July 25, 2022

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

Re: ENSC405 Project Proposal for *DIRTS*

Dear Dr. Scratchley,

This document contains the project proposal for Direct Interface for Rapid Testing Soil, or DIRTS, prepared by Everyday Planting Solutions.

Our objective at EPS is to research and design a product beneficial to both amateur gardeners and industrial agriculture. DIRTS will provide an easy-to-read status on the current state of the soil where it is placed, along with a simple phone application to give recommendations of plants that would survive well in the tested environment.

The purpose of this proposal is to provide a description of DIRTS' high-level functionalities and outline of the potential risks and benefits. The document also covers an analysis of the current market and competition for the product, followed by a projected schedule, estimated budget, and cost considerations for DIRTS.

Our team at Everyday Planting Solutions would like to thank you in advance for taking the time to review the project proposal of our device DIRTS. If you have any more questions or would like further information regarding our project or team, please contact mrehill@sfu.ca.

Sincerely,

Mehar Rehill

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Mehar Rehill
Chief Executive Officer
Everyday Planting Solutions

School of Engineering Science
ENSC 405W

Everyday Planting Solutions' DIRTS
(Direct Interface for Rapid Testing of Soil)
Proposal Document

Company 2

Mehar Rehill (CEO)

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Submitted To:
Dr. Craig Scratchley, ENSC 405W
School of Engineering Science
Simon Fraser University

Issue Date:
July 25, 2022

Executive Summary

Plants are key to all life forms on earth, and soil is one of the contributing factors for the subsistence of plants. Most people know that soil is essential for plant growth, but they do not necessarily understand the specific reason as to why it is so important. As Leonardo da Vinci once said, *"We know more about the movement of celestial bodies than about the soil underfoot."*

People with limited prior knowledge about plants or soil may wonder what types of plants will grow best in their environments. Everyday Planting Solutions is proposing an innovative solution to some well-established problems encountered by novice planters, DIRTS (Direct Interface for Rapid Testing of Soil). DIRTS is a promising technology for testing humidity, acidity, temperature, and NPK levels of a given soil sample. This data is further displayed to the user on their mobile device, followed by a descriptive analysis of the suggested plant types based on the soil results.

DIRTS consists of four sensors which measure the humidity, acidity, temperature, and NPK levels of the soil. The data from the sensor is transmitted to a user device via Bluetooth. Based on the received data, the user is given a list of suitable plants for the tested soil. The user can select the plant type based on climate and sunlight levels with descriptive plant growth cycle.

The global market of plants has expanded in the last decade, especially during the pandemic [5]. DIRTS aims to provide a general guide for people with no preceding insight about plants. It not only targets the household or agricultural market, but it is also useful for environmentalists, landscapers, and educational institutions. The provided database of the plants can be global or local based upon the user's preference.

Everyday Planting Solutions consists of five skilled engineers specialized in computer, systems, and biomedical engineering, with an expertise in app development and experience in geotechnical devices. We propose the engineering cycle for DIRTS including research, design, and software development to be within three months. We believe that with our hard work and skill, DIRTS will bring us one step closer to a greener earth.

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1. Introduction

Healthy soil is one of the essential factors in the growth of a plant, providing nutrients, anchorage for the roots, water, and regulating temperature. Over time and throughout the seasons, the soil in a specific location may alter, requiring outside help to achieve optimal conditions once again. For example, soil may become too acidic over time, such as from acid raid or water leaching away basic ions in the soil [1]. To monitor these conditions, Everyday Planting Solutions (EPS) is proposing an innovative take on well-established problems encountered by novice planters -the DIRTS (Direct Interface for Rapid Testing of Soil). DIRTS is a promising technology for testing humidity, acidity, temperature and NPK levels of a given soil sample, which is further displayed to the user on their device, followed by a descriptive analysis of the suggestive plant types based on the soil results.

DIRTS aims to provide a general guide for people with no preceding insight about plants. It not only targets the household or agricultural market, but it is also useful for environmentalist, landscape architectures and educational institutions. The provided database of the plants can be global or local based upon the users' preference.

The following documents provide a description of DIRTS high-level functionalities and outlines potential risks and benefits. The document also covers a vivid analysis of the current market and competition for the product, followed by a projected schedule, estimated budget, and cost considerations for DIRTS.

2. Project Overview

2.1 Scope

The goal of our company is to provide an affordable, robust, and easy-to-use system to an average home user, to make their gardening experience easy and more fun. The prototype will consist of following components: temperature sensor, moisture sensor, pH senor, NPK optical sensor, Arduino, Bluetooth module, and mobile application.

2.1.1 Temperature and Moisture Sensor

The device uses these sensors to measure the temperature and moisture level of the soil and keep monitoring them accordingly to the plant requirement.

2.1.2 pH Sensor

While some plants require acidic nature to grow, other flourish in basic nature. This will be monitored by using the pH sensor in the soil that provides us with a measurement of pH (H^+ ions). If pH is less than 7.0 then the soil is acidic, if 7.0 then neutral, and if greater than 7.0 then the soil is basic. The scale of the pH sensor is from 0.0 - 14.0.

2.1.3 NPK optical sensor

Plants need macronutrients consisting of Nitrogen, Phosphorus and Potassium for the growth [2]. Nitrogen is used for good green color, Phosphorus is used by plants to make seeds and new roots, and Potassium helps to make stems strong and is used to fight disease. To measure these nutrients, NPK sensor is used which is based on the working of an optical transducer. Three different LEDs will illuminate the soil beneath it and a LDR sensor will sense the reflected rays of light. The output based on the voltage levels will tell us the quantity of these nutrients in the soil [3].

2.1.4 Arduino

All the sensors will be connected to Arduino Uno to ensure that the sensors are collecting data in proper manner.

2.1.5 Bluetooth Module

Once the data is collected from the sensors via Arduino, it will be sent to a smartphone using a HL05 Bluetooth module connected to the Arduino.

2.1.6 Mobile Application

This provides user with the capability to understand the data in an easy manner and allows them to set the value for monitoring parameters of the device. Moreover, based on the data collected it also gives user a list of plants that are compatible with the soil type.

2.2 Proposed Design

DIRTS is an all-in-one plant sensor, designed to measure various properties of soil in one simple test. The sensor is inserted at the top level of any soil, with sensor probes to measure pH, moisture, NPK concentrations, and temperature. This data is then collected and transferred to a smartphone via Bluetooth. The collected data is further mapped with an existing database to check the suitable plant types for the given soil conditions.

The project is divided into three components: the hardware, consisting of sensors and MCU, the software, displaying the data and giving plant suggestions to the user, and a cloud database where the retrieved plant information is stored. We proposed a design that features the working of all three components in conjunction with each other. On the software side, we aim to design an application package as it would be easier to operate by the user and will also eliminate the need of an integrated screen on the sensor. The processes for each component of the device are represented in the high-level flowchart shown in Figure-1.

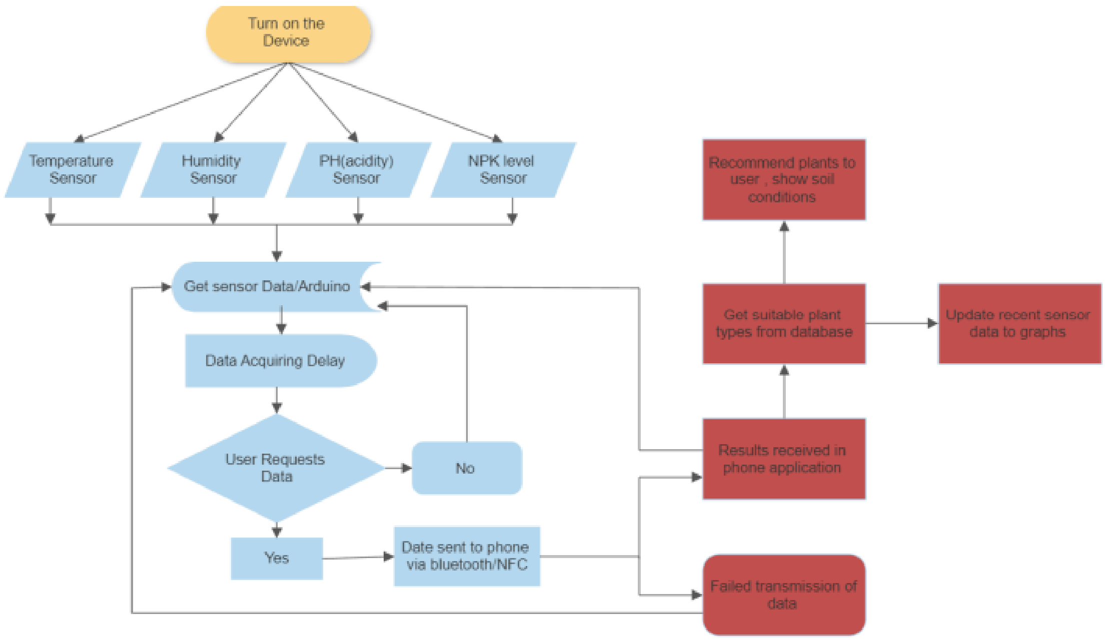


Figure 1: Describing the high-level flow chart

2.3 The Hardware

The final design of the device will consist of an enclosure that houses the entire electrical circuitry, only the probes will be sticking out of it. This is necessary to make the device rain-proof and dust-proof as the device is going to stay in soil for longer periods. The rectangular case shown in Figure-2 with internal compartments will separate the sensors from the Arduino and provide a uniform mass distribution across the device.

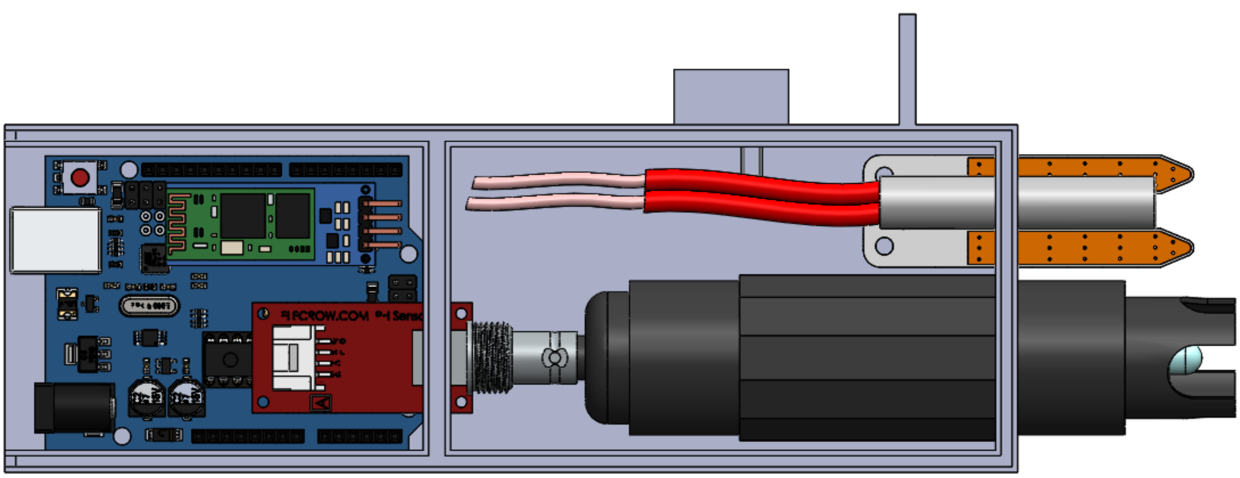


Figure 2: Displaying various sensors in an enclosure

The first task is to setup the device in the soil, perpendicular to the surface so that the probes are completely submerged in soil and ready to record the data. The top part of the enclosure will consist of the Bluetooth module that will ensure the proper connection with the smartphone so that the data can be sent properly. The setup of the sensor can be seen in the figure below.

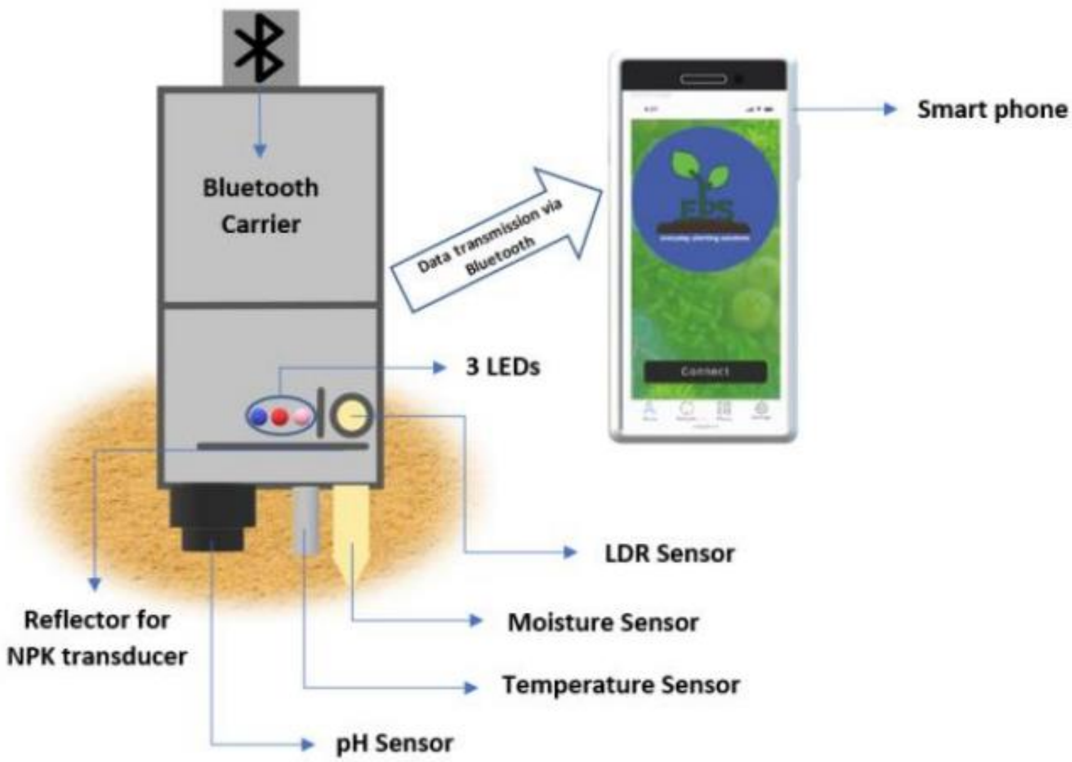


Figure 3: Sensor Connectivity with smartphone

The key features of the sensor shown above are described briefly in the form of flow chart presented below in the Figure-4

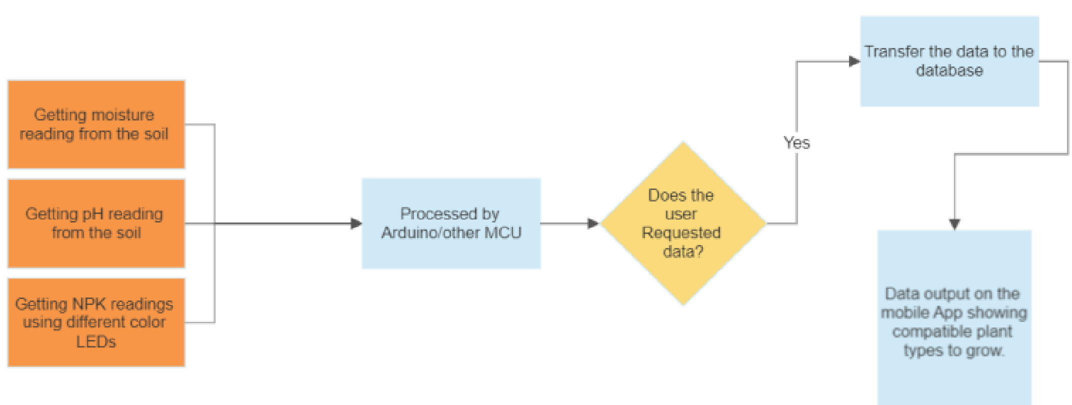
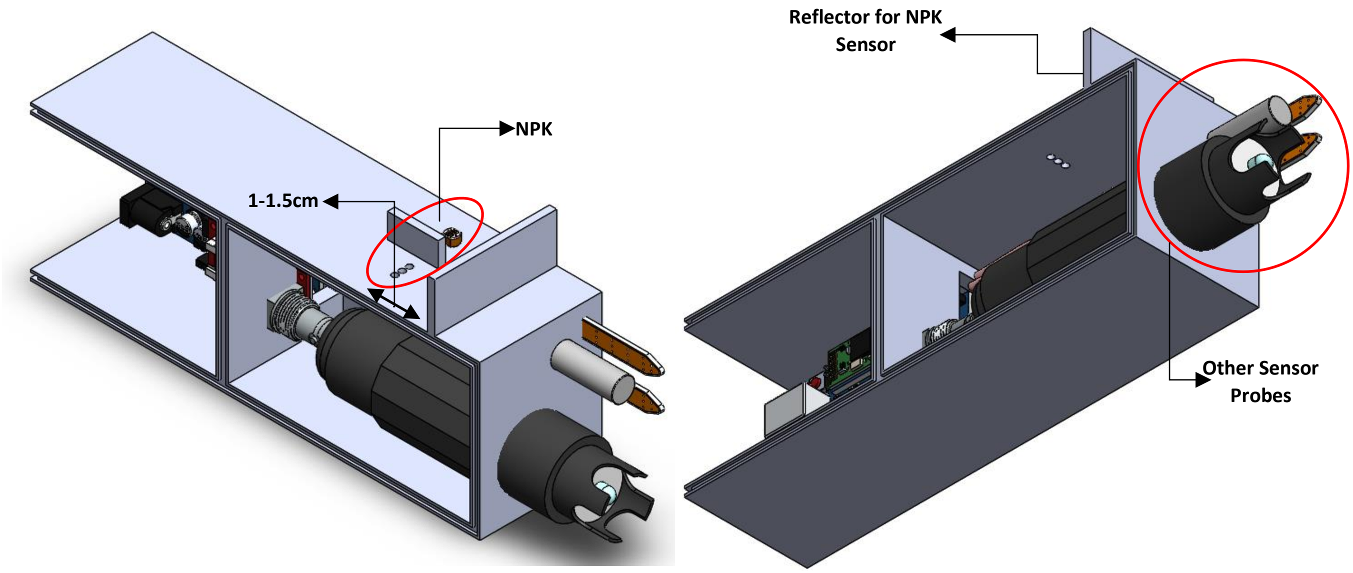


Figure 4: Flowchart describing key features of the senor

The LEDs and optical sensor on the side will act as NPK optical sensor and the plate underneath them is a reflector which creates a path for the light to reach the optical sensor by travelling the minimum distance (Optical Path Length). The soil will stay on top of the reflector to a height of 1-1.5cm from the LEDs [3].



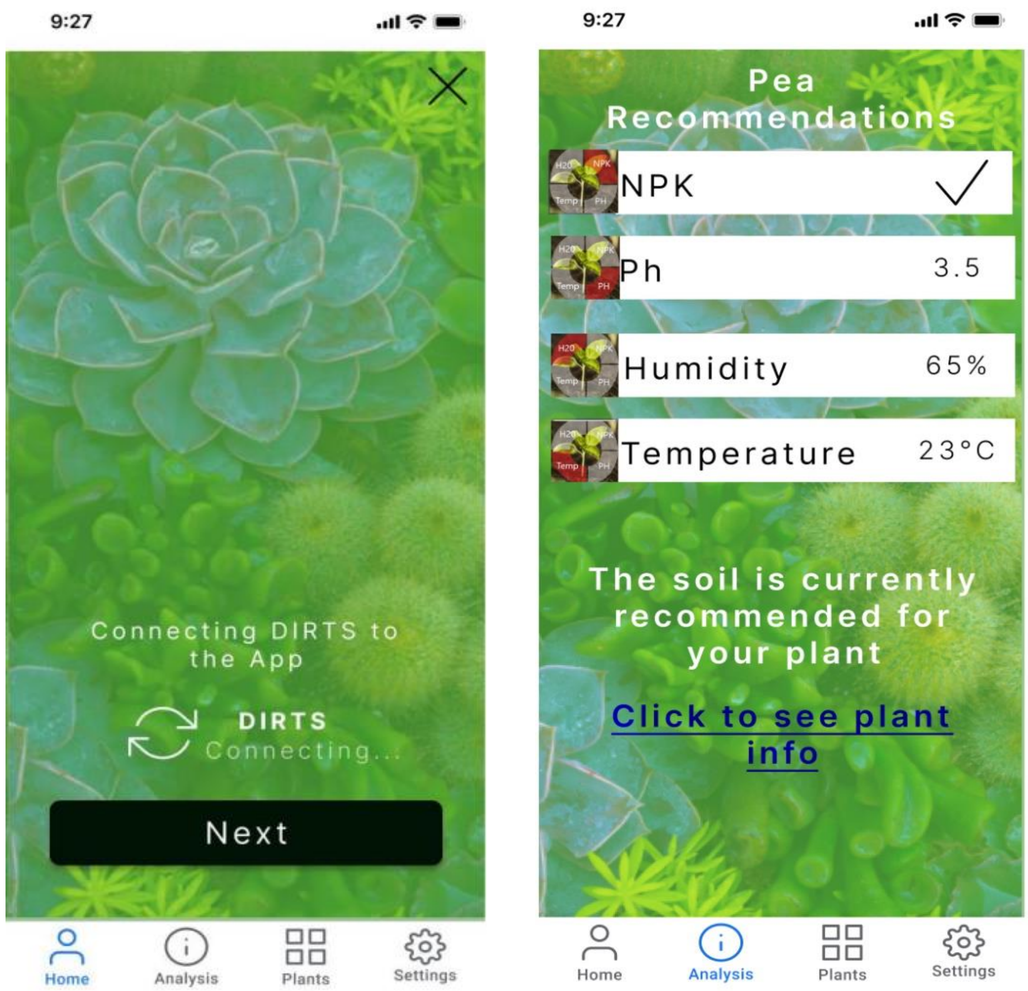
(a) (b)

Figure 5(a & b): Show two different views of the sensor describing the location of NPK sensor and the other probes

2.4 The Software

We intend to utilize Bluetooth to transfer data from the hardware to the software. This forgoes the use of wires and allows for the gardener to read information off in an easy way. The software is intended to be connected to and serves primarily as a data display for the gardener. There is little data processing in this software, so it could be used in low-end cellphones as well. It is intended that a cloud database is used in conjunction with the app. The cloud database stores information about specific plants and the type of soil they are ideal for.

Here is an outline of how we intend the gardener to use the application. First, the software application will obtain measurements from the hardware which is planted in the soil. The user is required to input the plant in a search function. The software application will utilize internet connection to retrieve specific plant information from our cloud database, then measurements from the current plant will be compared to the database information. Suggestions will show to the gardener in a readable format shown in Figure-6.



(a) (b)

Figure 6(a & b): Left: showing the connectivity screen. Right: showing the results after the values are matched

2.5 Risks Involved

Everyday Planting Solutions has evaluated the risks that the team may potentially encounter during development and usage of DIRTS. A risk severity scale used to categorize the risks by severity level.

	Product Development	**Product Usage**
Critical	Potential failure could collapse the critical objectives of the project	Danger would be severe for the user and can potentially destroy the sensor.
Moderate	Potential failure would result in the achievement of critical objectives with minimum satisfaction.	User would be safe, but possibility of damage to the sensor is high.
Minimal	Potential failure would result in the achievement of objectives with dissatisfaction.	Failure of whole system would not occur, but some potential damage can happen to the enclosure.

Table 1: Severity level for risks

2.5.1 Risks in product development

Risk	Severity	Probability	Impact	Mitigation Strategy
Incorrect or non-robust sensor parts	Critical	Highly likely	Delay due to repurchasing sensors	Research for alternatives
Inaccurate data results	Critical	Probable	Do not meet product expectation	Analyze the data and debug the sensors.
Framework building limitation	Critical	Probable	Damage to the electrical components	Redraw the 3d model and alternatives for framework material.
Integrate failures	Critical	Probable	Fail to transmit data between the sensors and the user interface	Test the integration with the dummy data at the early stage of development
Incomplete testing	Significant	Unlikely	Delay in the subsequent process	Allow some extra time
Delayed parts shipment	Significant	Probable	Delay in prototype-built time	Time management for parts purchase
Security breach in user data in the app	Significant	Probable	Disregards the security of the user's data	Client and server should be encrypted, and unauthorized access should be prevented
Overspending	Minimal	Probable	Not enough budget management	Cautious Budget management

Table 2: Describing the risks in product development

2.5.2 Risks in product usage

Risk	Severity	Probability	Impact	Mitigation Strategy
Leakage of the enclosure	Critical	Probable	Severe damage to circuit board (Arduino)	Reassure the waterproofing of the framework.
Potential harm to the user while placing the sensor in the soil	Moderate	Highly Likely	Possible harm to the user	Give detailed instructions in the user manual.

Table 3: Describing the risks in product usage

There should not be any major risks resulting from a lack of expertise. The only risk would be that something is unclear, and it takes time to research, but that falls more under temporal risks. Speaking of time-based risks, the main risks are the interfacing of the peripherals with the software and the software itself. Both of those can be sensitive to small errors or bugs, and if something small is malfunctioning it can take time to solve. These kinds of risks can be mitigated through simple attention to detail and rigorous testing throughout the development.

2.6 Benefits

DIRTS is meant to be utilized by everyday gardeners who lack knowledge about choosing the correct soil for the plant. Our assumption is that the gardener would like to grow a healthy plant reasonably quickly. This section outlines the benefits of DIRTS that largely outweigh the risks.

2.6.1 Stakeholders

Our product currently has an upfront cost, as it is still in the initial research and development phases. As the product develops and details become finalized, modifications and research can be made to decrease production costs. Currently, there exists little competition that utilizes mobile devices and soil sensors. The ones that do, they don't have an NPK sensor. This makes our product unique in the market.

2.6.2 Household Gardeners

For a household gardener, using DIRTS will allow them to see the health of the soil where they can determine its fertility. This especially becomes important when it comes to dealing with soil erosion. However, as a household gardener, knowing when to replace the soil is difficult. Guides online give a general range of when you might want to change the soil, but do not specify when [4]. Using our product, the gardener will know exactly when they should replace the soil without guessing. This will save them time as well, as we avoid planting on non-ideal soil. We do assume that the household gardener will always want to plant on ideal soil as for these types of gardeners, our product is perfect for.

2.6.3 Students

Students in agricultural institutes can also utilize our product in a different way. They would be able to learn more about the importance of soil fertility with the assistance of our sensor. Moreover, students will have the opportunity to explore differences in growth rates and sizes between ideal soil and non-ideal soil depending upon the provided data. Our product is designed to be used with little expertise in technology, so students spend less time learning about the sensor and more about gardening.

2.6.4 Community Gardens

Some communities grow small time gardens which they intend to harvest off. While we do not aim towards the farming market, community gardens can benefit from our easy-to-use sensor. We believe that volunteers of community gardens may not have professional expertise in gardening, hence they could benefit from our sensor [4]. The benefits are like household gardeners, although we expect that community gardens to be bigger than household gardens. This means that they are managing more soil, thus they benefit even more from our product. Keeping track of soil fertilities for every location in a community garden might get tedious, so having our sensor that can let the user know if the soil is fertile or not will save the gardener some tedium of taking note of how much a soil has been used for.

2.6.5 World

"Even in this hi-tech age, the low-tech plant continues to be the key to nutrition and health."- Jack Weatherford. DIRTS will create greener plants and can lower the entry bar of gardening, which will mean more plants and gardeners in this world. This contributes to improving the world situation in fighting climate change, as the lack of plants is known to be a factor in climate change.

3. Marketing Analysis

The largest selling factor of our product is the capability of performing all the targeted tests through one single device which hasn't been done so far. Our company believes that DIRTS will perform proficiently in our intended market as there is no such device which is affordable and at the same time designed for household and small-scale purposes. As a result, our market includes the public, who want to grow some plants at home and don't know where to start or not sure about the requirements of different plants. This market could be expanded further towards small scale agriculture and botany labs to monitor the plants.

3.1 Current Need

In a pre-pandemic survey (Early 2020), a study revels that 70% people named themselves as 'plant-parents'. This shows that people were already curious about plants but became full plant owners during pandemic. Americans spent roughly $8.5 billion (increment of 18.7%) on plants and gardening supplies as compared to 2019. During 2021 to 2028, an expected growth rate of 4.37% in indoor plant market is forecasted disregarding the impact of pandemic. The data is provided in the figure below is by Data Bridge Market Research [5].

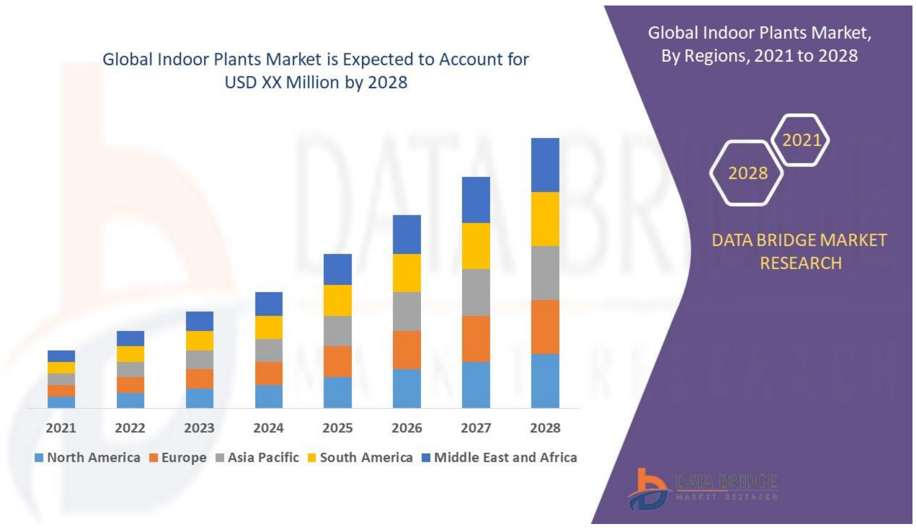


Figure 7: Statistical Data for Indoor Plants Market [5]

In addition to this, global lawn & garden consumables market was valued at USD 16.16 billion in 2021 and is expected to grow at a CAGR of 3.4% during the forecast period [6]. Polaris Market Research performed this analysis and then presented the data in the form of a bar graph presented below:

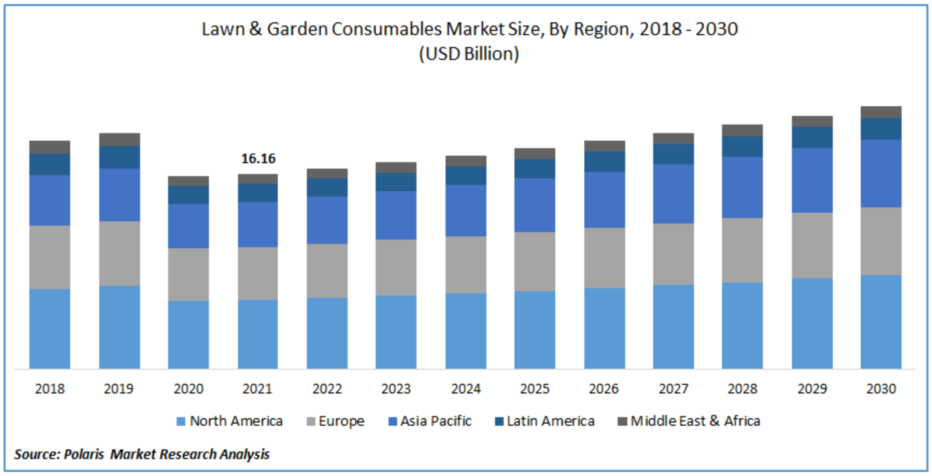


Figure 8: Statistical Data for Garden Consumables Market [6]

3.2 The Competition

There is a very similar product to ours on the market from **E-GreetShopping,** which offers various household products [7]. It is difficult to find information about this company online in English, as their headquarters appears to be in China. Judging from the information provided online the credibility of the company can be questioned, although their product is like ours (Figure-9), an elaborative distinction between our technologies is provided in following paragraphs.

Figure 9: 4-in-one soil sensor by E-GreetShopping [7]

The figure above shows their product named as 4 in 1 smart soil test kit. As of July 25, 2022, it has 16 reviews at a 3.5 star on amazon. This indicates that there is significant room for improvement in this device (assuming all reviews are legitimate). This device measures soil fertility, humidity, temperature, and light level data [7]. Other than light level, which our product measures pH instead, this product functions very similar to ours [8].
We would like to bring attention to the fertility measurement from E-GreetShopping's device. Nutrients in soil are generally identified as elements like Nitrogen, Phosphorus or Potassium. he competitor's device does not specify exactly what elements they are using to determine nutrients, which is not transparent to the user. From analysis of the device, we can see that they are using a conducting sensor meaning nitrogen (an important element of soil) cannot be measured. This means their device will be useless to gardeners who need to know the nitrogen content in soil. Our product will provide nitrogen, phosphorus, and potassium information that is transparent to the user.

Other competitors like **PlantCareTools** and **Renke** offer standalone sensors themselves and do not have Bluetooth capability [9]. This means there is either a display on the sensor itself that will tell the user the measurements or require wires to connect to a display [10]. The sample products from these companies are shown if Figure-10 and 11 respectively.

Figure 10: PlantCare Tools 4-in-1 sensor

Figure 11: Renke NPK sensor

The main issue in above products is that it will require the user to know what the measurements are about. Then, the user will need to search for their specific plant in a search engine. Our mobile application is the ideal way to handle this issue. The gardener will be able to easily search for information in the mobile application, then the mobile application will be able to make suggestions to the gardener even though he/she may not understand what the measurement is.

4 Project Planning

4.1 Project Timeline

To reduce the development time and excessive workload, we divided our company into teams to conquer the work separately. The teams include hardware, software, and database in which most of the work will be done parallel to each other. System integration, along with individual subsystem testing will follow which leads to the final testing phase of the complete system. A Gantt chart describing the timeline for first phase of the project can be seen in Figure-12.

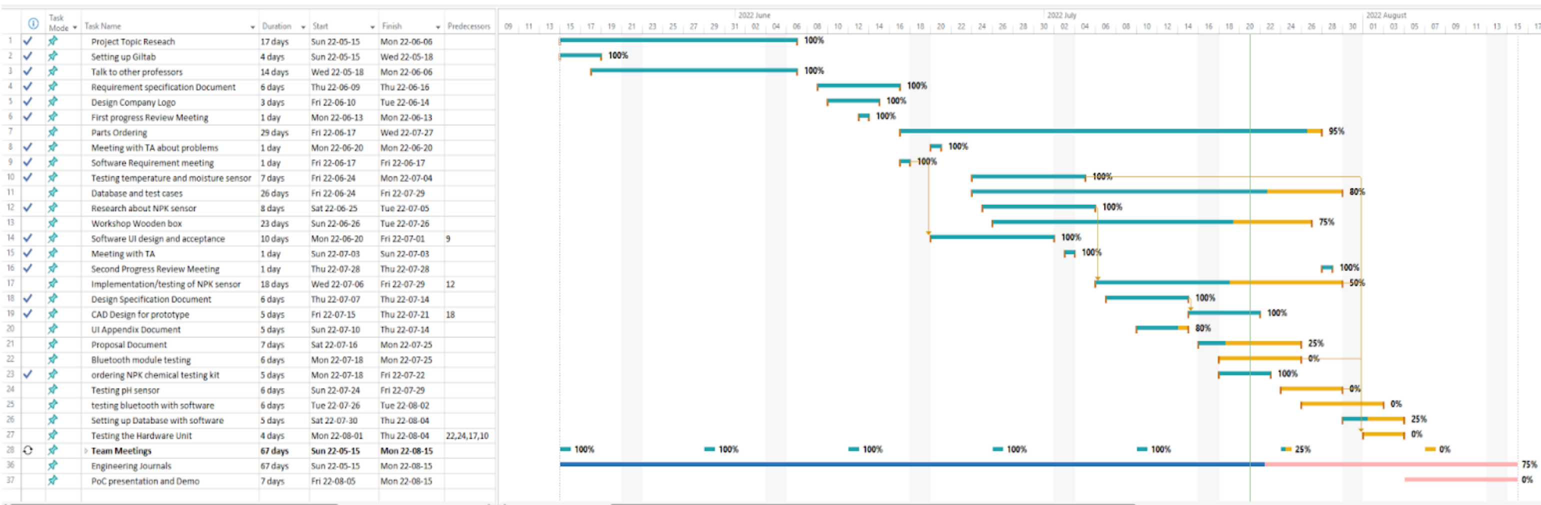


Figure 12: Project timeline shown in a form of Gantt chart

In Capstone-B (ENSC 440), our members will be developing a refined, miniaturized, presentable and easy-to-use version of DIRTS.

4.2 Milestones

There are several key moments during the semester that defines our milestones for the proof-of-concept. Below is the figure showing those milestones and corresponding duration over the semester.

Figure 13: Project timeline showing milestones over the semester

The timeline shown above in the figure is explained in much greater detail in the table below by dividing tasks roughly on a bi-weekly basis.

Mid May	Mid June	Mid July	Mid August
Team Formation, Project Topic Research, Parts list formation	Ordering parts, Requirement Specification, Progress Review Meeting 1, Software/Hardware Development Begins	Ordering parts done, Design and UI doc., Hardware testing begins, Software UI under construction with database, Proposal Document	Final testing and implementation, Proof-of-concept Demonstration

Table 4: Describing the milestones in a bi-weekly manner for 405W

5 Cost Considerations

5.1 Cost Estimate

The financial costs associated with the project include materials categorized from electrical, structural, and sensors. These are the main design materials that will be requiring parts to be ordered. An initial cost analysis was made after considering the availability of items at reasonable costs and units required. Testing equipment like extra MCUs and small sensors didn't add up to extra cost as they were salvaged from group members' possessions. Below in table, you can find a selection of materials based on the requirements and their associated costs.

	Name	**Price per unit (CAD)**	**Total cost (CAD)**
Electrical	Jumper cables	N/A	N/A
	Breadboard	$7.56	7.56
	Resistors	N/A	N/A
	LEDs	$1.29	$3.87
	Arduino Uno	$26.83	$26.83
	HC-05 Bluetooth Module	$16.99	$16.99
Structural	3D printing (SFU)	$0.03/g and $1/hr	$40
Sensors	Temperature Sensor RTD	$14.01	$14.01
	Analog pH Sensor	$44.64	$44.64
	Soil Moisture Sensor	$10.37	$10.37
	LDR sensor	$4.43	$4.43
		Total Cost	$168.7
		Overall Cost (12% tax + 15% contingency)	$214.25= $215

Table 5: Estimated cost projection for the whole project (so far)

While moving towards 440, several cost reductions/additions will be made in some aspects of microcontroller and structural design (3D printing). Moreover, with some possible investment through different resources, we hope to have a working prototype ready under the cost mentioned above.

5.2 Funding Sources

5.1.1 Engineering Science Student Endowment Fund

This fund is administered by Engineering Science Student Society (ESSS). They categorize projects into four different categories: Category A “Competition”, Category B “Entrepreneurial”, Category C “Class” and Category D “Miscellaneous” [11]. We will be contacting ESSS about the fund in 440 and since we meet the criterion in two out of four classes above, there shouldn’t be any difficulties in obtaining that.

5.1.2 Personal funding

During the proof-of-concept phase (ENSC 405W), the whole funding is done by the group members. One of the members purchases a part and then the cost is divided equally among the team. The budget for personal funding is expected to keep under $500 (max $100 each).

6 Company Details

6.1 Company’s Background and Name

Our company consist of five undergrad engineering from Simon Fraser University from different fields which happened to meet each other in a class full of students. The common thing which drives each other is the passion for creating innovative technology which is affordable and makes life a bit easier. Every member contributed with a different set of skills and ethical values, along with strong interpersonal skills for making this project successful.

The company was named Everyday Planting Solutions (EPS) because people cane deduces easily what the company is all about i.e., providing technologies for taking care of plants.

6.2 Product name

Our product has been named DIRTS which is an abbreviation for Direct Interface for Rapid Testing of Soil. The name, DIRTS, was first decided as company’s name but because of its length and describing specific use in its name, it was then mutually decided as a product name.

6.3 Company’s Logo

A bunch of logos were created by our team and in the end, we decided to go with the one that visually describes our focus well. The logo is given in the figure below:

Figure 14: Showing company's logo

6.4 Team Members

Mehar Rehill- CEO (Chief Executive Officer)

Mehar Rehill is a fifth-year biomedical engineering student at Simon Fraser University. She has prior knowledge of C++, CSS, html, and #C. Her former co-op was with a geotechnical company, where she was assigned with assembling, debugging and the calibration of the pressure, temperature, and inclination sensors. She is also acquainted with the designing of an electrical circuit using Altium and Eagle

Francis Chui- CAO (Chief Administrative Officer)

Francis Chui is a fifth-year computer engineer student at Simon Fraser University. In his work, he has worked with FPGAs and software. He worked as a Software Engineer in Test at LMI Technologies. His skills are generally in the software area and has some expertise with Git. Thus, he has been given a role to manage the Gitlab repository and to develop the software for DIRTS.

Kyle Granville- CSO (Chief Scientific Officer)

Kyle Granville is a fifth-year systems engineering student at Simon Fraser University. He has taken four co-op terms at two different companies, including as a system verification engineer at Maxim Integrated and a team lead deployment technician at Microserve. He has experience with FPGAs, microelectronics and circuit analysis, artificial intelligence, and robotics. He also has software coding experience with C/C++, python, VHDL, and C#. He is part of the team working on the hardware design of DIRTS.

Shravan Gupta- CTO (Chief Technical Officer)

Shravan Gupta is a fifth-year computer engineering student at Simon Fraser University. He has undergone six co-op terms with three different companies as Software Engineer where he gained valuable experience in C++, Python, React and SQL. He also learned to effectively communicate technical language with business owners and customers. Thus, is the company's CTO and oversees evaluating the company's system and infrastructure and ensuring its quality.

Gurparkash Singh- COO (Chief Operating Officer)

Gurparkash Singh is a fifth-year biomedical student at Simon Fraser University. His previous work experience includes electrical assembling and debugging, along with some experience in microcontrollers and calibration of sensors. His expertise lies in the hardware enclosure design as well as in the working of sensors with the help of fellow team members.

7 Conclusion

DIRTS aims to provide a base platform for people who have no prior knowledge about planting. It is a promising new technology, which is not only restricted to the field of agriculture or household gardening, but it can also be beneficial in environmental studies. The above documents outline the brief description of the overview of DIRTS followed by risks and benefits of the product. The document also provides a detailed description of market analysis and existing competition henceforth proving the accuracy and viability of our product. An elaborative cost analysis of the product, exhibiting our low cost of production is also included in the document.

The engineers at everyday planting solutions with their provided set of skills and expertise aspire to create DIRTS and bring us one step closer to greener earth, as Jay Kordich once said, *"All life on earth emanates from the green of the plant"*.

8 References

[1] College of Environment Science and Forestry, "Around Your World," State University of New York, [Online]. Available: https://www.esf.edu/pubprog/brochure/soilph/soilph.htm#:~:text=Soils%20tend%20to%20become%20acidic,inorganic%20acids%2C%20such%20as%20nitric. [Accessed 20 July 2022].

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