**Conceptual Designs for the “Hot Car Emergency”**

**Project Group B2**

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# Introduction

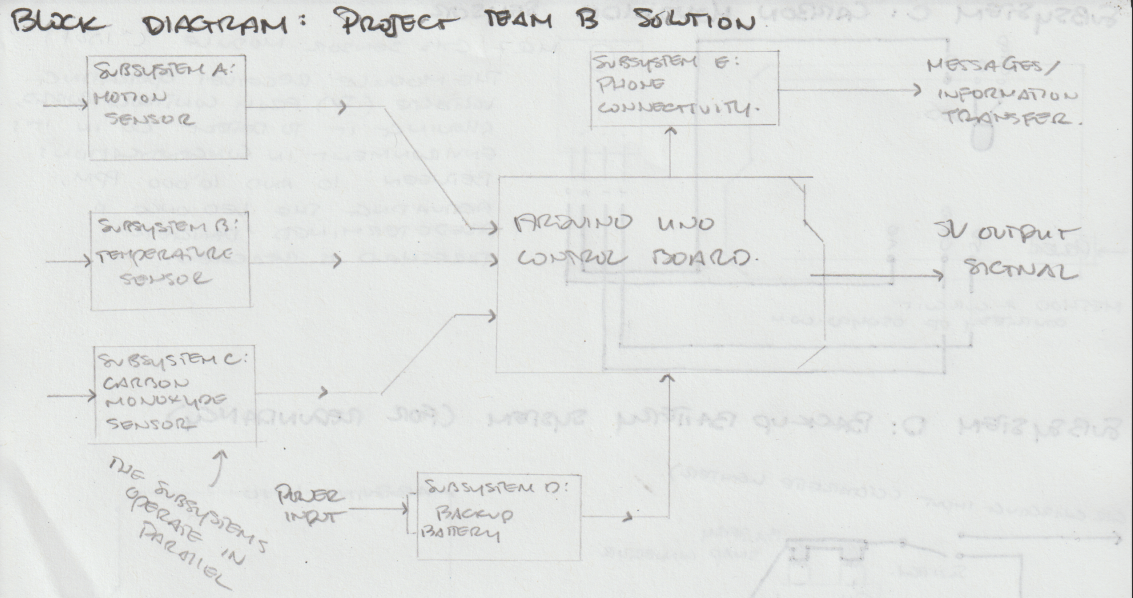
The problem statement created in Deliverable B is that *parents and legal guardians in the UAE require an affordable, intuitive, and easy to install device to ensure the safety of a vehicle occupant in dangerously high temperatures and CO levels*. An initial list of needs for this device was created and translated into design criteria, which was then compared to other similar products via technical benchmarking in Deliverable C. With this meticulous information crafted in the past deliverables, the group was able to divide the overall device into 6 main components, or *subsystems*. The first is to sense a vehicle occupant, the second and third are sensors to detect dangerous conditions (CO and temperature levels), the fourth is to ensure the device will run when the car is off, the fifth is to make sure the parent or guardian is notified of these conditions, and the sixth is to alarm bystanders of the vehicle occupant in the dangerous conditions of the car. These subsystems target every functional requirement determined in the last deliverable, and can meet every non-functional requirement and constraint.

In this deliverable, with requirements in mind, every group member developed their own concept for each subsystem that can work in tandem with any other concept of different subsystems using an Arduino. After rigorous analysis, the best subsystems were combined into three solutions. These solutions went through the second round of analysis to finally determine the optimal solution.

| **Subsystem** | **Designation** | **Definition** |
| --- | --- | --- |
| Occupant detection | Subsystem A | Motion sensors, vibration sensors, or other technical infrastructure intended to detect vehicle occupants. |
| Condition detection, Temperature | Subsystem B | Temperature sensor modules intended to detect ambient conditions in a vehicle, and weigh them against pre-outlined safety margins to assess environmental safety. |
| Condition detection, ambient CO | Subsystem C | Carbon Monoxide sensor modules intended to detect ambient CO concentrations in a vehicle and weigh them against pre-outlined safety margins to assess environmental safety. |
| Redundant battery system | Subsystem D | Power supply system designed to ensure continual operation of the solution and all its attached equipment independently of outside power sources. |
| Mobile connectivity | Subsystem E | Communications and connectivity infrastructure designed to send information, alerts and warnings to smartphones and mobile devices |
| Alarm system | Subsystem F | Light and speaker arrays designed to alert bystanders outside the vehicle of potentially dangerous conditions inside the vehicle |

*Table 1: Subsystem definitions*

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This block diagram describes the interactions between the subsystems and the Arduino control board and lists the inputs and outputs of the system.

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| **Subsystem** | **Person** | **Sketch** | **Description** |
| --- | --- | --- | --- |
| Occupant detection  ( A ) | Lauren |  | The overall concept for my drawings is a rectangular device with an LCD on the front, and sits like a GPS on the car's dashboard to ensure a full view of the backseat. Inside the 'box' of the device is an Arduino, which is connected to the exposed sensors on the outside of the box. My drawings describe the inside systems. For the motion sensor, a PIR sensor is used in this design. It uses infrared to detect human presence. It will be placed on the front of the device to have a circle view from the centre of the car. A potential flaw is that it cannot see the entirety of the car's insides, and could possibly miss a small child tucked into a corner of the backseat. More notes on the design are on the sketch. |
|  | Jake |  | This concept outlines a standalone, self-adhesive motion sensor attached to the main Arduino case body via wires. This peripheral configuration allows the motion sensor to be placed in an optimal position to detect movement in the back seat of the vehicle, keeping the front seats in range, and giving the operator flexibility in where they choose to store the device's core. |
|  | Qaswar |  | This design utilizes a PIR motion sensor to detect occupants in the vehicle's back seats when the car is locked. The sensor is built into the device, placed on the center console between the driver and the passenger seats. |
|  | Navi |  | This concept outlines a design for a clip-on, modular motion detector to be fitted on the air conditioning vents of the vehicle’s front console. This system allows for the motion detectors to be fixed securely and cheaply to the inside of the vehicle without requiring permanent modifications to the dash of the car or the air vents. |
| **Thermal Sensor**  **(B)** | Lauren |  | This is a sketch of an Arduino inside the device. A small opening of the rectangular device will expose a thermistor that will read the car's temperature, sending a signal back to the Arduino. A potential flaw in this design is that it sits on the dash, which may be hotter if the car has been recently used and is now parked. More notes on the design are on the sketch |
|  | Jacob |  | This circuit diagram outlines a potential execution for a temperature sensor design. Using the TMP36 temperature sensor allows the device to get accurate readings of temperatures from -40oC to 150oC - making this design adequate for cold weather conditions. The built-in LED could be installed near a window, and would alert bystanders of the occupant’s distress. |
|  | Qaswar |  | This sketch of the temperature sensing system uses a TMP 36 sensor, an Arduino UNO, and some hookup wires. This system aims to detect the temperature inside the car and determine if an occupant would be safe in that temperature. A small opening on the side of the device will expose the sensor to record an accurate temperature. |
| **CO Sensor**  **( C )** | Lauren |  | This is a sketch of an Arduino inside the rectangular device sitting on the dash (see my conceptual design in subsystem 1 for more context). A MQ7 probe will be exposed from the rectangular device, and connected to the Arduino inside. It can detect CO in the air from 20 to 2000ppm. More notes on the design are on the sketch. |
|  | Jake |  |  |
|  | Qaswar |  | This system design uses a MQ2 gas sensor that is able to detect the concentration of Carbon Monoxide in the air. The sensor will be able to determine if the car occupant is in danger or not. |
| **Continual Operation Mechanism**  **( D )** | Lauren |  | This is a sketch of an Arduino inside the rectangular device sitting on the dash (see my conceptual design in subsystem 1 for more context). This plan for continual operation is a battery-operated Arduino that can be recharged using the 5V battery in the car and uses standard batteries. A significant flaw in this conceptual design is that it is not very optimized. The system to charge the battery is difficult to design within the scope of my abilities. A simpler design would be better. More notes on the design are on the sketch |
|  | Jacob |  | This redundant battery system allows the Arduino board to remain in continual operation over an undetermined period. The board would draw it’s operating voltage from the battery at all times during operation, and the car’s 12V connection would continually charge the battery while the engine is running - effectively topping up the battery every time the car is driven, to ensure it will have enough reserves to work once the driver reaches their destination. Switches in the circuit also allow the Arduino to be shut off during installation and servicing. |
|  | Qaswar |  | The purpose of this system is to keep the device operating at all times. To achieve this, we will have the device operating off rechargeable batteries placed in a rechargeable battery case connected to the car cigarette lighter. While the car is running, the batteries will be charged and supplying the energy needed for the device to operate. While the engine is off, the batteries would be charged and ready to provide the voltage required for many hours. |
| **Mobile Communication**  **( E )** | Lauren |  | This is a block diagram of the theoretical concept of this Arduino system. The data collected from the sensors (motion, CO, and temperature) are sent to the Arduino, which is sent to a downloadable app for iOS and Android, which can send push notifications to a user's phone. There are two flaws in this design. Firstly, the app would be a necessary third-party download for users, which may decrease the effectiveness as not everybody would download it. Secondly, this system is currently being beta tested on Arduino forums, and maybe a gross undertaking. More notes on the design are on the sketch. |
|  | Jacob |  | This design utilizes already-existing Arduino libraries and telecommunications infrastructure to send relevant data about the status inside the car to the driver’s smartphone. It utilizes the Telefonica GSM/GPRS shield, and requires an activated SIM card to send the messages. |
|  | Qaswar |  | This system uses the SIM800L GSM/GPRS module, which can be used to send SMS text messages to another device. We will be using this to contact the guardian and alert them about the occupant locked in the car. A sim card needs to be purchased for this system to function. |
| **Alarm System**  **( F )** | Lauren |  | This is a block diagram of the theoretical concept of this Arduino system. The Arduino receives signals from the sensors, and if the conditions are dangerous enough, it will emit sound from a buzzer (which can be disarmed from a keypad) connected to the Arduino. A flaw in this design is a necessary running wire so that the sound is audible from outside the vehicle. This is risky in it getting damaged and is not aesthetically pleasing. |
|  | Jacob |  |  |
| **Navi’s ( Subsystems (B, C, D, E)** |  |  | The idea behind this design concept was so that all the material was in a concise location undisturbing or interfering with any of the patients regular use of the vehicle. Most parts necessary to build the model were to be located in a box, to be placed under the radio. This main ‘home box’ would be plugged into the car’s readily available automobile auxiliary power outlet, as the ‘home box’ has an adapter that is located on the back. Also located on the back is a location in which the battery is accessible (Ideally I would recommend that the battery used for this device be a lithium ion battery, as they are thin, able to stay charged for a long time, they are rechargeable, as well as have a lifespan for about ⅔ years). This is done to keep the device functionable at all times if possible. As the ‘home box’ would be plugged into the car it is possible for the device to be charging while taking power for usage. Through this mechanism the device will be able to function for long amounts of time over a long period of time, with repeated use. The CO sensor is also to be located on the sides of the box. There are vents located on the sides so that the air paces through the box, for the mechanisms to work to try and detect if the CO levels within the vehicle are a safe environment for children to be in. [The possible disadvantages to this is that the device (‘home box’) itself would generate a degree of heat which could possibly trick the sensors. A possible altercation and/or fix is to have a CO sensor connected with a cable to the box and attached in a different location within the vehicle. This ensures that the device will work better however the negative to this possible fix would be cable management. It is to be determined which idea is more suitable.] Finally is the alarm system. The alarm system itself is to be attached to the main ‘home box’ within the sides. This would be an ideal location as it would be in the center with much space for the sound to bounce / reach. The concept of this design is to make sure that if any passenger was in safety, this sound alarm would alert passerbys, gaining their attention to help the passenger. This would most likely work as a loud alarm sound, as well as i suggest there being a recorded message played at intervals. The recording can alert the passerbyers as to what the situation is. In most situations people would not want to walk towards someone just screaming, however they would approach someone screaming for help. A possible disadvantage for this however, is how this loud sound alarming system would affect the passenger. Though the passenger may be startled and/or scared it is done to ensure their safety. (prioritizing safety over comfortability.) |

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# Solution Benchmarking

Occupant Detection

| **Specification** | **Importance (scale of 5)** | **Propositions** | | | |
| --- | --- | --- | --- | --- | --- |
| Lauren | Jacob | Qaswar | Navi |
| Sensor model | -- | HCSR-501 | HC-SR505 | HC-SR04 | LV-EZ1 |
| Sensor accuracy | 4 | 7-meter radius | 3-meter radius | 4.5-meter radius | 6.45-meter radius |
| Price (± 10%) (CAD) | 3 | 12.95 | $3.50 | $3.95 | $32 |
| Execution complexity | 2 | Complex | Simple | Simple | Complex |
| Relative Size | 1 | ~2cm x 3cm x 3cm | ~ 2cm x 1cm x 4cm | ~ 6cm x 2cm x 3cm | ~2cm x 2cm x 2cm |
| Total score: | | 24 | 22 | 21 | 18 |

*Table 2: Team-generated solution benchmarking for subsystem A*

Temperature Sensor

| **Specification** | **Importance (scale of 5)** | **Propositions** | | | |
| --- | --- | --- | --- | --- | --- |
| Lauren | Jacob | Qaswar | Navi |
| Sensor model | -- | NTC Thermistor | TMP-36 | TMP-36 | DS18B20 |
| Sensor accuracy | 4 | -200 to 600 C | -40 to 150c | -40 to 150c | -55 to 125c |
| Total price | 3 | $0.95- $3.00 | $1.50 | $1.50 | $2.66 |
| Circuit complexity | 2 | Simple | complex | complex | Very complex |
| Relative Size | 1 | Very Small | Small | Small | Very large |
| Total score: | | 24 | 25 | 25 | 13 |

*Table 3: Team-generated solution benchmarking for subsystem B*

CO Sensor

| **Specification** | **Importance (scale of 5)** | **Propositions** | | | |
| --- | --- | --- | --- | --- | --- |
| Lauren | Jacob | Qaswar | Navi |
| Sensor model | -- | MQ7 | MQ7 | MQ2 | BME688 |
| Sensor accuracy | 4 | 10 to 10’000 ppm | 10 to 10’000 ppm | 300-10’000 ppm | 0.92 F1 score |
| Total price | 3 | $1.50 -$4.00 | $1.50 -$4.00 | $2.00 - $8.00 | $19.95 |
| Circuit complexity | 2 | complex | complex | Simple | Complex |
| Relative Size | 1 | ~5cm x 5cm x 5cm | ~5cm x 5cm x 5cm | 13cm x 9cm x 3cm | large |
| Total score: | | 26 | 26 | 18 | 18 |

*Table 4: Team-generated solution benchmarking for subsystem C*

Continual Operation System

| **Specification** | **Importance (scale of 4)** | **Propositions** | | | |
| --- | --- | --- | --- | --- | --- |
| Lauren | Jacob | Qaswar | Navi |
| Battery Model | -- | AA Rechargeable Batteries | NH22NBP 9v battery | AA Rechargeable Batteries | Kodak M531 |
| Lifespan | 4 | 400 charge cycles | <100 charge cycles | 400 charge cycles | 300 - 500 charge cycles |
| Total price | 3 | $19.99 | $15.99 | $19.99 | $6.99 |
| Complexity | 2 | Simple | complex | Simple | Very complex |
| Relative Size | 1 | small | large | small | Very small |
| Output voltage | -- | 1.5V | 9V | 1.5V | 3.7V |
| Total score: | | 18 | 18 | 18 | 26 |

*Table 5: Team-generated solution benchmarking for subsystem D*

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Mobile Connectivity

| **Specification** | **Importance (scale of 5)** | **Propositions** | | |
| --- | --- | --- | --- | --- |
| Lauren | Jacob | Qaswar |
| System model | -- | Pushsafer | Telefonica GSM/GRPS shield | SIM80L GSM/GPRS Module |
| Message range | 4 | unlimited | unlimited | unlimited |
| Total price | 3 | Free (but possible underlying costs for the app) | $22.99 | 15$ |
| Circuit complexity | 2 | complex | *Very* complex | Moderately Complex |
| Relative Size | 1 | small | *Very* large | Large |
| Total score: | | 26 | 18 | 24 |

*Table 6: Team-generated solution benchmarking for subsystem E*

Alarm System

| **Specification** | **Importance (scale of 5)** | **Propositions** | | |
| --- | --- | --- | --- | --- |
| Lauren | Jacob | Navi |
| Alarm system | -- | PS1240 Buzzer | LED array | EK1887C |
| Alarm range | 4 | 59 dB at 10cm | 11000- 13000 mcd | 2 Watts - 93dB at 1 meter |
| Total price | 3 | $1.05 | $7.05 | $9.26 |
| Circuit complexity | 2 | Simple | Simple | Very complex |
| Relative Size | 1 | small | small | Very large |
| Total score: | | 26 | 19 | 21 |

*Table 7: Team-generated solution benchmarking for subsystem F*

| **Subsystem** | **Design proposition total score** | | | |
| --- | --- | --- | --- | --- |
| **Lauren** | **Jacob** | **Qaswar** | **Navi** |
| **A** | **24** | **22** | **21** | **18** |
| **B** | **24** | **25** | **25** | **13** |
| **C** | **26** | **26** | **18** | **18** |
| **D** | **18** | **18** | **18** | **26** |
| **E** | **26** | **18** | **24** | **n/a** |
| **F** | **26** | **19** | **n/a** | **21** |
| **Total** | **144** | **128** | **106** | **96** |

*Table 8: Design evaluation scores for each subsystem proposition*

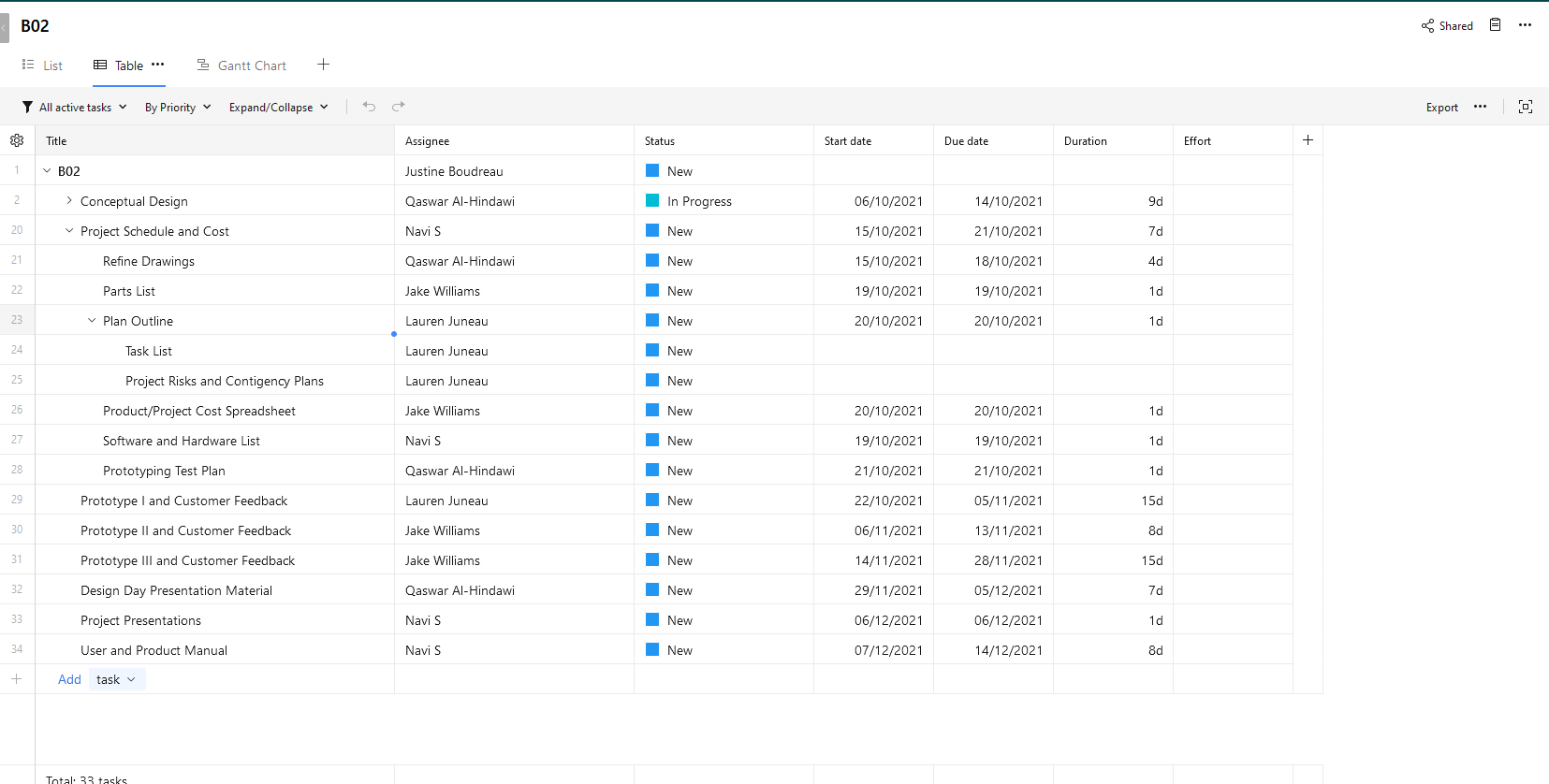
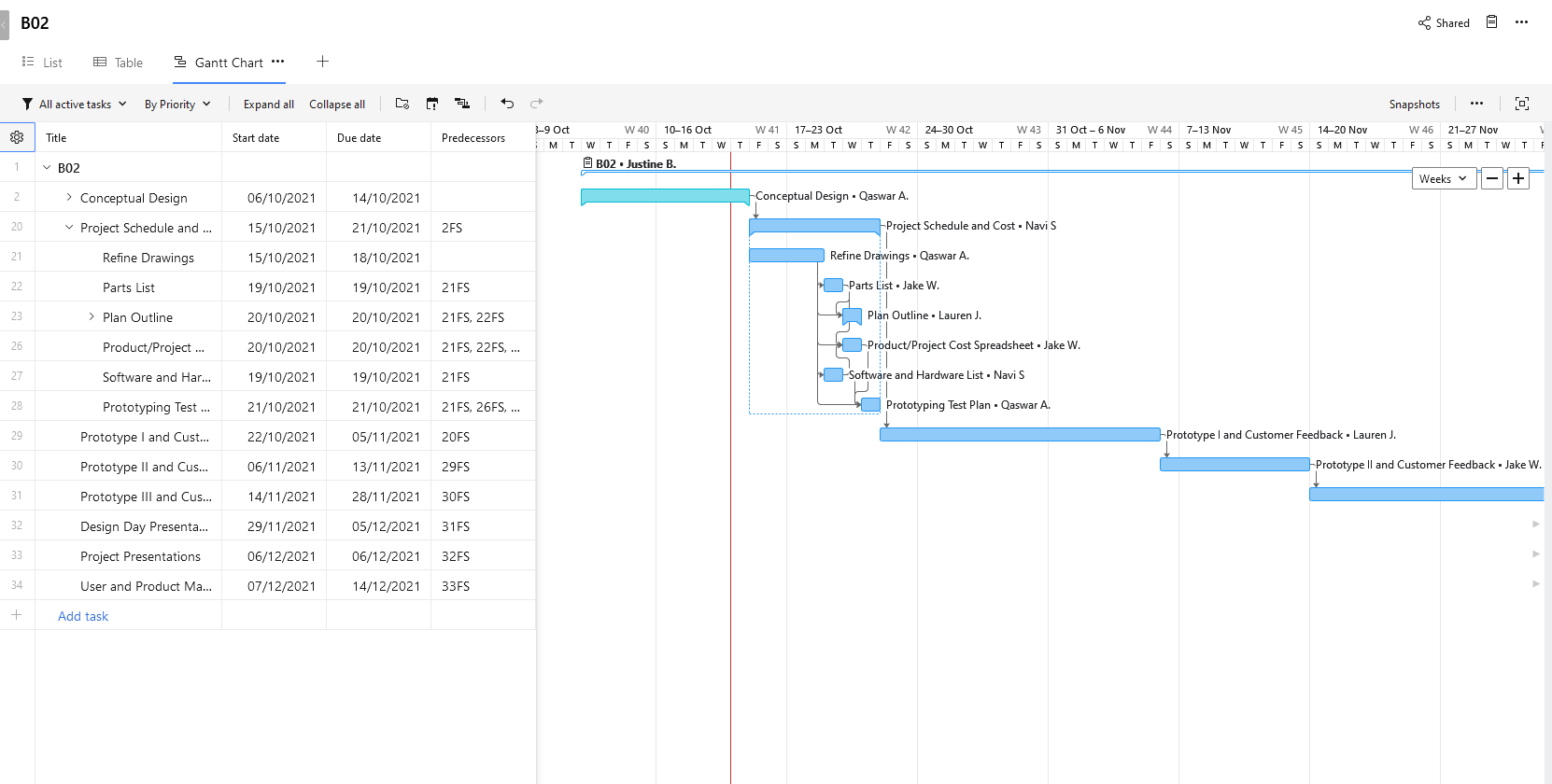
# Optimal Solution/Conclusion

In this portion of the project, several potential designs were outlined for every subsystem required on the solution. These propositions were then analyzed to determine their relative prices, circuit complexities, coding complexity, volume/size and sensor effectiveness, and scores were attributed accordingly. The results of these analyses were compiled in a series of benchmarking tables, and proportions ranked according to their overall score.

Based on the scores attributed in the benchmarking process, the best configuration of subsystem design propositions are the designs proposed by Lauren, with a total benchmarking score of 144 points. However, some of the other members' ideas should be implemented to optimize the final design. We have decided that a combination of Laurens Motion sensor, Mobile connectivity, Carbon monoxide detection, and Alarm subsystems with Navi's Continual operation and Jake's Temperature sensor subsystems will give us the best solution.

While the other occupant detection designs could work, the motion sensor used in Laurens design has the largest detection radius, which could be useful in small and large vehicles. We also considered using Jake's LED alert design. However, we ended up deciding that a sound alert would be more effective when alerting bystanders about the locked child. To minimize the cost without lowering the quality of our product, we will use a free android application that receives data from the Arduino and send notifications to the user's mobile phone. By considering all these factors, the combination of all these components represents the best possible combinations of available options.

Wrike Update

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*Higher quality images will be submitted alongside this document in a .pdf file*