MAX 12 Pages + 5 appendix + 3-5 team description + bill of material 12 points, times new roman, 1.15, number all pages‼!

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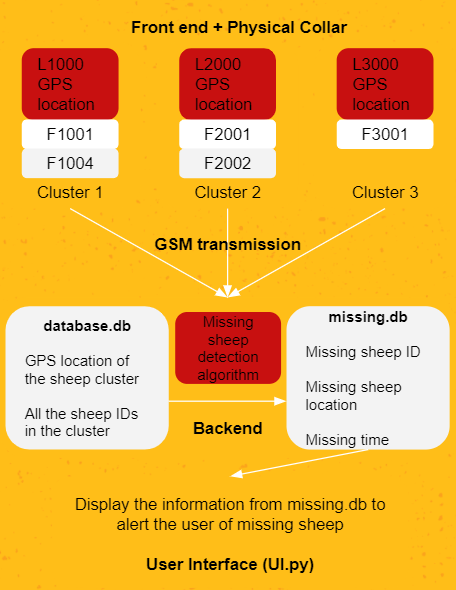
## Executive Summary

In Mthatha, South Africa, many farmers face problems with missing sheep. It is tedious work to look for the missing sheep as neither the shepherds nor the farmers have cars and information on where the sheep are. Therefore, they are looking for a cost effective solution to make finding missing sheep easier. As a team, our values are empathy, sustainability, functionality, and accessibility. Our scope was to make a reliable sheep tracking system that is accessible to everyone from the community to prevent the sheep from wandering off or mixing with other flocks. When addressing this opportunity, we prioritized the perspective of the stakeholders. In the opportunity overview, it was stated that “The livestock owners would benefit from a cost-effective solution to track their animals and find them when lost.” Stakeholder analysis gives us the two prioritized objectives: cost efficiency and functionality to track the sheep. The prioritization of these two values scoped out alternatives such as geo-fencing and thermal imaging with drones. Because fencing lacks the functionality to track sheep and thermal imaging with drones has excessive cost that cannot be afforded by the stakeholders. In the end, we decided to use Global System for Mobile (GSM) and Global Positioning System (GPS) to track the sheep with a clustering system which satisfied both of our prioritized objectives. GSM allows for transmission of data through a 2G cellular network, which was chosen since the infrastructure exists to support this system in Rosedale. We divided the flock into small groups, called clusters, with each cluster having a leader sheep with a GPS tracker to locate the cluster. Each leader sheep pings the followers within the cluster based on the Received Signal Strength Indication (RSSI), and the followers reply with their ID which is unique for each sheep using the wireless transceivers. After getting each follower sheep, every leader sheep sends the information to the database using GSM. The clustering algorithm is used to detect missing sheep, and if there are any, those sheep will be displayed in the User Interface (UI) with their ID, the most recent location and missing time. The customized color and engraved sheep ID on the tracker allow the stakeholders to easily identify and differentiate their sheep when looking for them. Our design made a delicate balance between cost efficiency and functionality by reducing the GPS modules needed, assuming that most of the leader sheep will be evenly distributed among the flock.

-add sustainability stuff

## Introduction

Small sheep owners in the small town of Rosedale, Mthatha are struggling with retaining their sheep. As livestock farming plays a major role in their economy, losing sheep is critical [1]. There are several situations where a sheep could get lost; They could simply wander off, get mixed up with different owners’ sheep, or could not be taken care of due to the absence of shepherds. Therefore, we and the stakeholders are seeking a solution that has reliable functionalities to track the location of lost sheep such that the loss can be prevented. Here, as the stakeholders include sheep owners and shepherds, the solution must be accessible in terms of cost (one of the most emphasized requirements by the stakeholder), portability, and ease of learning. Furthermore, as our team values sustainability as required by UNSDG 12, therefore a design with a responsible consumption and production process that is durable is also preferred.



*Figure 1 Sheep\_Link conceptual design flowchart*

The final proposed design is Sheep\_Link, an accessible and reliable Global Positioning System (GPS) Global System for Mobile Communication (GSM) missing sheep tracking system to prevent sheep loss. The system includes electrical GPS GSM tracker collar, backend database and frontend UI. To balance between the two most highlighted high-level requirements by the stakeholders: cost efficiency and functionality of location tracking, we decided to use cluster tracking method. There are two types of sheep trackers for each sheep, leader tracker and follower tracker. Each tracker stores a unique sheep ID: leader’s ID starts with an F, and follower’s ID starts with an L. Both types have wireless transceivers but only leader sheep has GPS GSM module to gather the location and transmit information to the backend database. When updating, leaders ping nearest followers based on the Received Signal Strength Indicator (RSSI), and followers respond by sending their IDs to the leader. Leader sends all the cluster IDs and its own current GPS location to the backend database. The cluster size is customizable depending how many leader trackers the user wants, having smaller cluster size provides more accurate location tracking with a trade-off to be a higher cost because GPS GSM module is the relatively expensive part of the tracker. Backend clustering algorithm will send missing sheep alerts including missing sheep location and missing time through the User Interface (UI) whenever a missing sheep is detected. Also, keeping the UNSDG 12 in mind, we designed the physical tracker to be using recyclable polymer [2], and rechargeable batteries

.U,{25078f3b-6605-4aba-a3c7-d3198bc79a0d}{69},0.6666666666666666,0.6666666666666666

Figure 2 Final prototype of the trackers and the backend

U,{25078f3b-6605-4aba-a3c7-d3198bc79a0d}{84},0.6666666666666666,0.6666666666666666U,{25078f3b-6605-4aba-a3c7-d3198bc79a0d}{85},0.6666666666666666,0.6666666666666666

*Figure 3 Final prototype of the UI and backend database*

We prototyped two fully functional follower trackers (F1001 and F1002 in Figure 2) with Bluefruit LE UART Friend and Arduino UNO R3. F1001 is powered by a 9V battery, and it has a complete case concealing the electronics with an adjustable belt strap. F1002 is powered by the laptop. With the available components in MyFab, we could only use Bluetooth transceivers with UART protocols. However, Bluefruit comes with a phone app that supports multiple UART modes, allowing us to ping several follower trackers at the same time. The GPS location of the phone is also available on the Bluefruit app. Therefore, we decided to use the phone as the leader sheep although there are other choices for us to proxy. Because the Bluefruit app is the best possible representation of the system. After being pinged by the leader, F1001 and F1002 will send their IDs to the Bluefruit app via UART. Since GSM module is not available in MyFab, we proxied by manually sending the received follower IDs and the GPS location to the backend database (the left laptop in Figure 2) also using the Blurfruit LE UART Friend. The backend database and UI (Figure 3) is fully developed using SQLite and python. The algorithm can detect both missing leader and follower. The UI displays all important information including missing location and missing time of the missing sheep. The UI is also designed for better accessibility: available in both English and Xhosa and requires no technical training. The final prototype for one collar costs us: Arduino UNO R3 ($24.95) + Bluefruit ($17.50) + Battery ($3.7) + 3D printed tracker case and collar strap ($3.50) = $49.65.

1. (Ethan)Select Background Details (we could copy and paste from the proposal for this part)
   1. Understanding the stakeholders:
      1. Who is affected and how?
      2. What is the value for stakeholders?
   2. Defining the scope:
      1. What are the limits to what we can do (and not do)?
      2. What is the primary goal of your team’s design? Provide details explaining the value proposition of your team’s design (i.e., benefits to the stakeholder and how these relate to the UN Sustainable Development Goals.[1])
   3. Describing the service environment:
      1. What is the situation in which it must work?
      2. What additional considerations and/or complications are added by the environment?
   4. Describe previous approaches to providing value in this or similar contexts:
      1. Making reference to previous solutions, reference designs, and literature.
      2. Examining what was previously tried.
      3. Assessing how well did it work.
   5. Are there specific standards or details that any solution must meet?

## Background

## Stakeholders

The sheep owners in the rural town of Rosedale, Mthatha are the primary stakeholders. The main factors that affect the stakeholders are the economic impacts due to the lost sheep, the effort required on their end for finding the sheep, and the accessibility of the product. The three corresponding values are economic, convenience, and accessibility. The stakeholders wish to secure their profit by finding the lost sheep, so it would be illogical to spend more funds on finding sheep compared to the gain. Furthermore, tracking the lost sheep takes effort on the owners’ end as currently, they need to search the vicinity usually 1-2 km away or nearby homesteads up to 5 km away without cars. Therefore, functionalities such as accurate tracking and locating of the lost sheep can bring the value of convenience to the stakeholders. Lastly, to maximize benefits for most sheep owners, accessibility is highly valued. Considering the technical abilities of the shepherds, implementing the solution should be easy for the shepherds to handle. In this proposal, we prioritize the needs and values of our primary stakeholders; however, secondary stakeholders such as shepherds and sheep are also important. The shepherds are underpaid and are often given a high workload; thus the owners have a precarious relationship with the shepherds. Reducing the shepherd’s workload by introducing high functioning designs that can motivate them to work, would secure the owners’ money by minimizing the chances of sheep getting lost. For the sheep, the solution should not reduce the economic value of the sheep both directly and indirectly, thus the solution should not harm the sheep.

## Scoping

With the internet and mobile network coverage, the assistance of shepherds, and the limitations on funding, our scope is to develop a **reliable** sheep tracking system that is **accessible** to every community member in Rosedale, which can **prevent** sheep from wandering off or mixing up with other flocks. The focus of the design will be its reliability to prevent the sheep from wandering off and its feasibility of being integrated into the daily lives of the shepherd.

## Team Values

Our teams had three main values that will be incorporated into the requirements model: Functionality, Accessibility and Sustainability. Functionality is one of the main priorities of the design since the shepherds are looking for a design that will address the issue of wandering sheep. This will include tracking capabilities and a system that is accurate and accounts for all possible instances of sheep wandering off. Additionally, in our teams’ values, we incorporate empathy into the design in the form of accessibility. We focus on making the product accessible to everyone in the community by keeping the cost affordable and making it easy to learn and operate. Aiming to make the system highly automated and user-friendly streamlines the training process, providing ease of learning for shepherds and sheep owners. In keeping with the 12th goal of UNSDG, sustainable consumption and production in mind, we aim to make the design durable to improve resource usage efficiency. The extended lifetime of the product reduces the cost for the stakeholders and is identified as responsible consumption promotion.

## Reference Designs

Fencing (sometimes electrified) is a popular option for animals wandering off problems. Fencing an area is simple and effective to prevent animals from leaving by creating a physical barrier. However, for our stakeholders, it is not a valid solution. Because many shepherds in Rosedale share a communal grazing area, the coordination of fencing would be complicated, and fencing would reduce the amount of grazing land the shepherds have. Price estimates to be 7500 – 15000 USD (9500-19000 CAD) for the amount of grazing land the shepherds have, which is very expensive when compared to the price requirements provided later [3]. Taking fencing as a reference design, the cost of our solution should be lower than this. Another option that has been used to find sheep is GPS tracking. This has been used for sheep tracking in countries such as Norway [4]. The Telespor system is the current “market-leading" solution and makes use of a GSM to locate sheep in real time. However, this is also costly at 290 CAD per sheep, with no flexibility since each sheep’s collar will make use of GPS technology [5].

## Requirements

The requirements model was developed to fulfil the needs of our stakeholders by successfully preventing sheep loss and ensuring that the design would be feasible to integrate. We incorporated our value proposition by deriving the high-level objectives from the three values. From each high-level objective, we developed detailed objectives to be our specific testing protocols. We will first verify each subsystem of our prototype to ensure that there are no errors or malfunctions, and then will validate the design by either physically testing is possible or otherwise theoretically predicting the outcome against each proposed requirement to holistically assess to what extent our design delivers the values to the stakeholders.

Functionality

Location Tracking

The primary functions of the design should include a lost sheep notification system and finding system to fully address the missing sheep issue. The first functionality requirement is that it must track the location of the sheep.

*Table 2 Criteria, metrics, and constraints for the finding system*

|  |  |
| --- | --- |
| Criteria: tracking range | |
| Farther is better (m) | Must ≥ 2000 m. Should ≥ 5000 m |
| Criteria: location accuracy: closeness of a measured location to the real location of the device at the time of measurement [6] | |
| The closer is better (m). GPS level accuracy is within 4.9m[7]. | Must not exceed 20m to provide an accurate location of the sheep |

Reliability

Reliability requirements make sure that the design can handle the different cases of the sheep wandering off, and that the shepherds can be notified within time to prevent the sheep through action.

|  |
| --- |
| Criteria: reliability of the notification communication |
| Lower percentage error of false alert (%) |
| Must not be interrupted and interfered with when transmitting messages. |
| Should allow notification documentation, record all the history notifications [8] |

Accessibility

Affordability

The requirement that was emphasized the most by the primary stakeholders was cost-efficiency. The stakeholder provided an ideal cost of 150 \* 12 CAD = 1800 CAD for the final product. However, recognizing the challenge to implement solutions with high functionality to accurately and reliably track the sheep's location, we justified cost constraint of the final design to be less than 3400 CAD because the average purchase price of the sheep in South Africa is approximately R1,300 and the average sheep output of small livestock owners is approximately R3,000 [9]. The average profit efficiency of the sheep was estimated to be about 65.5% [9]. Therefore, the strict profit made by each sheep can be estimated to be around R2,000. On average, small livestock owners have 150 sheep, and the rates of sheep loss has an average of 8% [10]. Hence, the minimum loss would be about 12 sheep. Therefore, we set the constraints for the budget to be (the strict profit each sheep makes + the price of the sheep) \* (the number of sheep that get lost) as the design should be profitable in the end. Therefore, our hard constraint is that our design *must* not exceed (R2,000 + R1,300) \* 12 ≈ R39,600 = 3410 CAD per year.

Portability

As part of the design for travel and ergonomics, the solution needs to be able to move around freely to track the sheep at different locations. Portability requirements for handheld devices were taken from the 2005 US human factors guide for the design of handheld devices. Two of the main concerns for devices are the weight and dimensions of the device. Note that the dimensions of the device are specified as the stow-away size; some devices may unfold but must stow away to a good size.

*Table 3 Criteria, metrics, and constraints for portability*

|  |  |
| --- | --- |
| Criteria: Device needs to be easy to move around, and shepherds must be able to use the device over the range of the grazing area (~5km through hilly terrain and villages). | |
| A lighter device is preferred (weight in pounds) | Widgets should be under 5.1 pounds if handheld. [11] |
| A smaller stowaway volume is preferred (size of dimensions in mm) | Widget should stow away to under 100x125x255mm in size [11]. |

Ease of Learning

The product should have the option to display information in the local language Xhosa [12]. Since the solution will be implemented with local shepherds, there also needs to be education in teaching them how to use the design solution. The less time it takes for the shepherds to learn how to use the design the better. This will depend on the quality of the user interface and should contain features such as one-click information finding and intuitive graphics.

Sustainability

UN SDG 12: Responsible consumption and production

Responsible consumption and production objectives relate to the materials used for the physical collar [13]. The goal is to use materials that have the smallest carbon footprint and can be recycled if the product were to be taken apart. An additional consideration is the impact of the battery, using rechargeable batteries instead of lithium batteries reduced soil and air contamination [14].

Durability

High durability reduces product costs for the stakeholders by reducing the amount of maintenance needed. Besides the cost, durability also encourages responsible production by increasing resource efficiency. Considering the grazing area is close to water sources, the product needs to be waterproof, dustproof and drop proof.

|  |
| --- |
| Criteria: Device needs to work for an extended period without malfunctioning |
| The lifetime of design [15] |
| Must pass waterproof and dustproof test from IP5 to IP6 [16] |
| Must pass drop test for ANSI/ISEA 121-2018 [17] |
| Working at least two weeks without charging [18] |

1. (Arielle)Design Process and Key Design Decisions
2. (Arielle)The path to development of the prototype:
   1. Insights into the presented conceptual design that were gleaned from the prototyping process.
3. (Ethan) Comparison to previous approaches (i.e., reference designs) (i.e., tell the audience why your solution is an appropriate choice in relation to the reference designs).
   1. Mention geofencing, the GPS TLS tracker, RFID scanning, paint/collar
4. Design Process and Key Design Decisions

In our project management plan, the team is divided into three divisions: hardware of the tracker, physical design of the collar, and software, which include the backend database and front-end UI. Three engineers from our team are assigned to be the lead of each division, and deadlines for design milestones are set to check the progress of all three divisions and merge the work.

Key decisions for the conceptual design:

1. Use GPS to track the sheep's location:

As required by the stakeholder, they would like to track the exact location of the missing sheep. We interpreted the latent need behind this requirement to be the need to minimize the effort spent when searching for missing sheep. GPS is used to monitor the sheep’s location all the time and notify the shepherds once the sheep leaves the cluster. Notifying the shepherds, the exact location of the wandering sheep before it goes too far away allows the shepherds to efficiently target the wandering sheep and get it back immediately, which reduces the workload. Thus, we believe it is the best solution that satisfies the stakeholder’s needs.

1. Use clustering methods to reduce the cost:

However, the tradeoff for using such expensive GPS trackers is the excessive cost. The stakeholders not only value functionality, but also value cost efficiency. However, we recognized the conflict in satisfying both. The clustering method we introduced in section\_\_ leaves the choice of whether to be cheaper but have a larger location uncertainty or to have a smaller location uncertainty but be more expensive to the stakeholder. (add details about the clustering calculation?)

1. Use GSM to transmit information:

From the context provided by the stakeholders, the town of Rosedale has mobile phone coverage. Furthermore, research has shown that Mthatha has full 2G GSM coverage provided by Vodacom, Telkom, and MTN [19]. GSM network is significantly cheaper than Wi-Fi, 3G, 4G, and 5G networks and therefore reduces the cost. Here, it should be noted that as great as GSM is for increasing affordability, this is in exchange for the speed of the connection. Since the current market is working with the 5th generation of digital networks, GSM being the 2nd generation implies its lack of rapidity. Nevertheless, as 2G network is still integrated into our daily lives, the connection speed is sufficient for this application and if the stakeholders wish for a faster connection, a simple upgrade in the network to 3G or higher is all that is needed.

1. Accessibility of the UI:

To make the product easy to use for the shepherds and sheep owners, we designed the UI to have both English and Xhosa versions. Also, the one-click-to-update feature is very user-friendly, requiring zero technical training.

To demonstrate the full functionality of the conceptual design, we decided to prototype both types of the trackers, the physical collar, the backend database with the UI. These are the three main tasks for the three divisions in our PM plan.

Key decisions for the prototype:

1. We fully prototyped one battery powered follower tracker with the hardware concealed in the complete physical collar to demonstrate the design concepts. The second follower prototype is only powered by the laptop to save batteries (practicing UNSDG 12 responsible production). We decided to prototype two followers because we need to test the clustering functionality based on the RSSI strength.
2. We decided to use Bluefruit Connect phone app as the leader sheep because the app has multiple UART mode, accurately representing the idea of leader sheep calling multiple follower sheep at once. Furthermore, the app allows us to acquire the GPS location of the phone, representing the GPS module to be implemented in the product. The leader communicates with the backend using Bluetooth, which is a proxy of the GSM transmission because MyFab does not have a GSM module. Then we need to manually send the information (GPS and the collected follower IDs) to the backend.
3. We fully prototyped the backend database using SQLite and Python and prototyped the UI using PyQt5. We chose to use database because compared to txt files and excel, SQL database is the most efficient way to store and handle large number of update messages because we need to use python to extract write information into the database to detect missing sheep. We chose to use PyQt5 to write the UI because it is intuitive and widely used.

Influence of Reference Designs on Process

The most relevant reference design that influenced our thinking as a group was the Telespor system from Norway mentioned earlier in the reference design section. The main drawbacks of the solution that made it unsuitable for our opportunity was that it is costly and would be hard to integrate into the shepherd’s operation due to language constraints (the Telespor system is not offered in the local language Xhosa). Our design addresses these two issues by offering flexiblity on how many GPS modules to include, lowering the price point. Additionally, we have designed our UI to be usable in many languages including Xhosa and features such as one-click updates ensure that the design is accessible to the shepherds. However, our design is not as developed as the telespor system, and further improvements on battery life and design of the leader sheep’s collar may increase the price of the design.

Verification

To ensure the high-fidelity prototype is functional, reliable and error-free, we tested each subsystem with repeated trials. We did not integrate the trackers and the backend database because we do not have the GSM transmission module. Using the Bluefruit and the Bluefruit Connect phone app to proxy does not allow the collected information to be automatically sent to the backend.

Electronic Subsystem

To test the electronic pinging system, we needed to test three components:

1. Whether RSSI range can be used for clustering
2. Pinging the sheep and how it responds with the identification number
3. The feasibility of powering the system and running the circuitry with the 9V battery

Testing of the RSSI was done through graphing the RSSI against distance. Through experimentation, it was found that the RSSI strength decays in a non linear fashion.

U,{b508eb49-565c-45c0-b0f7-5246b4fcdc2b}{30},0.6666666666666666,0.6666666666666666

From this testing, we found that RSSI strength works for clustering, but becomes very unreliable at longer distances since the signal strength falls off quickly. The next set of verification tests we performed are the different cases of pinging sheep. After setting up the follower sheep collars, we used the Bluefruit app to test if we can ping both sheep, and each individual sheep (simulating the case where the other sheep is out of range).



The results of the test showed that we could ping multiple sheep using the multiple UART function of the app, which gave us confidence in our final design, since we are able to ping all nearby sheep with a single message. Lastly, the arduino was sufficiently powered by the 9V battery and supplied constant power throughout our 1 hour testing sessions. This showed us that the battery life of the prototype was adequate, and can be improved through further research and development.

Physical collar

1. The base of the tracker perfectly fits the Arduino (Figure\_), and the Bluefruit and the battery are “soldered” or taped onto the second layer. These all prevent the electronics from moving inside the case even when shaking and/or dropping to the ground from 1-meter height (the standing height of a sheep).



1. The hardware was found to be fully waterproof such that the tracker inside was safe from any damage when proxy waterproofing in the form of rubber bands was added. This was tested by putting tissues inside the cover and sinking it under water for 2 hours, following the test for waterproof and dustproof level IP5 and IP6.
2. The engraved sheep ID in 3D printing is clear and easy to see.

Backend Database and Clustering Algorithm

The backend algorithm passed all testing cases that would be encountered: no missing sheep, missing follower sheep and missing leader sheep. We created a three-leader sheep flock for this testing, therefore there will be three data entries into the database for each update.

*Table 1 Initialized leader sheep and clusters*

|  |  |  |
| --- | --- | --- |
| Leader Sheep ID | Cluster Sheep IDs | Case 0 initializing the database  Algorithm output: no missing sheep. |
| 1000 | 1001, 1002, 1003, 1004, 1005 |
| 2000 | 2001, 2002, 2003, 2004, 2005 |
| 3000 | 3001, 3002 |
| 1000 | 1001, 2001, 1002, 1003, 1005 | Case 1: 2001 and 1004 changed clusters  Algorithm output: no missing sheep. |
| 2000 | 2002, 2003, 2004, 2005 |
| 3000 | 3001, 3002, 1004 |
| 1000 | 1001, 2001, 1002, 1003, 1005 | Case 2: missing follower sheep when it leaves the flock  Algorithm output: missing sheep 1004, the most recent GPS location of the cluster (sheep 3000’s location), and the missing time. |
| 2000 | 2002, 2003, 2004, 2005 |
| 3000 | 3001, 3002 |
| 1000 | 1001, 1002, 1003, 1004, 1005 | Case 3: missing leader sheep when it has an empty cluster Algorithm output: missing sheep 3000, the most recent GPS location of 3000, and the missing time. |
| 2000 | 2001, 2002, 2003, 2004, 2005, 3001, 3002 |
| 3000 |  |

User Interface

The User Interface is a python file, after running, the UI will pop up with a clickable button allowing the user to manually refresh the page. The UI automatically reads the output of the backend clustering algorithm from another database that stores the missing sheep information. One shortcoming of the database is that it does not automatically refresh.

Validation Chart

To ensure the high-fidelity prototype is delivering the values (functionality, accessibility and sustainability) we would provide to the stakeholders, we assessed and/or tested the prototype against each detailed objective.

Functionality

|  |
| --- |
| Criteria: tracking range |
| GPS has global coverage, allowing sheep to be tracked anywhere in the world. |
| Criteria: location accuracy: closeness of a measured location to the real location of the device at the time of measurement [6] |
| The leader trackers have GPS level accuracy which is within 1m < 20m [7].  Depending on the number of leader trackers the follower tracker location uncertainty is:  Max location uncertainty = 150 / (16% leaders \*150) \* 2m + 1m = 14.5m < 20m  Min location uncertainty = 150 / (50% leaders \*150) \* 2m + 1m = 6m < 20m  We assumed the sheep activity range when grazing is 2m [20] and the worst-case scenario is all sheep stand in a row forming a linear cluster. |
| Criteria: reliability of the notification communication |
| Since the sheep are clusters based on the RSSI, and RSSI sometimes is not a perfect estimation of distance. Our testing result has a 20% fail to report rate when the follower tracker’s distance from the leader sheep is already further than the calculated cluster radius but it still does not disconnect. |
| Bluetooth wireless transceiver and GSM both have stable, reliable signal. |
| The backend database is implemented in SQL, allowing to store large number of updates. |

Accessibility

|  |
| --- |
| Criteria: low cost |
| Depending on the number of leader trackers the follower tracker location uncertainty is:  Max cost with 16% leaders: 125\*12.93 CAD + 24\*17.28 CAD = 2030.97 CAD < 2300 CAD  Min cost with 50% leaders: 75\*12.93 CAD + 75\*17.28 CAD = 2265.75 CAD < 2300 CAD  BOM for each leader tracker and follower tracker is in Appendix II. |

|  |
| --- |
| Criteria: Device needs to be easy to move around, and shepherds must be able to use the device over the range of the grazing area (~5km through hilly terrain and villages). |
| Tracker is 0.22 pounds < 5.1 pounds. |
| Tracer is 85x70x45mm < 100x125x255mm in size. |
| Criteria: Ease of Learning |
| The UI has both English version and Xhosa version and is easy to use with no prior experience and/or training needed. |

Sustainability

|  |
| --- |
| Criteria: UN SDG responsible consumption and production |
| The design can be fabricated using recyclable polymer PET [21] and rechargeable batteries. |
| Criteria: Device needs to work for an extended period without malfunctioning |
| The design can be designed to pass waterproof and dustproof test from IP5 to IP6 [8]. |
| The design can be designed to pass the drop test for ANSI/ISEA 121-2018 [21] by soldering all the electronics onto the surfaces and using shock absorption polymers [22]. |
| The design can use rechargeable batteries that sustain two weeks without charging [10]. |

GSU reflection

The GSU student provided us with new perspectives to include a broader range of stakeholders, such as the local government, local environments, and local businesses. We incorporated these considerations into our design by making our design more sustainable by using green materials and rechargeable batteries to protect the local water-dam environment and comply with local government environmental regulations. The material that we can use is PET which is a representative of recyclable polymer. PET is a clear, strong, and lightweight plastic [23] that can be used as the material for the case and can be able to pass the drop test and protect the inner modules. PET is fully recyclable, and it is the most recycled plastic in the U.S and worldwide [23], so this material can support us to pass the requirement of UN SDG12. In addition, the GSU student asked us if there will be any alternatives in case of technical difficulty, addressing this issue, we recognized that it is risky to assume fully reliable 2G GSM coverage in Rosedale without further research. Research shows that near the water dam, Rosedale is not fully covered by sable 2G nor 3G/4G networks. Research tells us that in the future we can implement a hopping algorithm [] to solve this problem if at least one sheep is in the 2G GSM coverage.

1. (Edwin) Discussion of the Final Outcome (Design and Prototype)
   1. Why your conceptual design is a valid solution to the identified stakeholders needs that provides value, making links to your value proposition.
   2. What limitations and assumptions your team made while deciding on your final design and prototype. (Ethan, Edwin, Emre)
   3. How your team’s prototype relates to the design concept and how the prototype provides insight into the feasibility of your design. (Ethan, Edwin, Emre)
   4. How your team worked together to create this final prototype.(PM plan, look at the presentation PM plan)

With the provided context of finding wandering sheep in Rosedale, Mthatha, our proposed design Sheep Link prevents sheep wandering by tracking the GPS location and notifying the shepherds before a sheep wanders off too far. Because it is tedious for the shepherds and the sheep owners to find the sheep when they wander off too far away due to their lack of cars. By analyzing the stakeholder’s explicit and latent needs, our value proposition is summarized with three key words: sustainability, functionality, and accessibility. Our product successfully delivers these values by satisfying the corresponding requirements. The requirements for functionality are location tracking and reliability, the requirements based on accessibility are affordability, portability, and ease of learning, lastly, the requirements for sustainability are durability and UNSDG12. This tracker can reliably track the wandering sheep’s GPS location, integrating with the engraved sheep IDs on the physical collar and their customizable colors, sheep can be easily differentiated from other owners. Also, Bluetooth signals are stable even if there are obstacles. The accuracy of the tracker depends on the number of leaders the owner selects. Our product can satisfy all the requirements from the value of functionality. There is a small issue for affordability since if the owners want accuracy, they need to make some sacrifices in pricing. The more leader collars, the more accurate the tracker can work, but the leader collar is about $20, so the owners need to decide on what kind of performance they want based on the cost. Lastly, for sustainability, we use a rechargeable battery, and we select durable and sustainable materials for the case. We fulfill the UN SDG 12. Our design of the case passes the IP6 test for waterproof and dustproof by easy sinking tissues test, so basically, our design is a valid solution to the problem of wandering sheep

(b)We assume cell phones as our leader sheep and laptop as our database. We have consistently completed the design of follower sheep by using the Arduino as the main module, and the data of the follower is transmitted to cell phones which are the leader sheep by Bluetooth since we cannot work with modules for GSM and GPS, and we use Bluetooth as a backup plan for transmitting data. There are not any limitations to the collar design, and we assume the materials that we apply are green materials that are recycled polyester. For the electronics of the system, the main limitation is the battery life of the prototype. Since we as a team did not have access to rechargeable batteries, we powered the collar using a 9V battery which has a lifetime of around 24 hours when powering an arduino board. For the backend, we assumed all the stakeholders has access to an electronic device capable of running SQLite databases and has PyQt5 library for the UI.

(c)For the collar design, it is the exact shape we want for the actual product, but the dimension of the case should be changed when we apply the design to the final product. The priority of the case is to protect the modules inside and pass waterproof and dustproof. The three layers design is what we want for the protection of the GPS GSM module on the bottom layer, and the middle layer is used to make users easy to recharge the batteries. The two ears design is the connection part between the sheep, and our product can make sheep feel comfortable by the application of adjustable stray. The product is safe for both sheep and users since there are no sharp edges on the case. The backend of the system is tested using real life scenarios where we fed data to the backend manually through the BluefruitConnect app. The algorithm was able to report missing sheep correctly in each scenario. The test results show that the algorithm is also likely to work under real life conditions.

The electrical system proxies the design concept by using bluetooth connections to mimic transmitting data over a GSM network. The prototype shows us that the collars need to be constantly running and searching for nearby devices, and this could cause problems if the connection is unstable. Moreover, the necessity for the collar to always be on would also raise concerns over powering the system. Overall, the prototyping has shown that connecting to multiple devices in a nearby network is possible, but more advanced knowledge must be used to scale this to larger networks with unstable connections, and looking into a way to not always have the electronics can help reduce the power consumption of the system and is a path for further development.

Throughout the semester, our team cooperated in a highly efficient and highly functional manner for this project. Arielle is the project manager; she monitors the progress of the project. Tab organizes the folders and documents everything. Yiqun is responsible for the procurement and budgeting. During the prototyping phase, there are three divisions, Ethan and Arielle are electrical engineers for the hardware division, developing the circuits for the tracker. Emre is the software engineer for the software division, developing the database and the UI. Yiqun is the mechanical engineer for the collar design division, designing the physical collar. Tabitha researched for the application of GSM and 2G network, which is the only part of our system that we did not prototype due to limited access to resources. We update each other weekly in our group chat, and design milestones are set to integrate and merge the works from all three divisions.

1. Conclusion and/or Next Steps
   1. Your value proposition in relation to the context, your design that is intended to realize that value proposition, and how these may be refined in future iterations of the design cycle. (Arielle)
   2. (Ethan, Edwin, Emre)How the current prototype supports your arguments about the validity of your design.
   3. What your suggested next steps are to further develop your design concept, including what other tests could be done with the current prototype and what other prototypes could complement the current one in providing more insights into your conceptual design. (Ethan, Edwin, Emre)

Value proposition:

Develop a sustainable, reliable sheep tracking system that is accessible to every community member in Rosedale, Mthatha.

Team (in the Appendix)

* Team value statement (half page) Tabitha
  + Description of their holistic, team values statement describing this makes them suited to design and build a prototype for the context

Our team values related to this project include empathy, sustainability, functionality, and accessibility. We value empathy which allows us to perceive the stakeholders’ needs and context on an emotional level, making us more passionate about solving the issue. Furthermore, this helps us to more sensibly balance conflicting requirements such as cost efficiency and functionality. Additionally, our value of empathy also connects to considering the environment which aligns with the UNSDGs and leads to our value of sustainability. Valuing sustainability helps us to be more conscious about the production process and lets us seek a more durable and cost-efficient design that matches the stakeholders’ context. Nevertheless, being a team of engineers, our value of functionality is also apparent, making sure that despite us aiming for a sustainable design, the functionality is at its best. We are invested in taking care of all the functional needs of the solution and satisfying the stakeholder's needs. Moreover, we greatly value accessibility which is also rooted in our value of empathy. As we empathize with the financial and educational backgrounds of the stakeholders, we wish to produce a design that is accessible to all stakeholders by being affordable and easy to learn. We as a team truly make every design decision based on our team and the stakeholders’ values, aiming toward the best design. We have developed a precise and rigorous requirements model derived from the values to efficiently and effectively assess all design candidates. As our final design and its prototype have met all values while passing the numerous functionality tests, we believe that our team is suited to continue with this project.

Tabitha is in charge of our team’s research and document management. Furthermore, in terms of the final design, she was responsible for researching and making theoretical applications of the Global System for Mobile Communication (GSM) for front-end and back-end communication. Her research experience in extracurricular design teams, as well as past in-course group work such as Praxis I and II, allowed her to better tackle research tasks. These research skills were also applied to securing the requirements model such that it was rigorous and detailed along with developing testing and verification methods for the detailed objectives. Moreover, highlighting her organizational skills, she was given the role of organizing the Microsoft SharePoint folder and documents. These organizational skills were also infused with artistic skills from previous experiences in graphic design and visual art competitions which helped with her designing the design pitch brochure for the final presentation.

Ethan oversees the integration of electrical components into the final design. This included the setup of the follower sheep Arduino and connecting the bluefruit bluetooth module. The functionality of the follower sheep collar was controlled using C code on the arduino IDE, and linked through the bluefruit app on the mobile phone. His experience with circuitry from past courses helped to get the Arduino system set up, however most of the specifics relating to the prototype had to be learnt from scratch. Additionally, the integration of the battery and research into the possible routes forward in terms of power supply was a key role Ethan took on for the prototype. For the design pitch document, he contributed to streamlining the requirements model, background research and the testing protocols for the collar.

Yiqun is responsible for the mechanical design and budget tracking. In terms of the final design, he builds the 3D design of the collar. His Cading skills learned from last year and practiced during widget labs support him in the tasks of the physical design of the final product. These skills combining the critical thinking of how to fulfill the requirements help him to develop a detailed physical collar. In addition, he keeps on track of the budgets carefully during the whole design process to take notes of every cost and keep eye on the remaining budget to have the team have enough money to complete the task. This knowledge is used when fill the bill of materials since we need to minimize the cost of the actual product.

Arielle is the team’s project manager and tech lead. In Phase A, she was responsible for leading the team to frame the opportunity and explore different viable solutions. Her leadership experience with past extracurricular activities provides her insights in discovering the latent needs of the stakeholders. In Phase B, she continues her project manager role and divided the team into three divisions: hardware, software, and physical collar design. Her rich experience with managing group projects allows her to make the team highly functional by distributing tasks and assigning roles based on everyone’s interests and strength. Furthermore, her experience in hardware research, software projects and CADing makes her suitable for the role of tech lead. She monitors and provides technical help for each division when needed and integrates the subsystems for each milestone to verify and validate the design.

Bill of Materials (in the Appendix) (Edwin)

To help a future design team reproduce and/or learn from your prototype it is important to   
provide details on the parts used. The Bill of Materials would have a table with at minimum a   
list of parts in the prototype, their purpose, their costs, and (where applicable) links to product   
pages or datasheets. It would also provide rationale for choice of parts. You should distinguish   
between parts that were acquired using your team project budget and parts that were obtained   
as part of Widget Labs (including both parts acquired as part of a lab kit and parts acquired   
from Widget Lab Assignment budgets).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Components | Units | Unit Cost | Total Cost | Purpose | Links |
| Microcontroller plus USB | 1 | $8.82 | $8.82 | control the functions of embedded systems | [24] |
| Wireless transceiver | 1 | $0.66 | $0.66 | frequency is 2.4GHz, and it is a combination of radio transmitter and receiver | [25] |
| GPS GSM module | 1 | $4.39 | $4.39 | SIM800 is the module we select since it is cheap, and it is the module that can get the GPS data and transmitted by GSM | [26] |
| 9V battery | 1 | $3.98 | $3.98 | Power up the whole product | [27] |
| Jumper wires | 10 | $0.1345 | $1.345 | Connect these important technical units | [28] |
| 3D printing | 100 grams | $0.03 | $3 | The design of the collar which is the case for these modules |  |

U,{afcb13d2-ba40-46c4-b400-53a25bad8aa0}{64},0.6666666666666666,0.6666666666666666

Microcontroller plus USB and the total cost of them is $8.82

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Wireless transceiver is very cheap, and the frequency is 2.4GHz, and the price is $0.64



The GPS GSM module we chose is SIM800 which is $4.35

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The 9V battery which is the power source is $1.98



Jumper wires are cheap, for one wire, it is only $0.1345, each tracker will need maximum 10 wires, so the price is $1.345



The price of 3D printing is cheap since the material of PLA is $0.03 per gram, and the weight of the tracker is 100 grams, so the price for each case is $3.

There is no GPS module in the collar for follower sheep, so the price for follower sheep is $15.785 and the price for leader sheep is $20.135. The price is a little higher than what the stakeholders desire, but the reason why we want GPS is to maintain the accuracy of the tracking. Since there are 150 sheep, the trackers they purchase are for follower sheep, and the price for follower sheep is close to what they want. They can decide how many leaders they want and the more leaders, the more accurate they can view.

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