaneously focusing on ride comfort, aesthetics, and a luxury feel. Furthermore, the larger size of the vehicle, and therefore surface area not only gives the interior a spacious, comfortable feel but also gives the vehicle ample area for solar panels to charge the car more than what would realistically be asked of the car in a single day.

The initial problem given was that Sparkyville needed a new and green way to transport tourists from the airport to different areas of Sparkyville and the greater Sparkyville area. What the team came up with not only meets these expectations but crushes them, providing the most luxurious, spacious, and powerful design out of all other proposals. Keeping a simple model in mind, that being "a car" and executing it to perfection. Making the car green by being carbon-neutral with an entirely electric propulsion, relying on zero fossil fuels for any of the vehicle operation. All other designs seemingly tried to "reinvent the wheel" whereas this design

perfected it. Ensuring an extremely safe, comfortable, green, and aesthetic ride for all of the project stakeholders.

If more time and resources were given, the team would have improved multiple things to be flawless. To start, the team would change the transmission, to make a lighter design with less resistance, coupled with a more powerful motor to make the vehicle's drivetrain impenetrable. Then, the team would make a wider chassis out of all metal, ensuring the durability of the car backbone under all conditions. Finally, the team would add more or larger batteries, allowing the vehicle to hold more charge and output greater power, therefore increasing the top speed and overall range of the vehicle.

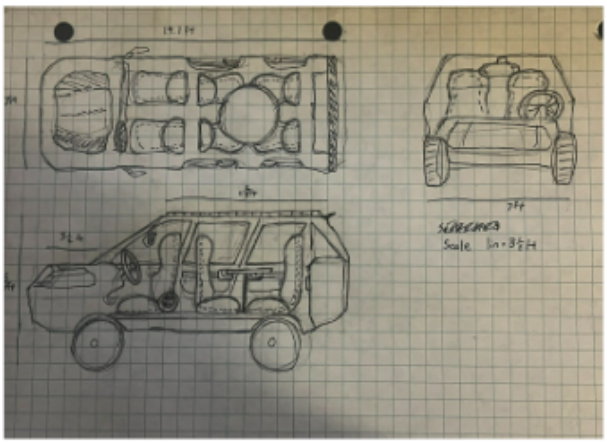
References

"How Vehicle Safety Has Improved over the Decades." *NHTSA*, www.nhtsa.gov/how-vehicle-safety-has-improved-over-decades. Accessed 28 Apr. 2024.

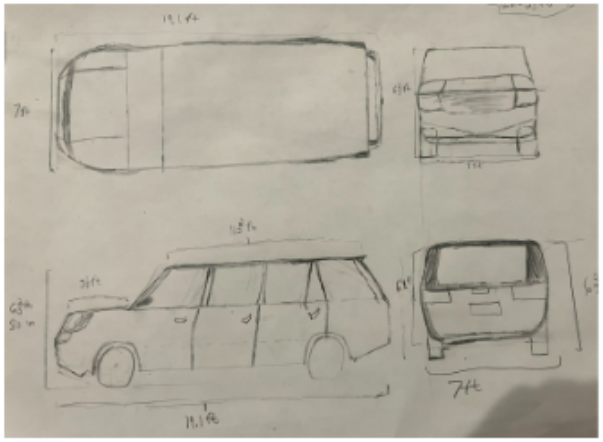
Syed, Zayna. "Air Quality Remains Poor in Phoenix, Where Pollution Outlasted the Pandemic Shutdown." *The Arizona Republic*, Arizona Republic, 27 Dec. 2023, www.azcentral.com/story/news/local/arizona-environment/2021/10/16/phoenix-residents-breathing-bad-air-nearly-half-year/8424313002/.

Appendices:

Appendix A:



Interior



Exterior

Appendix B:

$$Compound\ Interest = P \times (1 + i)^{n}$$

$$ROI = \frac{Net\ Profit}{Initial\ Investment} \times 100\%$$

$$Annual\ Loan\ Payments = P \times \frac{i}{1-(1+i)^{-n}}$$

$$Load\ Power = \frac{Voltage^{2}}{Resistance}$$

$$Solar\ Panel\ Efficiency = \frac{Load\ Power}{Power\ Available}$$

$$\frac{20\ (\text{gear } B_1, B_2)}{10\ (\text{gear a})} \times \frac{30\ (\text{gear } C_1, C_2)}{20\ (\text{gear } B_1, B_2)} \times \frac{50\ (\text{gear D})}{30\ (\text{gear } C_1, C_2)} = 5.000\ (\text{Gear ratio of } 5{:}1)$$

Appendix C:

```
% Author: Von Whipple
% Date: 22 March 2024
% Title: MATLAB Solar Panel Lab
area_solar_panel = 250
Luminance = [43 56 69 82 95 108 121]
Luminous_efficacy = 125
Power_available = (Luminance.*area_solar_panel)/Luminous_efficacy
Voltage = [0.05 0.2 0.35 0.5 0.65 0.8 0.95]
Resistance = 23.8
Load_power = Voltage.^2/Resistance
Solar_panel_efficiency = Load_power./Power_available
```

```
plot(Solar_panel_efficiency,Power_available)
xlabel('Solar panel efficiency')
ylabel('Power available')
```

Appendix D:

```
#include <Wire.h>
#include "Adafruit_TCS34725.h"


// Pick analog outputs, for the UNO these three work well
// use ~560  ohm resistor between Red & Blue, ~1K for green (its brighter)
#define redpin 3
#define greenpin 5
#define bluepin 6
#define motorpin 9
int LightThreshold = 4;
// for a common anode LED, connect the common pin to +5V
// for common cathode, connect the common to ground


// set to false if using a common cathode LED
#define commonAnode true


// our RGB -> eye-recognized gamma color
byte gammatable[256];




Adafruit_TCS34725 tcs = Adafruit_TCS34725(TCS34725_INTEGRATIONTIME_50MS,
TCS34725_GAIN_4X);


void setup() {
  Serial.begin(9600);
  //Serial.println("Color View Test!");


  if (tcs.begin()) {
```

```
    //Serial.println("Found sensor");
  } else {
    Serial.println("No TCS34725 found ... check your connections");
    while (1); // halt!
  }


  // use these three pins to drive an LED
#if defined(ARDUINO_ARCH_ESP32)
  ledcAttach(redpin, 12000, 8);
  ledcAttach(greenpin, 12000, 8);
  ledcAttach(bluepin, 12000, 8);
#else


  pinMode(A1, INPUT);
  pinMode(13, OUTPUT);
  pinMode(11, OUTPUT);
  pinMode(redpin, OUTPUT);
  pinMode(greenpin, OUTPUT);
  pinMode(bluepin, OUTPUT);
  pinMode(motorpin, OUTPUT);
#endif


  // thanks PhilB for this gamma table!
  // it helps convert RGB colors to what humans see
  for (int i=0; i<256; i++) {
    float x = i;
    x /= 255;
    x = pow(x, 2.5);
    x *= 255;


    if (commonAnode) {
      gammatable[i] = 255 - x;
    } else {
      gammatable[i] = x;
    }
    //Serial.println(gammatable[i]);
```

```
  }
}


// The commented out code in loop is example of getRawData with clear
value.
// Processing example colorview.pde can work with this kind of data too,
but It requires manual conversion to
// [0-255] RGB value. You can still uncomments parts of colorview.pde and
play with clear value.
void loop() {
  int lightreading = analogRead(A1);
//Defining the input data as a variable
if (lightreading < LightThreshold) {
digitalWrite(13, HIGH);
digitalWrite(11, HIGH);
}
else {
digitalWrite(13, LOW);
digitalWrite(11, LOW);
/*f the input data is too high (too much light)
then the lights stay off
*/
}
  float red, green, blue;

  tcs.setInterrupt(false);  // turn on LED


  delay(60);  // takes 50ms to read


  tcs.getRGB(&red, &green, &blue);

  tcs.setInterrupt(true);  // turn off LED

  Serial.print(lightreading);
  Serial.print("R:\t"); Serial.print(int(red));
  Serial.print("\tG:\t"); Serial.print(int(green));
  Serial.print("\tB:\t"); Serial.print(int(blue));
```

```
//  Serial.print("\t");
//  Serial.print((int)red, HEX); Serial.print((int)green, HEX);
Serial.print((int)blue, HEX);
  Serial.print("\n");


//  uint16_t red, green, blue, clear;
//
//  tcs.setInterrupt(false);  // turn on LED
//
//  delay(60);  // takes 50ms to read
//
//  tcs.getRawData(&red, &green, &blue, &clear);
//
//  tcs.setInterrupt(true);  // turn off LED
//
//  Serial.print("C:\t"); Serial.print(int(clear));
//  Serial.print("R:\t"); Serial.print(int(red));
//  Serial.print("\tG:\t"); Serial.print(int(green));
//  Serial.print("\tB:\t"); Serial.print(int(blue));
//  Serial.println();



#if defined(ARDUINO_ARCH_ESP32)
  ledcWrite(1, gammatable[(int)red]);
  ledcWrite(2, gammatable[(int)green]);
  ledcWrite(3, gammatable[(int)blue]);
#else
  analogWrite(redpin, gammatable[(int)red]);
  analogWrite(greenpin, gammatable[(int)green]);
  analogWrite(bluepin, gammatable[(int)blue]);
#endif
if (red > 100) {
digitalWrite(motorpin, LOW);
}
```

```
else {
  digitalWrite(motorpin, HIGH);
}
}
```