MECH 2412

Conceptual Design Report

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Introduction:

This report was conducted for the MECH 2412 Mini Design Project course offered as a part of York University's Mechanical Engineering program. The course has four major learning outcomes, being machine shop practice, conventional machining methods, digital modelling and applying the three aforementioned learning outcomes to work in a group to design for a problem. This project embodies the last learning outcome The objective of this report is to outline the beginning of the course-long project and all the research and ideas that form the base of this project. The initial goal of the project was to design a "go-kart" like vehicle. Due to the enforcement of the "go-kart" archetype not being strict, our group decided to stray away from the idea of just making a race car and make something more practical.

The details of this report will include the analysis of three different audiences. The first being the stakeholders, the people that will be directly and indirectly affected by the new design. The second would be an analyst of the market and lastly would be the product design itself, to see if it is viable. This report will also include brainstorming of the design and drawings of our proposed vehicle. By the end of this report, a clear idea of what we want to be developed will be painted.

1.0) Problem Background and Context:

Recently, hiking around the areas outside of the GTA, like the Limehouse Conservation Area, have been very popular after people are recovering from the pandemic. This means those hiking trails have been flooded with people looking to take in the fresh air. As a result of this, the hiking trails outside of the GTA have seen an influx of injuries and missing people. It is believed that horseplay and negligence are the main causes of most of these cases because people have been cooped up in their houses for so long. Nevertheless, there are countless people that are lost, with families waiting for their return.

However, the provincial government of Ontario can only send so many search and rescue teams before they lose too much manpower. There is also the concern of the cost of the rescue teams over the span of several months, which would cost a relatively significant amount of the provincial budget for services. While the government will still dispatch human search and rescue teams, the government has hired an engineering firm to develop a technology that will help the search and rescue locate people more easily without bringing danger to themselves. The engineering firm in turn hired the students at York University to design a programmable emergency aid robot of sorts with a few guidelines like having collision avoidance and being controlled by an arduino.

This kind of search technology is necessary due to the limitations of the human body. First off, the human body is relatively fragile when compared to a machine. A single fall could break a bone and render a whole limb unusable. While the one in danger is the victim, the search party is in the same danger trying to find them. This means, the proposed design must be rugged enough to take many falls without going offline. Machine recognition has gotten better over the past few years, so much so that it exceeds the human eye. With artificial intelligence, the proposed design would be able to spot victims more swiftly and efficiently than a human, saving both time and money.

2.0) Stakeholders and Stakeholder Analysis:

Stakeholder	**Connection to the Problem**	**Importance**	**Needs of Stakeholder**
Hikers	They are directly affected by the problem, they are at risk of getting lost or injured.	High	Safe and well-maintained hiking trails, and effective emergency response systems.
Provincial Government of Ontario	They are responsible for ensuring the safety of the public and managing the search and rescue operations.	High	Cost-effective and efficient solutions, ensure public safety
Search and Rescue Teams	They are the ones dealing with the problem firsthand. This technology could assist them in their operations.	High	Effective tools and technologies that can aid in their operations, and ensure their safety
Engineering Firm	They are hired by the provincial government to develop a technology solution to the problem. They have a financial and professional stake in this.	Medium	Clear guidelines and requirements, and adequate resources to develop their solution

Students at York University	They are tasked by the engineering firm to develop the emergency aid robot. They have an academic and professional stake in the project.	Medium	Clear project guidelines, adequate resources, and support from the university
General Public	They have a general interest in public safety and the resolution of the problem. They have the potential to become direct stakeholders if they go hiking.	Low	Assurance about public safety, transparency about measures taken to address the solution.
Emergency Medical Services	They are the first responders who provide medical treatment to the injured/lost hikers. The proposed technology could assist them by providing them with initial medical aid, reducing response time.	Medium	Effective communication with the search and rescue teams, tools and technologies that can aid in their operations.

3.0) Market Analysis:

There are existing products on the market that meet the needs of stakeholders, such as a variety of search and rescue equipment and autonomous robots designed for emergency aid.

Search and Rescue Equipment: Companies like CMC Pro and Cascade Rescue offer a wide range of search and rescue equipment, such as harnesses, hardware, anchor devices, etc. These tools are designed to aid in any rescue operations (*Search & Rescue (SAR)* 2024). However, these tools require human operation and aren't suitable for all terrains/weather conditions.

Emergency Aid Robots: There are several examples of rescue robots which have been developed to assist in emergency situations. For example, Pliant Energy Systems have developed a robot called Velox, which can navigate through water, ice, and snow (Gossett, 2024). Hydronalix developed a remote controlled robot called EMILY, which acts as a lifeboat. These robots can fulfil the stakeholders needs, but they may be out of budget.

Autonomous Vehicles for Rescue: There are autonomous vehicles specifically designed for rescue operations. Such as Fotokite Sigma, which is an advanced unmanned aerial system designed to support first responders (*Fotokite Sigma* 2024). This robot is fully autonomous and actively tethered, allowing safe and reliable operation through any weather conditions. But once again, they are out of the stakeholders budget (cost upwards of $60k USD), as they want mass production of their equipment.

While these products offer valuable assistance in search and rescue operations, they do not fully meet the specific needs of our stakeholders. The proposed programmable emergency aid vehicle could fill the gap by combining the capabilities of these aforementioned products with additional capabilities such as flares, a built-in speaker, and GPS.

4.0) Design Objectives:

Primary Objectives:

There are **2** primary objectives.

Durability and Reliability:

- ➔ *Regular Maintenance:*
  - ◆ The vehicle is going to travel off-road most of the time so it has to be very consistent with its performance.
  - ◆ Has to go on without failure in harsh conditions.
- ➔ *Material Selection:*
  - ◆ This means the quality of the materials used has to be robust.
  - ◆ So it can withstand the wear and tear and environmental conditions like mud, rocks, water.
  - ◆ We would avoid using corrosive material as they would not last very long in such conditions.
- ➔ *Weight Distribution:*
  - ◆ A strong but lightweight material is going to be used for the design of the body.
  - ◆ As it is going to be fixed with some, but very important systems such as the battery and control system and the backup systems.

Carrying Capacity:

- *Space Optimization:*
  - The prime purpose of the vehicle is going to be transporting emergency aid.
  - Proper compartmentalization for the body so maximum supplies can be carried with the least amount of damage to the product.
  - Such as medical supplies, water, food and even trained personnel amongst other things that are required in such dire situations.
- *Load Distribution:*
  - We have to keep the weight of the system to a minimum.
  - As the main focus is going to be on maximising the storage capacity WITHOUT compromising its performance as both of these things go hand in hand.
- *Adjustability:*
  - We have to consider all the things that can be needed in such emergency situations.
  - All of the supplies that's going to be carried.
  - So have to make it adjustable to support all that

Secondary Objectives:

Energy Efficiency:

- *Driving Force Efficiency:*
  - Selecting the motor that can cover more distance with less fuel weight or battery weight.
  - And that it has ample power to carry that aid through the rough atmosphere.
- *Aerodynamic:*
  - We have to keep drag force to a minimum so less energy is wasted.

Sustainability:

- *Eco-friendly material:*
  - Selecting material which has least amount of negative impact on the environment in the long run
- *Transportation:*
  - Easy to disassemble so it can be transported around easily.

Interface and control:

- *Elementary Control System:*

- Easy to understand controls so can be used over easily in high stress conditions.

➔ *Flexibility:*
- Customization of controls for different users or conditions.

5.0) Requirements:

Requirement Type	Requirement	Source	Validation Approaches and Timing
Functional	The safety vehicle will contain necessary items to help someone survive in the wild. It will be equipped with a first aid kit, flare gun kit (1 flare gun and 4 flares) , 1 walkie talkie connected to the nearest Search and Rescue network, 12 energy bars, 4 two litre water bottles, map of the park/region, 1 compass, 2 flashlight, 1 whistle, and 1 rope as well as other necessary items specific to the climate and region where the lost individual is. Once it reaches the individual the container will be automatically unlocked.	Hikers, General Public, Provincial Government of Ontario, Search and Rescue Teams	A container will be designed that can be attached to the search and rescue vehicle. It will be tested to ensure it can fit all the necessary items mentioned while also having extra storage for any items the lost individuals have with them. It will go through terrain tests to ensure the container does not fall off or open. It will also be designed with strong locks and materials to ensure animals do not break it. The earliest test point is once the design phase has ended and prototypes of the design are built. The latest test point is after the final vehicle design has been fully built.
Functional, Interface	The safety vehicle will be equipped with a GPS tracking system that will notify nearby Emergency Services of its location at all times. It will also have speakers that can be activated by the lost individual or by the Rescue Team that will release a sound notifying nearby search teams of the vehicle's location. Once the vehicle finds the lost individual, it will automatically notify the search and rescue teams and emergency services.	Hikers, Search and Rescue Teams, General Public, Emergency Medical Services	To validate these features the vehicle will be placed in multiple hard to reach areas where it will usually be deployed (mountains, deserts, forests, etc.). There the GPS features will be tested to ensure it is accurately showing the vehicle's precise location. “Practise runs” will also take place during testing to ensure the vehicle is able to identify the lost individual and stop where they are. The speakers will also be activated with people standing certain distances away to ensure it can clearly be heard. The testing can begin during the design phase when we are looking for the best

			devices (GPS, speakers, etc.). The latest testing can begin at the end of the design phase as the final choices for the GPS and speakers will affect the vehicle's design.
Economic, Regulatory	The vehicle's design must be cost effective and meet the budget placed by the Government of Ontario and Engineering Firm. The materials used can not be expensive while also ensuring the vehicle functions as desired. It will have to remain durable enough to survive obstacles and animal encounters while searching. The communication devices must also be kept safe and function properly at far distances. Making the vehicle cost effective can make it easier to produce more if the design is approved. This will decrease the number of people needed to be sent to search and help find the missing individuals faster.	Provincial Government of Ontario, Engineering Firm, Students at York University	Calculations on the max stress and strains applicable to the chosen materials will be conducted to ensure it can survive damage. Physical tests will also be conducted where the vehicle is hit and dropped to see how it is affected or deforms. In depth calculations and tracking on the material spendings for the device will be done before beginning production to ensure the team stays within budget. The earliest testing and calculations can begin during the design phase as the materials and costs will affect the vehicle's design. The latest durability testing can begin after the design phase with prototypes of the vehicle.
Functional	The design of the search and rescue vehicle must be able to traverse any terrain and obstacles it can encounter. The vehicle will have All-Terrain wheels with a flexible suspension system to allow it to go over small objects. The structural materials will be durable enough to survive falls and animal attacks. In the case the vehicle reaches an obstacle it can not pass, it must be able to find another route. It will also need a strong and long lasting battery to maximise the distance and time it can search.	Hikers, General Public, Provincial Government of Ontario, Search and Rescue Teams	The vehicle will go through different terrain tests to see how fast and easily it can move. Obstacles will also be placed in front to examine how it goes over and moves around if needed. It will also be dropped from multiple different heights as well as being hit by rocks and other objects to test its durability. The vehicle will be put to run for as long as it can to test its battery life and determine the maximum distance it can travel. The testing can begin during the design phase as we test different wheels and materials to choose. The latest testing can begin once prototypes have been built.

6.0) Constraints:

Materials:

- Specific materials needed for the vehicle
- Durable material
- Lightweight materials

Components:

- Components not to depend on each other in case of any accident.
- Vehicle should be able to work without a couple of easy to break components

Size:

- Smaller vehicles are more manoeuvrable.
- Hence, smaller than a hatchback car.
- Maximum space for one person with the aid.
- Should be accessible to remote areas without any difficulties.
- Have to consider how the vehicle will be stored and transported to the areas of the operations

Modularity:

- The assembly and disassembly of the vehicle has to be simple.
- Has to be easily maintainable
- Should be easily customizable
- Like addition of new technology or removal of old one

Remotely controlled integrated:

- Has to be controlled remotely from a good distance.

Safety Standards:

- Has to comply with all the national and international off-road vehicle safety rules and regulations so the market can be expanded.
- The safety of all personnels involved has to be accounted for.
- The safety of the product has to be considered very seriously as that will affect the outcome of the mission.

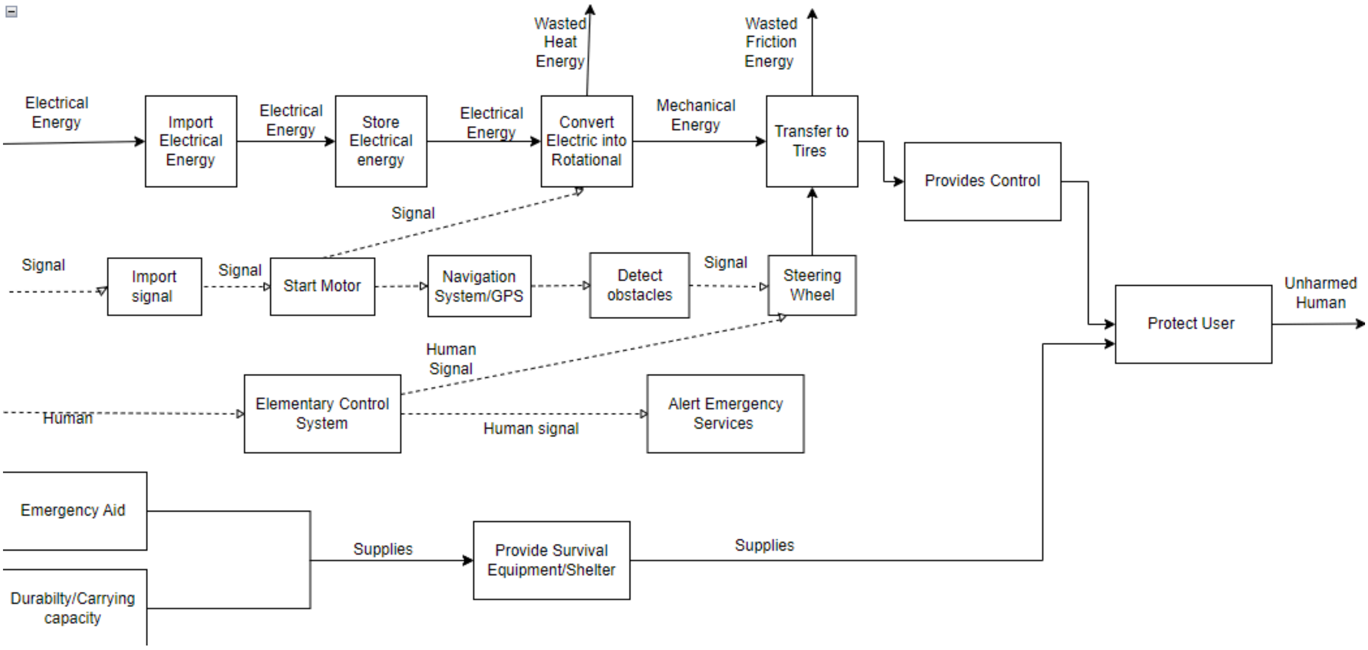
Environmental Impact:

- Sustainable material should be used.
- Biodegradable so less severe impact on the environment.

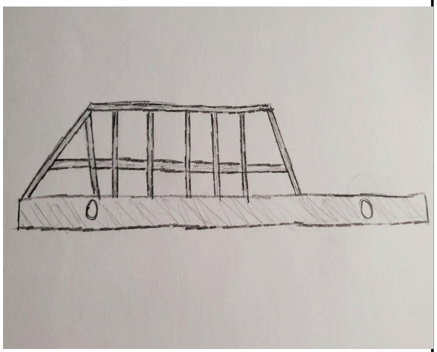
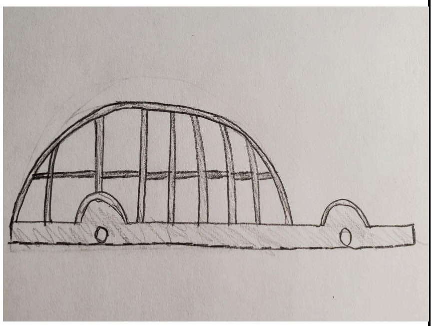
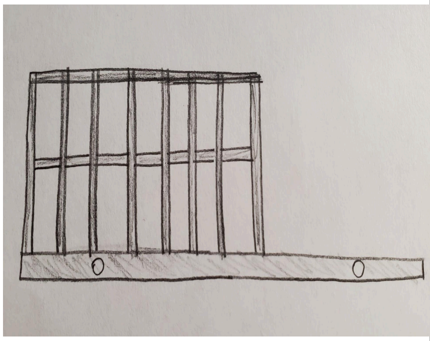
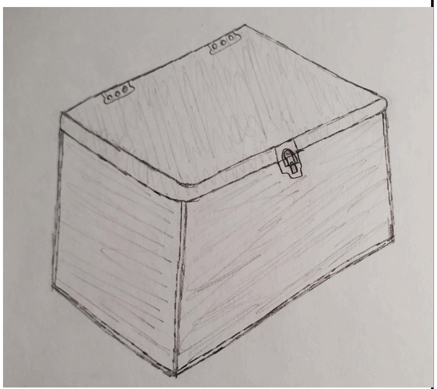
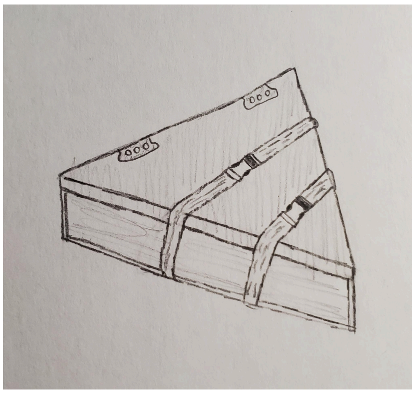
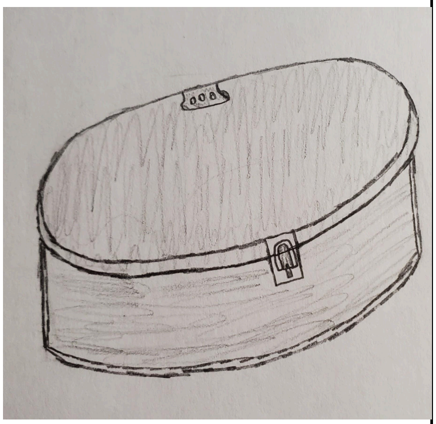
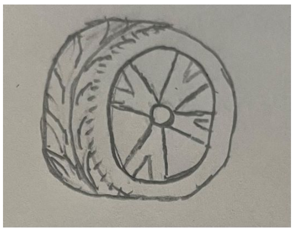
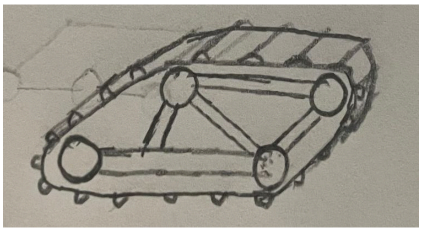
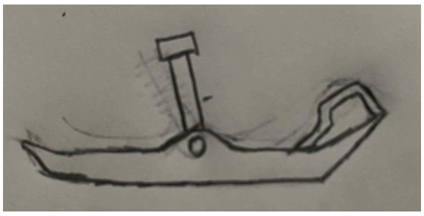
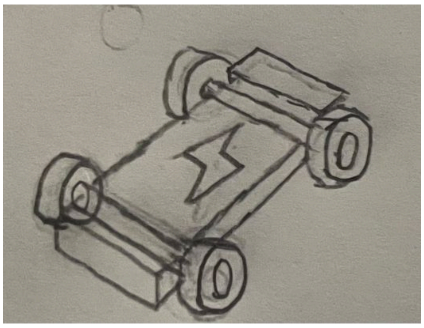
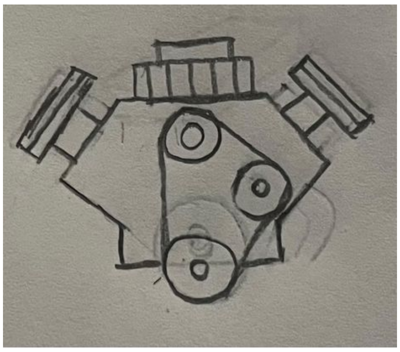
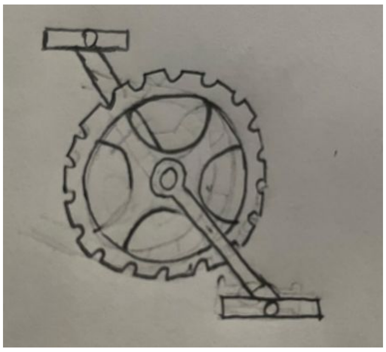
User Requirements:

- Vehicle must meet the very specific needs for aid deliveries.
- It should be easy to operate
- Should be able to be maintained easily in the field.
- Less prone to problems affecting longevity.

7.0) Function Structure Diagram:

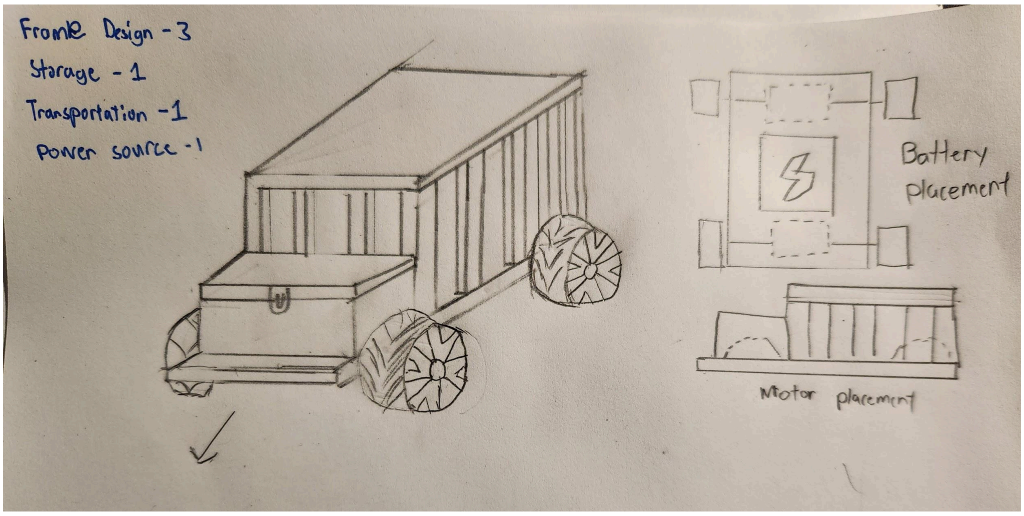


8.0) Morphological Chart:

	Option 1	Option 2	Option 3
Frame Design			
Storage			
Method of Contact with Ground			
Power Source			

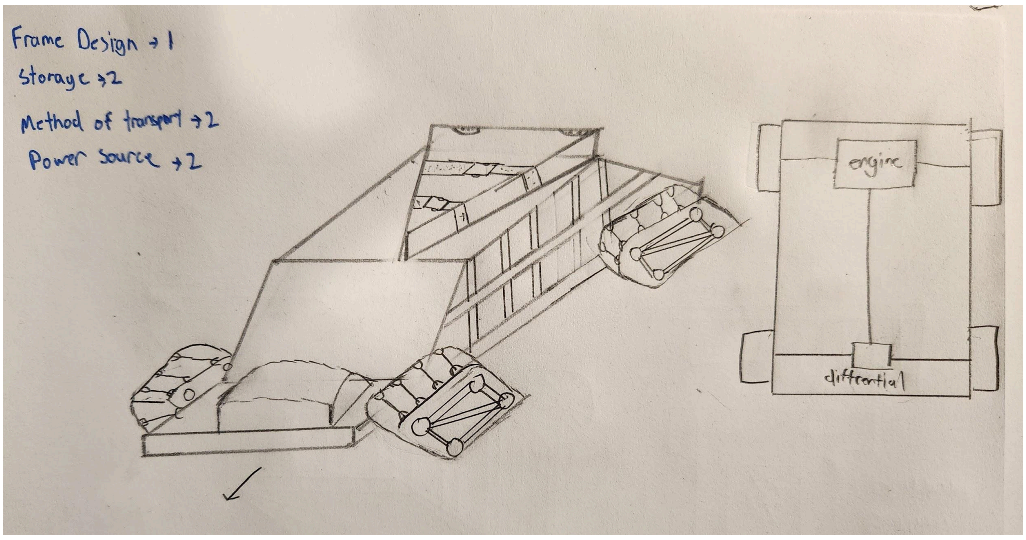
9.0) Conceptual Designs:

9.1) Proposed Design 1:



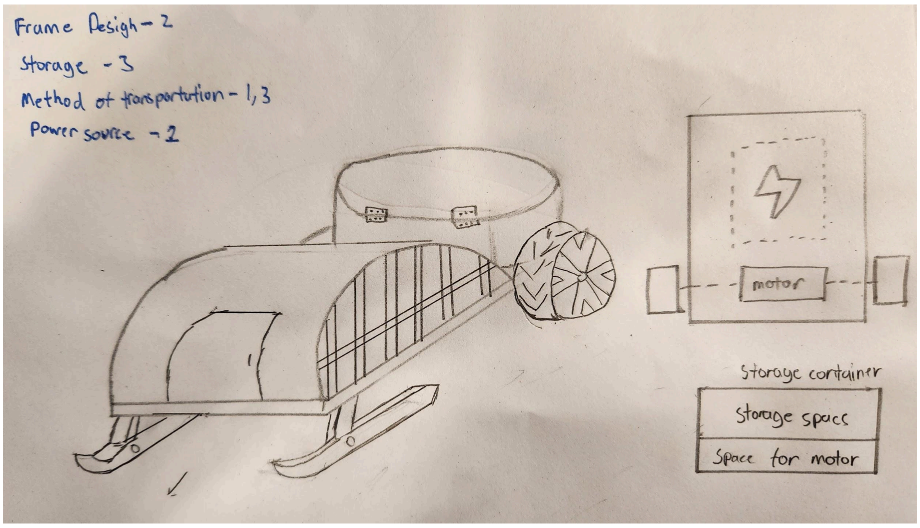
This design features the storage container facing the front with the square/rectangular frame in the back. The power source for this design was to go with a battery and electric motor, this would have to create a few bumps in the frame. The other electronics would also need to be stored in the storage container, however, it will be covered with an access door for both providing a flat bottom for the storage and ease of access.

9.2) Proposed Design 2:



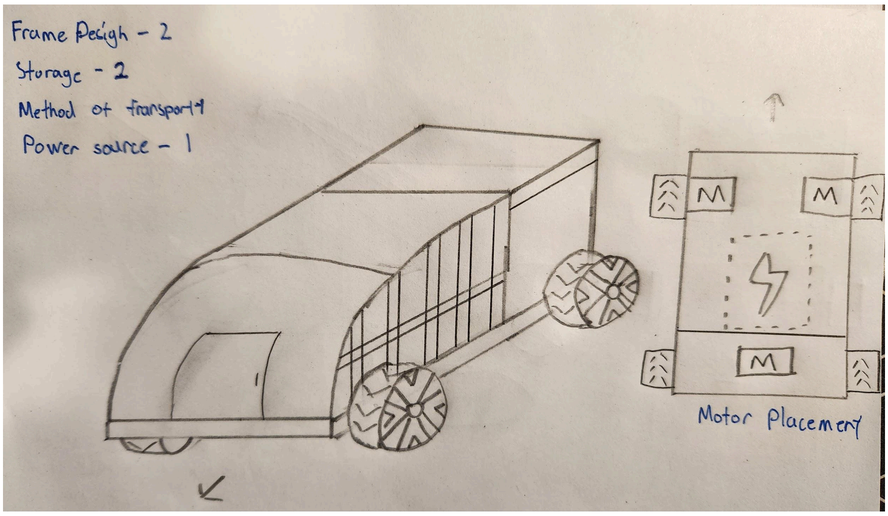
This Design features a thinner design with a sloped frame with the storage being found on the top of the vehicle. This would allow more space for the passenger and would allow access of the contents. Using the second power source option to provide enough power to the second type of transportation type to power through even the wettest of conditions. This design should be lower to the ground to offer almost a stretcher-like design.

9.3) Proposed Design 3



This design has a smoother and more aerodynamic design due to the two skis placed in the front of the vehicle. This vehicle design is essentially rear-wheel drive due to the motor and wheel placement but the weight distribution when it is full should more than make up for the downforce needed for it to be balanced. Steering might be difficult due to the skis. The storage container still follows the first design with an access door under the storage to house the motor and other electronics. The other electronics might also include the battery in that compartment.

9.4) Proposed Design 4



This design ultimately uses the second frame design but with a modification that is connected to the first storage design. It keeps the aesthetics and aerodynamics of the third design while being simple in shape. This design is all-wheel drive due to the placement of three motors. The storage compartment is located in the back which allows access from both the inside and outside due to it being connected to the frame. Once again, the bottom of the storage compartment will house the back motor, battery and other electronics.

10.0) Design Selection:

Durability and Reliability
- Weight: 30%
- Durability and reliability are most important as the vehicle must be able to handle extreme conditions and consistently perform to ensure the safety and effectiveness of search and rescue operations.

Carrying Capacity
- Weight: 25%
- The design should be able to carry with it multiple tools, equipment and people without hindering performance. This is so rescuers can be more efficient and any injured people can be treated immediately

Energy Efficiency
- Weight: 20%
- Being able to minimize fuel or battery consumption is paramount as refuelling or rechargeable would be very difficult during an operation. A design with good aerodynamics would be preferred to minimize drag.

Sustainability
- Weight: 15%
- Minimizing environmental effects, being able to be adaptable to its environment and efficient with resources to minimize waste

Interface and control
- Weight: 10%
- Control system is weighted least because in most cases the people operating the vehicle would already be trained, but it should be simple and easy to understand by anybody during high-stress situations.

Design 1: (7/10)
- Design 1 is durable and reliable due to its robust chassis and tires, its carrying capacity is good since it is efficient with its space, it lacks aerodynamics due to its boxy shape making it less energy-efficient, it is electrically powered making it environmentally friendly and has a simple design.

Design 2: (7/10)
- Design 2 has a durable chassis however it would be unreliable due to the tracks and the situations it's limited to. It has good use of space with more room for the passenger and storage. It's aerodynamic but depending on the environment the tracks can be less efficient than normal tires as they would consume more fuel. Since it is gas-powered it also wouldn't be eco-friendly.

Design 3: (5/10)

- Design 3 wouldn't be durable since the chassis doesn't connect with the back of the vehicle, it's not reliable since the skis would limit it to snowy conditions. It has decent storage capacity but could be better, it is aerodynamic in the front reducing drag, and electrically powered making it sustainable. Due to its unique design, it could require more training prior to operating it.

Design 4: (9/10)

- Design 4 is durable and reliable due to its chassis and its AWD design making it good for almost any environment, it makes good use of space to maximize storage capacity and passenger comfort, it's very aerodynamic, electrically powered and minimizes wasted resources making it eco-friendly and it has a simple design similar to most vehicles improving the user experience.

Conclusion: After considering all our design goals, design 4 is our best possible choice as it scores highest in all areas compared to other designs.

11.0) Conclusion and Future Work:

The conceptual design phase has provided a comprehensive foundation for the development of the Arduino-controlled Search and Rescue Vehicle. The stakeholders of this project and their needs have been identified and implemented into our design through the design requirements. A market analysis was conducted to help identify solutions to our stakeholder's needs as well as help understand ways to stand out and improve existing solutions. The design objectives helped to create a framework for our vehicle's design while ensuring it completes every necessary function. Through these objectives, we determined the constraints of the design that must be taken into account to ensure we balance performance, cost, and reliability. All of this information was used to create a Function Structure Diagram to organise our ideas and how the vehicle will function. We then created multiple design ideas for different aspects of the vehicle in the Morphological Chart that would help build four different final designs. As a group, we analysed all four of the designs through criteria based on the vehicle's functions and constraints and chose the one that best matched our goals and met as many objectives as possible.

The next steps in the design journey of the Search and Rescue vehicle are to begin the development of the coding necessary for the Arduino to control the vehicle and begin the testing of different potential materials. Given the Arduino device's pivotal role as the brain of the vehicle, our team is dedicated to ensuring it properly operates and responsiveness to diverse situations on its journey. The wiring and other Arduino components will be integrated into our design. Once this is completed we will begin the material selections that balance both cost efficiency and reliability in maintaining structural integrity through any obstacle. Our team will conduct extensive research on different material options and conduct durability tests on each material to determine the final choice. These steps are crucial in preparing our team for the creation and assembly of the final vehicle design.

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