A Mini-Project report on,

“HydroHive-Terrace Watering System”

Automation and Robotics Department

2025-26

CERTIFICATE

This is to certify that Shrigovinda T Kulkarni 01FE23BAR047, Prajwal S Mullolli-01FE23BAR034, Sujal Patil 01FE24BAR410, Bhoomika Hotagi 01FE23BAR035 & Katila R Nag -01FE23BAR026 have successfully submitted the project titled "HydroHive-Terrace Watering System" as the part Mini Project course for the academic year 2025-26 Odd.

Guide, **Head of the Department**

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Automation and Robotics Department

2025-26

Student Declaration

We the students of Automation and Robotics, 5TH semester declare that all the sheets, CAD, report files and images submitted to department as a part of Mini Project are solemnly modelled, captured and generated by us.

We hereby declare that we have not copied any files or reused the existing ones submitted at any level of course or competitions. The course in-charge, department and University can use the report, models & files for any academic purpose and issues rising out of any copy-right infringement will be liable to us.

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INDEX

List of Figures

List of Tables

Abbreviation List

Abbreviation	Definition
ED	Engineering Design
FR	Functional Requirement
CR	Controller Requirement
AR	Actuation Requirement
IR	Interface Requirement
USB	Universal Serial Bus
SB	Solenoid Box
MC	Main Cabinet
ADC	Analog to Digital Converter
LED	Light Emitting Diode
FEA	Finite Element Analysis
ESTRN	Engineering System TRade-off and Negotiation
LCA	Life Cycle Assessment
PMMA	Polymethyl Methacrylate
ABS PC	Acrylonitrile Butadiene Styrene – Polycarbonate
GPIO	General Purpose Input/Output

HTML	HyperText Markup Language
CSS	Cascading Style Sheets
PHP	Hypertext Preprocessor
MySQL	My Structured Query Language
EDP	Engineering Design Process
IOT	Internet Of Things

1. INTRODUCTION

The Mini Project course is designed to provide us with practical exposure to real-world engineering problem solving by systematically applying the Engineering Design Process (EDP). Unlike traditional theory-oriented courses, this course emphasizes learning through hands-on design, implementation, testing, and iterative improvement of an engineering solution. It bridges the gap between conceptual knowledge and practical application, preparing us for industry-oriented challenges.

The Engineering Design Process serves as a structured and logical framework that guides engineers from problem identification to solution realization. In this course, we begin by clearly defining a real-world problem and understanding user requirements, constraints, and objectives. This is followed by background research, brainstorming of multiple design alternatives, and selection of the most feasible solution based on technical, economic, and sustainability considerations.

Once a design concept is finalized, the process moves toward system modelling, component selection, and implementation, using appropriate tools, software, and hardware. Prototyping and simulation play a crucial role in validating the design before final realization. The course also emphasizes testing, evaluation, and iterative refinement, allowing us to improve system performance based on observed results and feedback.

By following the Engineering Design Process, the Mini Project course helps us develop essential engineering skills such as critical thinking, teamwork, communication, documentation, and project management. It encourages creativity while maintaining a disciplined approach to design. Overall, this course enables we to gain confidence in transforming innovative ideas into functional engineering solutions in a structured and professional manner.

2. THEME

"AGRICULTURE – TERRACE FARMING"

Terrace farming is an innovative agricultural practice that enables food production in limited or unconventional spaces such as building rooftops and terraces. With rapid urbanization and decreasing availability of cultivable land, terrace farming has emerged as a practical solution to grow vegetables, fruits, and medicinal plants within city environments. This method helps individuals and communities participate in agriculture even when traditional farmland is not accessible.

In terrace farming, crops are grown in containers, grow bags, or raised beds placed on rooftops. The soil used is usually a mixture of compost, coco peat, and garden soil, which makes it lightweight and suitable for terraces. Plants such as tomatoes, leafy vegetables, chilies, herbs, and flowering plants are commonly grown due to their adaptability and short growth cycles. Proper drainage, sunlight exposure, and regular watering are essential factors for successful terrace farming.

One of the major advantages of terrace farming is its contribution to environmental sustainability. It helps reduce the urban heat effect by lowering rooftop temperatures and improves air quality by increasing green cover. Additionally, terrace farming promotes the use of organic waste by converting kitchen waste into compost, thereby reducing household waste generation. This practice also encourages water conservation when combined with drip irrigation or rainwater harvesting techniques.

Terrace farming also offers economic and health benefits. It reduces dependency on market-purchased vegetables and ensures access to fresh, chemical-free produce. For many households, it serves as a supplementary source of income or a cost-saving measure. Moreover, engaging in terrace farming promotes awareness about food production, healthy eating habits, and responsible resource utilization.

From an engineering perspective, terrace farming provides opportunities to apply automation, sensors, and smart irrigation systems to optimize plant growth. Technologies such as soil moisture sensors, automated watering systems, and weather monitoring can enhance efficiency and reduce manual effort. Thus, terrace farming represents a meaningful intersection of agriculture and technology, making it an ideal theme for engineering mini projects focused on sustainability and innovation.

2.1 HYDROHIVE- TERRACE WATERING SYSTEM

HydroHive is a smart terrace watering system designed to automate and optimize the irrigation of plants grown on rooftops and terrace gardens. The system ensures efficient water usage by watering plants only until the soil moisture reaches 70%, thereby preventing over-watering and under-watering. It also allows users to schedule watering for specific plants, reducing manual effort while maintaining optimal plant health.

This system is particularly useful in urban households, apartments, and small residential buildings where terrace farming is practiced. HydroHive operates in two modes: an automatic mode, where watering is controlled based on soil moisture, weather, and temperature conditions, and a manual mode, where users can water plants instantly or schedule watering through a web interface. The system currently supports two plants, each monitored independently, and includes a multilingual voice assistant that supports Kannada, Hindi, Marathi, and English, along with terrace farming tips, making it accessible and user-friendly.

The importance of HydroHive lies in its contribution to sustainable urban agriculture and smart water management. By storing soil moisture values in a database, the system enables monitoring and analysis of plant conditions over time. Through automation, intelligent decision-making, and user interaction, HydroHive helps conserve water, improve plant health, and encourage terrace farming practices, demonstrating how engineering and automation can effectively address modern agricultural challenges in cities.

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2.2 Literature Survey & Market Survey

A. Literature Survey

Table No. 2.2.1 - List of papers/articles

Sl. No.	Article Name	Author & Publisher	Year
01	Optimized Water Scheduling Using IoT Sensor Data in Smart Farming	Venkatra Krishna Kishore, K., Yaswanth Kumar, B., Venkatramaphanikumar, S. Springer, Singapore	2020
02	IoT based water management	C. Rajurkar, S. R. S. Prabaharan and S. Muthulakshmi IEEE	2017
03	An Internet of Things (IoT) based sustainable water management	S. Narendran, P. Pradeep and M. V. Ramesh IEEE	2017
04	Real Time Internet of Things (IoT) Based Water Quality Management System	Saif Allah H. AlMetwally , Mohamed K. Hassan , Mohamed H. Mourad Elsevierv	2020
05	IoT-Based Water Management Systems: Survey and Future Research Direction	S. Ismail, D. W. Dawoud, N. Ismail, R. Marsh and A. S. Alshami IEEE	2022
06	Enhancing agricultural water management through sensor-based irrigation systems	Nagabhooshanam, N., Sharma, K., Kaur, M., Singh, R., & Murthy, N. B. C. S. N Taylor & Francis(publisher)	2025
07	IoT-Based Terrace Farming System for Cities	L. J. Ballais, T. N. Sharma, H. W. Thu, S. D. A. P. Sanadeera, A. Taparugssanagorn and M. N. Dailey, IEEE	2021

08	Innovative Dashboard Designs for Real-Time Smart Farming Data Visualization	Astri Idayu Athesan, & Mohd Faizul Emizal Mohd Ghazi	2024
09	Smart Watering System for Terrace Garden Using LabVIEW	L S S Pavan Kumar Chodisetti K Monisha Sindhu; M Naveen Kumar Manikanta Venkateswara Rao Ch	2024
10	Sustainable smart agricultural approach in terrace farming through sensor fusion technology	Komathi J, Srirangarajalu N Kumaresan G	2025

Optimized Water Scheduling Using IoT Sensor Data in Smart Farming (2020)

This paper discusses how Internet of Things (IoT) technology can be used to improve irrigation scheduling in agriculture. The authors explain that in traditional irrigation systems, water is supplied either manually or based on fixed time schedules. Such methods do not consider real-time soil or environmental conditions, which often results in water wastage and inefficient irrigation. To solve this problem, the paper proposes an IoT-based smart irrigation system that uses sensor data to decide when irrigation is required.

In the proposed system, sensors such as soil moisture, temperature, and humidity sensors are placed in the agricultural field. These sensors continuously monitor the condition of the soil and surrounding environment. The collected data is transmitted through IoT communication modules to a central controller or cloud platform. Based on the received data, the system analyzes the water requirement of crops and automatically schedules irrigation.

The paper highlights that real-time monitoring plays a major role in optimizing water usage. When the soil moisture level falls below a certain threshold, the system activates irrigation, and when sufficient moisture is detected, water supply is stopped. This automated decision-making reduces human effort and ensures that crops receive the right amount of water at the right time. The authors also mention that such optimized irrigation systems help in conserving water and improving crop yield.

The system described in the paper is mainly designed for smart farming environments and large agricultural fields. It focuses more on data collection, analysis, and optimization techniques rather than simple hardware implementation. Still, the overall concept clearly shows how IoT can make irrigation more intelligent and efficient [1].

What We Have Taken from This Paper for Our Project

From this paper, we have taken the fundamental idea of using soil moisture sensor data to control irrigation automatically. The concept of monitoring soil conditions in real time and making irrigation decisions based on sensor values is directly applied in our project.

We have also adopted the idea of threshold-based control, where irrigation is turned ON when soil moisture is low and turned OFF when adequate moisture is reached. While the paper uses advanced data analysis methods, our project simplifies this approach by using a microcontroller-based system suitable for terrace farming.

Additionally, this paper helped us understand the importance of automating irrigation to reduce water wastage and human involvement. Using this concept, our project implements an automatic irrigation system that is efficient, low-cost, and practical for small-scale and urban farming applications.

IoT Based Water Management (2017)

This paper explains how Internet of Things (IoT) technology can be applied to manage water resources efficiently. The authors focus on the growing problem of water wastage due to manual control and lack of proper monitoring systems. Traditional water management methods depend heavily on human operation, which can lead to errors, delays, and inefficient use of water. To overcome these issues, the paper proposes an IoT-based water management system that automates monitoring and control.

In the proposed system, different types of sensors are used to measure parameters such as water level, water flow, and water usage. These sensors are connected to a microcontroller and IoT communication modules, allowing real-time data to be sent to a monitoring system. Based on this data, water supply can be controlled automatically using actuators like motors and valves. The system also supports remote monitoring, enabling users to check water usage and system status from anywhere.

The paper highlights that IoT-based water management systems improve efficiency by providing accurate data and timely control. Automated water distribution reduces wastage and ensures that water is supplied only when required. The authors suggest that such systems can be applied in various areas such as residential buildings, industries, agriculture, and smart cities.

Although the paper discusses water management in general, it clearly explains how automation and real-time monitoring can improve water usage. The focus is more on system architecture and concept rather than detailed agricultural implementation [2].

What We Have Taken from This Paper for Our Project

From this paper, we have taken the concept of automated water control using sensors and actuators. The idea of using valves and motors to control water flow automatically is directly applied in our project through the use of pumps and solenoid valves.

We also adopted the concept of real-time monitoring and control, where the system continuously checks water-related parameters and responds accordingly without manual intervention. This helped us design an irrigation system that operates automatically based on sensor input.

Additionally, this paper helped us understand how IoT-based systems can reduce water wastage and improve efficiency. Using this knowledge, our project applies automated water management specifically for irrigation, making water usage more controlled and efficient in terrace farming.

An IoT-Based Sustainable Water Management (2017)

This paper focuses on the use of Internet of Things (IoT) technology to achieve sustainable water management. The authors explain that increasing population, urbanization, and climate change have created serious challenges related to water scarcity. Traditional water management methods are not sufficient to handle these challenges, which makes the adoption of smart technologies necessary. The paper proposes an IoT-based framework that helps in monitoring and managing water resources in a more efficient and sustainable manner.

In the proposed system, IoT sensors are used to collect data related to water usage, environmental conditions, and system performance. These sensors continuously send data to a central monitoring platform where it can be analyzed. The collected information helps in understanding water consumption patterns and identifying areas where water can be conserved. The authors emphasize that continuous monitoring enables better planning and decision-making related to water distribution.

The paper mainly discusses the system architecture and conceptual design of sustainable water management using IoT. It highlights how automation and real-time monitoring can reduce water wastage and support long-term conservation. However, the paper does not focus much on specific hardware implementation or real-time control of irrigation systems. The discussion is more theoretical and oriented towards sustainability goals rather than practical field deployment [3].

What We Have Taken from This Paper for Our Project

From this paper, we have taken the importance of sustainability and water conservation as a key objective of our project. The idea that water should be used efficiently and responsibly guided the overall design of our irrigation system.

We also adopted the concept of continuous monitoring using IoT sensors, which helps in making better decisions related to water usage. In our project, this idea is implemented by continuously monitoring soil moisture levels to ensure that water is supplied only when required.

Additionally, this paper helped us understand how IoT-based systems can support long-term water conservation. Using this understanding, our project focuses on reducing water wastage through automated irrigation, making it suitable for sustainable terrace farming practices.

Real-Time IoT-Based Water Quality Management System (2020)

This paper focuses on monitoring water quality using Internet of Things (IoT) technology. The authors explain that water quality plays a very important role in agriculture, domestic usage, and industrial applications. Poor quality water can negatively affect crop growth, soil health, and overall agricultural productivity. Traditional methods of water quality testing are usually manual, time-consuming, and done only at specific intervals, which may not detect sudden changes in water quality.

To overcome these limitations, the paper proposes a real-time IoT-based water quality monitoring system. In this system, different sensors are used to measure water quality parameters such as pH level, temperature, turbidity, and conductivity. These sensors continuously collect data from the water source and transmit it to a monitoring system through IoT communication modules. The data is displayed in real time, allowing users to observe changes in water quality instantly.

The authors highlight that real-time monitoring helps in early detection of water contamination and allows quick corrective actions to be taken. The system can also generate alerts when the measured parameters exceed safe limits. This improves reliability and reduces the risk of using unsuitable water for agriculture or other purposes. The paper mainly focuses on system design and data monitoring rather than irrigation control.

Although the paper is centered on water quality management, it clearly demonstrates how IoT enables continuous monitoring and real-time data transmission. The system improves efficiency compared to conventional water testing methods and supports better water resource management [4].

What We Have Taken from This Paper for Our Project

From this paper, we have taken the concept of real-time monitoring using IoT sensors. The idea of continuously collecting data and observing system conditions in real time helped us design a more responsive irrigation system.

We also adopted the principle of using sensor data to support better decision-making. In our project, instead of water quality parameters, we monitor soil moisture levels to decide when irrigation should be turned ON or OFF.

Additionally, this paper helped us understand the importance of reliability and timely response in IoT-based systems. Using this understanding, our project ensures that irrigation actions are taken immediately based on sensor readings, improving water usage efficiency in terrace farming.

IoT-Based Water Management Systems: Survey and Future Research Directions (2022)

This paper is a survey study that reviews various Internet of Things (IoT) based water management systems developed by different researchers. Instead of proposing a single system, the authors analyze multiple existing solutions related to water monitoring, irrigation management, and resource optimization. The paper gives a broad understanding of how IoT technologies are being applied in the field of water management.

The authors discuss different types of sensors, communication technologies, and system architectures used in IoT-based water management. They also compare the advantages and disadvantages of various approaches. Important issues such as data accuracy, system reliability, energy consumption, scalability, and cost are clearly explained. The paper highlights that although many systems show promising results, most of them face challenges when implemented in real-world conditions.

One of the major points discussed in the paper is that many IoT-based water management systems are either too expensive or too complex for small-scale users. The authors also mention that lack of standardization and user-friendly design limits the adoption of these systems. The paper concludes by suggesting future research directions, such as developing low-cost, simple, and efficient water management solutions [5].

What We Have Taken from This Paper for Our Project

From this survey paper, we have taken a clear understanding of existing IoT water management technologies and their limitations. The challenges discussed in the paper helped us decide the design approach for our project.

We adopted the idea of building a simple, low-cost, and practical system rather than a complex one. The paper motivated us to focus on ease of use, affordability, and real-world applicability.

Additionally, this paper helped us understand the importance of reliability and efficiency in IoT systems. Using these insights, our project emphasizes stable sensor readings and automatic irrigation control, making it suitable for terrace and small-scale farming applications.

Enhancing Agricultural Water Management Through Sensor-Based Irrigation Systems (2025)

This paper focuses on improving agricultural water management by using sensor-based irrigation systems. The authors explain that agriculture consumes a major portion of available freshwater resources, and inefficient irrigation practices often result in significant water loss. Traditional irrigation methods depend on fixed schedules or manual judgment, which do not accurately match the actual water requirements of crops. To solve this problem, the paper proposes a sensor-based automated irrigation approach.

In the proposed system, sensors such as soil moisture sensors and environmental sensors are used to monitor field conditions continuously. These sensors collect real-time data related to soil moisture levels and climatic conditions. Based on this data, the irrigation system supplies water only when required by the crops. The paper highlights that this method helps maintain optimal soil moisture levels, which is essential for healthy crop growth.

The authors also discuss the advantages of automation in agriculture, such as reduced labor requirements, improved irrigation accuracy, and better utilization of water resources. The system aims to increase crop yield while minimizing water wastage. The paper mainly focuses on large-scale agricultural fields and advanced sensor-based techniques to manage irrigation efficiently.

Overall, the study clearly shows that sensor-based irrigation systems play a crucial role in improving water efficiency and supporting sustainable agriculture [6].

What We Have Taken from This Paper for Our Project

From this paper, we have taken the core concept of sensor-based irrigation, where irrigation decisions are made based on soil moisture levels. This concept is directly applied in our project by using soil moisture sensors to control water supply automatically.

We also adopted the idea of maintaining optimal soil moisture for healthy plant growth. Our system ensures that plants receive water only when required, preventing over-irrigation and under-irrigation.

Additionally, this paper helped us understand the importance of automation in reducing manual effort and improving efficiency. Using this idea, our project implements an automated irrigation system suitable for terrace farming, making water management easier and more effective.

IoT-Based Terrace Farming System for Cities (2021)

This paper focuses on the application of Internet of Things (IoT) technology for terrace farming in urban areas. The authors explain that due to rapid urbanization and limited land availability, terrace farming has become an important solution for growing food in cities. However, managing terrace farms manually can be difficult due to limited time, lack of technical knowledge, and irregular water management practices. To address these challenges, the paper proposes an IoT-based terrace farming system.

In the proposed system, various sensors are used to monitor environmental parameters such as soil moisture, temperature, and humidity. The sensor data is transmitted to a controller and can be monitored remotely using IoT platforms. This allows users to keep track of their terrace farm conditions without being physically present. The system helps in improving plant health and maintaining suitable growing conditions.

The paper emphasizes the importance of automation and remote monitoring in urban farming. By using IoT technology, terrace farming becomes more efficient and less dependent on manual effort. However, the paper mainly focuses on monitoring and data collection rather than detailed automation of irrigation control.

Overall, this study highlights how IoT can support sustainable urban agriculture by making terrace farming more manageable and efficient [7].

What We Have Taken from This Paper for Our Project

From this paper, we have taken the idea of applying IoT technology specifically to terrace farming. This helped us clearly define the application area of our project.

We also adopted the concept of remote monitoring of farming conditions, which influenced our system design to support real-time observation of sensor data.

Additionally, this paper guided us in understanding the importance of automation in urban farming environments. Using this understanding, our project enhances terrace farming by implementing automated irrigation using pumps and solenoid valves, making water management easier for city-based users.

Innovative Dashboard Designs for Real-Time Smart Farming Data Visualization

This paper focuses on the importance of data visualization in smart farming systems. The authors explain that modern smart farming generates a large amount of data from sensors such as soil moisture, temperature, humidity, and other environmental parameters. However, raw sensor data in numerical form is difficult for farmers to understand and use effectively. To solve this problem, the paper proposes innovative dashboard designs that present real-time farming data in a clear and user-friendly manner.

The paper discusses different dashboard elements such as charts, graphs, indicators, and status alerts that help users quickly understand the current condition of the farming system. Real-time visualization allows farmers to monitor changes in environmental conditions and system performance without technical expertise. The authors emphasize that good dashboard design improves decision-making and reduces dependency on manual data interpretation.

The study highlights how real-time dashboards can be accessed through web or mobile applications, enabling remote monitoring of farming activities. This is especially useful for urban and small-scale farmers who may not always be physically present at the farm. The paper mainly focuses on software design and user interface aspects rather than hardware automation.

Overall, the paper clearly shows that effective data visualization plays a crucial role in making IoT-based smart farming systems more practical, usable, and efficient [8].

What We Have Taken from This Paper for Our Project

From this paper, we have taken the concept of real-time monitoring and clear data presentation. The idea that sensor data should be easy to understand influenced how we plan to observe and analyze system performance in our project.

We also adopted the principle that user-friendly interfaces improve system usability, especially for non-technical users. Although our current project focuses more on hardware automation, this paper guides future improvements such as adding dashboards or display interfaces.

Additionally, this paper helped us understand the importance of remote access and system transparency. Using these ideas, our project aims to provide a smart irrigation solution where system behavior is based on real-time data and can be easily monitored.

Smart Watering System for Terrace Garden Using LabVIEW

The paper “Smart Watering System for Terrace Garden Using LabVIEW” presents an automated irrigation solution specifically designed for terrace and small-scale gardening applications. The study focuses on overcoming the limitations of manual watering by introducing a smart system that monitors soil conditions and controls water supply automatically. By using real-time sensing and software-based control, the proposed system aims to ensure optimal watering while minimizing water wastage and human intervention.

In the proposed system, soil moisture sensors are used to continuously monitor the moisture content of the soil. The sensor data is interfaced with a data acquisition system and processed using the LabVIEW platform, which provides a graphical programming environment for system monitoring and control. Based on predefined threshold values set within the LabVIEW interface, the system automatically activates or deactivates the watering mechanism, ensuring that plants receive the required amount of water. The LabVIEW-based dashboard also allows users to visualize sensor data and system status in real time.

The paper highlights that the integration of software tools like LabVIEW with sensor-based automation enhances system reliability, monitoring accuracy, and user interaction. The proposed solution is particularly suitable for terrace gardens and urban farming environments, where controlled watering is essential. Although the system relies on LabVIEW for implementation and monitoring, the core concept of soil moisture–based automated irrigation demonstrates an effective approach for smart watering applications [9].

Sustainable Smart Agricultural Approach in Terrace Farming through Sensor Fusion Technology

The paper "Sustainable Smart Agricultural Approach in Terrace Farming through Sensor Fusion Technology" presents an intelligent and sustainable solution for terrace farming by integrating multiple sensors through sensor fusion techniques. The study addresses the challenges of urban and terrace farming, such as limited space, inefficient water usage, and lack of real-time monitoring. By combining data from different environmental sensors, the proposed system aims to improve decision-making accuracy and resource utilization while promoting sustainable agricultural practices.

In the proposed approach, various sensors such as soil moisture, temperature, humidity, and light intensity sensors are deployed to continuously monitor plant and environmental conditions. Instead of relying on a single sensor, sensor fusion technology is used to combine data from multiple sources, providing more reliable and accurate information about crop requirements. The fused sensor data is processed by a control unit, which determines appropriate actions such as irrigation scheduling and environmental adjustments.

The paper emphasizes that sensor fusion enhances system reliability and reduces errors caused by faulty or fluctuating sensor readings. By making irrigation decisions based on combined sensor data, the system ensures optimal water usage and improved crop health. The authors highlight that this approach supports sustainability by minimizing water wastage, reducing manual intervention, and improving productivity in terrace farming environments. Overall, the study demonstrates how sensor fusion–based smart agriculture can effectively support sustainable and efficient terrace farming systems [10].

B. Market Survey

1) Tuya-Based 8-Zone Wi-Fi Sprinkler Controllers

Tuya-based sprinkler controllers are widely adopted due to their compatibility with the Tuya Smart ecosystem. These controllers support multi-zone irrigation, typically up to eight zones, making them suitable for medium to large home gardens and lawns. Users can create custom schedules, enable rain-skip functions, and control watering remotely through a smartphone application. Integration with voice assistants like Alexa and Google Assistant enhances user convenience.

However, these controllers primarily focus on scheduling and connectivity. Advanced sensing features such as soil moisture measurement and water flow monitoring are not built-in, requiring additional external sensors. This increases system complexity and overall cost. Hence, while Tuya-based controllers are user-friendly and scalable, they lack comprehensive real-time environmental feedback.

2) IFITech Wi-Fi Irrigation Timer

The IFITech Wi-Fi irrigation timer is designed with compactness and simplicity in mind. It is especially suitable for balcony gardens, terrace gardens, and small green spaces. The device supports app-based control, automatic scheduling, and voice assistant integration, enabling users to manage watering even when away from home.

A key concern with this product is its varying weather resistance. Since IP ratings differ across models, long-term outdoor reliability depends on proper installation and environmental conditions. Additionally, the system does not offer detailed analytics or sensor-based decision-making, limiting its intelligence compared to premium solutions.

3) LinkTap Smart Water Timers

LinkTap represents the premium segment of smart irrigation products. It stands out due to its real-time flow monitoring, leak detection, and water usage analytics. These features allow precise tracking of water consumption and immediate alerts in case of abnormal flow or leakage, making it highly suitable for water-sensitive applications.

The system also offers long-range connectivity and robust performance. However, despite its advanced flow monitoring, soil moisture sensing is not integrated by default and must be added externally. The higher cost may also limit adoption among students or small-scale users.

4) Solar / Wi-Fi Smart Water Timers (Multi-Brand Solutions)

Solar-assisted smart water timers are gaining popularity due to their energy efficiency and low maintenance requirements. These devices typically combine solar panels with battery backup, enabling reliable operation even in power-constrained environments. Core features include remote control, scheduled watering, and rain-delay functionality.

While these systems are ideal for sustainable setups, they usually lack advanced analytics, such as flow-rate measurement or historical data visualization. As a result, they are better suited for basic automation rather than intelligent water management.

5) DIY Soil-Moisture Smart Watering Kits

DIY smart watering kits are highly popular among students, researchers, and hobbyists. These kits usually include soil moisture sensors, relay modules, pumps or valves, and basic microcontroller support. Their primary advantage lies in real-time soil moisture measurement and low cost.

However, these solutions require users to design and develop their own mobile application or dashboard for monitoring and control. Reliability, durability, and scalability depend heavily on the user's implementation skills. Despite these challenges, DIY kits provide excellent learning opportunities and flexibility for customization.

2.3 Project Gantt Chart

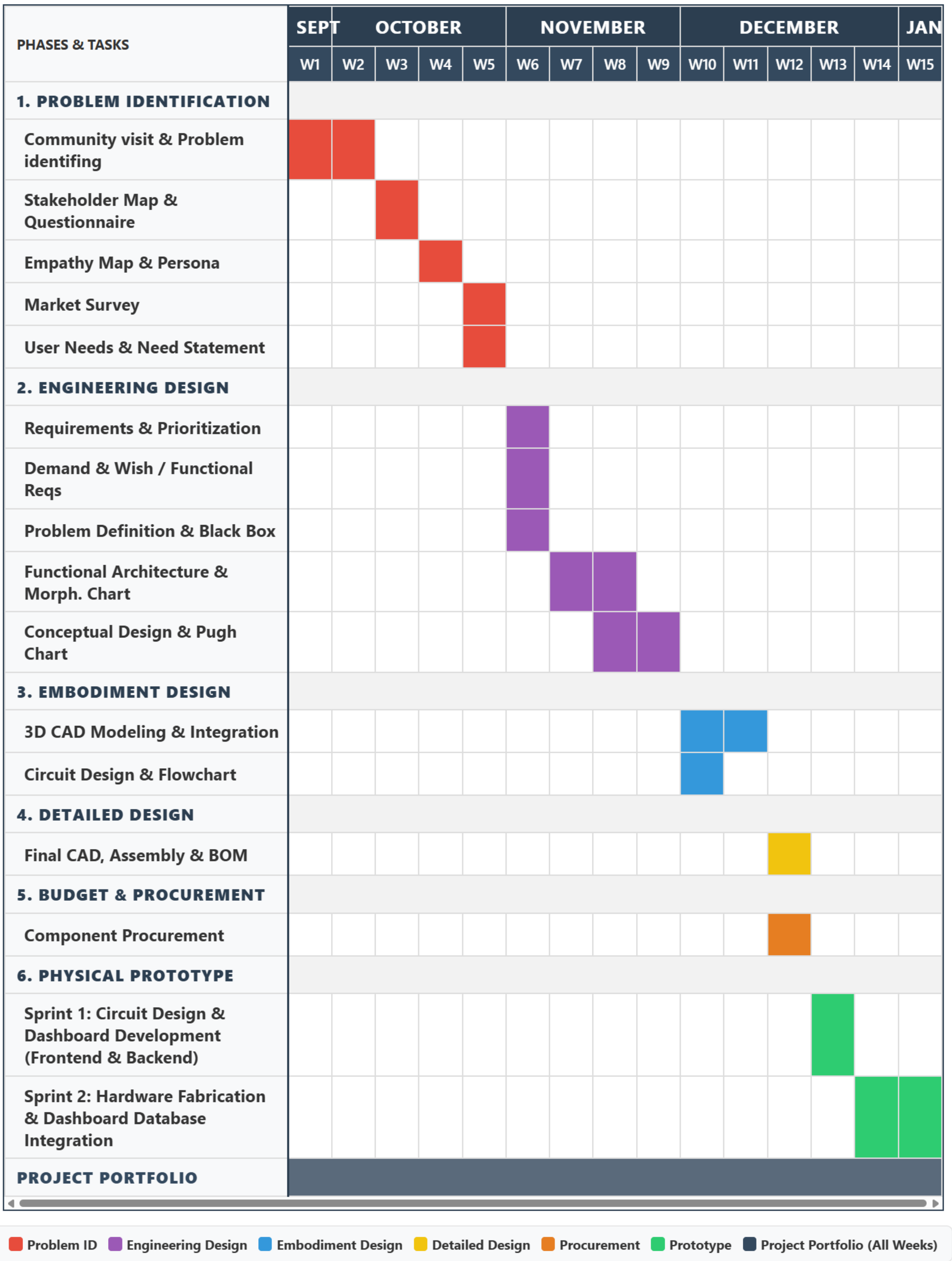

Fig 2.3.1 Project Gantt Chart

The Gantt chart shown in Fig. 2.3.1 illustrates the structured project timeline planned from September to January, mapping all major phases and tasks in a sequential and time-bound manner. The project begins with problem identification, including community visits, stakeholder mapping, and user need analysis, followed by the engineering design phase where requirements, functional architecture, and concept selection are carried out. The embodiment design phase focuses on 3D CAD modeling, circuit design, and system flowcharts, which then lead to detailed design, budgeting, and procurement activities. Finally, the physical prototyping phase is executed through two Scrum-based sprints covering circuit and dashboard development, hardware fabrication, and full system integration. Overall, this Gantt chart ensures clear task distribution, effective time management, and smooth progression from concept to a functional prototype.

3. Product Vision Board

3.1 Product vision Board Overview and Its Role in the Project

The Product Vision Board is a tool used to understand and plan the overall idea of a product. It helps in clearly defining what the product is, who will use it, and what problems it is meant to solve. The board includes details like the product vision, target users, user needs, important features, and business goals. It helps the team stay focused and work in the same direction. By keeping goals clear, it also helps in making better decisions during product development. Overall, the Product Vision Board acts like a guide or roadmap for developing a successful product.

The Product Vision Board gives a clear and organized overview of the smart terrace farming system proposed in this project. It helps in understanding the overall direction of the project by combining the vision, target users, user needs, product features, and business goals in one place. This makes sure that the project stays focused and well planned from the initial stage to the final implementation.

The main vision of the project is to make terrace farming easier with the help of intelligent automation, so that people with any level of experience can grow healthy vegetables and herbs at home. By reducing manual work and improving water usage, the system supports sustainable and efficient urban farming.

The target users include urban households, apartment residents, working professionals, elderly people, and families who are interested in eco-friendly living. Identifying these users helps in designing a system that is compact, easy to operate, and suitable for small terrace or balcony spaces. The system is especially useful for people who have limited time or physical effort to spend on manual gardening.

The user needs focus on common problems such as irregular watering, lack of information about soil moisture, and wastage of water due to manual irrigation. These issues are solved by using automatic watering based on soil moisture, real-time monitoring, and alert notifications for low water levels or system errors. This helps in maintaining healthy plant growth while also saving water.

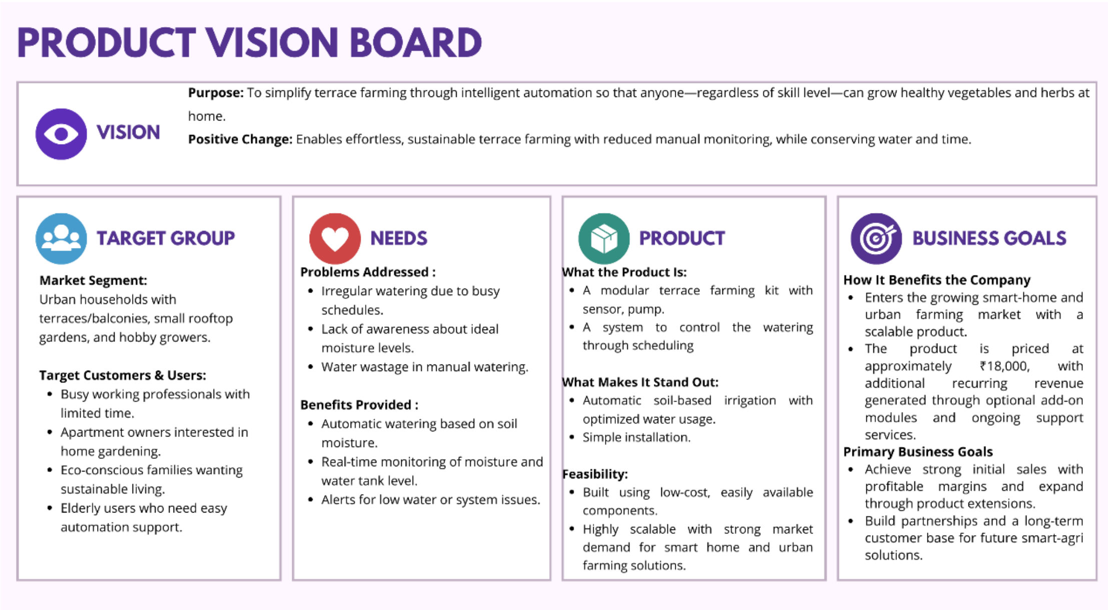

Fig 3.1.1 Product vision board

Figure 3.1.1 illustrates the Product Vision Board of the proposed smart terrace farming system, presenting a clear overview of the project's vision, target users, identified needs, product features, and business goals. The vision focuses on simplifying terrace farming through intelligent automation to enable sustainable and efficient plant growth with minimal manual effort. It identifies urban households, working professionals, elderly users, and eco-conscious families as the primary users while addressing issues such as irregular watering, lack of soil moisture awareness, and water wastage. The product is described as a modular automated irrigation kit with sensors and scheduling capabilities, offering real-time monitoring and optimized water usage, while also highlighting scalability, affordability, and long-term business potential, as shown in Fig. 3.1.1.

4. Design Thinking

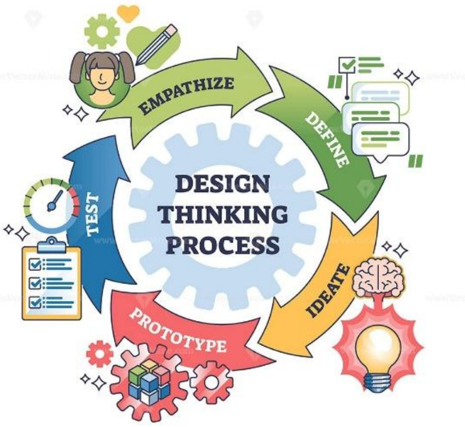

Fig 4.1 Design thinking process

The given image explains the Design Thinking process in a simple and easy-to-understand manner. As shown in Fig. 4.1, the process consists of five main stages: Empathize, Define, Ideate, Prototype, and Test, which are arranged in a circular flow. This circular arrangement shows that design thinking is not a one-time process but an iterative one, where improvements are made continuously based on feedback and results.

The Empathize stage focuses on understanding the user’s needs, problems, and experiences. This is followed by the Define stage, where the actual problem is clearly identified. In the Ideate stage, different ideas and possible solutions are generated through brainstorming and creative thinking. The Prototype stage involves creating simple models or mock-ups of the selected ideas, and the Test stage is used to evaluate these prototypes in real situations to check their effectiveness.

The image also includes creative elements such as light bulbs, gears, and icons, which represent innovation, imagination, and problem-solving. Overall, the image shows that design thinking is a balanced approach that combines creativity with logical steps to develop user-focused and practical solutions.

4.1 Stakeholder Map

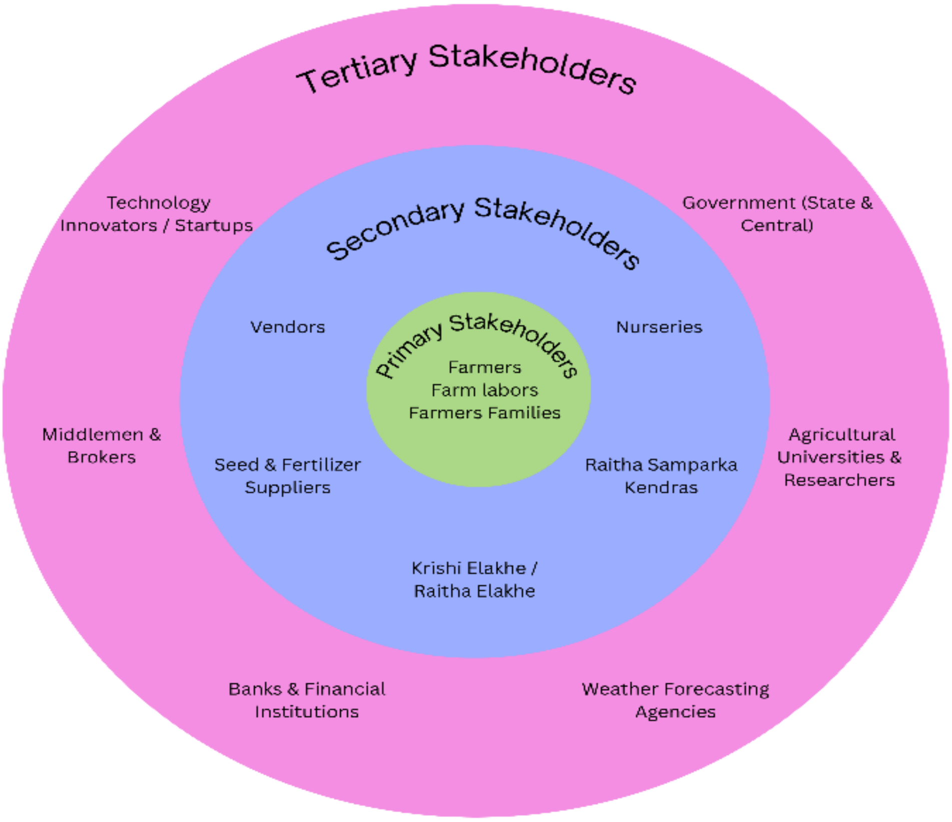

Fig 4.1.2 Stakeholder Map

The image illustrates the stakeholder classification involved in the project using three concentric layers, representing primary, secondary, and tertiary stakeholders. As shown in Fig. 4.1.2, this layered structure helps in understanding the level of involvement and influence each group has in the system.

Primary stakeholders include farmers and gardeners, who are the direct users of the system. They interact with the project in real field conditions by using the system for irrigation and crop management. Their inputs regarding crop type, water requirements, and practical challenges are crucial. Feedback from these users helps improve usability, efficiency, and overall performance of the system.

Secondary stakeholders consist of nurseries and fertilizer/pesticide shops. They support the project indirectly by supplying seeds, plants, fertilizers, and pesticides that complement the irrigation system. They may also guide farmers on suitable inputs and practices so that irrigation schedules match crop and soil needs, leading to better productivity.

Tertiary stakeholders, as indicated in Fig. 4.1.2, include university students and professors. Their role is mainly academic and technical. Students contribute through research, system development, testing, and documentation, while professors provide guidance, validation of design, and technical mentoring. Their involvement ensures that the project follows proper engineering standards and innovative practices.

4.2 Empathy Map

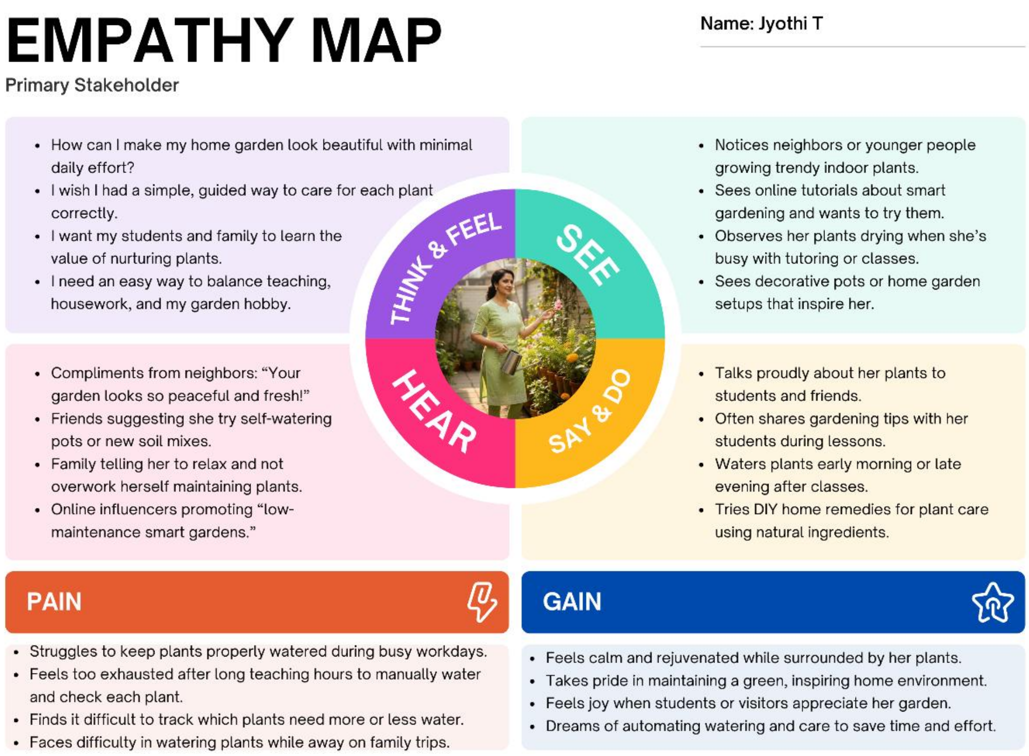

Fig. 4.2.1 Empathy Map of Primary Stakeholder – Mrs.Jyothi T

Fig. 4.2.2 Empathy Map of Primary Stakeholder – Mr.Prashant

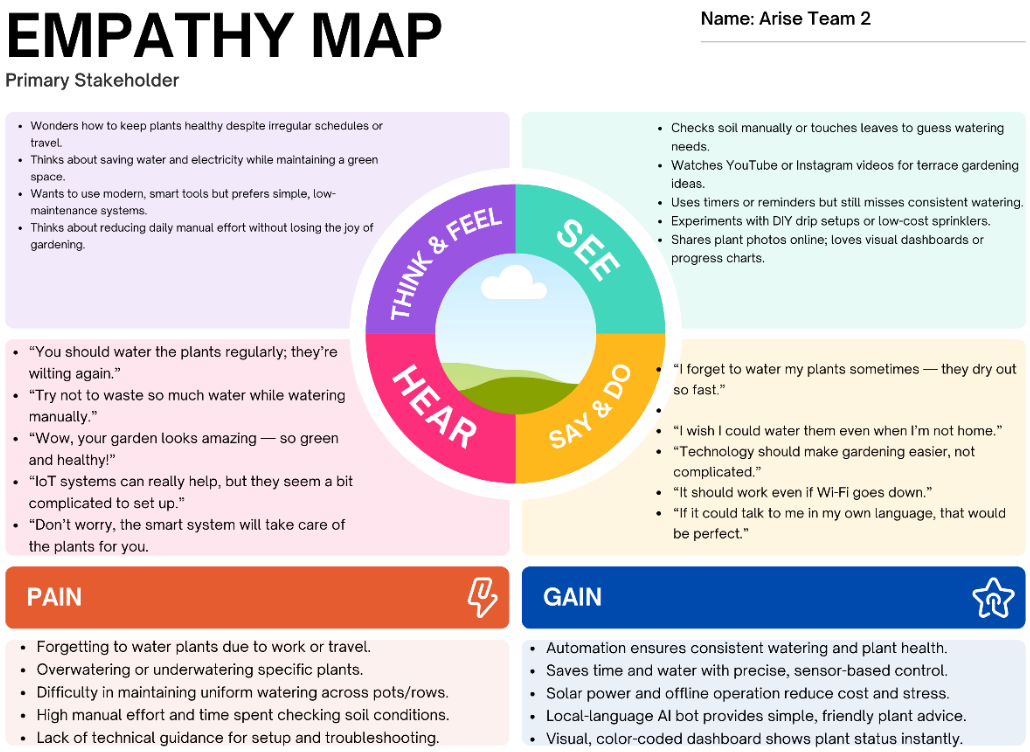

Fig 4.2.3 Team Empathy Map of Primary Stakeholder

The empathy maps of individual primary stakeholders highlight key pain points such as forgetting to water plants due to busy schedules, improper watering practices, and the high manual effort required to monitor plant health, as shown in Fig. 4.2.1 and Fig. 4.2.2. These challenges indicate a clear need for reliable and easy-to-use automation in terrace farming. The identified gains include consistent plant watering, reduced water wastage, time savings, and improved plant health through sensor-based control. Additionally, users value simple technology that works even with limited connectivity and provides clear, visual feedback. Based on the common pain points and gains observed in Fig. 4.2.1 and Fig. 4.2.2, a consolidated team empathy map for the primary stakeholders was developed, as presented in Fig. 4.2.3.

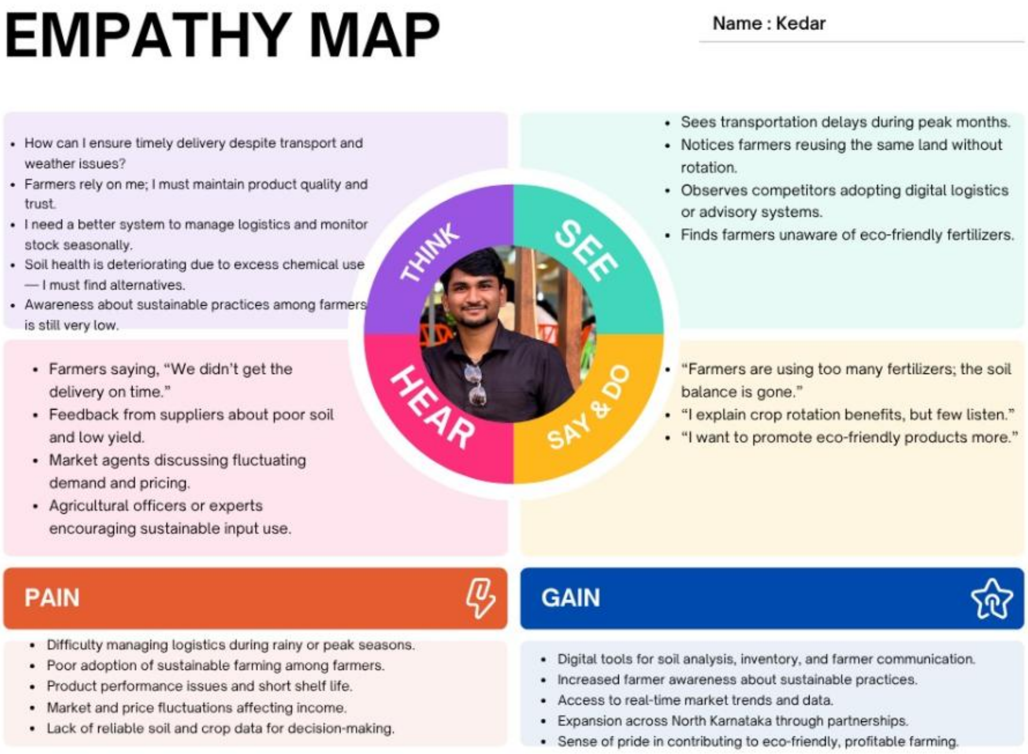

Fig. 4.2.4 Empathy Map of Secondary Stakeholder – Mr.Kedareshwar Gowda

Fig. 4.2.5 Empathy Map of Secondary Stakeholder – Mr.Venkatesh

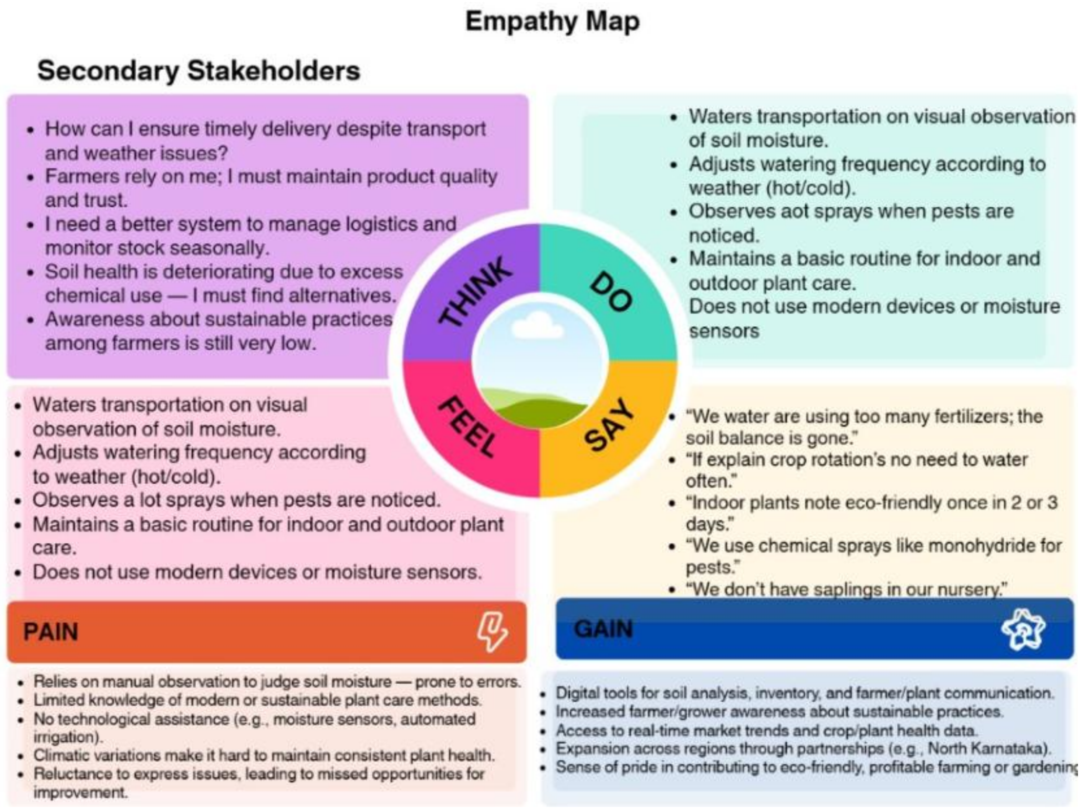

Fig 4.2.6 Team Empathy Map of Secondary Stakeholder

The empathy maps of individual secondary stakeholders reveal major pain points such as dependence on manual observation for soil moisture, limited awareness of modern and sustainable farming technologies, and difficulties in maintaining consistent plant quality due to climatic and logistical challenges, as shown in Fig. 4.2.4 and Fig. 4.2.5. These issues often lead to inefficient watering practices, excessive chemical usage, and reduced trust in technology-based solutions. The identified gains emphasize the need for digital tools for soil analysis, inventory management, and improved communication with farmers and customers. Secondary stakeholders also value access to eco-friendly practices, data-driven decision-making, and scalable systems to expand their operations. Based on the common pain points and gains observed in Fig. 4.2.4 and Fig. 4.2.5, a consolidated team empathy map for secondary stakeholders was developed and is presented in Fig. 4.2.6.

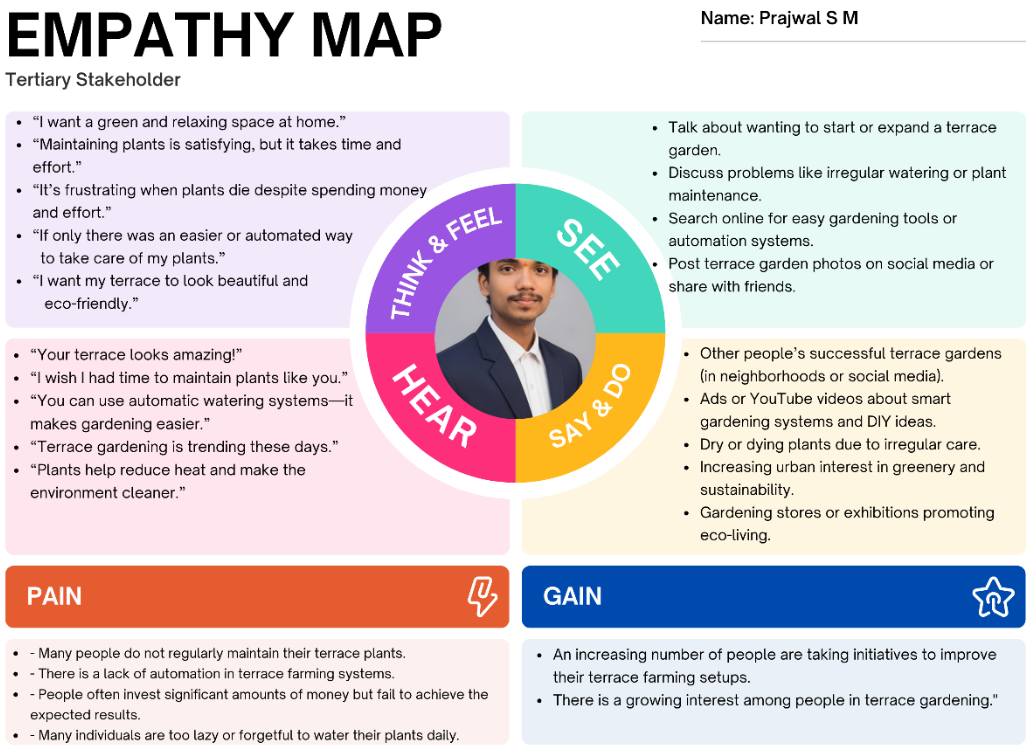

Fig. 4.2.7 Empathy Map of Tertiary Stakeholder – Mr.Prajwal

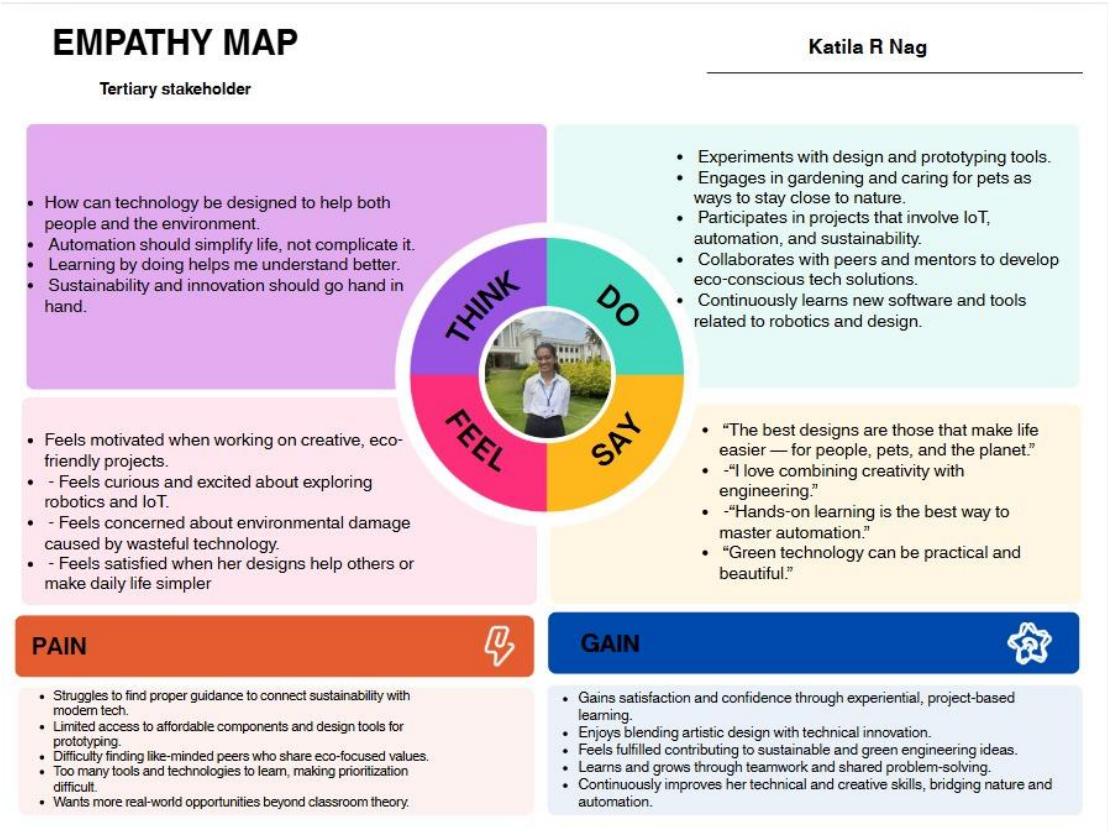

Fig. 4.2.8 Empathy Map of Tertiary Stakeholder – Ms.Katila

Fig. 4.2.9 Empathy Map of Tertiary Stakeholder – Dr. Vinod Kumar V.Meti

Fig 4.2.10 Team Empathy Map of Tertiary Stakeholder

The empathy maps of individual tertiary stakeholders highlight pain points such as irregular maintenance of terrace plants, lack of automation support, time and effort required for daily care, and difficulty in finding proper guidance to combine sustainability with modern technology, as shown in Fig. 4.2.7, Fig. 4.2.8, and Fig. 4.2.9. These challenges often lead to plant failure despite investment of time and money, causing frustration among users. The identified gains include growing interest in terrace gardening, appreciation for automated and easy-to-use systems, and the desire to integrate creativity with technological innovation. Tertiary stakeholders also value solutions that make gardening relaxing, sustainable, and visually appealing. Based on the common pain points and gains observed in Fig. 4.2.7, Fig. 4.2.8, and Fig. 4.2.9, a consolidated team empathy map for tertiary stakeholders was developed and is presented in Fig. 4.2.10.

4.3 User Persona

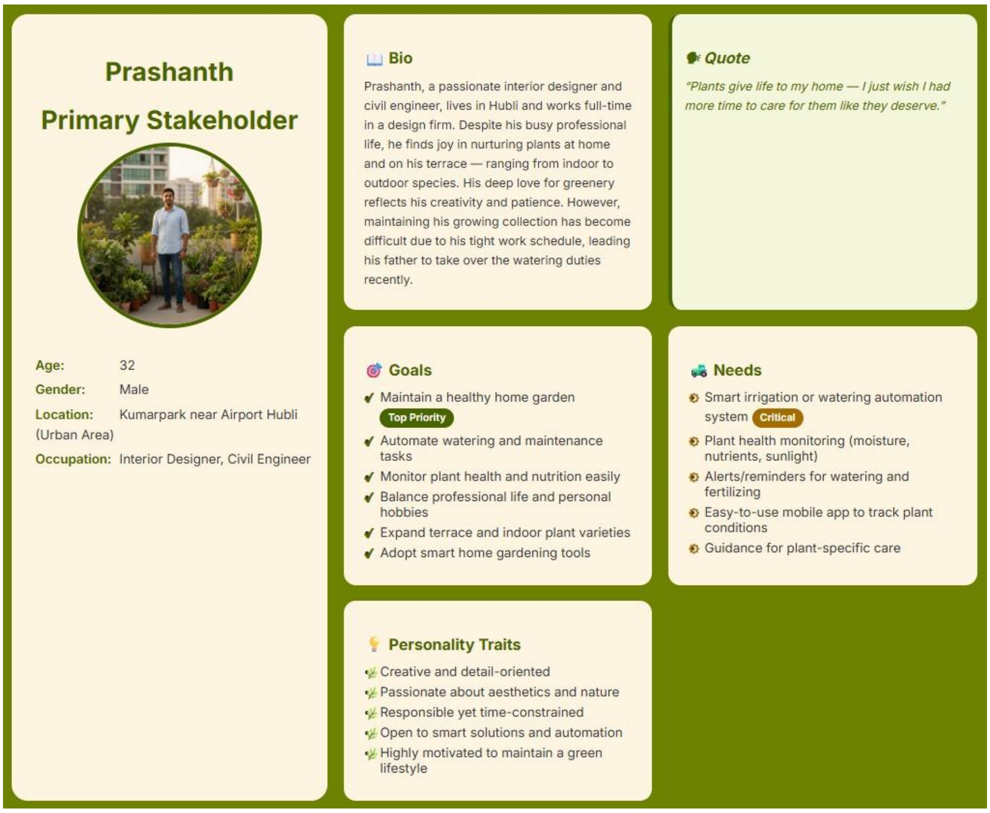

Fig. 4.3.1 Persona of Primary Stakeholder – Mr.Prashanth

Fig. 4.3.2 Persona of Primary Stakeholder – Mrs.Jyothi T

The primary stakeholder personas describe typical urban users who are interested in terrace gardening but face difficulties in regular maintenance due to their daily routines. As shown in Fig. 4.3.1, Prashanth is a working professional who enjoys gardening but struggles to manage watering and plant care because of his busy schedule, creating a need for automation and smart monitoring. Similarly, Fig. 4.3.2 presents Jyothi T, a science teacher who is passionate about plants but finds it challenging to maintain them during travel or vacations. Both personas clearly show the need for an easy-to-use automatic watering system, plant health monitoring, and timely reminders. These personas help in understanding real user needs and are useful for designing a simple and effective smart terrace farming solution.

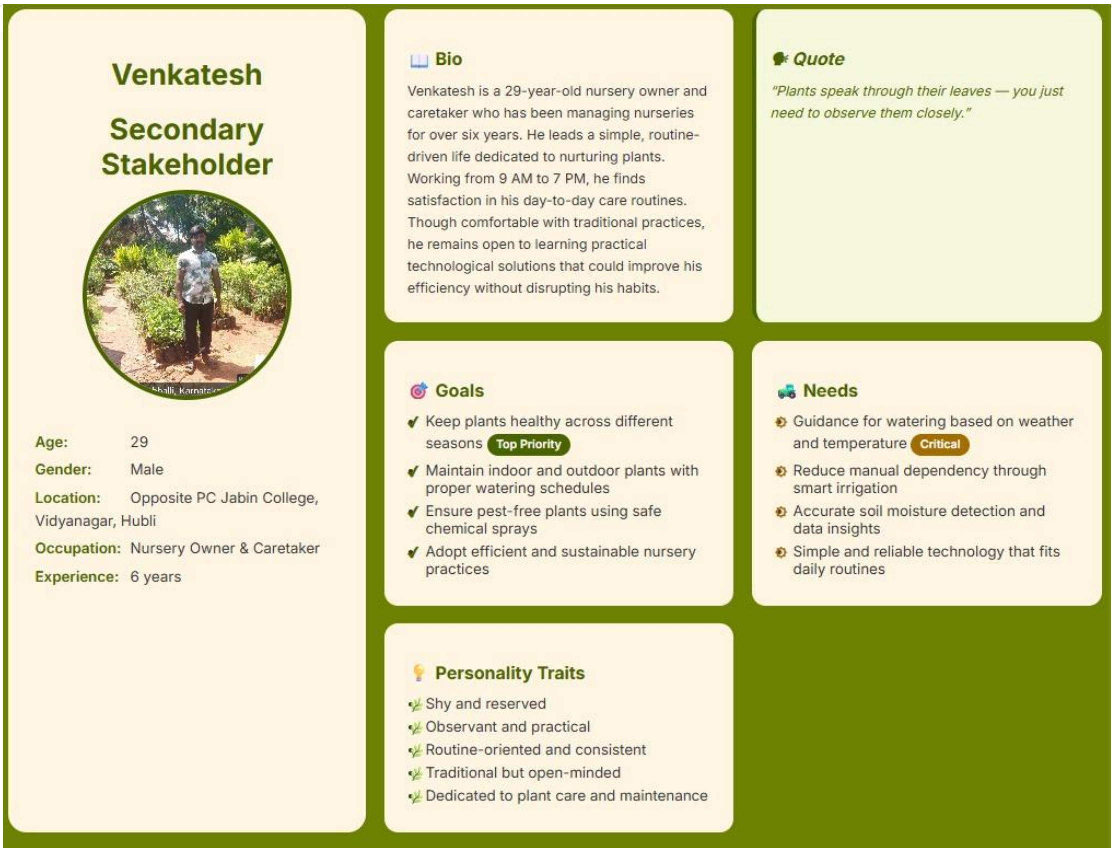

Fig. 4.3.3 Persona of Secondary Stakeholder – Mr.Venkatesh

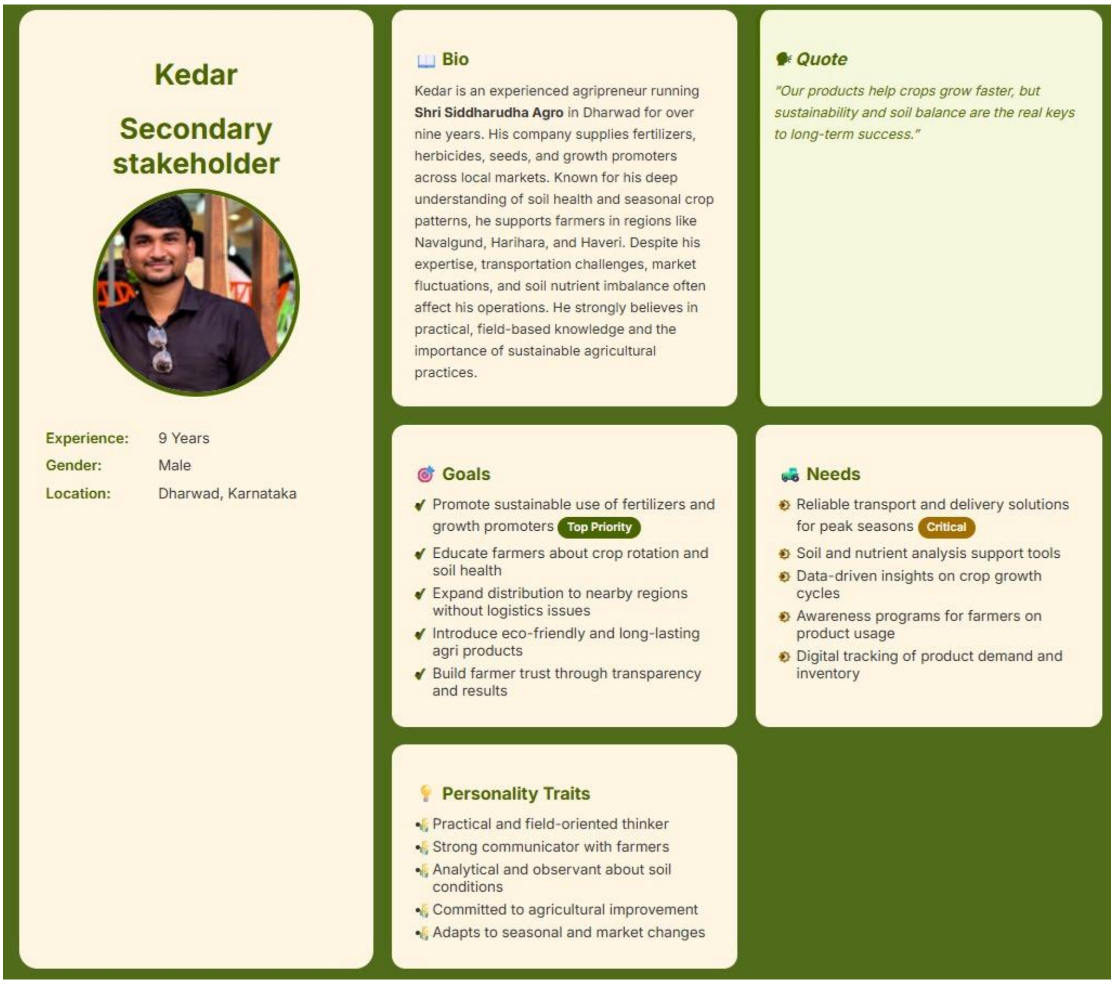

Fig. 4.3.4 Persona of Secondary Stakeholder – Mr.Kedareshwar Gowda

The secondary stakeholder personas represent professionals who are closely involved in plant care, nursery management, and agricultural support services. As shown in Fig. 4.3.4, Kedar is an agripreneur who focuses on sustainable farming practices and faces challenges related to logistics, soil health analysis, and farmer awareness, highlighting the need for data-driven and reliable support tools. Similarly, Fig. 4.3.4 presents Venkatesh, a nursery owner who relies on traditional methods and routine-based care but is open to simple technologies that can reduce manual effort without disturbing his daily practices. Both personas emphasize the importance of accurate watering guidance, soil moisture monitoring, and practical, easy-to-adopt solutions. These secondary stakeholder personas help in understanding operational and support-level requirements, which are essential for designing scalable and farmer-friendly smart irrigation systems.

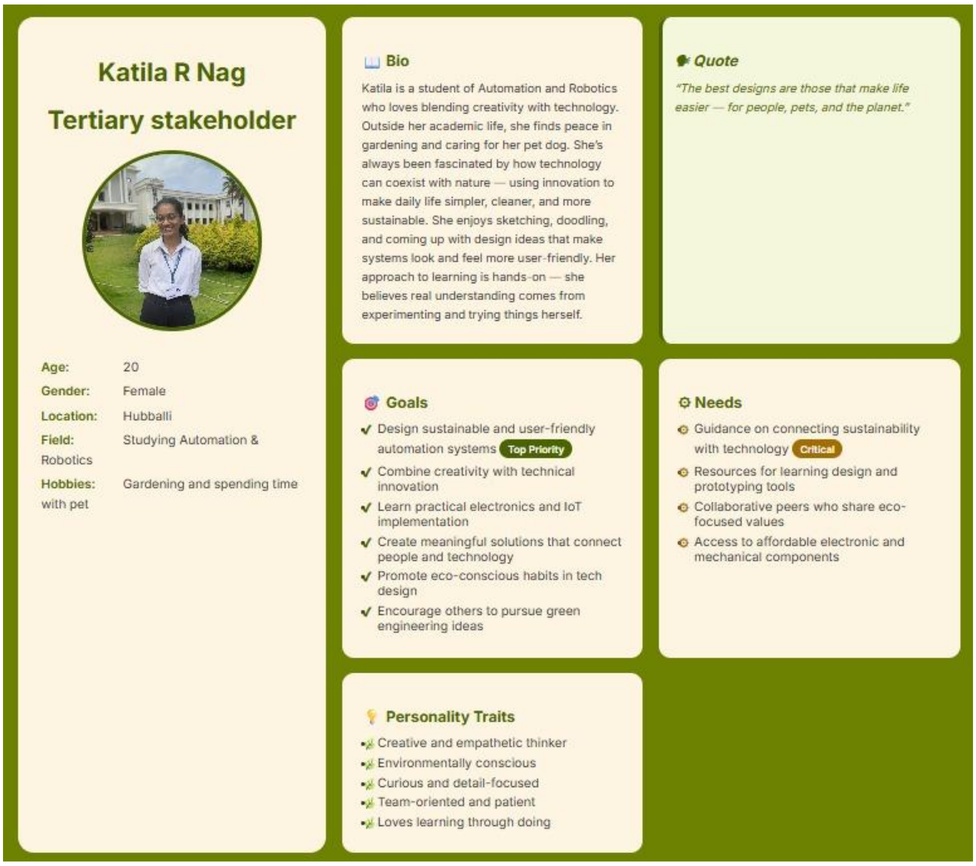

Fig. 4.3.5 Persona of Tertiary Stakeholder – Ms.Katila

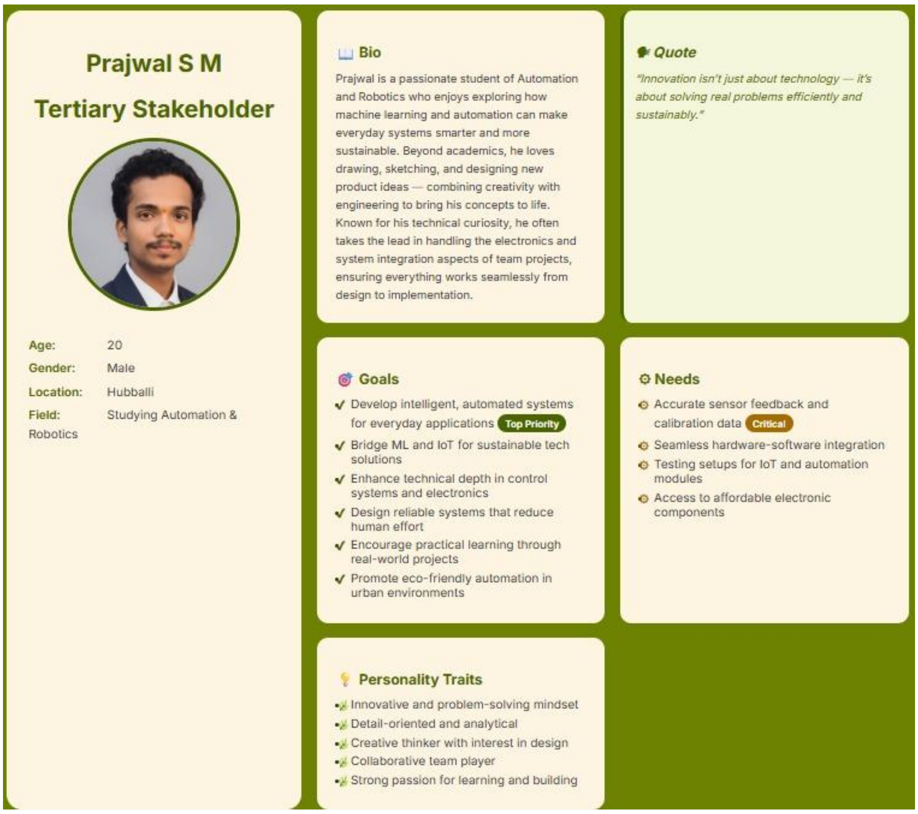

Fig. 4.3.6 Persona of Tertiary Stakeholder – Mr.Prajwal

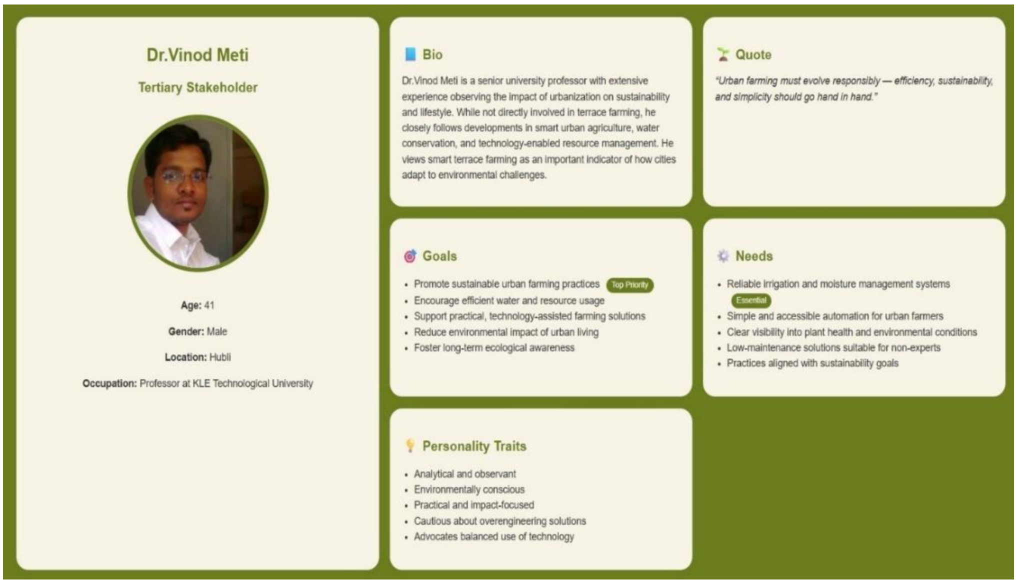

Fig. 4.3.7 Persona of Tertiary Stakeholder – Dr. Vinod Kumar V.Meti

The tertiary stakeholder personas represent people who support and influence the project through learning, research, and guidance. As shown in Fig. 4.3.5 and Fig. 4.3.6, students like Katila R Nag and Prajwal S M are interested in using automation and technology to create simple and sustainable solutions, but they need proper guidance, affordable components, and practical exposure to implement their ideas. Fig. 4.3.7shows Dr. Vinod Meti, who focuses on sustainability, simple automation, and responsible use of technology in urban farming. All these personas highlight the importance of learning by doing, eco-friendly innovation, and practical applications rather than complex systems. These tertiary stakeholder personas help align the project with academic learning, sustainability goals, and real-world usefulness.

4.4 User Needs

Table 4.4.1 Customer Statements and Interpreted Needs

SL. NO	CUSTOMER STATEMENTS	INTERPRETED NEEDS
1	I want my plants to get watered automatically every day.	Need a reliable way to ensure plants receive regular watering.
2	I have different plants that need watering at different times.	Need flexibility to manage watering based on plant type.
3	I want to turn the water on and off using my phone.	Need convenient remote access to control watering.
4	I want it to water only when the soil is dry.	Need a way to water plants based on their soil condition.
5	I want the system to stop watering when it rains.	Need a way to avoid watering during rainfall.
6	Sometimes I want to water the plants myself.	Need the option to operate watering manually.
7	I have both indoor and outdoor plants, so I want to control them separately.	Need to manage different plant zones independently.
8	I don't want to waste water while watering the plants.	Need an efficient method that reduces water wastage.
9	I want to know when the tank has low water.	Need awareness of water availability in the tank.
10	I already have drip lines, so I want this to work with them.	Need compatibility with existing watering systems.
11	I want to see how my plants are doing every day.	Need a simple way to check plant condition regularly.
12	I want to get a message if my plants look unhealthy.	Need timely alerts about plant health.
13	I'd like to track how much my plants have grown.	Need a way to monitor plant growth over time.
14	I want weekly updates about my plants' condition.	Need regular summaries of plant performance.

15	I want it to use weather updates to plan watering.	Need watering management based on changing weather.
16	I want to know if my soil has enough nutrients.	Need information about soil nutrient condition.
18	I want alerts if the temperature becomes too high or low.	Need awareness of extreme environmental conditions.
19	I want to understand my plant's condition easily using colors or icons.	Need clear and simple visual indicators of plant status.
20	I'd like to see how my plants have improved over time.	Need a record of plant progress and history.
21	I want the setup to be easy and not take much time.	Need a quick and simple installation process.
22	I want an app that's easy to use and understand.	Need an intuitive and user-friendly system interface.
23	My family should also be able to check the plants.	Need shared access for multiple users.
24	I want each plant's details shown separately.	Need a clear view for individual plant information.
25	I'd like to use voice commands.	Need hands-free or convenient control options.
26	I want the system to work even if there's no internet.	Need reliability in both connected and offline conditions.
28	I want it to support my language.	Need communication support in preferred language.
29	I want it to be easy for older people to use.	Need simple and accessible operation for all users.
30	I want the app to look calm and nature-inspired.	Need an aesthetically pleasant and nature-themed interface.
31	I want the system to work smoothly without much fixing.	Need a dependable setup with minimal maintenance.
32	I want it to last long even in sun and rain.	Need durable materials suitable for outdoor use.

33	I want it to use less electricity.	Need an energy-efficient.
34	I want to replace parts easily if they break.	Need easy access and replacement of components.
35	I don't want water outlets to get blocked.	Need a reliable water flow without clogging issues.
36	I prefer to use eco-friendly methods for my plants.	Need environmentally responsible gardening practices.
38	I'd like reminders for pruning and seasonal work.	Need helpful notifications for periodic plant care.
39	I want it to add plant food when needed.	Need proper nourishment support for healthy plant growth.
40	I want it to be affordable to use in the long run.	Need a cost-effective and long-term solution.

5. Engineering Design – Problem Definition

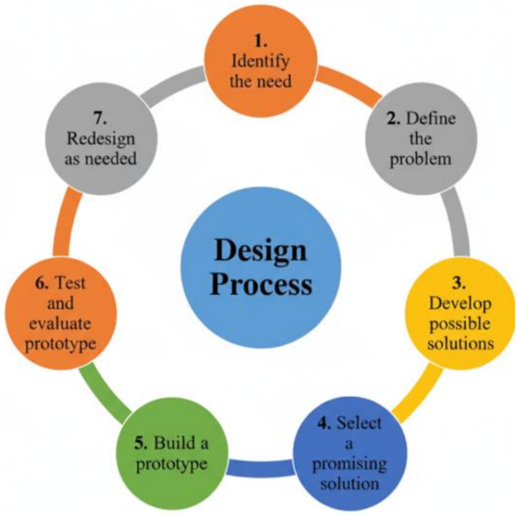

Fig 5.1 Engineering design process

Engineering design is a systematic and step-by-step approach used by engineers to develop effective solutions to real-world problems. It focuses on identifying a need, analysing the problem, generating possible solutions, and finally implementing and improving the best solution. This approach ensures that the final outcome is practical, efficient, safe, and cost-effective.

As shown in Fig. 5.1, the engineering design process begins with identifying the need, where the actual requirement or problem is recognized. This is followed by defining the problem clearly, which helps in setting proper goals and constraints. In the next step, possible solutions are developed through brainstorming and technical analysis, and then the most promising solution is selected based on feasibility and performance.

Further, the selected solution is converted into a prototype, which helps in visualizing and testing the idea in a practical form. The prototype is then tested and evaluated to check whether it meets the desired requirements. If any issues are found, the design is redesigned and improved, showing that engineering design is an iterative process.

In technical projects, this design approach plays a crucial role as it provides a clear roadmap from problem identification to final implementation. It helps students and engineers organize their work, reduce errors, improve innovation, and achieve reliable results. Overall, Fig. 5.1 highlights how engineering design helps transform ideas into workable and optimized technical solutions.

5.1 Requirement list

Table 5.1.1 Sources and Identified Requirements

R NO.	SOURCE	REQUIREMENT
1	Client	The system shall automatically initiate and control a regular watering cycle based on a predefined schedule
2	Client	The system shall allow users to configure independent watering schedules for each plant or zone.
3	Client	The system shall provide the ability to remotely turn the watering process on or off at any time
4	Client	The system shall monitor soil moisture levels and automatically initiate watering when the soil moisture value rises above 600 (indicating dry soil).
5	Client	The system shall provide a manual override function.
6	Client	The system shall regulate water flow using valves or actuators.
7	Survey	The system shall monitor key plant condition parameters and present plant status.
8	Client	The system shall provide a dashboard-based mode selection that allows users to switch between Automatic mode and Manual mode.
9	Client	The system shall adjust schedules based on weather.
10	Team	The system shall monitor ambient temperature and humidity.
11	Survey	The system shall provide visual indicators for plant health.
12	Client	The system shall support multi-user access.
13	Client	The system shall allow stakeholders to input plant information.
14	Survey	The system shall support voice-based control through integrated or connected voice-assistant services
15	Client	The system shall support localization in multiple regional languages.
16	client	The system shall provide a nature-inspired user interface theme
17	Team	The system shall provide eco-friendly usage suggestions.
18	Team	The system shall provide fertilizer reminders.

19	Team	The system shall securely store all user, plant, and system data using encrypted databases or protected storage mechanisms
20	Team	The system shall operate as a closed-loop control system by continuously monitoring soil moisture levels to control the irrigation process.
21	Survey	The system shall optimize water usage intelligently.
22	Survey	The system shall use durable, weather-resistant hardware.
23	Team	The system must be designed for quick and simple installation.
24	Team	The system must use a durable outdoor-rated enclosure (for example, IP65) to protect internal hardware from dust and rain, ensuring reliable operation in terrace farming conditions.
25	Team	The system must be designed for 1 node operation
26	Team	The system must be in size of less than or equal to 300x300x300 mm
27	Team	The system shall estimate soil nutrient levels using sensor data or user inputs
28	Team	The system shall perform predictive maintenance analysis
29	survey	The system shall support integration with voice assistants such as Alexa and Google Assistant
30	Team	The system shall enable users to track plant growth using uploaded or auto-captured photos

5.2 Prioritized Requirements

Table 5.2.1 Prioritized Requirements

R NO.	REQUIREMENT	PRIORITY	REMARK
1	The system shall automatically initiate and control a regular watering cycle based on a predefined schedule	10	Essential for autonomous plant care
2	The system shall allow users to configure independent watering schedules for each plant or zone.	9	Different plants have unique water needs
3	The system shall provide the ability to remotely turn the watering process on or off at any time	10	Critical for remote management
4	The system shall monitor soil moisture levels and automatically initiate watering when the soil moisture value rises above 600 (indicating dry soil).	10	Vital for plant health and water efficiency
5	The system shall provide a manual override function.	8	Needed for instant user intervention
6	The system shall regulate water flow using valves or actuators.	9	Ensures efficient water usage
7	The system shall monitor key plant condition parameters and present plant status	8	Improves transparency of plant health
8	The system shall provide a dashboard-based mode selection allowing users to switch between Automatic mode and Manual mode.	9	Enables flexible user control through the dashboard

9	The system shall adjust schedules based on weather.	8	Improves water conservation
10	The system shall monitor ambient temperature and humidity.	8	Essential for environmental analysis
11	The system shall provide visual indicators for plant health.	7	Helps users understand status easily
12	The system must be designed for quick and simple installation.	9	Makes system user-friendly
13	The system shall support multi-user access.	8	Useful for shared terrace farming
14	The system shall allow stakeholders to input plant information.	7	Allows personalized watering logic
15	The system shall support voice-based control	8	Improves accessibility
16	The system shall support localization in multiple regional languages.	6	Useful for regional users
17	The system shall provide a nature-inspired UI theme	5	Improves aesthetic appeal
18	The system shall use durable, weather-resistant hardware.	9	Ensures long system life
19	The system shall provide eco-friendly usage suggestions.	8	Encourages sustainable use
20	The system shall provide fertilizer reminders.	7	Helps maintain proper nutrition
21	The system shall securely store all user, plant, and system data using encrypted databases or protected storage mechanisms.	9	Important for user privacy
22	The system shall operate as a closed-loop control system where real-time soil moisture feedback	9	Ensures precise and efficient watering based on actual soil conditions

	is continuously monitored to control irrigation.		
23	The system shall optimize water usage intelligently.	9	Ensures minimal wastage
24	The system must be designed for 1-node operation	9	Simplifies control architecture
25	The system must be within 300×300×300 mm size	9	Ensures compact installation
26	The system shall use an outdoor-rated enclosure (IP65) to protect internal hardware	9	Ingress Protection (IP) rating that tells you how well an electrical device is protected from dust and water
27	The system shall enable users to track plant growth using uploaded or auto-captured photos	6	Tracking plant growth visually is one of the most engaging and motivating features for terrace gardeners. It helps them see real progress and stay consistent.
28	The system shall estimate soil nutrient levels using sensor data or user inputs	6	It is essential for maintaining plant health and giving accurate care recommendations, making it a high-priority feature.
29	The system shall perform predictive maintenance analysis	6	It helps prevent system failures by detecting issues early, ensuring reliable operation and reducing maintenance costs.

30	The system shall support integration with voice assistants such as Alexa and Google Assistant	5	It improves user convenience and hands-free control

5.3 System Composer- Requirement List

Table 5.3.1 System Composer Requirements List

Sl. No.	**Requirement ID**	**Requirement Description**	**Remarks**
1	FR-01	The system shall continuously acquire soil moisture data.	Implemented using Sensor_Data subsystem
2	FR-02	The system shall acquire ambient temperature data.	Provided by Weather subsystem
3	FR-03	The system shall acquire ambient humidity data.	Provided by Weather subsystem
4	FR-04	The system shall detect rainfall conditions.	Rain sensor logic in Weather block
5	FR-05	The system shall compare soil moisture with a predefined threshold.	Implemented using comparator logic
6	FR-06	The system shall disable irrigation during rainfall.	Rain override logic applied
7	FR-07	The system shall automatically activate irrigation when soil moisture is below threshold.	Automatic control mode
8	FR-08	The system shall deactivate irrigation when soil moisture reaches optimum level.	Feedback-based control
9	FR-09	The system shall support manual irrigation control.	Manual toggle in User Interface
10	FR-10	The system shall support voice-command-based irrigation control.	Simulated voice command input
11	CR-11	Manual commands shall override automatic irrigation logic.	Priority-based switching logic

12	CR-12	Voice commands shall override automatic irrigation logic.	Implemented using control switch
13	CR-13	Rain detection shall have highest priority over all irrigation commands.	Safety and water-saving feature
14	CR-14	The controller shall generate a single control signal for pump and solenoid valve.	Centralized control signal
15	AR-15	The system shall control a water pump using digital ON/OFF signals.	Pump modeled as binary actuator
16	AR-16	The system shall control a solenoid valve using digital ON/OFF signals.	Valve modeled as binary actuator
17	AR-17	Pump and solenoid valve shall operate synchronously.	Ensures coordinated water flow
18	IR-18	The system shall visually indicate pump status.	Dashboard lamp indicator
19	IR-19	The system shall visually indicate solenoid valve status.	Dashboard lamp indicator
20	IR-20	The system shall plot soil moisture and actuator states over time.	Scopes used for visualization

5.4 Product Benchmarking

Table 5.4.1 Product Benchmarking of HydroHive–Terrace Watering System

Sl. No.	Parameter	Blackt Electrotech Automatic Watering System	HydroHive–Terrace Watering System
1	Type of System	Automatic timer-based drip watering system	Smart sensor-based terrace watering system
2	Target Users	Indoor plant owners, small home gardens	Terrace gardeners and urban households
3	Automation Level	Fixed schedule-based automation	Fully automated with adaptive control
4	Sensors Used	No soil moisture sensing	Soil moisture and environmental sensors
5	Water Control Method	Time-based watering	Need-based watering using sensor data
6	Power Source	USB rechargeable battery	Solar / battery-assisted power
7	User Interface	Manual button-based setting	App-based / dashboard monitoring
8	Water Efficiency	Moderate water saving	High water efficiency and reduced wastage
9	Scalability	Limited to few plants	Scalable for large terrace gardens
10	Suitability for Outdoor Use	Limited	Highly suitable
11	Cost	Low-cost commercial product	Cost-effective academic prototype
12	Innovation Level	Basic automation	Smart, sustainable, and customizable

5.5 Constraints

Table 5.5.1 Constraints

SL. NO.	REQUIREMENT
1	The system must use a durable outdoor-rated enclosure (for example, IP65) to protect internal hardware from dust and rain, ensuring reliable operation in terrace farming conditions.
2	The system must be designed for 1 node operation
3	The system must be in size of less than or equal to 300x300x300 mm

5.6 Problem Definition

Urban terrace farmers often struggle with busy schedules, unpredictable weather, and irregular watering, leading to inconsistent plant growth. To address this, we propose an automatic watering system that provides scheduled irrigation and remote control, ensuring reliable and efficient plant care with minimal effort. Designed to be compact, portable, energy-efficient, and user-friendly, the system suits terraces of all sizes.

6. Engineering Design- Conceptual Design

Conceptual Design

Conceptual design is the initial and most important stage of the design process. In this stage, the main focus is on understanding what the system should do and how it should work, without going into detailed calculations, dimensions, or material selection. It can be considered as the idea blueprint of a project rather than the final technical drawing.

During the conceptual design stage, the designer first clearly identifies the problem that needs to be solved and understands the user needs along with overall system requirements. Based on this understanding, multiple possible solution ideas are generated without focusing on detailed calculations or constraints. These concepts are then evaluated and compared to select the most feasible and effective solution. Finally, the selected idea is represented using simple sketches, block diagrams, and functional layouts to clearly visualize the working of the system and communicate the concept effectively.

Importance of Conceptual Design

1. Prevents wrong-direction development

Directly jumping into detailed design may lead to solving the wrong problem. Conceptual design ensures the correct problem is addressed from the beginning.

2. Encourages creativity and innovation

Since there are no strict technical constraints at this stage, designers are free to explore innovative and creative solutions.

3. Saves time and cost

Changes made during the conceptual stage are easy and inexpensive. Correcting errors after fabrication can be costly and time-consuming.

4. Enables comparison of multiple solutions

Different concepts can be compared based on factors such as:

- Cost
- Feasibility
- Sustainability
- Reliability
- User convenience

This helps in selecting the best possible solution early.

5. Improves communication

Conceptual sketches and diagrams help team members, guides, and evaluators clearly understand and visualize the proposed system.

6. Forms the foundation for detailed design

All future stages like CAD modelling, analysis, prototyping, and manufacturing are based on decisions taken during the conceptual design phase.

6.1 Black Box

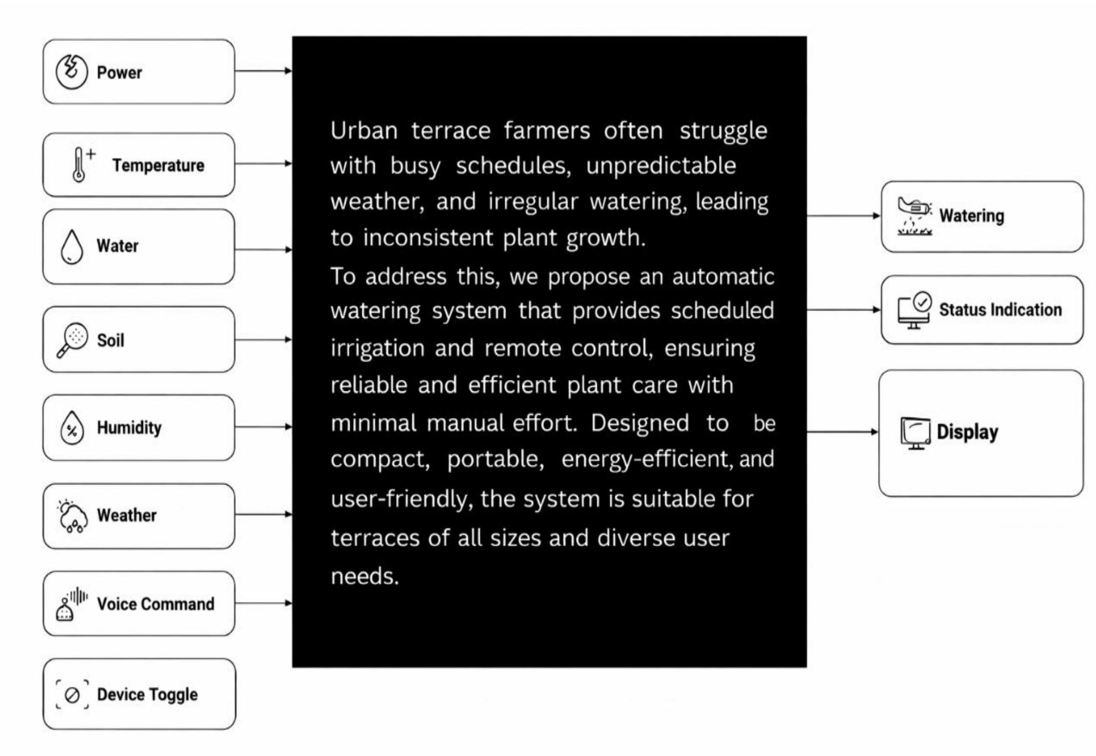

Fig 6.1.1 Black box

The flow shown in the diagram begins with multiple inputs being supplied to the black-box controller of the automatic terrace watering system. Inputs such as power supply, temperature, water availability, soil moisture, humidity, weather conditions, voice commands, and device toggle signals are collected through sensors and user interfaces. These inputs continuously provide real-time information about both environmental conditions and user preferences.

Inside the black box, the control unit processes all incoming data using predefined control logic, threshold values, and scheduling rules. The system evaluates soil moisture levels along with weather and humidity data to determine whether irrigation is required. If sufficient rainfall or moisture is detected, watering is automatically suppressed to avoid wastage. Manual and voice commands are also interpreted, allowing the user to override or control the system when needed.

Based on the processed decisions, the controller generates output signals to the watering mechanism, ensuring that water is supplied only when necessary and in appropriate amounts. At the same time, the system provides status indications to inform the user about pump operation, system activity, and any abnormal conditions. All relevant information is finally displayed on a display unit, enabling easy monitoring and understanding of the system's current state. Overall, this flow ensures efficient, reliable, and user-friendly automatic irrigation for urban terrace farming, as illustrated in Fig. 6.1.1.

6.2 Functional Architecture

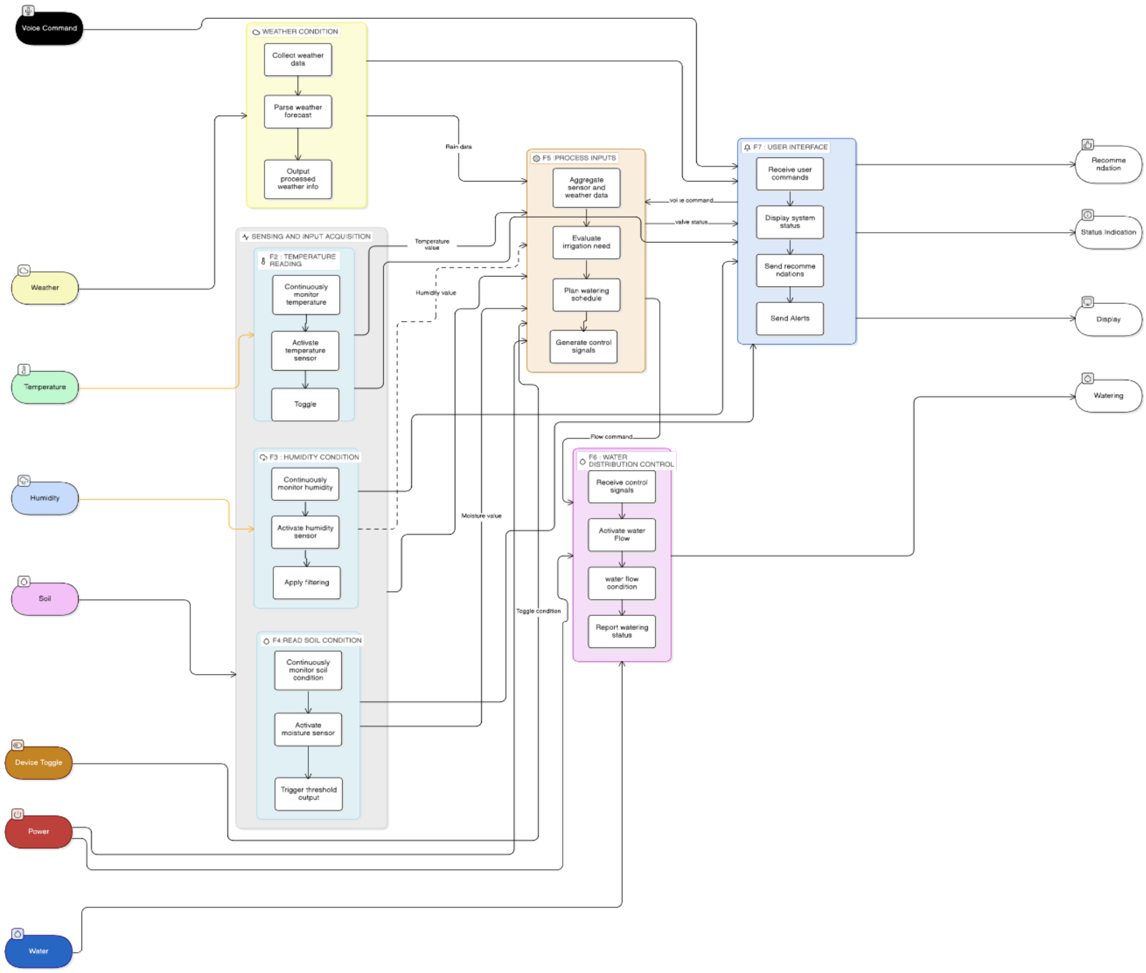

Fig 6.2.1 Functional Architecture Diagram

The functional architecture diagram illustrates the detailed working and interaction of different subsystems within the automatic terrace watering system. It begins with input sources such as weather data, temperature, humidity, soil condition, device toggle, power supply, water source, and voice commands, which are continuously monitored through dedicated sensing and input acquisition blocks. The weather condition block collects and processes forecast information, while the temperature, humidity, and soil moisture blocks continuously sense environmental parameters and generate corresponding signals.

All sensed data is forwarded to the processing unit, where irrigation requirements are evaluated by aggregating weather and sensor inputs. Based on this evaluation, the system plans an appropriate watering schedule and generates control signals. These control signals are then sent to the water distribution control block, which manages valve operation, activates water flow, monitors flow conditions, and reports watering status.

The user interface block receives user commands, displays system status, sends alerts, and provides recommendations to the user. Manual and voice commands are also integrated into the control flow, allowing user intervention when required. The final outputs of the system include watering action, status indication, and display information. Overall, this functional architecture clearly demonstrates how sensing, decision-making, control, and user interaction are integrated to achieve efficient, automated, and reliable terrace irrigation, as shown in Fig. 6.2.1.

6.3 Morphological Chart

Table 6.3.1 Morphological Chart

Function Sub-Function	**Code**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Soil Moisture Condition	A	Capacitive Soil Moisture Sensor	Resistive Soil Sensor	FDR Sensor	TDR Sensor	Gravity Moisture Sensor
Humidity Condition	B	DHT11	Weather API	SHT31	DHT22	BME688
Weather Condition	C	Google Weather API	Open-Meteo API	OpenWeatherMap	Local Rain Sensor	AccuWeather API
Processing Unit	D	ESP32	Jetson Nano	Raspberry Pi 5	Arduino Mega	STM32
Watering Schedule Planning	E	On-device Timer	Webpage Scheduler	Mobile App Scheduler	AI Adaptive Scheduling	Soil-based Auto Scheduling
Water Activation Mechanism	F	Submersible Pump	Surface Pump	Gravity Valve	Booster Pump	Peristaltic Pump
Water Flow Control	G	Solenoid Valve	Motorized Ball Valve	Pilot-operated Diaphragm Valve	Zone Manifold	Smart Sprinkler Heads
Send Recommendations	I	Mobile App	Dashboard	WhatsApp Bot	SMS Portal	Telegram Bot
Display System Status	J	Mobile App	Dashboard	WhatsApp Bot	LEDs	Telegram Bot

Notify User of Events	K	Mobile App	Dashboard	WhatsApp Bot	SMS Portal	Telegram Bot
Device Toggle	L	Toggle Switch	App Override	Push Button	Key Lock Switch	Switch Button
Power Supply	M	Solar Power	Battery Pack	DC Adapter	Hybrid System	Li-ion Battery
Temperature Measurement	N	DHT11	BME280	Open-Meteo API	DHT22	BME688

6.4 Concepts

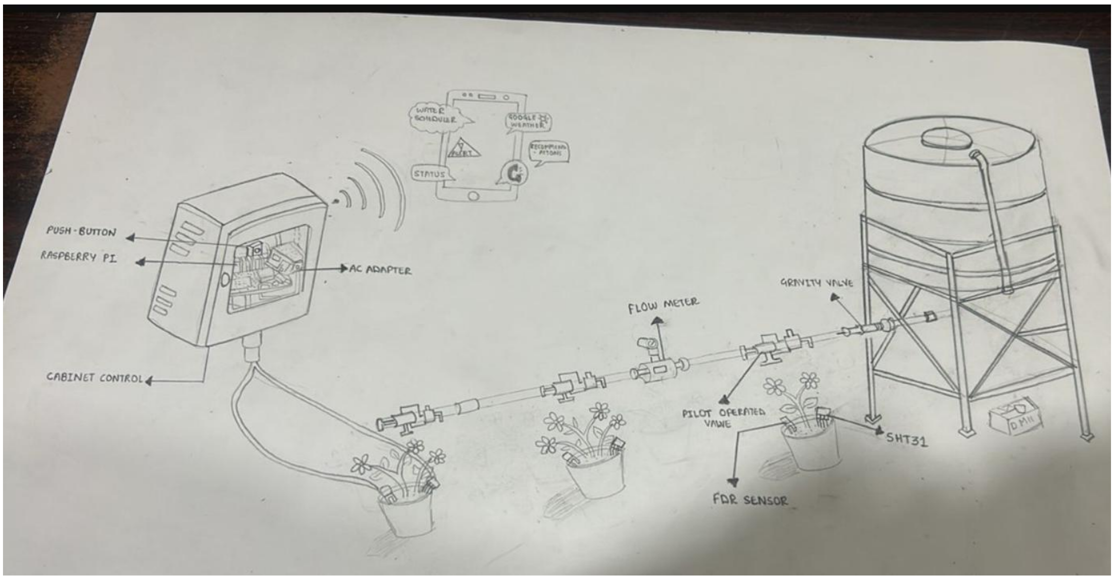

Fig. 6.4.1 Conceptual Design–01

The conceptual design provides efficient irrigation through multi-pot water allocation, enabling water supply to multiple plants simultaneously. Individual valves are used to control the flow to each pot, ensuring accurate and need-based watering. A weather-proof enclosure protects the system components from outdoor conditions, improving durability and reliability, as shown in Fig. 6.4.1.

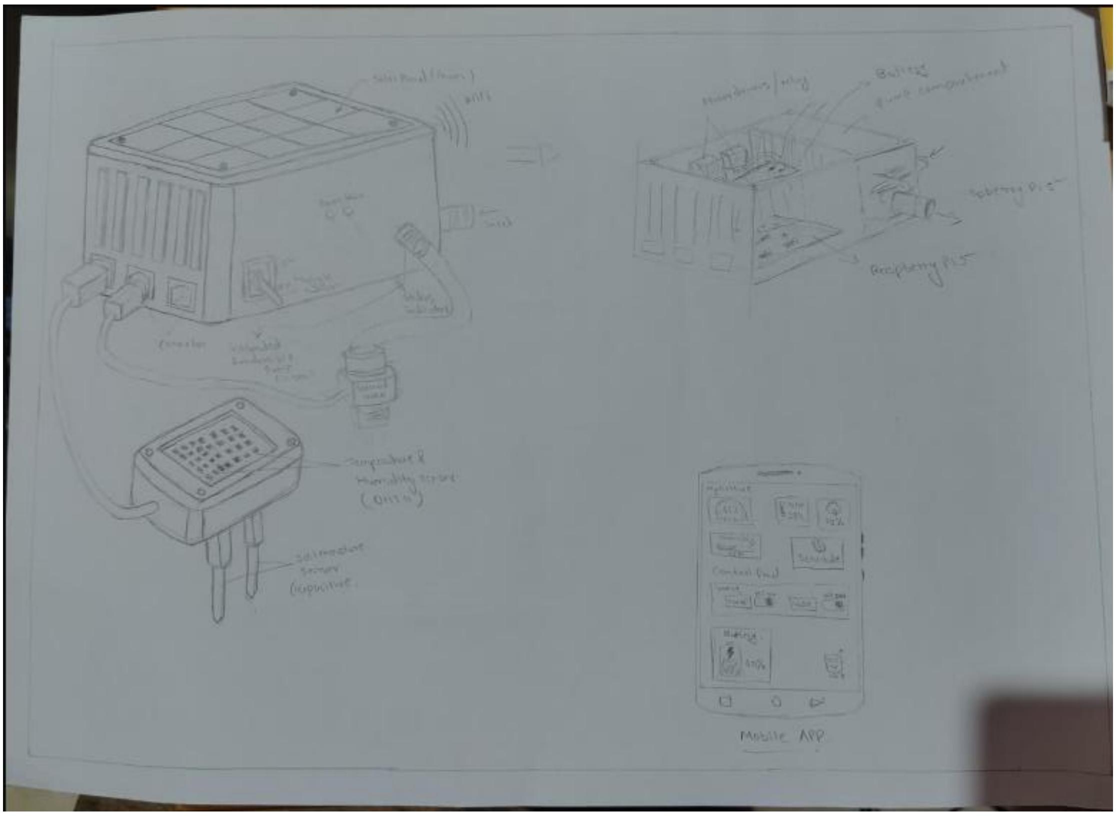

Fig 6.4.2 Conceptual design-02

The conceptual design emphasizes portability and ease of use, making it suitable for on-site applications. It is highly portable and allows the sensor module to be easily swapped when required, enabling flexibility and maintenance convenience. The system is user-friendly with minimal setup and also supports seamless integration of additional modules for future expansion, as shown in Fig. 6.4.2.

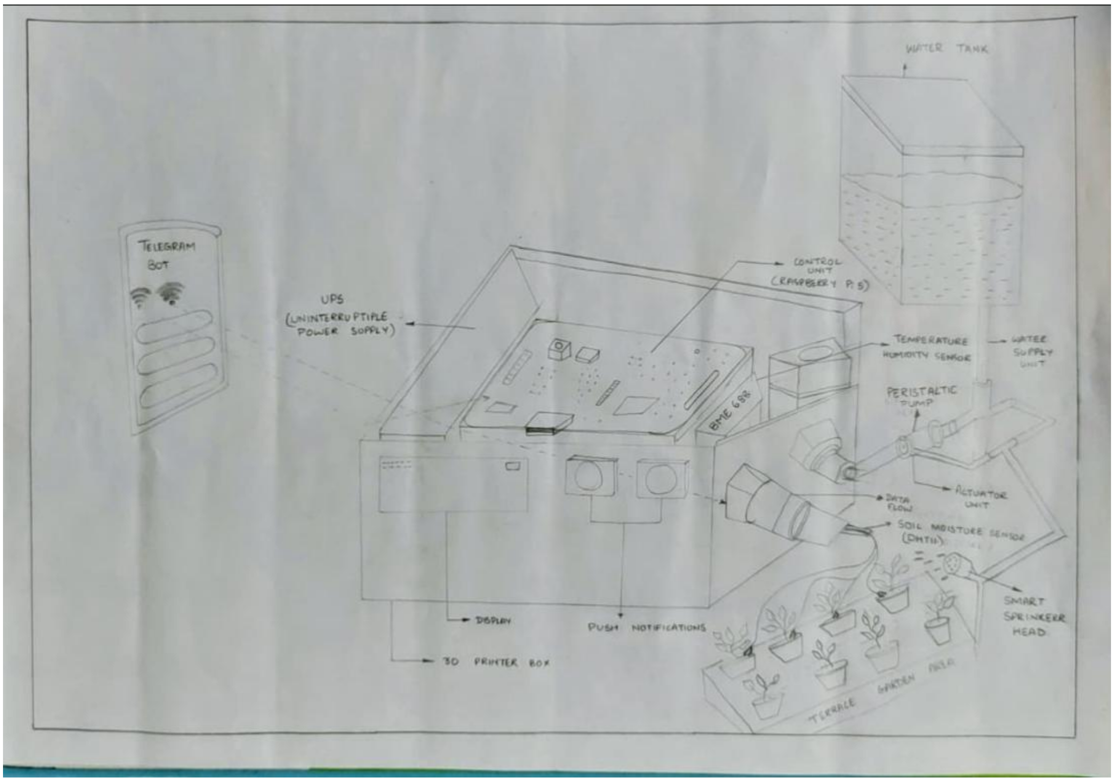

Fig. 6.4.3 Conceptual Design–03

The conceptual design highlights an innovative and compact prototype suitable for modern urban lifestyles. It includes a reliable Li-ion battery backup to ensure uninterrupted operation and offers precise water control for efficient irrigation. The compact enclosed structure enhances safety and durability, making the system practical and highly relevant for urban terrace gardening, as shown in Fig. 6.4.3.

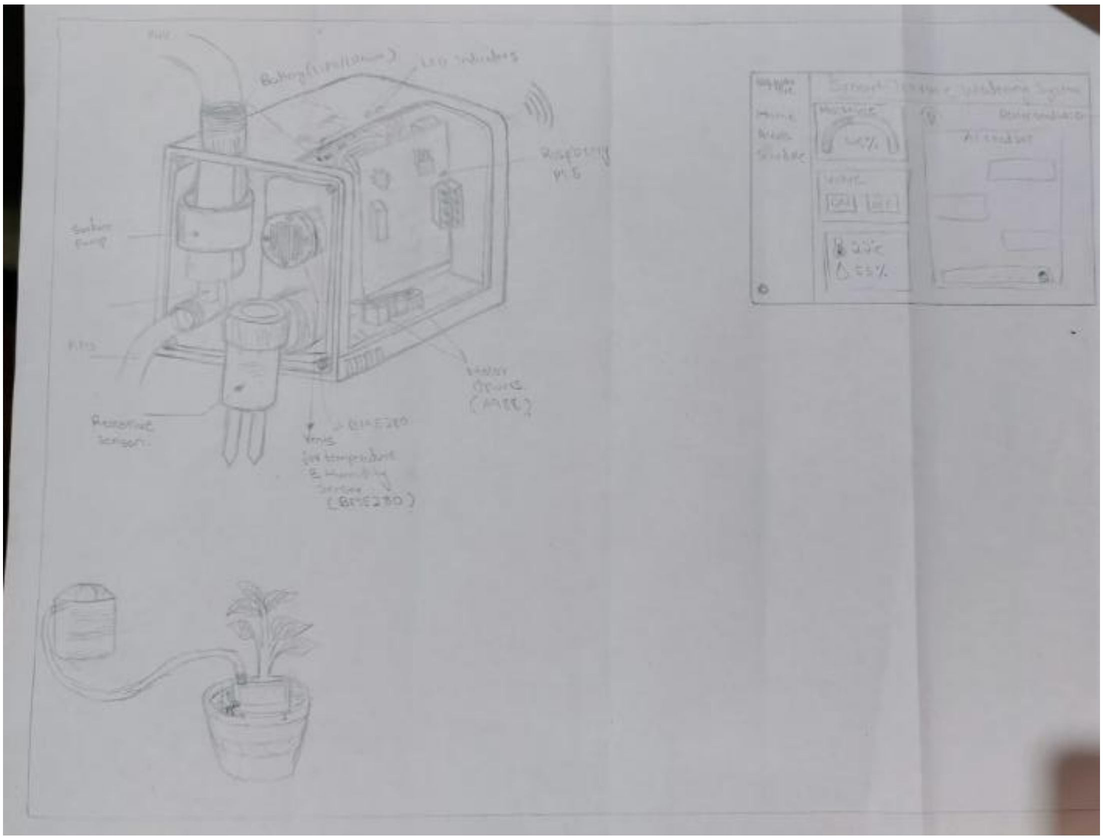

Fig. 6.4.4 Conceptual Design–04

The conceptual design focuses on a compact and space-efficient form factor with a fully integrated all-in-one enclosure. It features an aesthetically refined design suitable for modern homes while incorporating sensor fusion to improve accuracy and overall system performance. These features make the design both functional and visually appealing for urban terrace applications, as shown in Fig. 6.4.4.

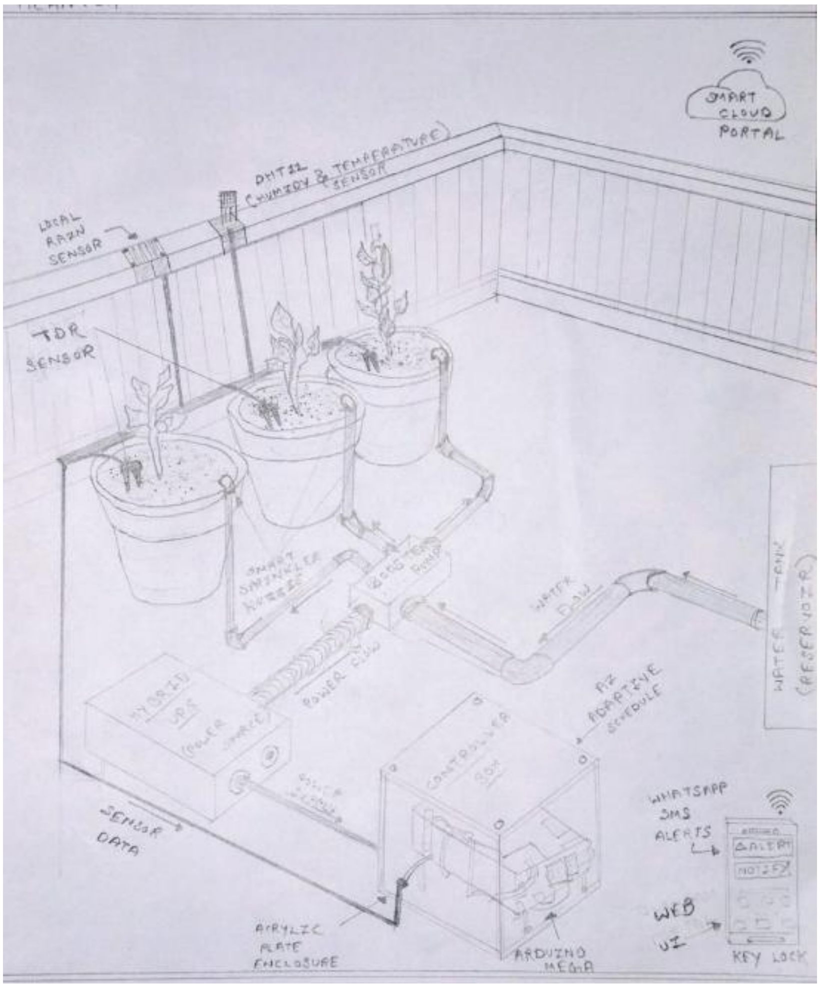

Fig. 6.4.5 Conceptual Design–05

The conceptual design emphasizes durability and flexibility for terrace applications. All electronic components are housed in a weather-resistant acrylic enclosure to withstand outdoor conditions. The modular structure allows customization for different pot or planter configurations, and a hybrid solar–battery power approach ensures reliable and energy-efficient operation, as shown in Fig. 6.4.5.

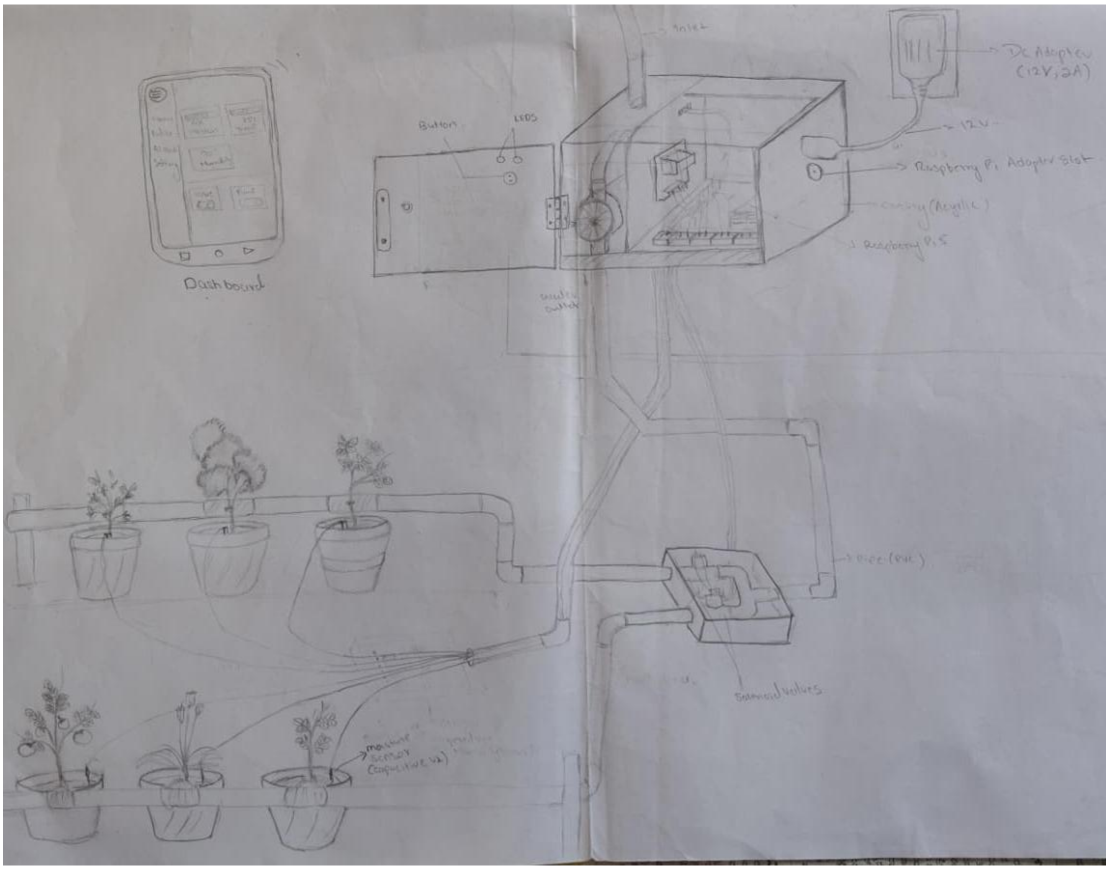

Fig. 6.4.6 Conceptual Design–06

The conceptual design focuses on cost-effectiveness while maintaining reliable performance. It follows an integrated system-based approach to ensure seamless coordination among all components. The design also supports easy scalability for future upgrades and allows quick installation and configuration with minimal technical effort, as shown in Fig. 6.4.6.

6.5 Concept Evaluation

Concept evaluation is the stage in the design process where the different solution ideas generated during conceptual design are carefully analyzed and compared to select the most suitable one. At this stage, each concept is evaluated based on practical factors rather than just creativity.

In concept evaluation, aspects such as feasibility, cost, performance, reliability, energy efficiency, and user convenience are considered. This helps in understanding whether the proposed idea can be realistically implemented using available resources and technology. By comparing multiple concepts, the best possible solution is chosen before moving to detailed design and fabrication.

Why Concept Evaluation is Needed

Concept evaluation is needed to ensure that the selected design is effective, practical, and economical. It helps avoid selecting ideas that may look good on paper but are difficult or expensive to implement. This stage reduces the risk of design failure, saves time and cost, and minimizes rework at later stages. Concept evaluation also helps designers justify their choice of concept logically, making it easier to explain decisions to guides, evaluators, and team members.

6.5.1 Screening

Table 6.5.1.1 Screening

Criteria	Importance	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
Total System Cost	5	0	1	-1	0	-1	1
Feasibility	4	0	-1	-1	1	0	1
Sensor Accuracy	5	0	0	1	1	-1	1
Energy Consumption	3	0	1	-1	0	1	0
Environmental Robustness	3	1	0	-1	1	1	0
Ease of Installation	2	-1	1	-1	1	0	0
User Interface	4	-1	1	-1	1	-1	1
Scalability	2	-1	1	-1	-1	1	1
Aesthetics	2	0	0	-1	1	1	1
Actuation Reliability	4	0	0	0	1	1	1
SCORE (+1)		3	16	5	24	14	26
SCORE (-1)		8	4	25	2	14	0
FINAL SCORE		-5	12	-20	22	0	26

6.5.2 Scoring

Table 6.5.2.1 Scoring

Criteria	Importance	Design 01	Design 02	Design 03	Design 04	Design 05	Design 06
Total System Cost	5	0	15	5	0	5	15
Feasibility	4	0	4	4	12	0	12
Sensor Accuracy	5	0	0	15	15	5	15
Energy Consumption	3	0	9	3	0	9	0
Environmental Robustness	3	9	0	3	9	9	0
Ease of Installation	2	2	6	2	6	0	0
User Interface	4	4	12	4	12	4	12
Scalability	2	2	6	2	2	6	6
Aesthetics	2	0	0	2	6	6	6
Actuation Reliability	4	0	0	0	12	12	12
TOTAL SCORE	—	17	52	40	74	56	78
RANK	—	6	4	5	2	3	1

6.6 System Composer Architecture

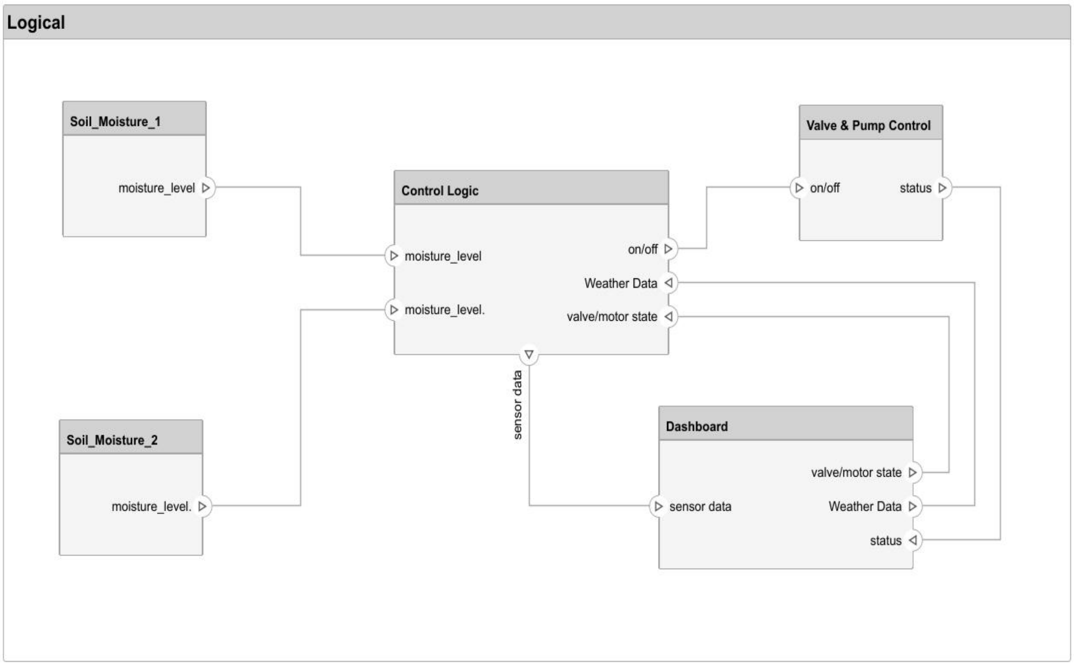

Fig. 6.6.2 Logical Architecture Diagram (MATLAB)

The logical architecture diagram illustrates the interaction between sensing, control, actuation, and monitoring components of the automatic terrace watering system. Two soil moisture sensing blocks, namely Soil_Moisture_1 and Soil_Moisture_2, continuously measure moisture levels from different zones and provide this data to the Control Logic block. The Control Logic acts as the central decision-making unit, where sensor inputs and weather data are analyzed to determine the ON/OFF state of the irrigation system.

Based on this decision, control signals are sent to the Valve & Pump Control block, which manages the operation of the pump and valves and reports their status back to the system. A Dashboard block receives sensor data, weather information, and valve or motor status to provide real-time system visualization for the user. This logical separation of sensing, processing, actuation, and visualization improves system clarity, modularity, and scalability, as shown in Fig. 6.6.2.

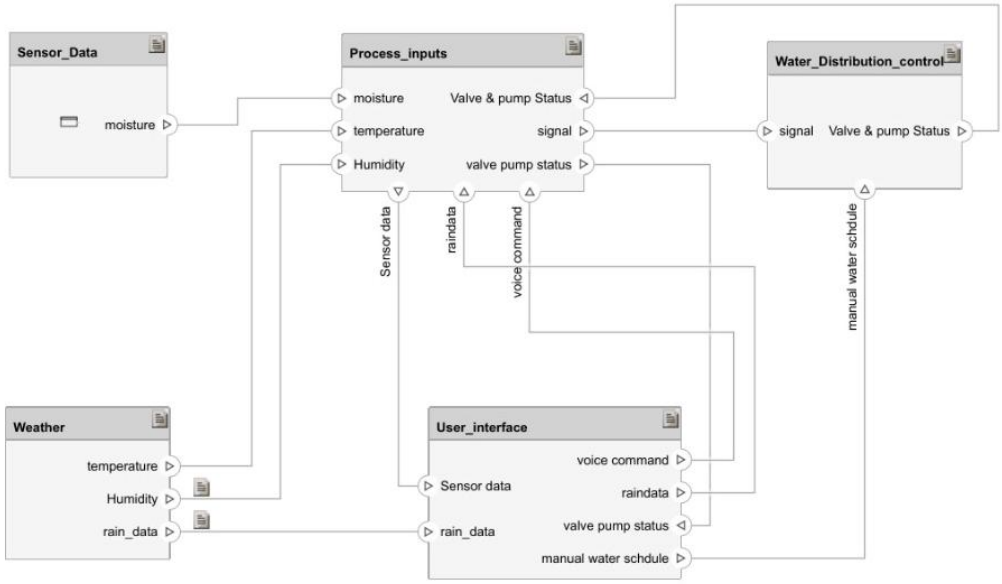

Fig 6.6.3 Physical Architecture Diagram (MATLAB)

The physical architecture diagram illustrates the actual hardware components and their interconnections in the automatic terrace watering system. It shows how the Sensor_Data unit collects soil moisture information, while the Weather module provides temperature, humidity, and rainfall data. These physical inputs are connected to the Process_Inputs unit, which represents the controller responsible for processing sensor signals, rain detection, and voice command inputs.

The Process_Inputs unit sends control signals to the Water_Distribution_Control module, which physically operates the pump and valve mechanisms for water flow regulation. The User_Interface module is connected to the controller to allow manual scheduling, voice-based control, and monitoring of valve and pump status. This physical architecture clearly represents the flow of data and control between sensors, controller, actuators, and user interfaces, ensuring reliable and coordinated system operation, as shown in Fig. 6.6.3.

6.7 Finalized Concept

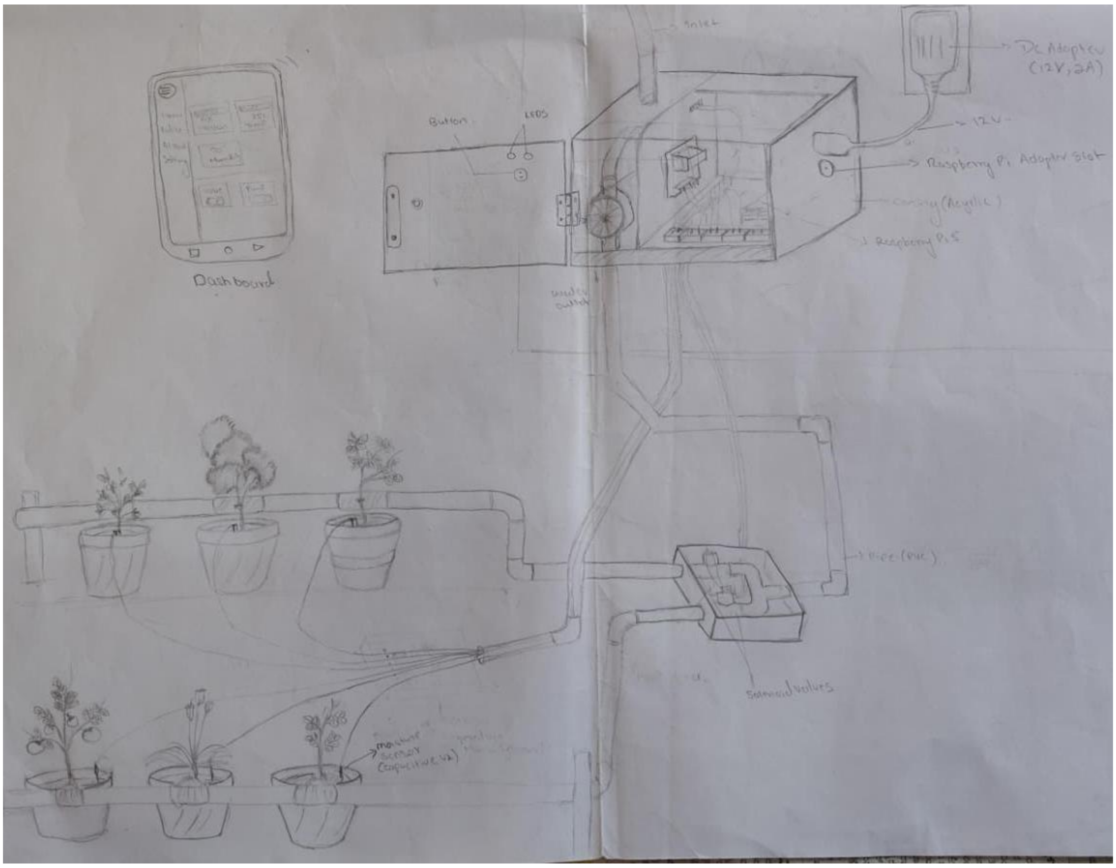

Fig 6.7.1 Finalized Conceptual design

The conceptual design focuses on cost-effectiveness while maintaining reliable performance. It follows an integrated system-based approach to ensure seamless coordination among all components. The design also supports easy scalability for future upgrades and allows quick installation and configuration with minimal technical effort, as shown in Fig. 6.7.1.

7. Embodiment – Detailed Design

Embodiment in the Engineering Design (ED) process is the phase where a selected concept is transformed into a clear and workable physical solution. In this stage, designers decide how the system will be structured, which components will be used, how they will be arranged, and how energy, signals, and materials will flow through the system. It focuses on defining the overall form, layout, mechanisms, and interfaces of the product rather than just the idea behind it.

Embodiment is important because it converts theoretical concepts into realistic designs that can be evaluated for feasibility, safety, cost, and performance. It helps identify practical issues such as space limitations, component compatibility, ease of assembly, maintenance, and manufacturability at an early stage. This stage also supports design optimization by comparing different layouts or configurations before finalizing the design. Overall, embodiment ensures that the chosen concept can be effectively implemented and forms a strong foundation for detailed design and prototyping.

7.1 Free Hand Sketch

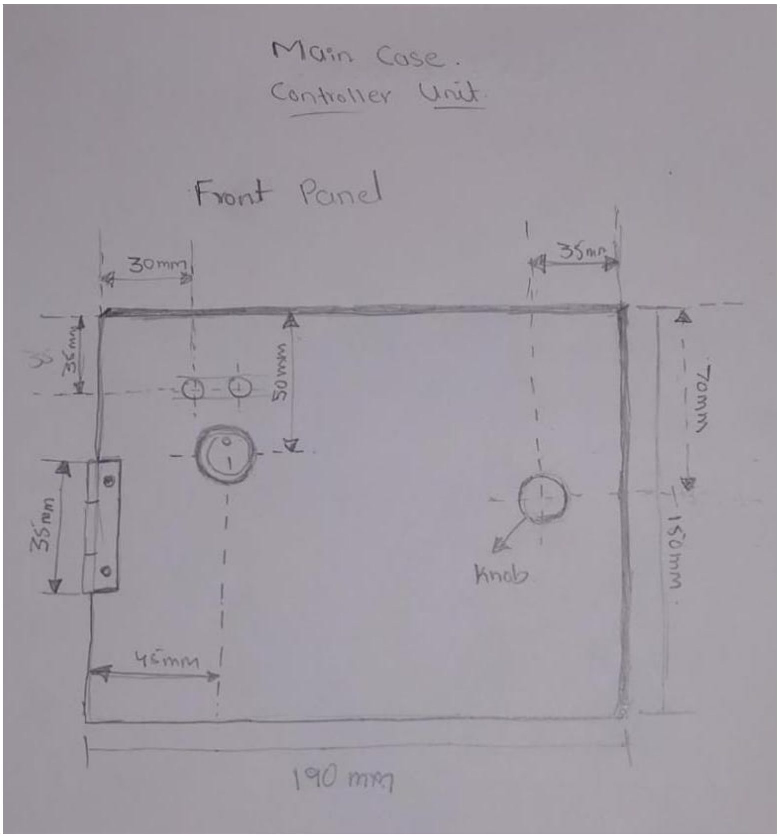

Fig 7.1.1 Free Hand Sketch of Front Panel of Main Cabinet

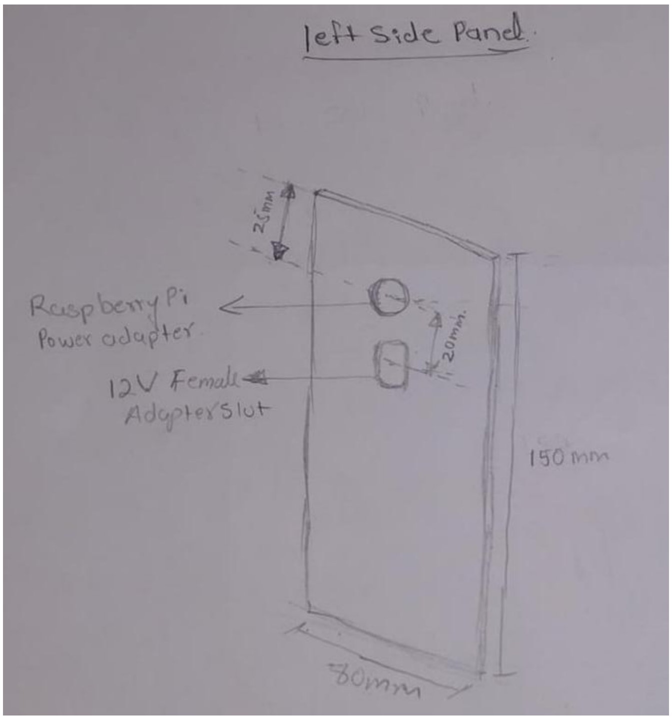

Fig 7.1.2 Free Hand Sketch of Left Panel of Main Cabinet

The initial design of the Main Cabinet was developed using free-hand sketches to visualize the layout and dimensions before CAD modelling. The free-hand sketch of the Front Panel illustrates the placement of control elements such as indicator holes, switches, and a control knob along with overall panel dimensions (Fig. 7.1.1). Similarly, the free-hand sketch of the Left Panel shows the provision for external connections, including the Raspberry Pi power adapter and 12 V female adapter slot, ensuring ease of accessibility and proper cable routing (Fig. 7.1.2). These sketches helped in finalizing the component positioning, dimensions, and functional requirements prior to detailed CAD drafting.

7.2 CAD Model & Drawings

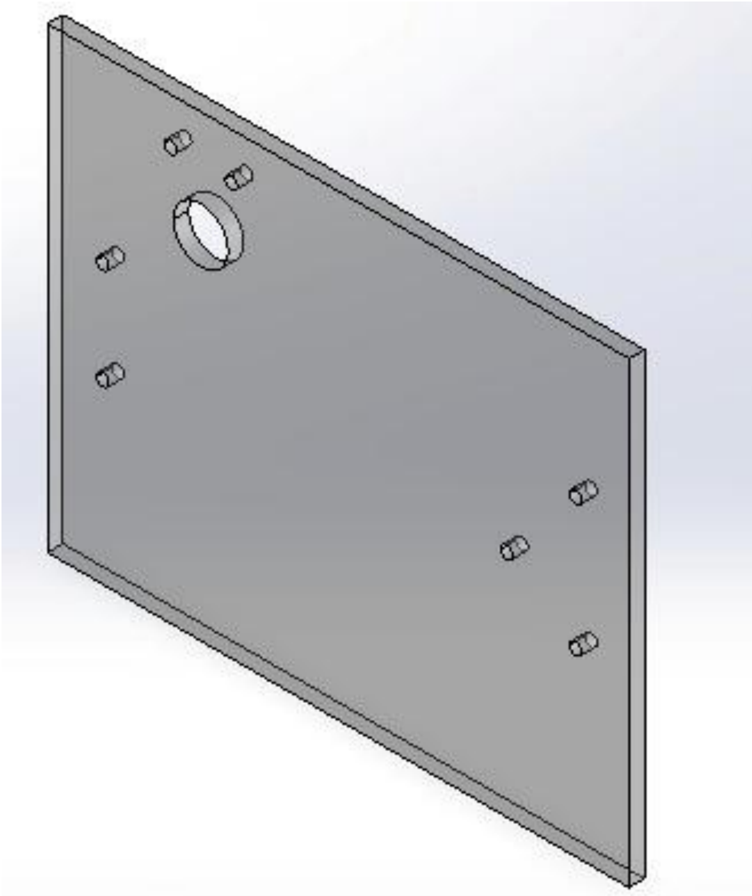

Fig 7.2.1 Front Plate-Main Cabinet

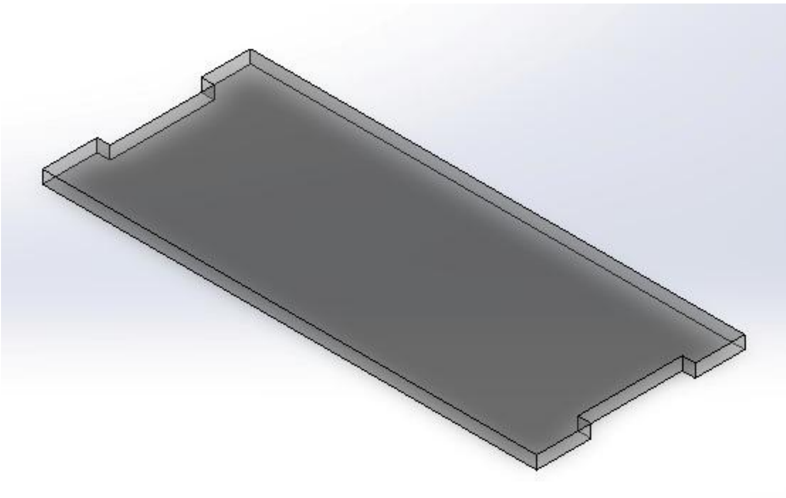

Fig 7.2.2 Bottom Plate-Main Cabinet

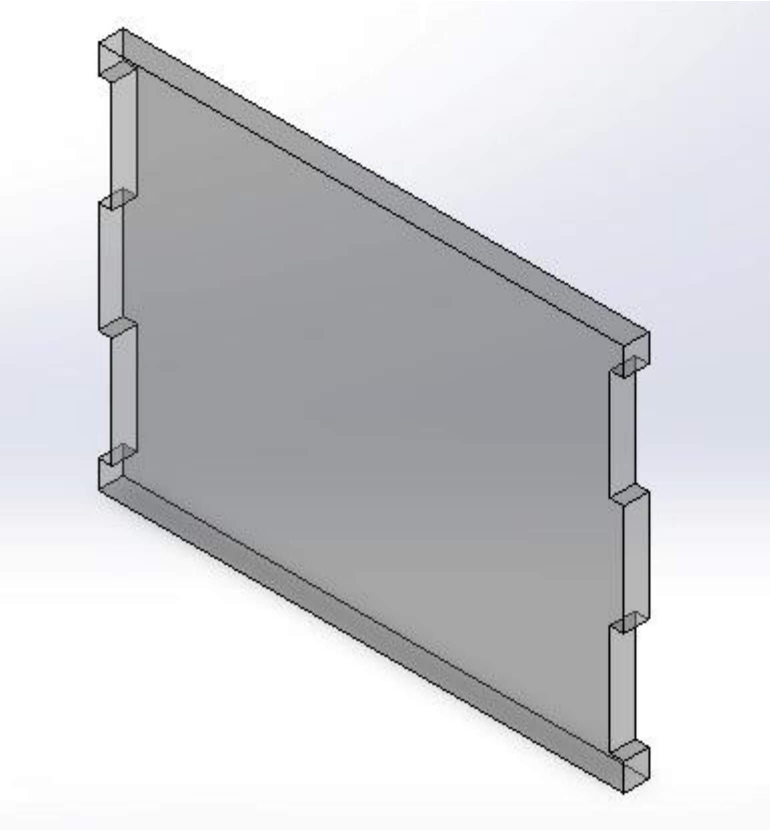

Fig7.2.3 Base Plate-Main Cabinet

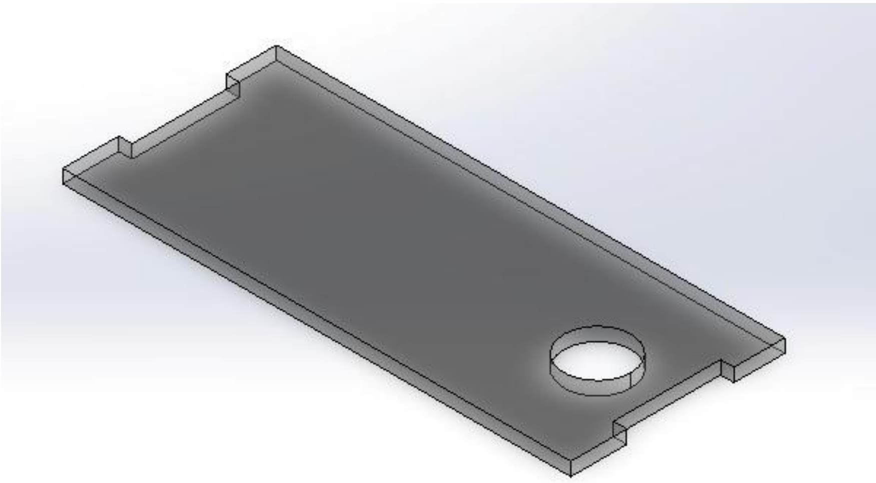

Fig 7.2.4 Top Plate-Main Cabinet

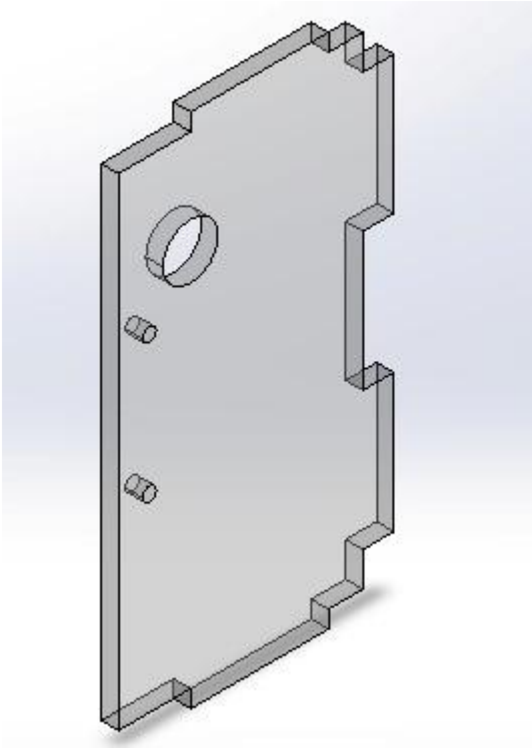

Fig 7.2.5 Right Plate-Main Cabinet

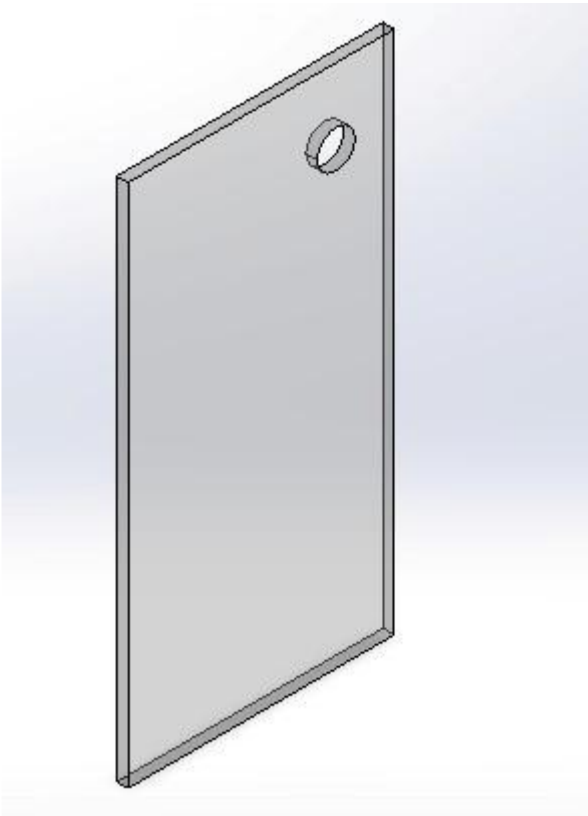

Fig 7.2.6 Internal Plate-Main Cabinet

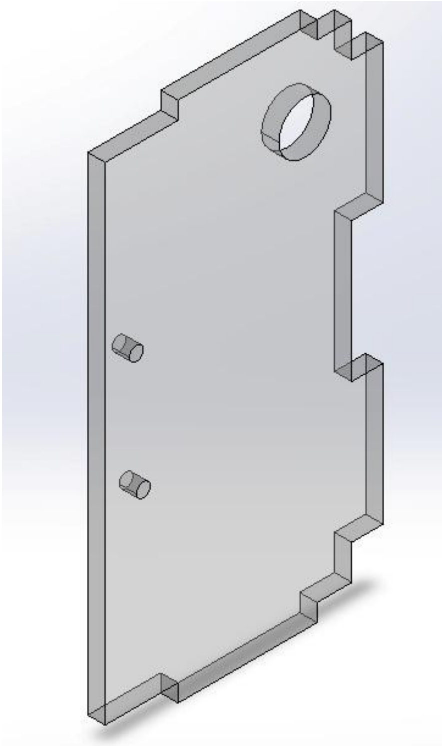

Fig 7.2.7 Left Plate-Main Cabinet

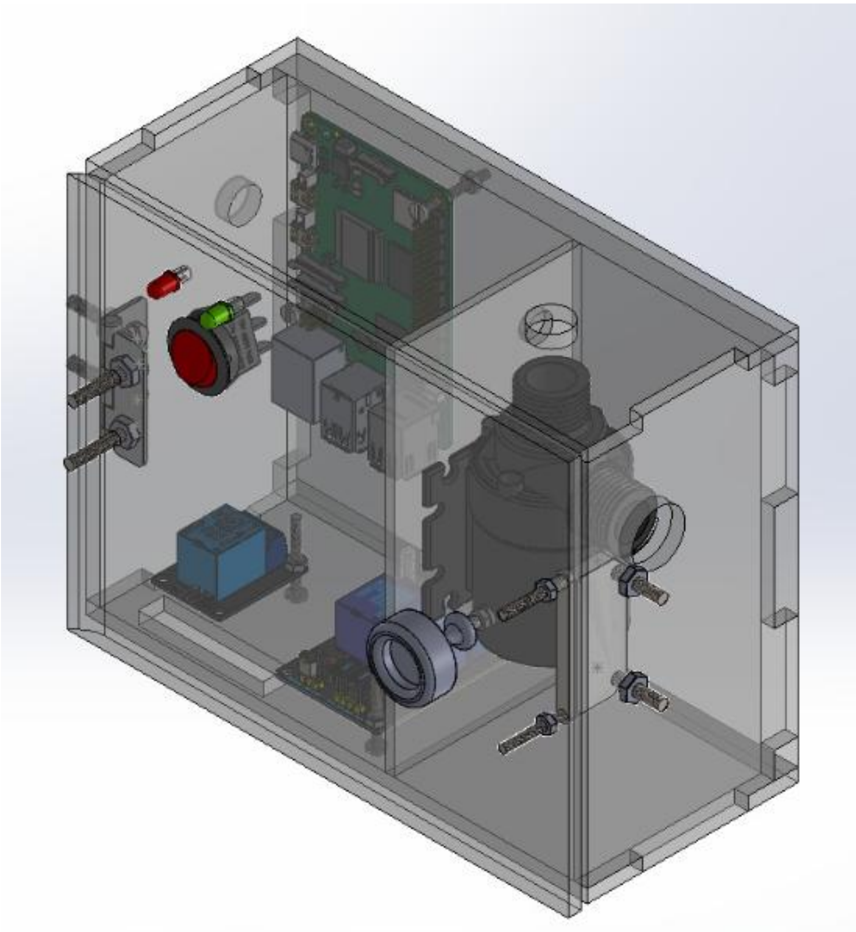

Fig 7.2.8 Assembly of the Main Cabinet

The Main Cabinet of the HydroHive terrace watering system is composed of multiple sheet-metal components designed to provide structural strength and protection for the internal electronics. The Front Plate enables access to internal components and supports user interaction (Fig. 7.2.1). The Bottom Plate forms the lower enclosure and contributes to overall stability (Fig. 7.2.2). The Base Plate serves as the primary structural foundation on which the cabinet and internal components are mounted (Fig. 7.2.3). The Top Plate protects the system from dust and environmental exposure while completing the enclosure (Fig. 7.2.4). The Right Plate and Left Plate act as the side walls of the cabinet, ensuring rigidity and proper alignment of all parts (Fig. 7.2.5 and Fig. 7.2.7). The Internal Plate is used for mounting electronic modules and wiring in an organized manner inside the cabinet (Fig. 7.2.6). All these individual components are assembled accurately to form the Main Cabinet Assembly, which provides a compact, robust, and functional enclosure for the HydroHive system (Fig. 7.2.8).

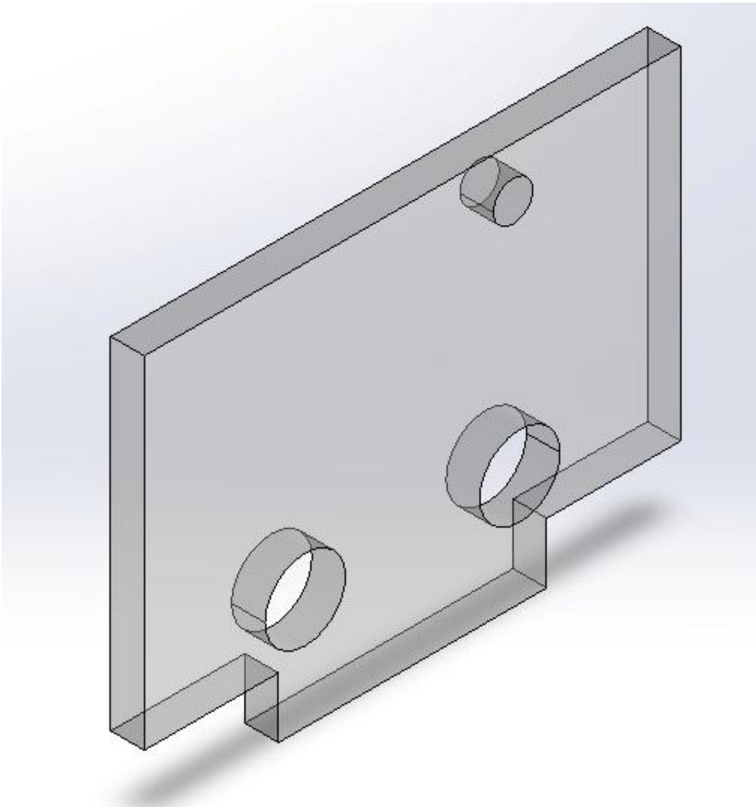

Fig 7.2.9 Front Plate-Solenoid Box

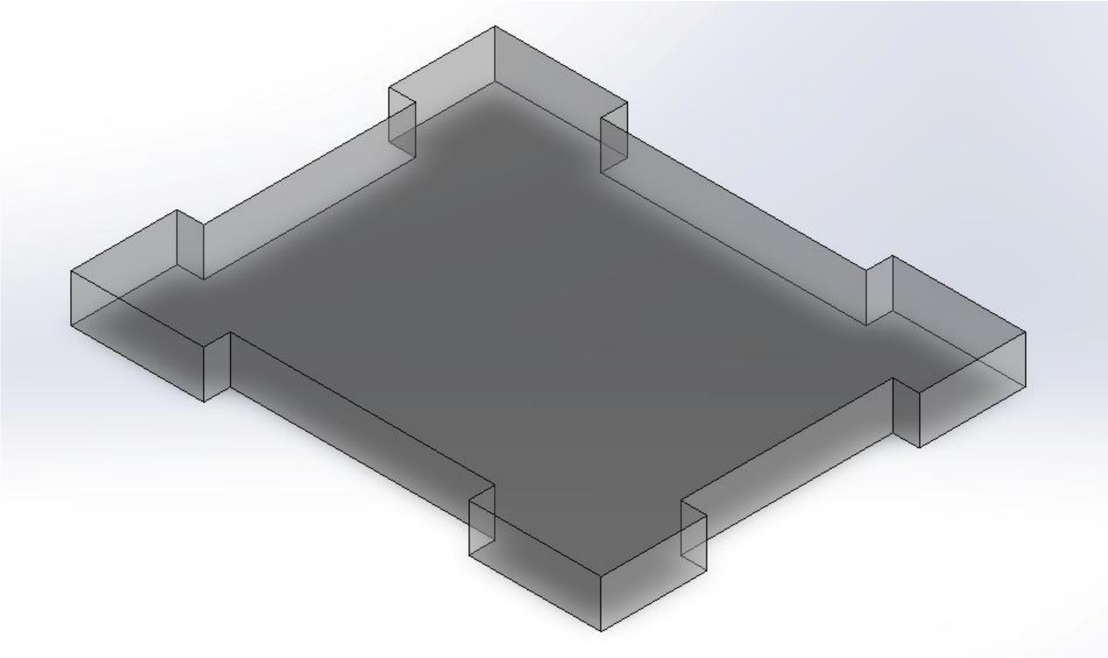

Fig 7.2.10 Base Plate-Solenoid Box

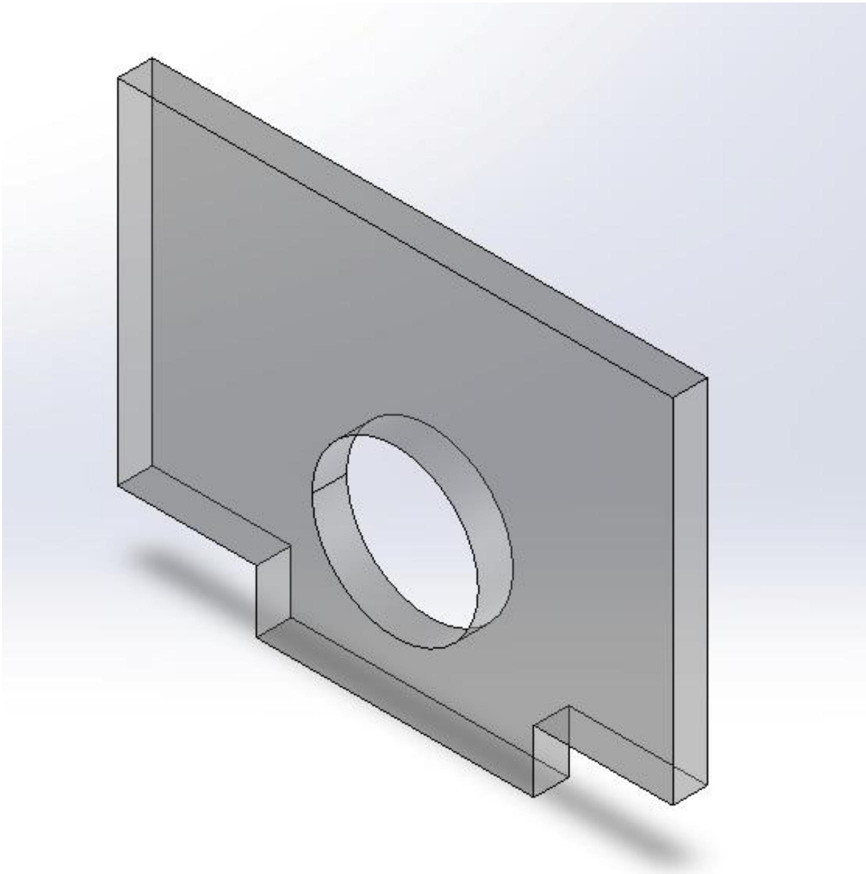

Fig 7.2.11 Back Plate-Solenoid Box

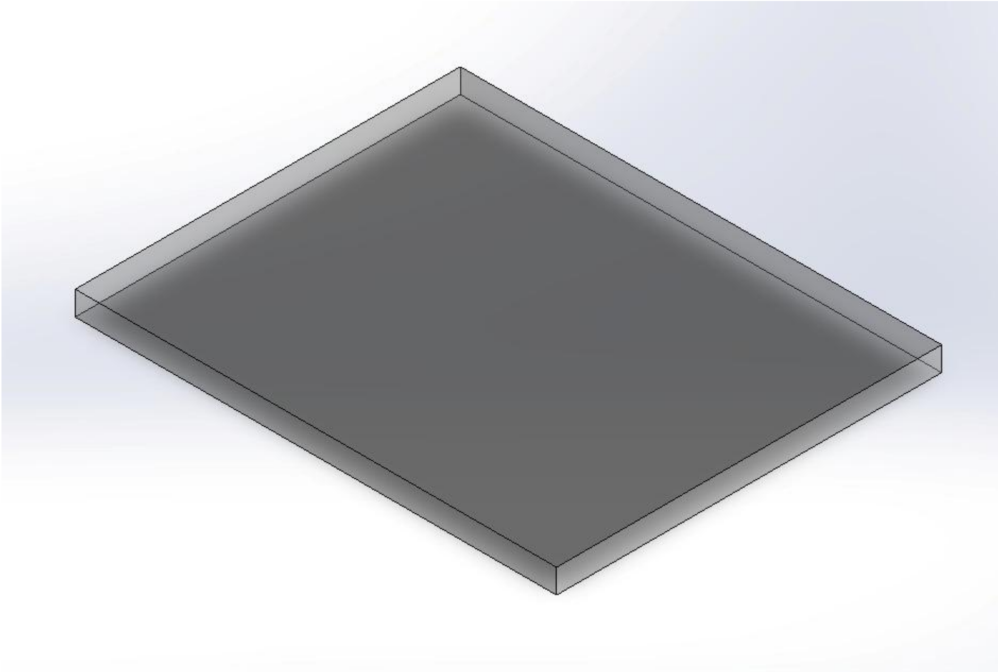

Fig 7.2.12 Top Plate-Solenoid Box

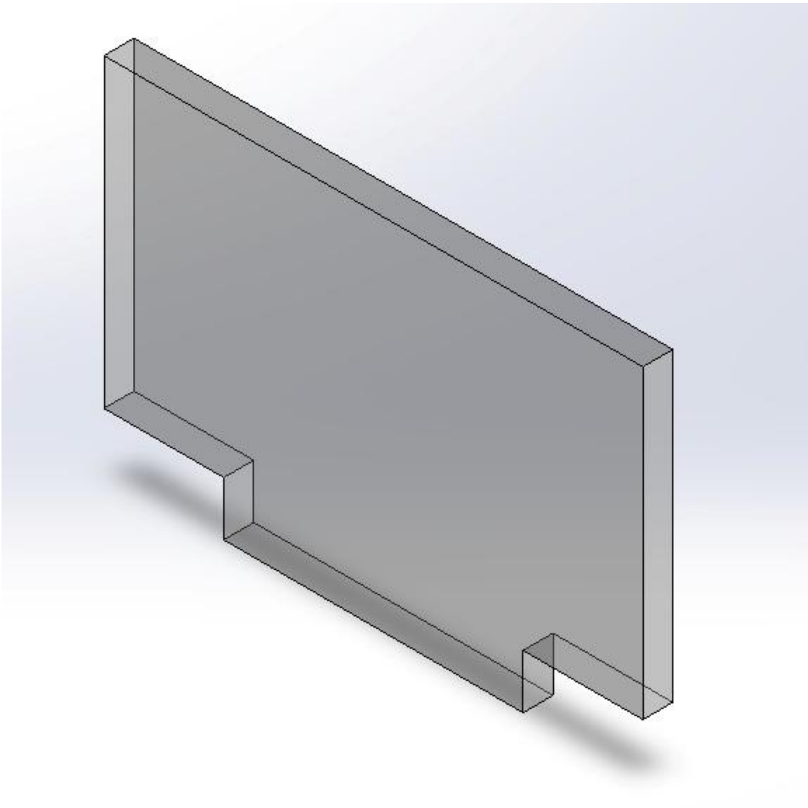

Fig 7.2.13 Left Plate-Solenoid Box

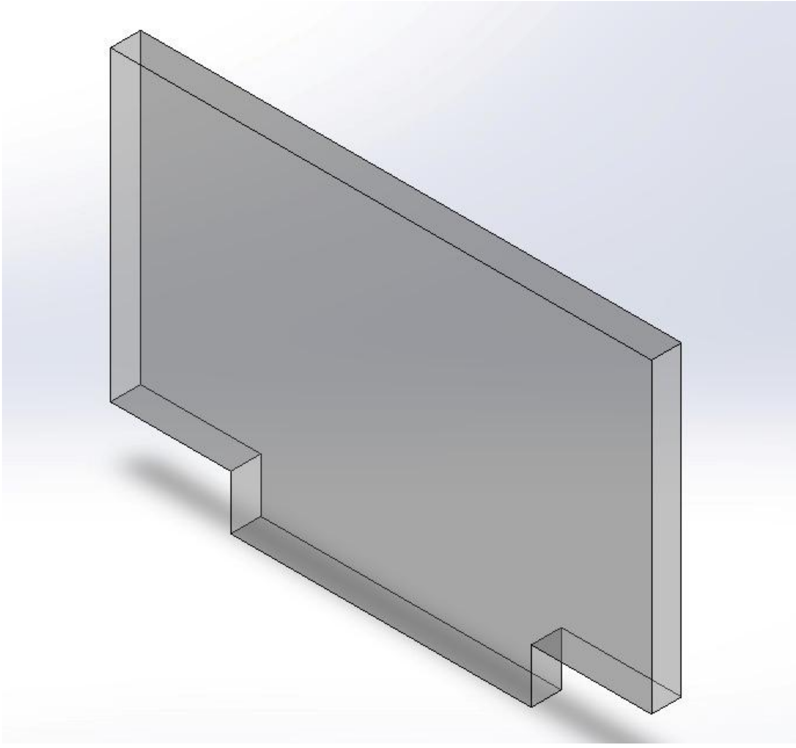

Fig 7.2.14 Right Plate-Solenoid Box

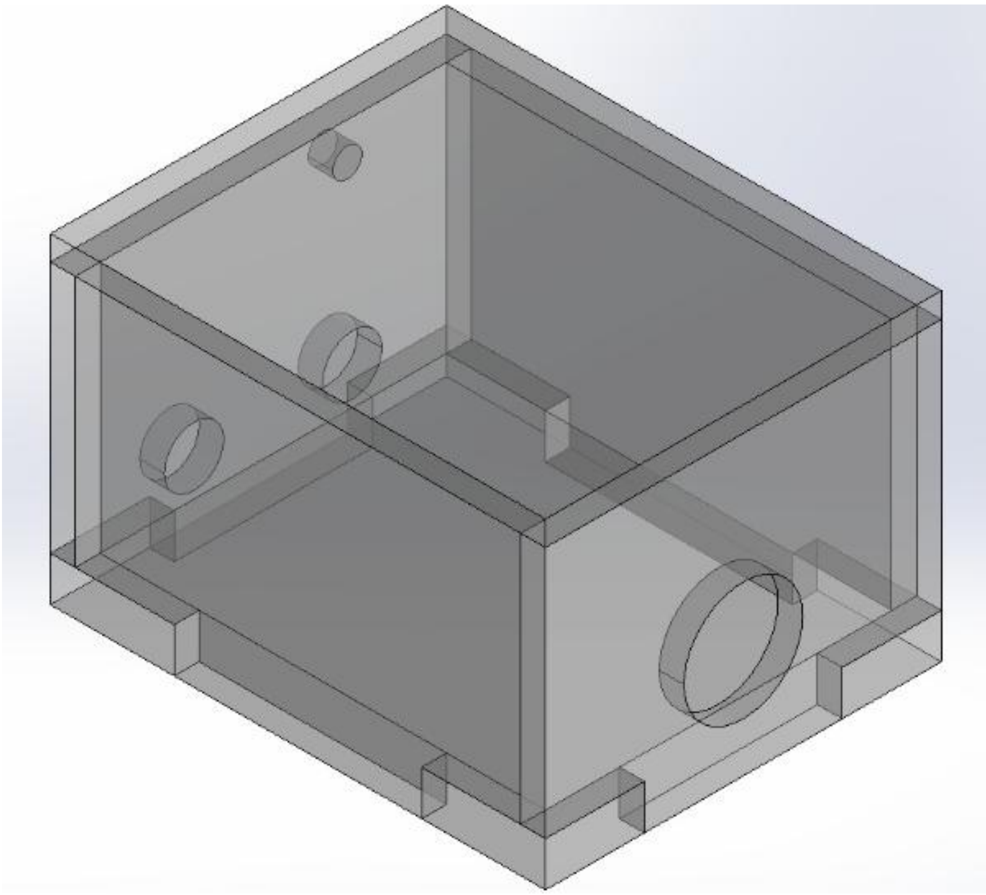

Fig 7.2.15 Assembly of Solenoid Box

The Solenoid Box is designed to house and protect the solenoid valves and related wiring used for controlling water flow in the HydroHive terrace watering system. The Front Plate provides access for installation and maintenance of the solenoid valves (Fig. 7.2.9). The Base Plate serves as the mounting foundation for the solenoid valves and internal fittings, ensuring proper alignment and stability (Fig. 7.2.10). The Back Plate supports cable routing and provides enclosure from the rear side (Fig. 7.2.11). The Top Plate protects the solenoid components from dust, moisture, and external environmental conditions (Fig. 7.2.12). The Left Plate and Right Plate form the side walls of the solenoid box, contributing to structural rigidity and secure assembly of all components (Fig. 7.2.13 and Fig. 7.2.14). All these individual parts are precisely assembled to form the Solenoid Box Assembly, which ensures safe housing, proper functioning, and ease of maintenance of the solenoid valves, as shown in Fig. 7.2.15.

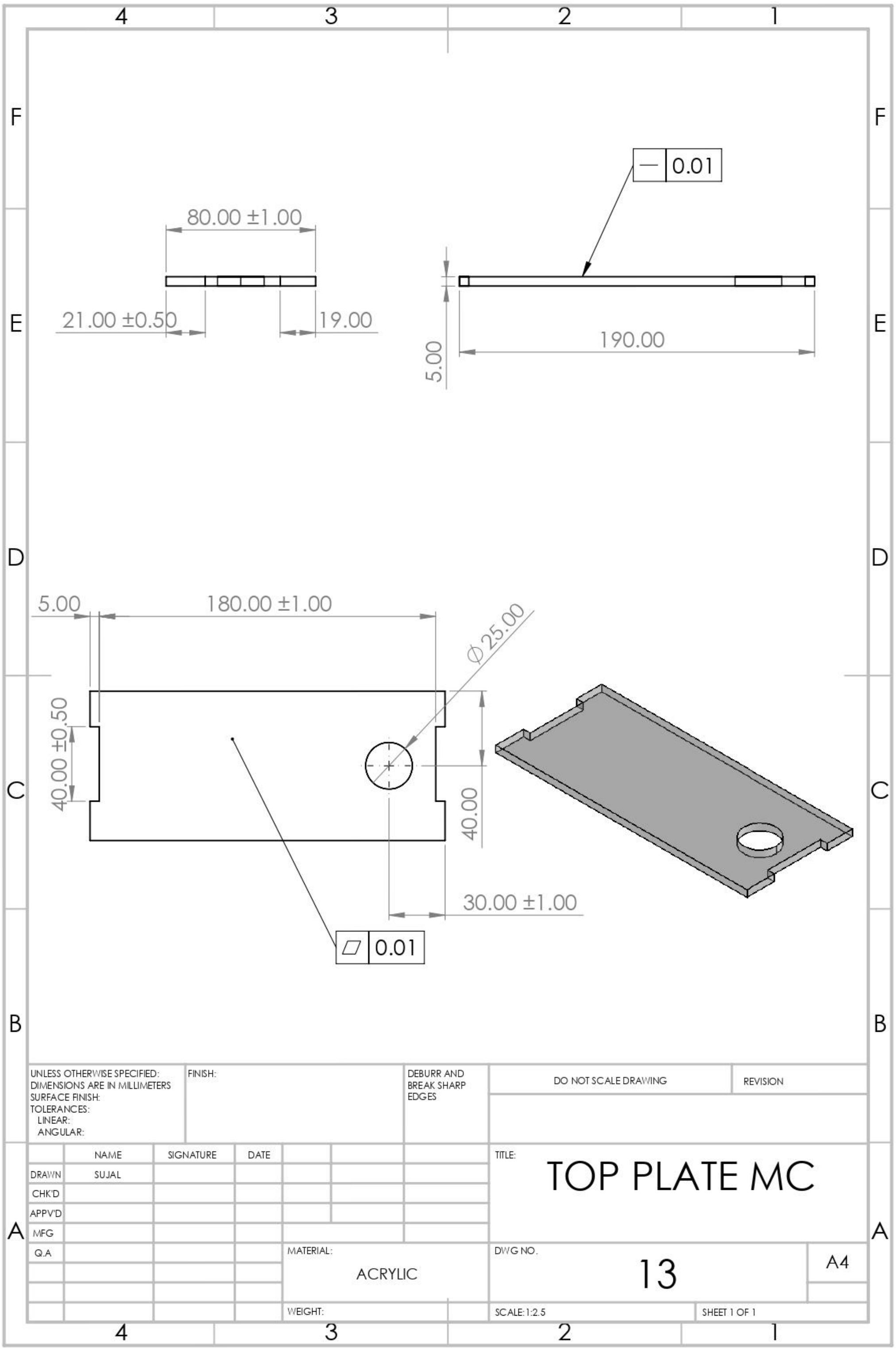

Fig 7.2.16 Drafting of Top Plate Main Cabinet

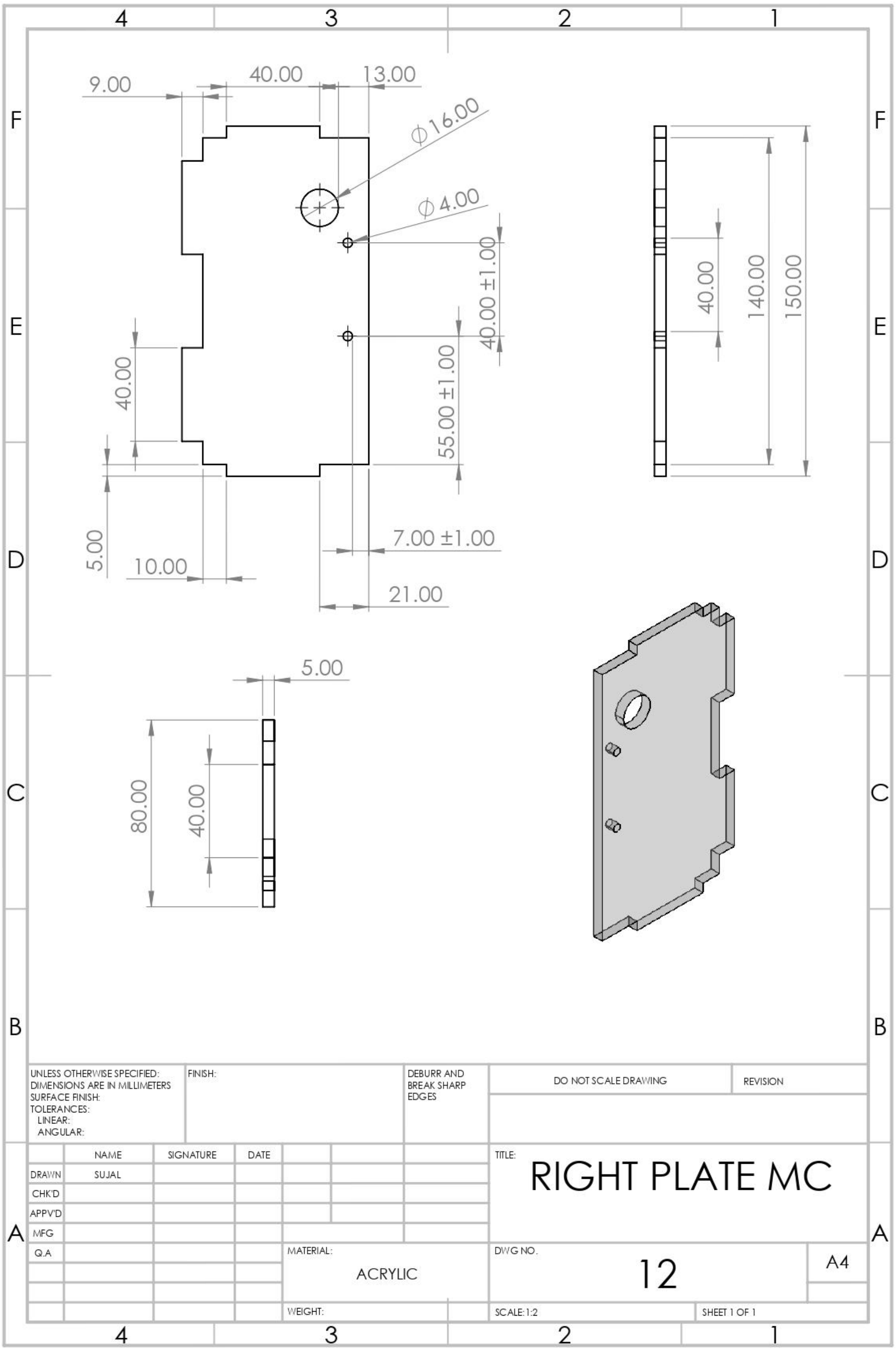

Fig 7.2.17 Drafting of Right Plate Main Cabinet

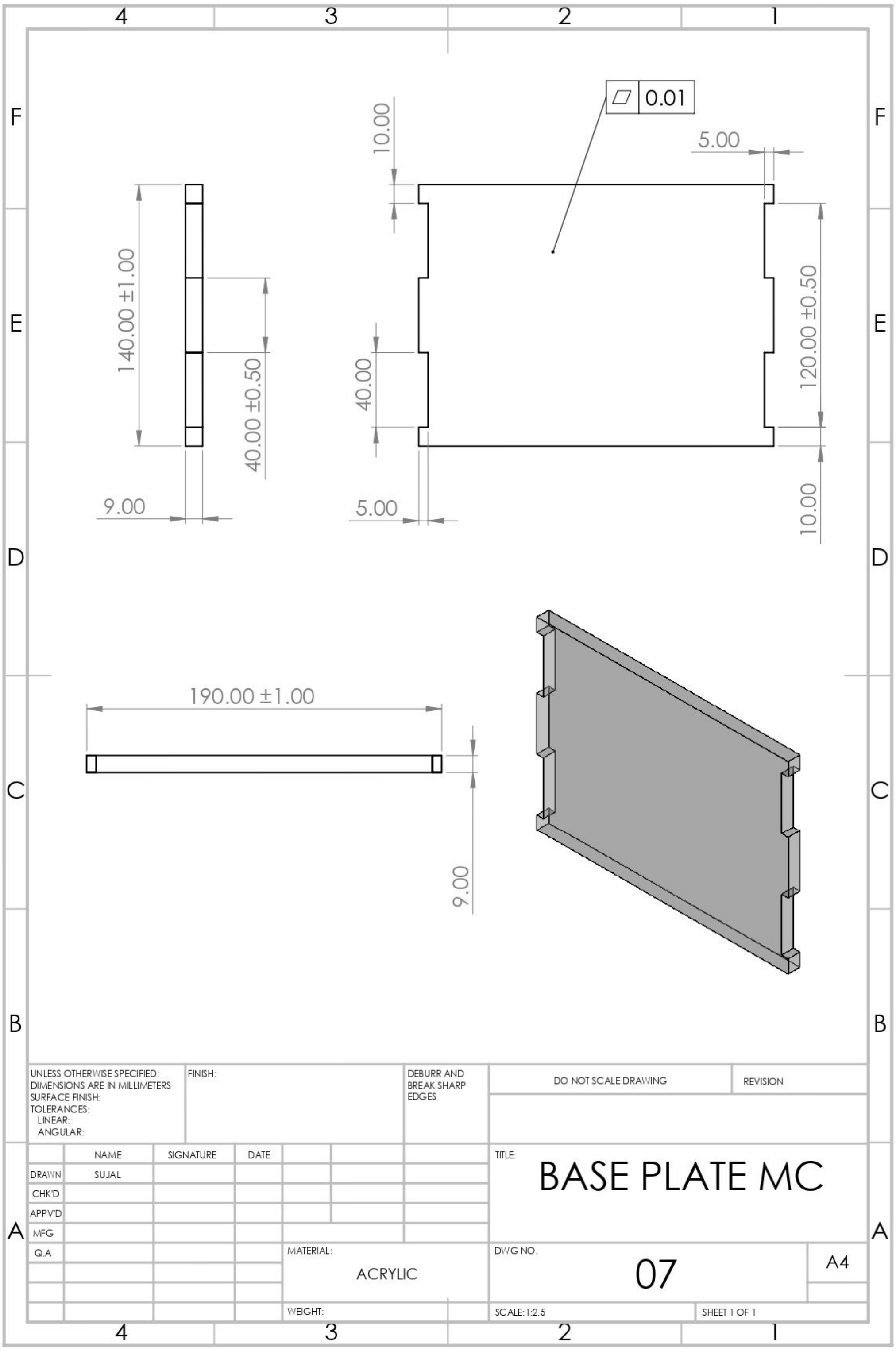

Fig 7.2.18 Drafting of Base plate Main Cabinet

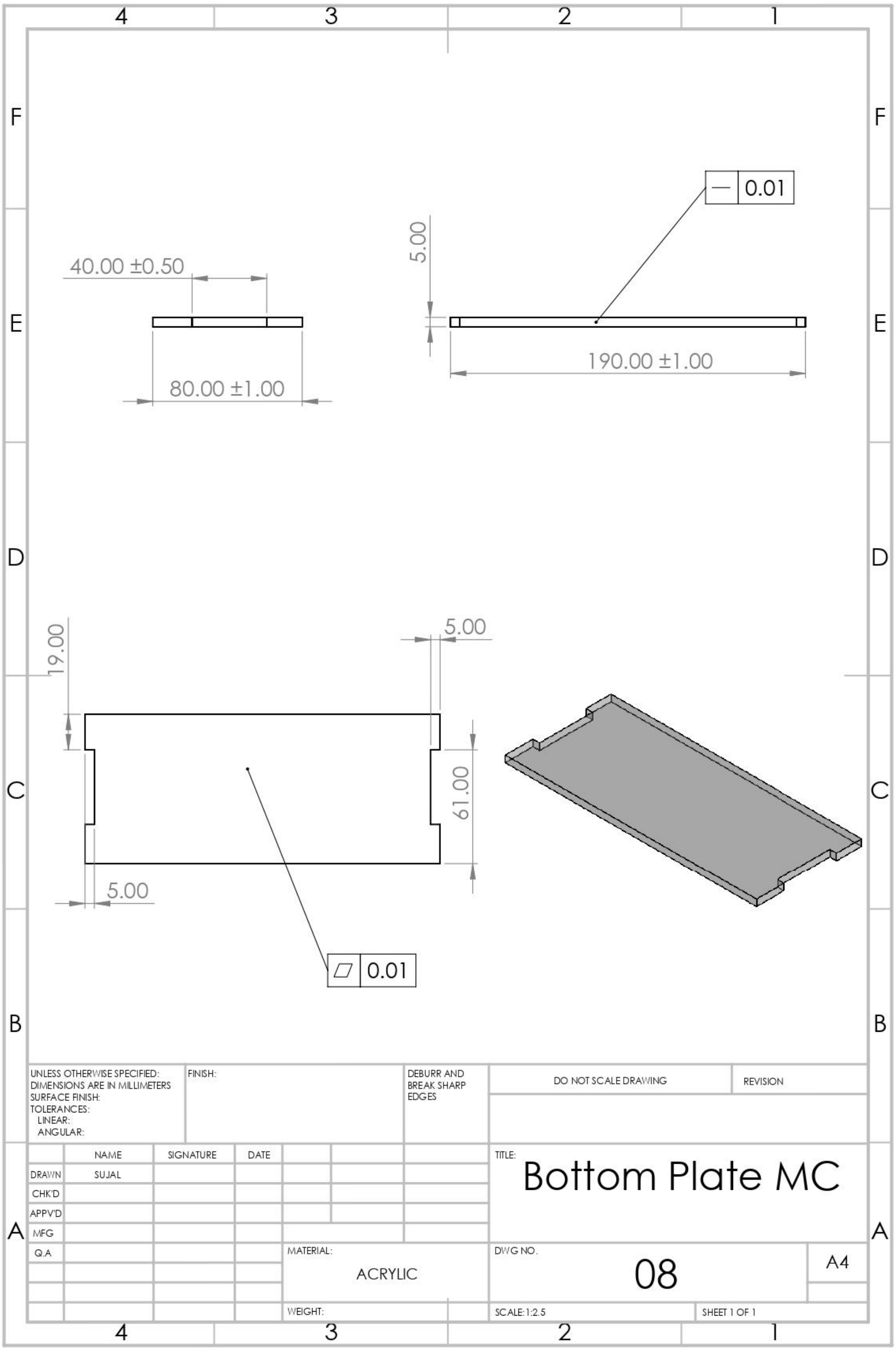

Fig 7.2.19 Drafting of Bottom Plate Main Cabinet

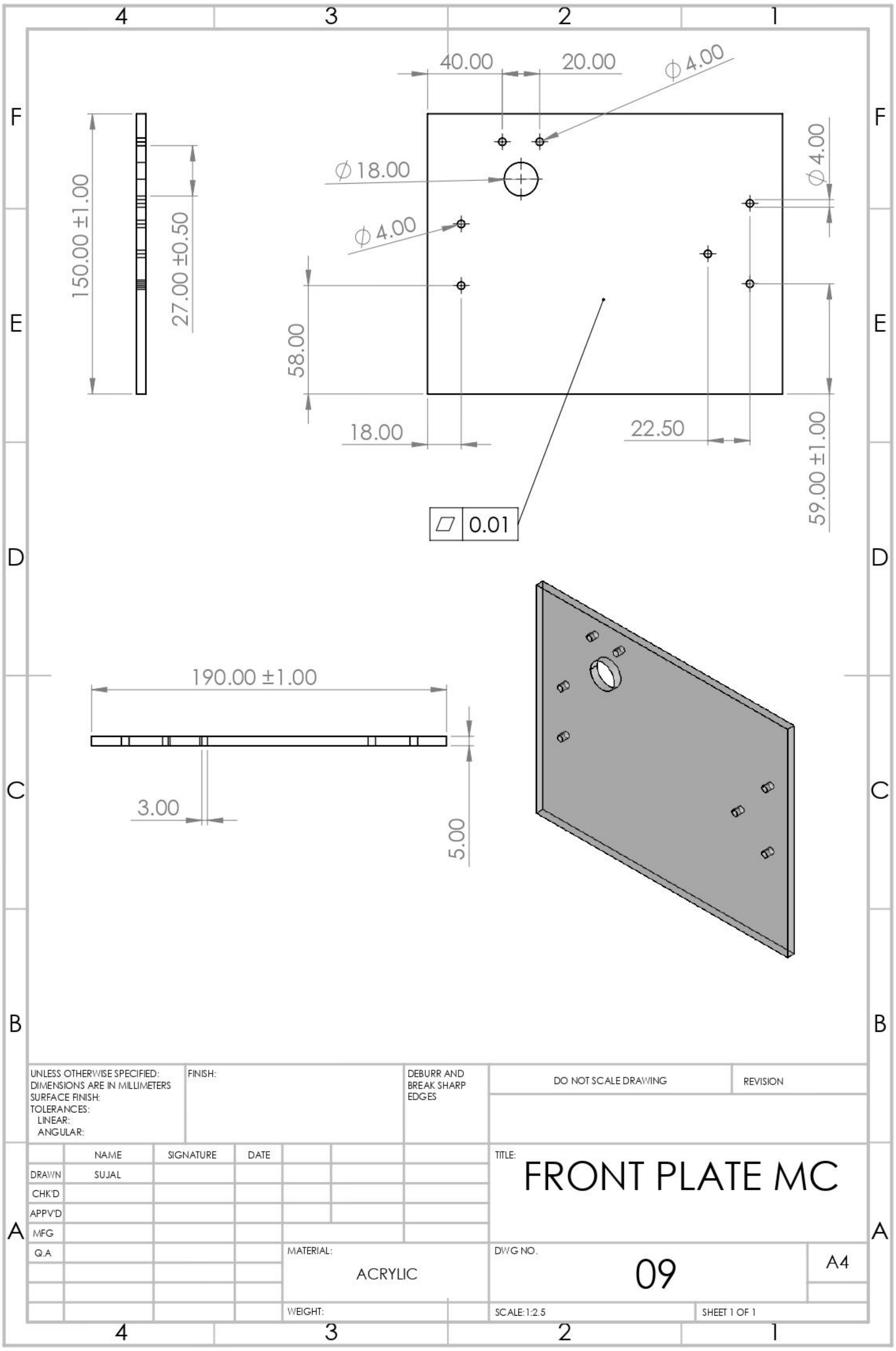

Fig 7.2.20 Drafting of Front Plate Main Cabinet

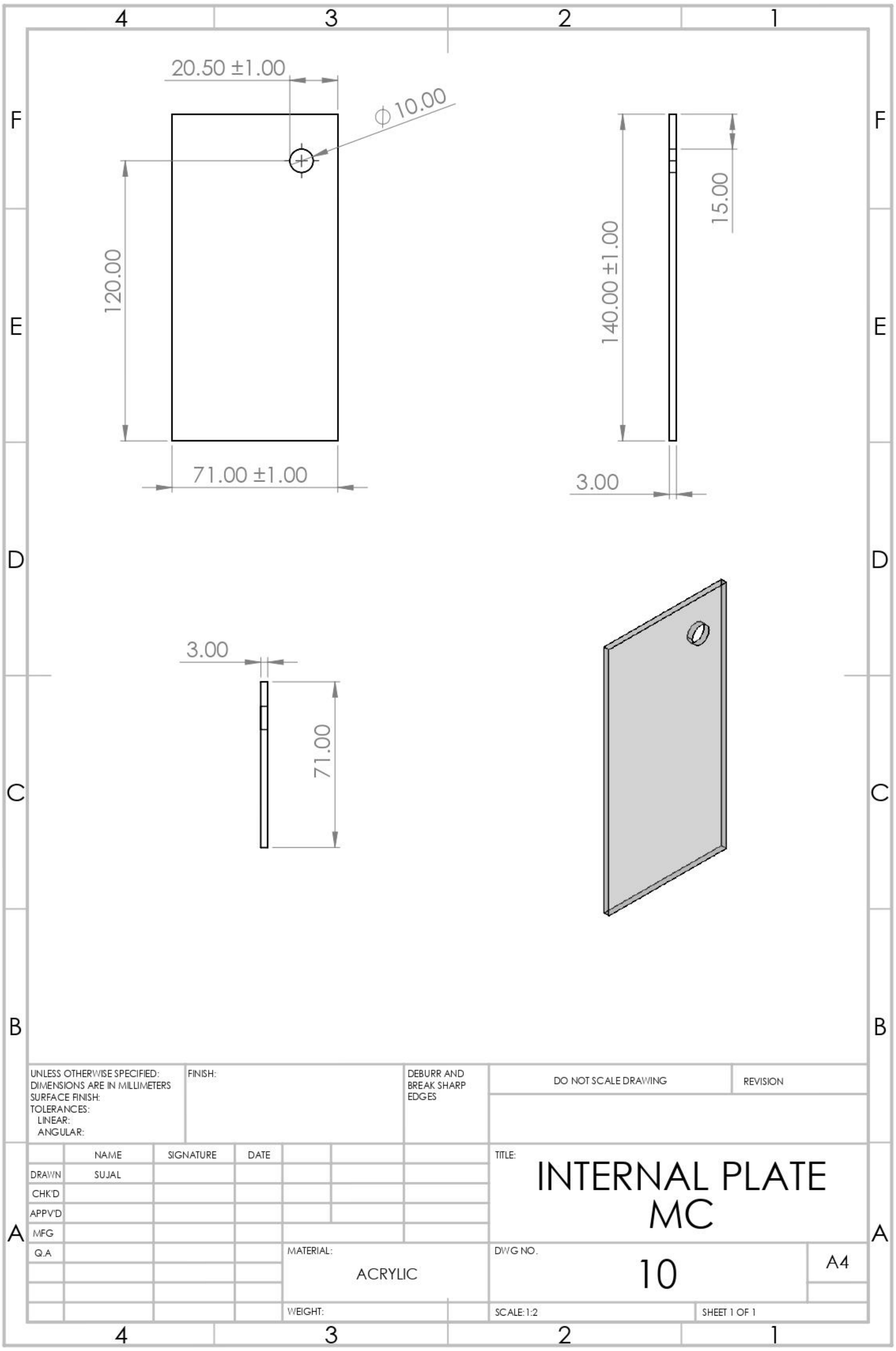

Fig 7.2.21 Drafting of Internal Plate Main Cabinet

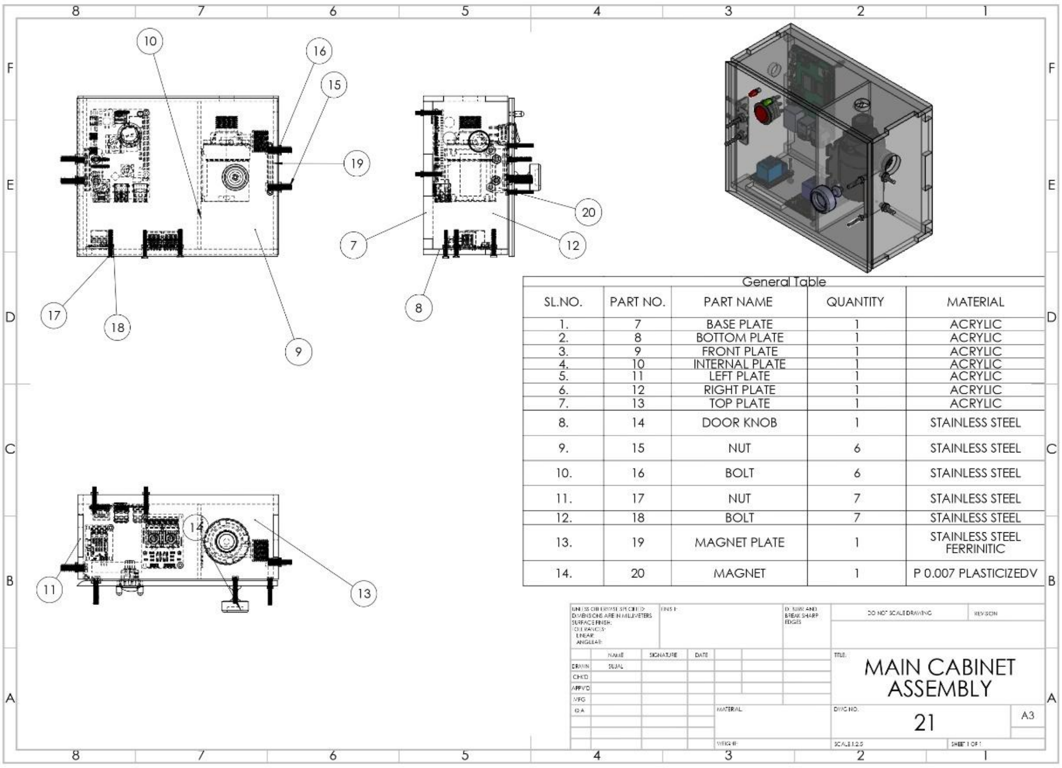

Fig 7.2.22 Drafting of Assembly of Main Cabinet

The detailed drafting of the Main Cabinet components was carried out to ensure dimensional accuracy and ease of manufacturing. The Top Plate, Right Plate, Base Plate, Bottom Plate, Front Plate, and Internal Plate of the Main Cabinet were drafted individually to clearly define dimensions, hole locations, and structural features required for fabrication (Fig. 7.2.16 to Fig. 7.2.21). These detailed part drawings help in maintaining proper fit, alignment, and structural integrity during fabrication. All the drafted components were then assembled to form the Main Cabinet Assembly, verifying overall dimensions, clearances, and assembly feasibility, as shown in Fig. 7.2.22.

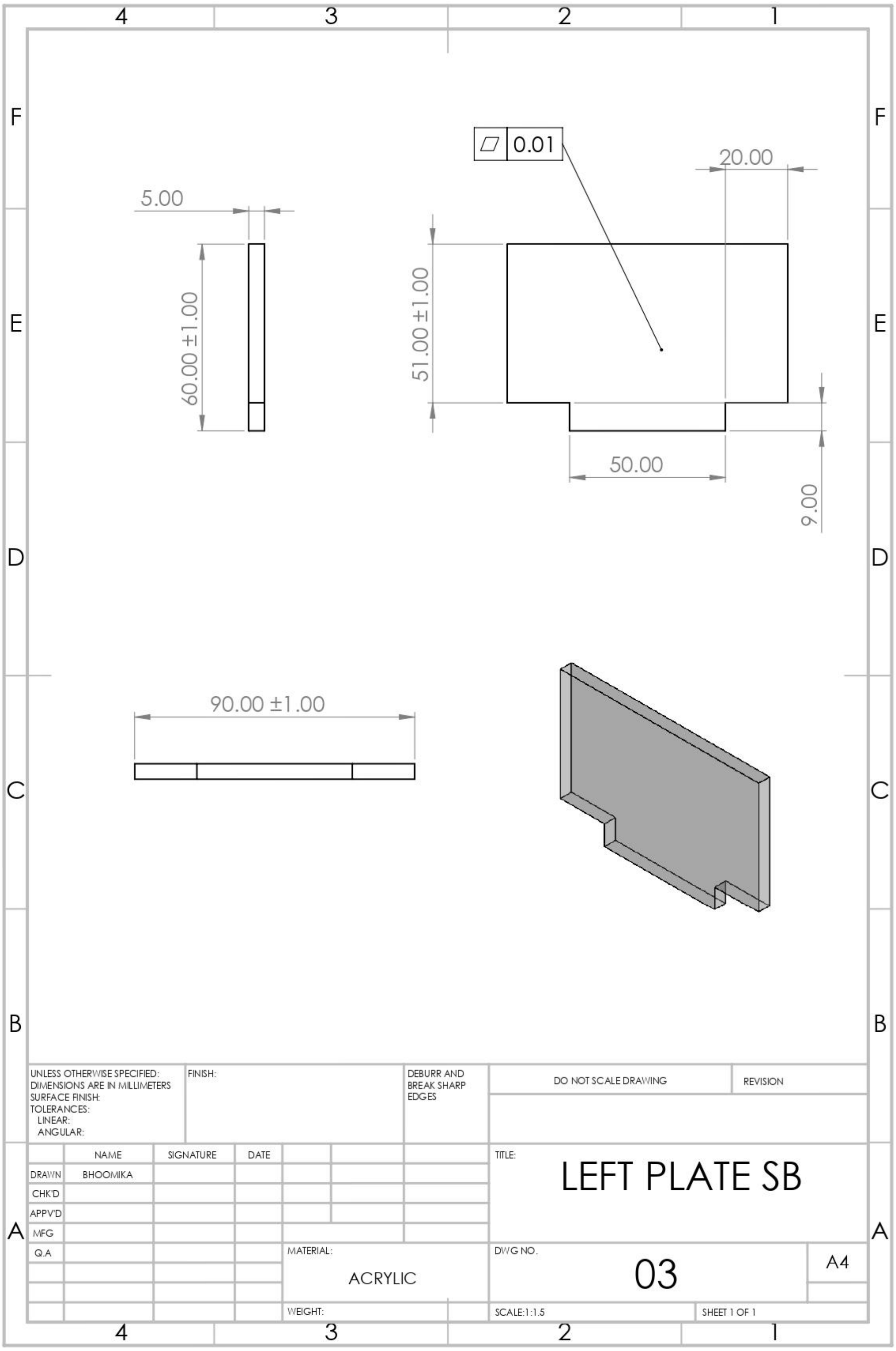

Fig 7.2.23 Drafting of Left Plate of Solenoid Box

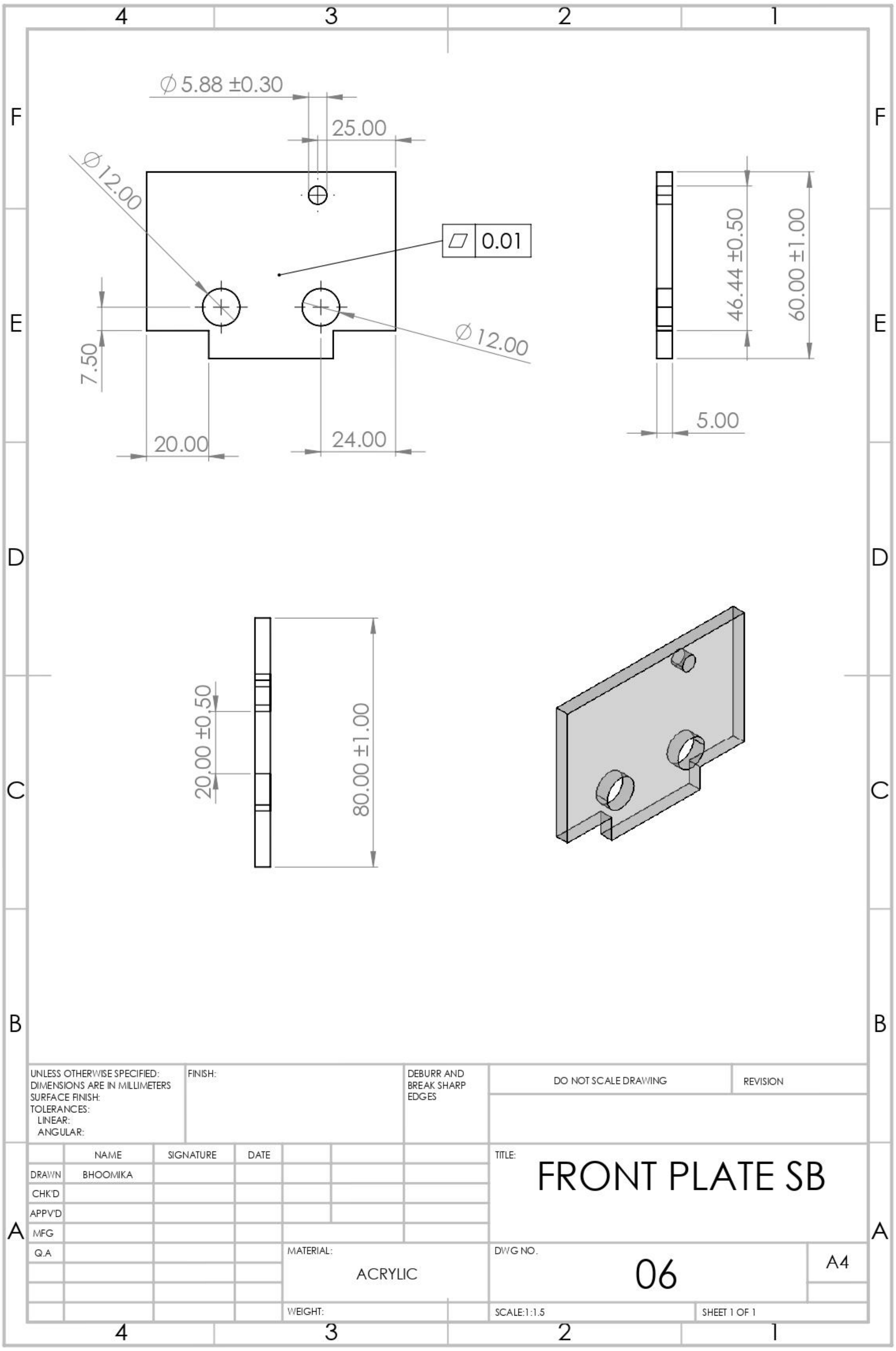

Fig 7.2.24 Drafting of Front Plate of Solenoid Box

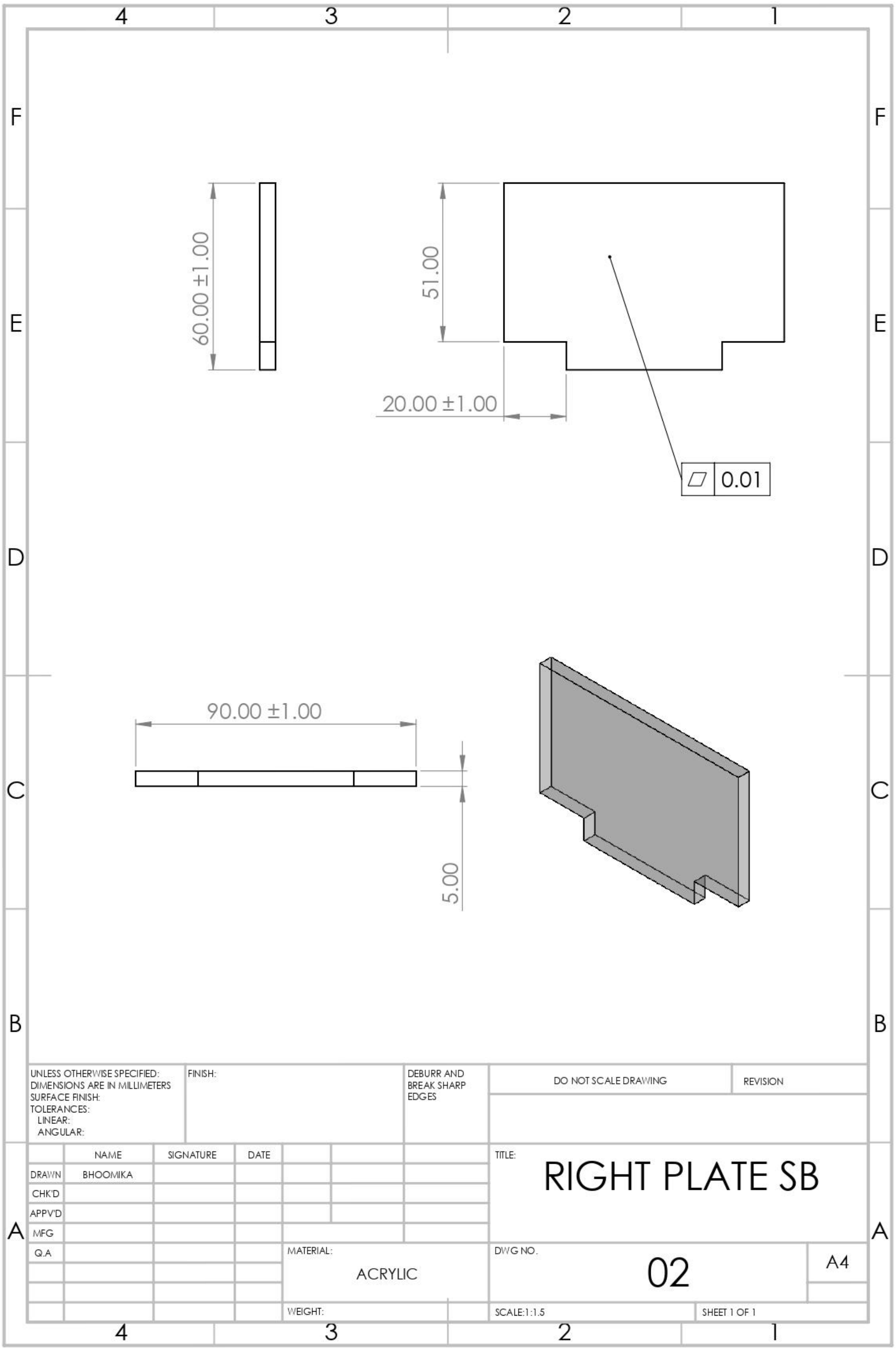

Fig 7.2.25 Drafting of Right Plate of Solenoid Box

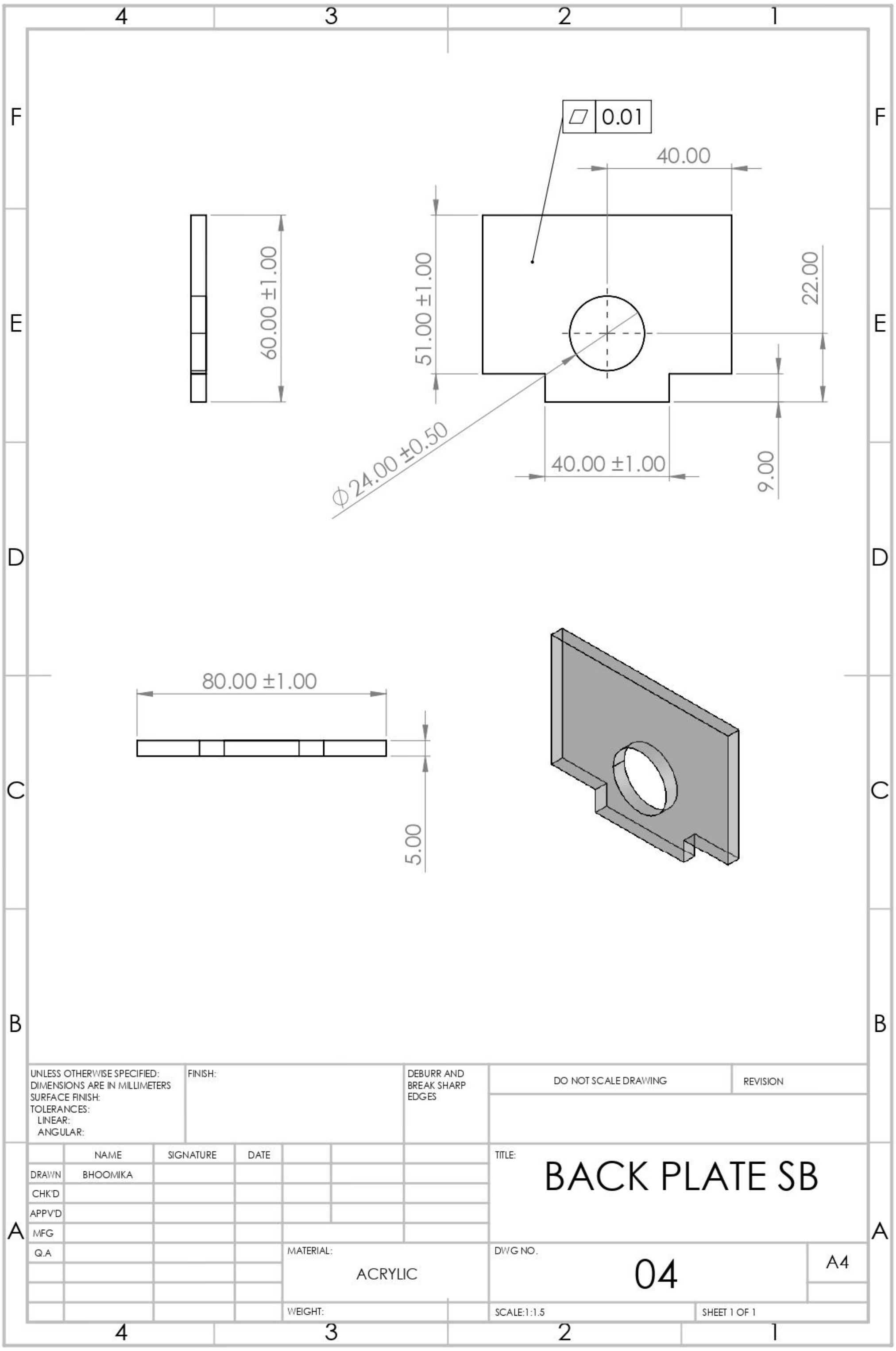

Fig 7.2.26 Drafting of Back Plate of Solenoid Box

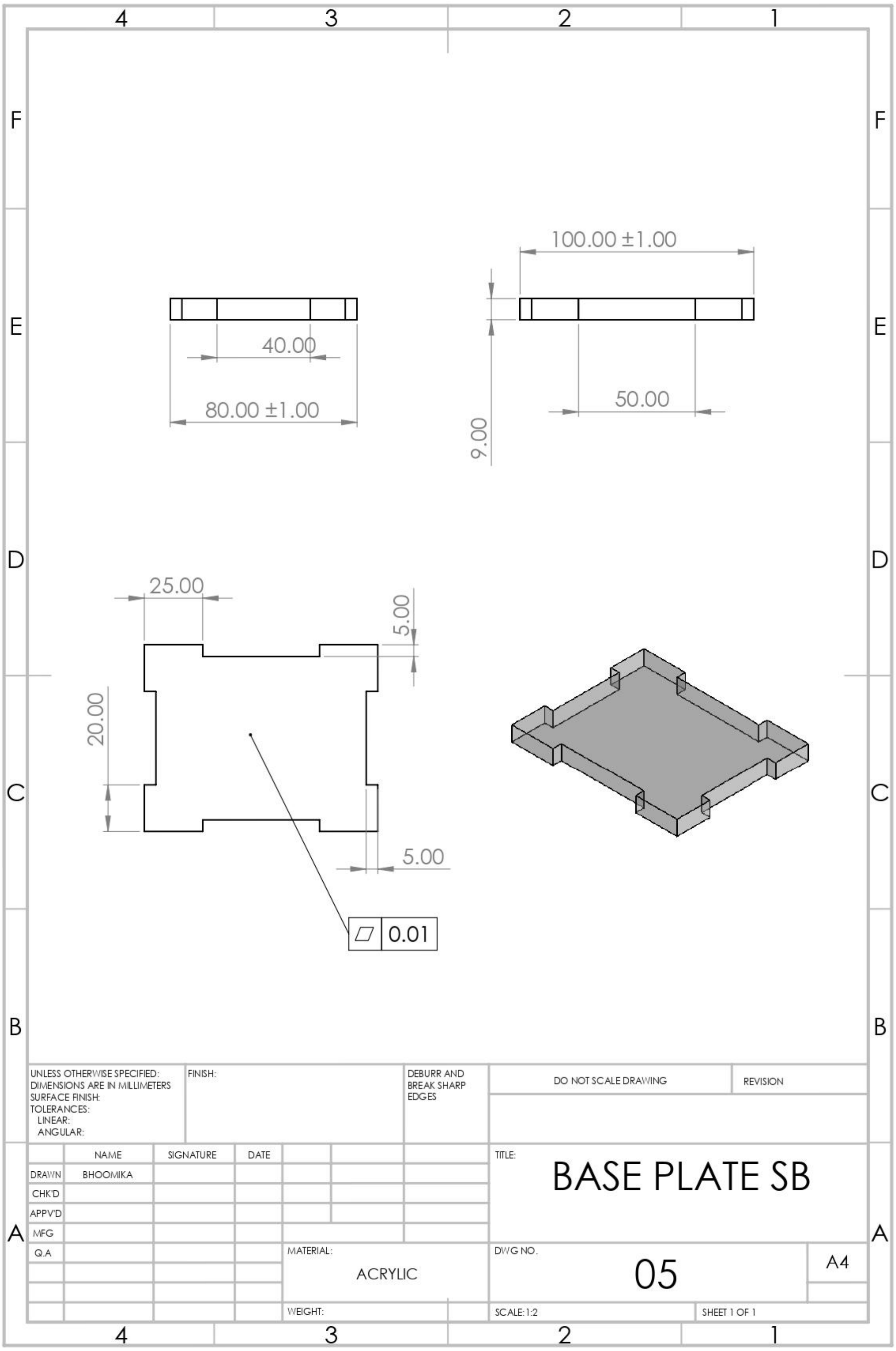

Fig 7.2.27 Drafting of Base Plate of Solenoid Box

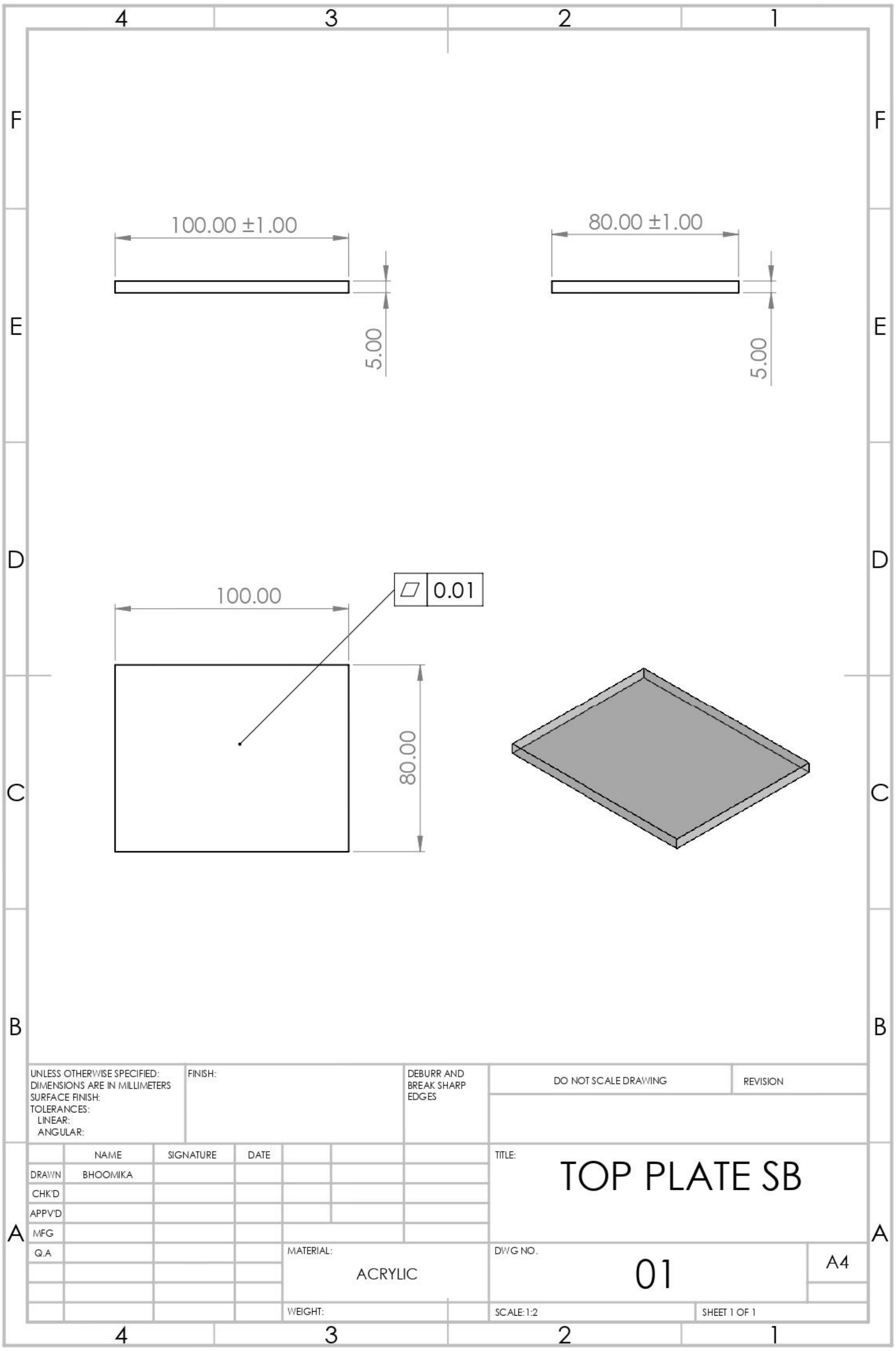

Fig 7.2.28 Drafting of Top Plate of Solenoid Box

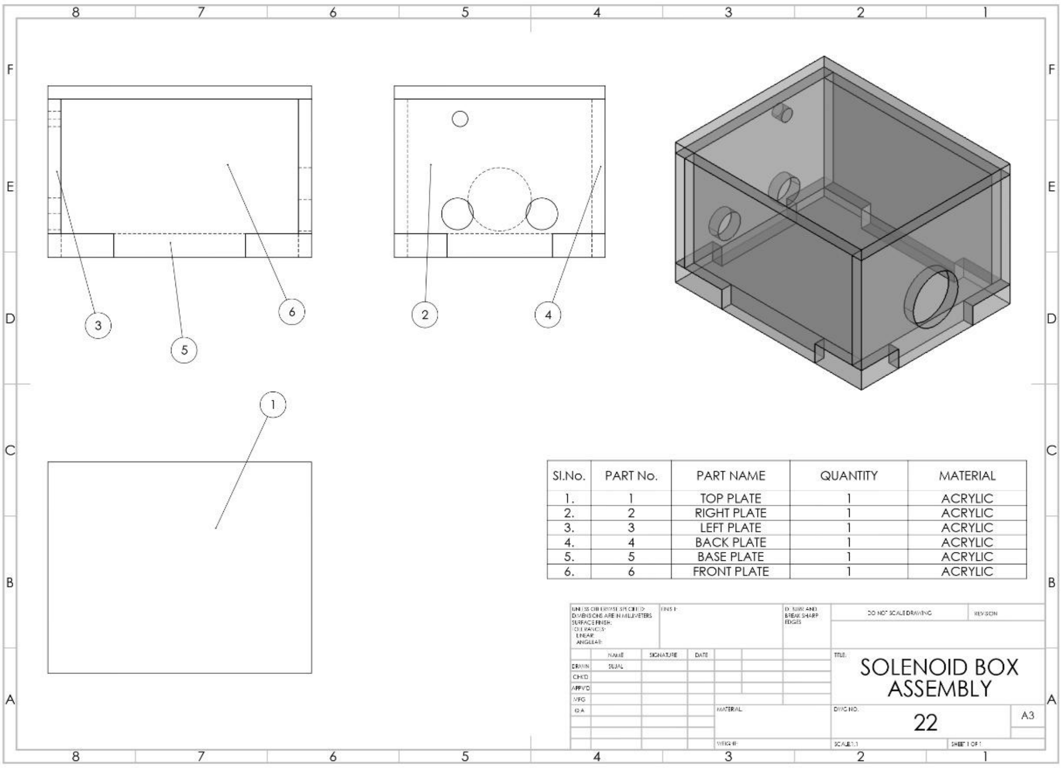

Fig 7.2.29 Drafting of Assembly of Solenoid Box

The detailed drafting of the Solenoid Box components was carried out to ensure precise dimensions and proper assembly of the enclosure. The Left Plate, Front Plate, Right Plate, Back Plate, Base Plate, and Top Plate of the Solenoid Box were drafted individually to define exact dimensions, hole positions, and mounting features required for fabrication (Fig. 7.2.23 to Fig. 7.2.28). These detailed drawings ensure accurate manufacturing, correct alignment, and structural rigidity of the solenoid box. All the drafted components were then assembled to form the Solenoid Box Assembly, validating the overall fit, clearances, and design feasibility, as illustrated in Fig. 7.2.29.

7.3 Circuit design

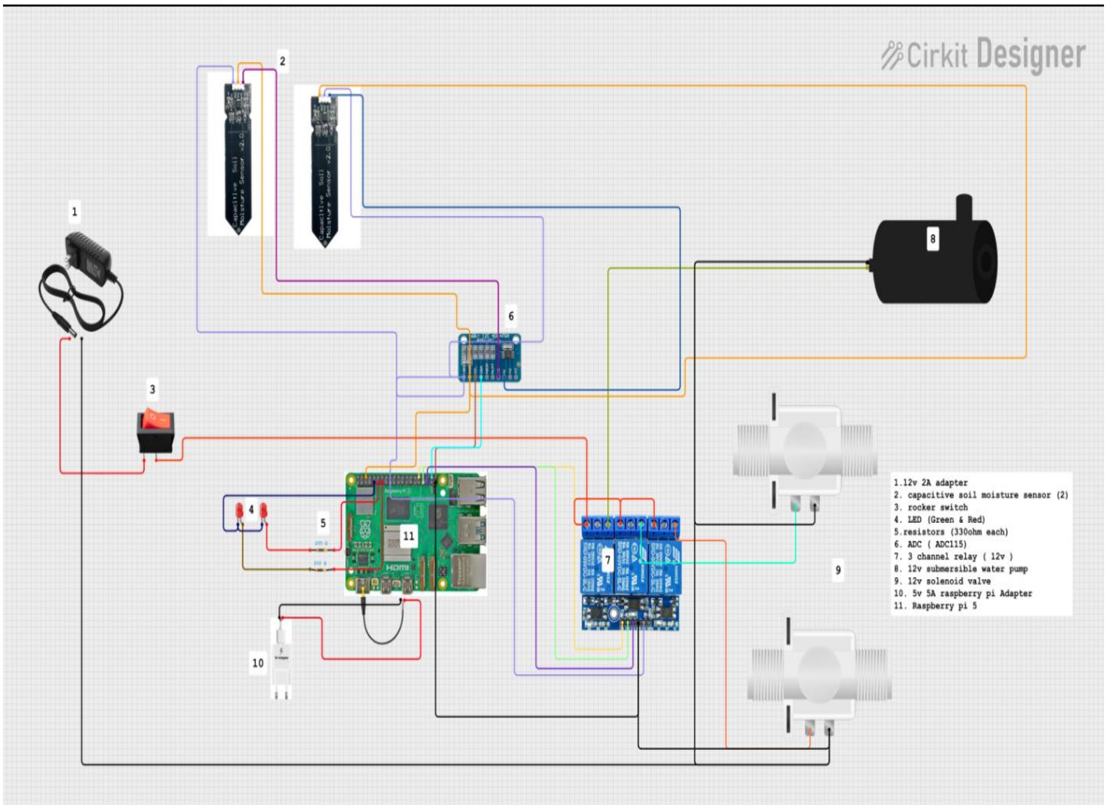

Fig. 7.3.1 Detailed Design of the Complete Circuit Diagram

The circuit diagram represents the complete hardware implementation of the automatic terrace watering system and shows how sensing, control, and actuation components are interconnected. Two capacitive soil moisture sensors are used to continuously monitor the moisture level of the soil in different pots or zones. These sensors provide analog signals, which are converted into digital form using an ADC module before being sent to the Raspberry Pi controller. The Raspberry Pi acts as the central processing unit, where sensor data is analyzed and control decisions are made.

A relay module is interfaced with the Raspberry Pi to safely control high-power devices such as the water pump and solenoid valves. Based on the moisture condition and control logic, the Raspberry Pi activates or deactivates the relay, which in turn controls the pump and valve operation to regulate water flow. LED indicators and resistors are included to provide visual feedback on system status and relay operation. Separate power supplies are used, with a 5 V adapter powering the Raspberry Pi and a 12 V adapter supplying the pump and solenoid valves, ensuring electrical isolation and safe operation.

Overall, this circuit is used to automate irrigation by integrating soil sensing, digital processing, and controlled actuation. It minimizes manual watering, prevents water wastage, and ensures plants receive water only when required. The detailed circuit layout highlights reliable power management, safe switching, and modular integration of components, making the system suitable for terrace environments, as shown in Fig. 7.3.1.

7.4 Flowchart

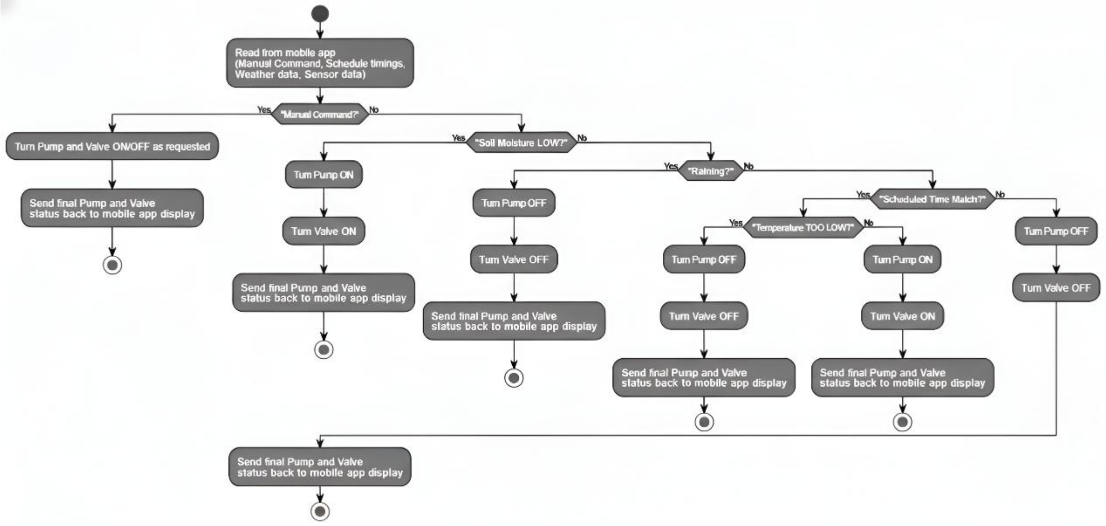

Fig. 7.4.1 Control Logic Flowchart for Automated Terrace Irrigation System

Figure 7.4.1 illustrates the logical flow of operation of the smart terrace watering system, showing how the system makes decisions based on user commands, sensor inputs, weather conditions, and scheduled timings. The flow begins with the system reading inputs from the mobile application, which include manual commands, scheduled watering times, weather information, and real-time sensor data such as soil moisture and temperature. These inputs form the basis for all subsequent decision-making in the system (Fig. 7.4.1).

The first decision checks whether a manual command has been issued by the user through the mobile application. If a manual command is present, the system directly turns the pump and valve ON or OFF as requested by the user, bypassing automatic decision logic. After executing the command, the final status of the pump and valve is sent back to the mobile application for user confirmation and monitoring (Fig. 7.4.1).

If no manual command is detected, the system proceeds to automatic mode, where it evaluates the soil moisture level. When the soil moisture is found to be low, the system considers environmental safety checks before watering. It verifies whether it is currently raining or whether the ambient temperature is too low. If rain is detected or the temperature is below the defined threshold, the system turns the pump and valve OFF to prevent overwatering or plant stress. The system then updates the pump and valve status to the mobile application (Fig. 7.4.1).

If there is no rain and temperature conditions are suitable, the system checks whether the current time matches the scheduled watering time. If the schedule matches, the pump and valve are turned ON to irrigate the plants. Once watering is completed or if the schedule does not match, the system ensures the pump and valve are turned OFF to conserve water and energy. In all cases, the final operational status is communicated back to the mobile application for real-time user visibility (Fig. 7.4.1).

Overall, the flowchart demonstrates a hybrid control strategy that combines manual control, sensor-based automation, weather awareness, and time-based scheduling. This structured logic ensures efficient water usage, prevents unnecessary irrigation, and provides user flexibility and transparency through continuous feedback to the mobile dashboard, as depicted in Fig. 7.4.1.

7.5 Product Analysis

The Smart Irrigation System for Terrace Farming is an IoT-enabled solution designed to automate irrigation while providing comprehensive monitoring and control through an integrated web-based dashboard. The system continuously monitors soil moisture, temperature using distributed sensors installed in the terrace gardening area. The collected data is processed by a controller and displayed on the dashboard, enabling users to remotely observe real-time plant conditions and irrigation status. The primary objective of the system is to optimize water usage, enhance plant health and reduce the dependency on manual irrigation practices in urban terrace farming environments.

The dashboard forms the central interface of the system and offers multiple intelligent features to enhance usability and automation. It supports irrigation scheduling, allowing users to define time-based watering plans based on plant requirements and seasonal variations. In addition, the system incorporates voice assistance with multilingual support, enabling users to interact with the irrigation system using voice commands in different languages, thereby improving accessibility and ease of operation for a diverse user base.

A key functional feature of the system is the closed-loop control mechanism for soil moisture–based irrigation. In automatic mode, the controller continuously compares real-time soil moisture values with predefined threshold levels while also considering environmental parameters such as temperature and weather conditions. When the soil moisture level falls below the threshold, the system automatically actuates the irrigation valves to supply water, and once optimal moisture is achieved, the valves are deactivated. This closed-loop operation ensures precise irrigation, prevents overwatering and underwatering, and promotes efficient water management.

The dashboard provides two distinct operational modes to ensure flexibility and reliability. In Auto mode, irrigation decisions are made autonomously by analysing soil moisture, temperature and weather data, enabling intelligent and adaptive irrigation without user intervention. In Manual mode, users can directly control the irrigation valves through the dashboard based on personal judgment or specific agricultural needs such as planting, fertilization or maintenance activities. The availability of manual control also serves as a fallback mechanism in case of sensor failure or abnormal operating conditions.

From a technical perspective, the system is modular and scalable, allowing additional sensors, valves or irrigation zones to be integrated with minimal system modification. The use of low-power components ensures energy-efficient continuous operation, making the system suitable for long-term deployment. Overall, the Smart Irrigation System for Terrace Gardening with dashboard integration, closed-loop control, scheduling, voice assistance, and dual operational modes provides a reliable, user-centric, and sustainable solution for modern urban agriculture.

7.5.1 Structural Analysis

Structural analysis is the process of evaluating a structure or component to determine how it responds to applied loads, supports, and environmental conditions. It helps engineers understand stress, strain, deformation, and stability of a structure to ensure that it is safe, strong, and reliable during its intended use. Structural analysis predicts whether a component can withstand forces such as weight, pressure, vibration, and thermal effects without failure or excessive deformation. It is an essential step in engineering design to verify that the structure meets strength, safety, and performance requirements before manufacturing.

Finite Element Analysis (FEA) is a numerical computational method used to perform structural analysis by dividing a complex geometry into many small, finite elements. Each element is mathematically analysed, and the results are combined to predict the behavior of the entire structure. Using FEA, engineers can calculate stresses, strains, displacements, factor of safety, and failure zones under real-world loading conditions. FEA is widely used in software tools like SolidWorks, ANSYS, and Abaqus because it allows accurate analysis of complex shapes and materials while reducing the need for physical prototypes.

Relationship Between Structural Analysis and FEA

Structural analysis defines what needs to be evaluated (strength, deformation, safety), while FEA provides how it is evaluated using computational methods. In modern engineering practice, FEA has become a key tool for performing structural analysis efficiently, accurately, and cost-effectively, making it indispensable in product design and validation.

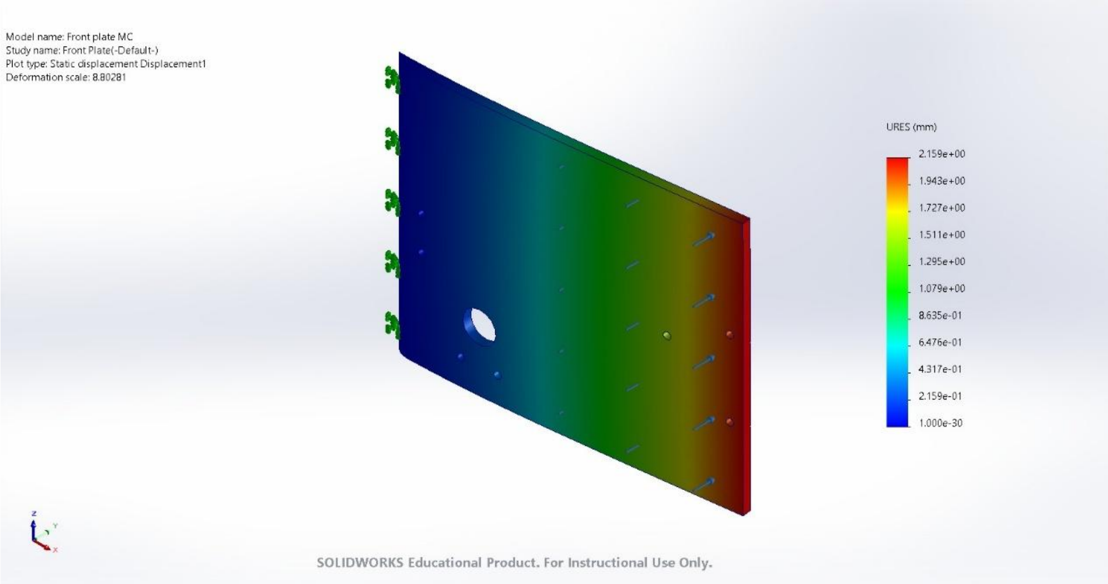

Fig. 7.5.1.1 Static Strain Distribution Plot of Front Plate of Main Cabinet

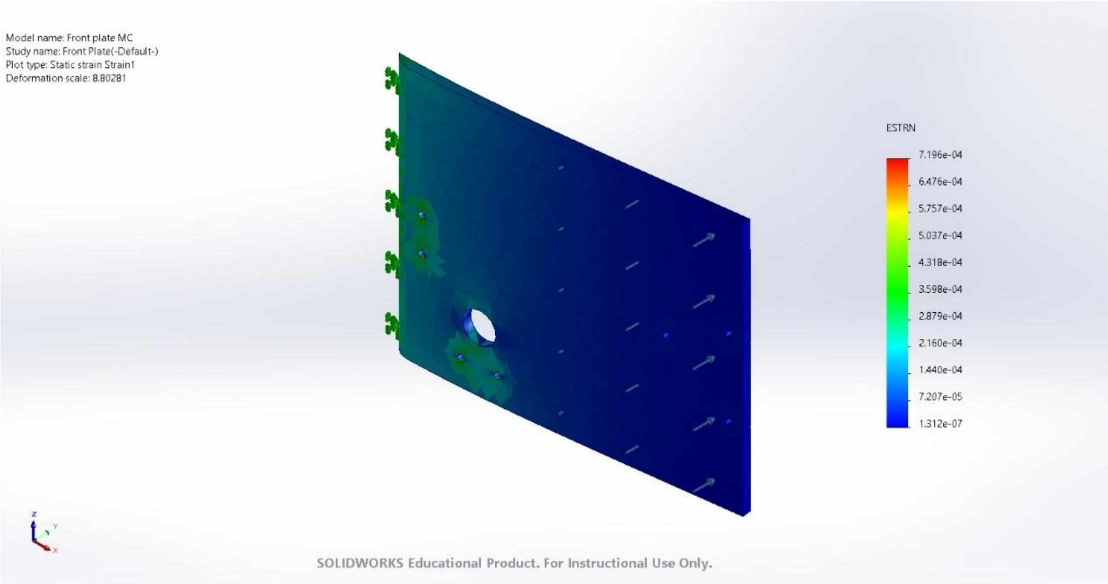

Fig. 7.5.1.2 Equivalent Strain (ESTRN) Contour of Front Plate under Static Loading

The static strain analysis of the Front Plate of the Main Cabinet was performed using SOLIDWORKS Simulation to evaluate deformation behavior under applied loading conditions. The strain distribution plot shows that the majority of the plate experiences low strain values, indicating stable structural behavior, while localized higher strain regions are observed near mounting holes and load application areas due to stress concentration effects (Fig. 7.5.1.1). The equivalent strain (ESTRN) contour further confirms that the maximum strain remains well within permissible limits of the selected material, validating the structural safety and suitability of the design for practical operation (Fig. 7.5.1.2).

The HydroHive Main Cabinet components were designed and analyzed using SOLIDWORKS CAD and Simulation to validate structural safety and design feasibility. The Front Plate of the Main Cabinet was subjected to static structural analysis under a normal load of 10 N, simulating practical operating conditions. The analysis showed a maximum von Mises stress of 2.684×10^6 N/m², which is significantly lower than the material yield strength of 4.5×10^7 N/m² for Acrylic (medium-high impact). This confirms that the component operates well within safe stress limits. The maximum resultant displacement was 2.159 mm, indicating acceptable deformation without compromising functionality or structural integrity. The generated high-quality solid mesh ensured accurate results and reliable stress distribution prediction. Overall, the SolidWorks simulation validated that the designed Front Plate is structurally safe, lightweight, and suitable for real-world application, demonstrating the effectiveness of SolidWorks as a tool for design verification and product optimization

7.5.2 Sustainability Analysis

Sustainability refers to the practice of designing and developing systems, products, and processes in a way that meets present needs without compromising the ability of future generations to meet their own needs. In engineering, sustainability focuses on minimizing environmental impact, conserving resources, reducing energy consumption, and promoting responsible material usage throughout a product's entire life cycle.

Sustainability is important because engineering products directly impact the environment through material extraction, manufacturing, transportation, usage, and disposal. Unsustainable designs lead to excessive carbon emissions, energy consumption, pollution, and resource depletion. By adopting sustainable practices, engineers can reduce carbon footprints, lower energy demand, minimize waste, and support long-term environmental and economic stability. Sustainable design also aligns with global environmental goals and encourages responsible innovation.

SolidWorks plays a crucial role in sustainability by enabling Life Cycle Assessment (LCA) during the design stage itself. Using the SolidWorks Sustainability tool, designers can evaluate environmental impacts such as carbon footprint, total energy consumption, air acidification, and water eutrophication based on material choice, manufacturing process, region, transportation, and end-of-life scenarios. This allows engineers to compare different materials and processes virtually and select environmentally better options before actual manufacturing, saving both cost and resources.

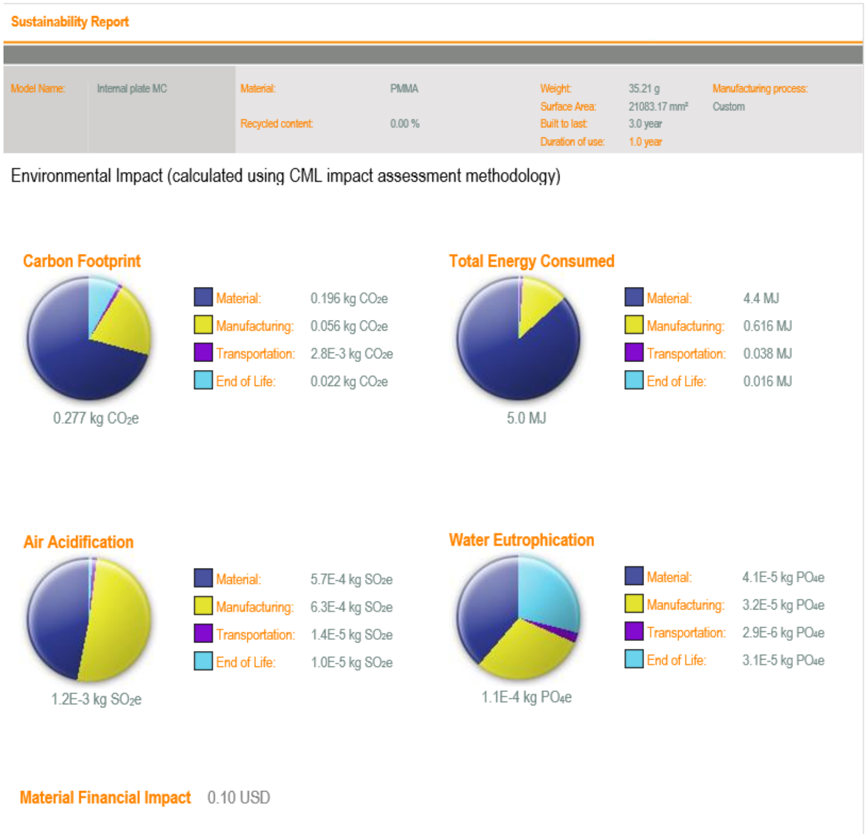

Figure 7.5.2.1: Sustainability Impact Analysis of Internal Plate MC Using PMMA Material

Figure 7.5.2.2: Comparative Sustainability Analysis of PMMA and ABS PC Materials

Based on the sustainability graphs shown in Fig. 7.5.2.1 and the comparative sustainability report in Fig. 7.5.2.2, ABS PC was selected as the baseline material, and PMMA was chosen as the new design material for comparison. The baseline ABS PC material shows a higher carbon footprint (0.342 kg CO_2e) compared to PMMA, which exhibits a lower carbon footprint of 0.277 kg CO_2e, indicating reduced greenhouse gas emissions. Similarly, the total energy consumed for PMMA is 5.0 MJ, which is slightly lower than 5.1 MJ for ABS PC, making PMMA more energy efficient.

Further analysis shows that air acidification impact is significantly lower for PMMA (1.2×10^{-3} kg SO_2e) compared to ABS PC (1.8×10^{-3} kg SO_2e), indicating reduced emissions that contribute to acid rain. In terms of water eutrophication, PMMA again performs better with 1.1×10^{-4} kg PO_4e, whereas ABS PC shows a higher impact of 1.7×10^{-4} kg PO_4e, which implies lower nutrient pollution in water bodies. Overall, the graphs clearly indicate that PMMA is a more sustainable material choice compared to ABS PC, as it results in lower environmental impact across all evaluated categories while maintaining similar functional performance. These observations and conclusions are derived from the sustainability assessment shown in Fig. 7.5.2.1 and Fig. 7.5.2.2.

8. Prototyping

Scrum Chart

Sprint 01: Circuit Design & Dashboard Development (Frontend & Backend)

Fig 8.1 Pump–Solenoid Valve Connection Setup

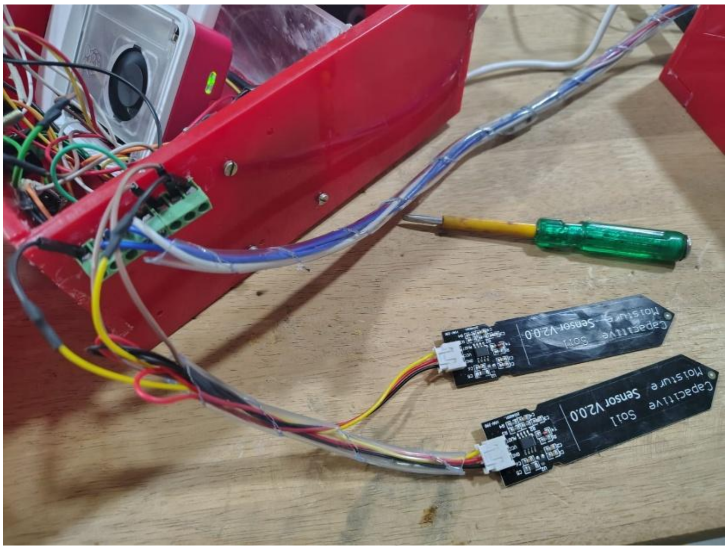

Fig 8.2 Capacitive soil moisture sensor connection

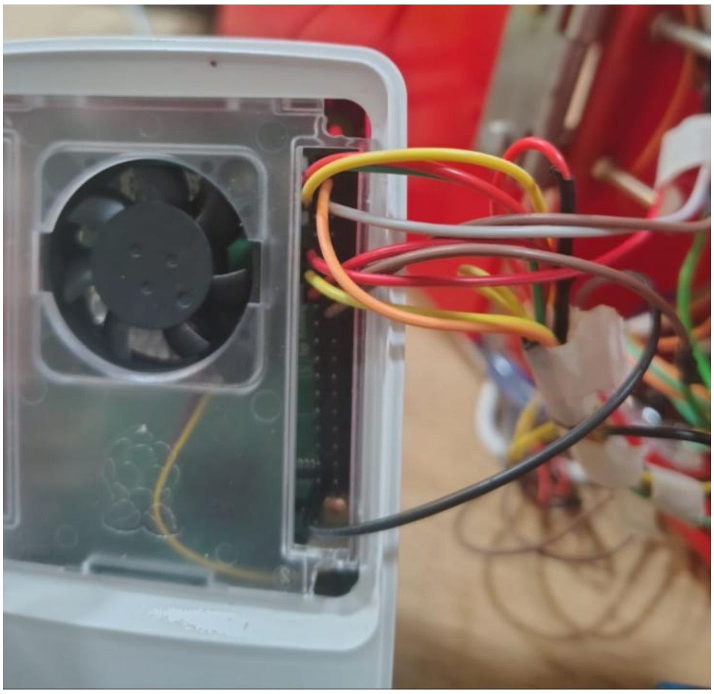

Fig 8.3 Connection of Raspberry Pi 5 to other components

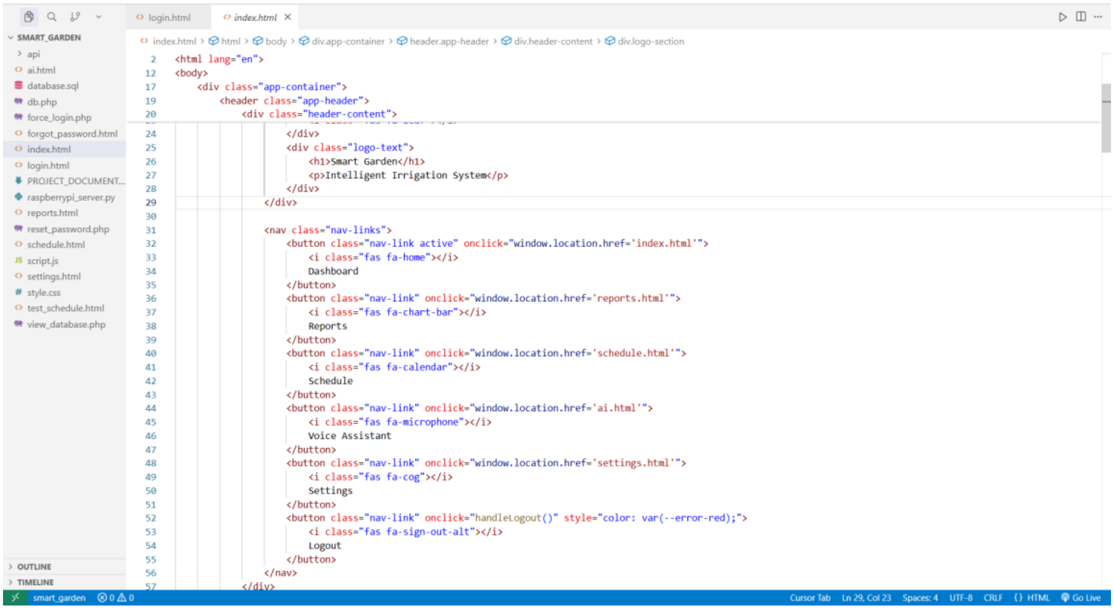

Fig 8.4 Frontend and Backend Source Code of the Dashboard Module

Sprint 02: Hardware Fabrication & Dashboard Database Integration

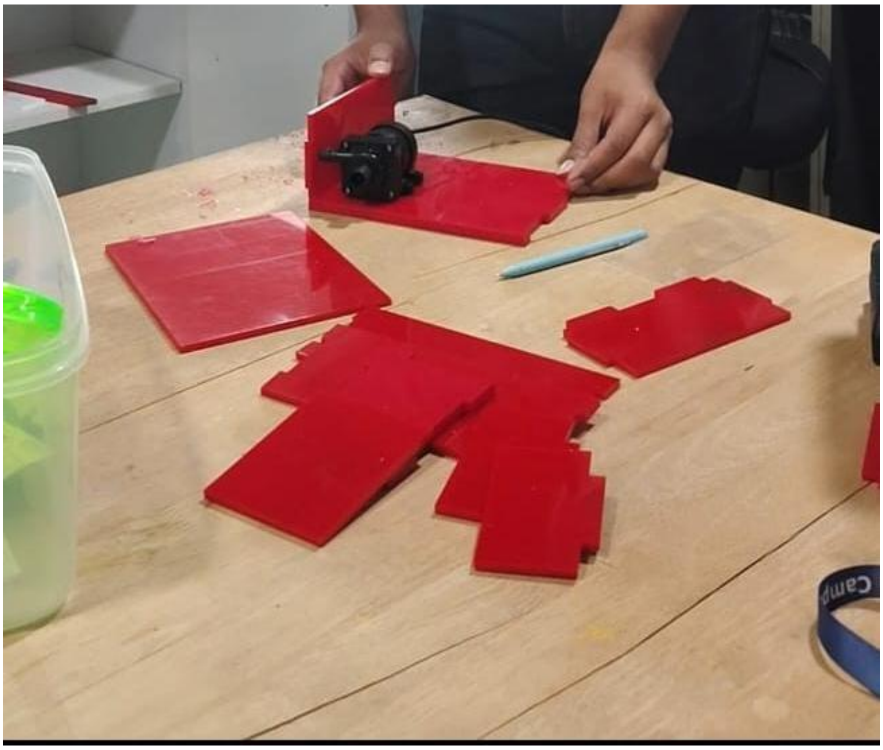

Fig. 8.5 Phases of Assembly of the Main Cabinet

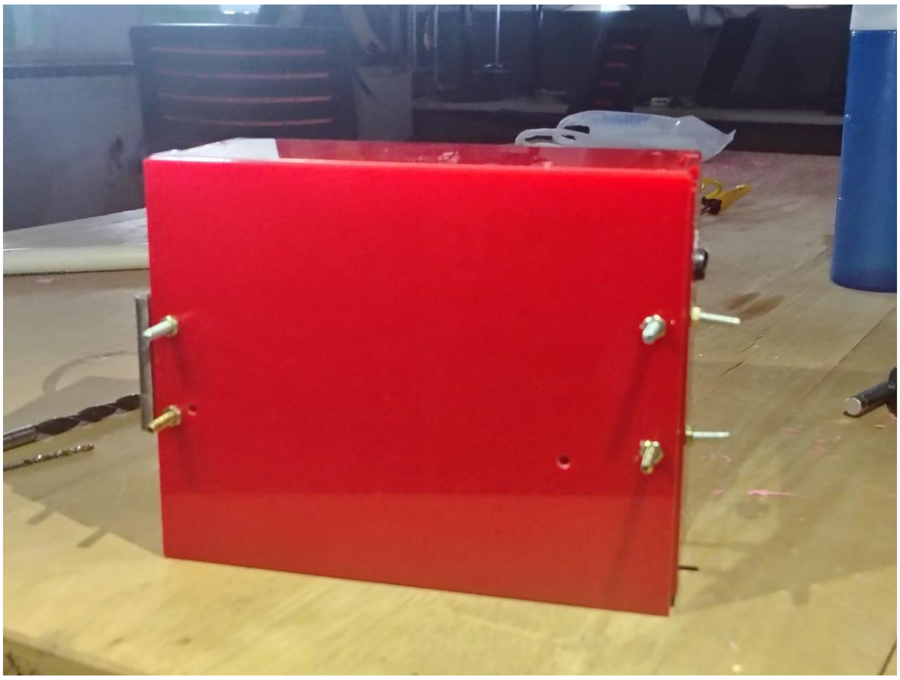

Fig 8.6 Assembled Main Control Cabinet Enclosure

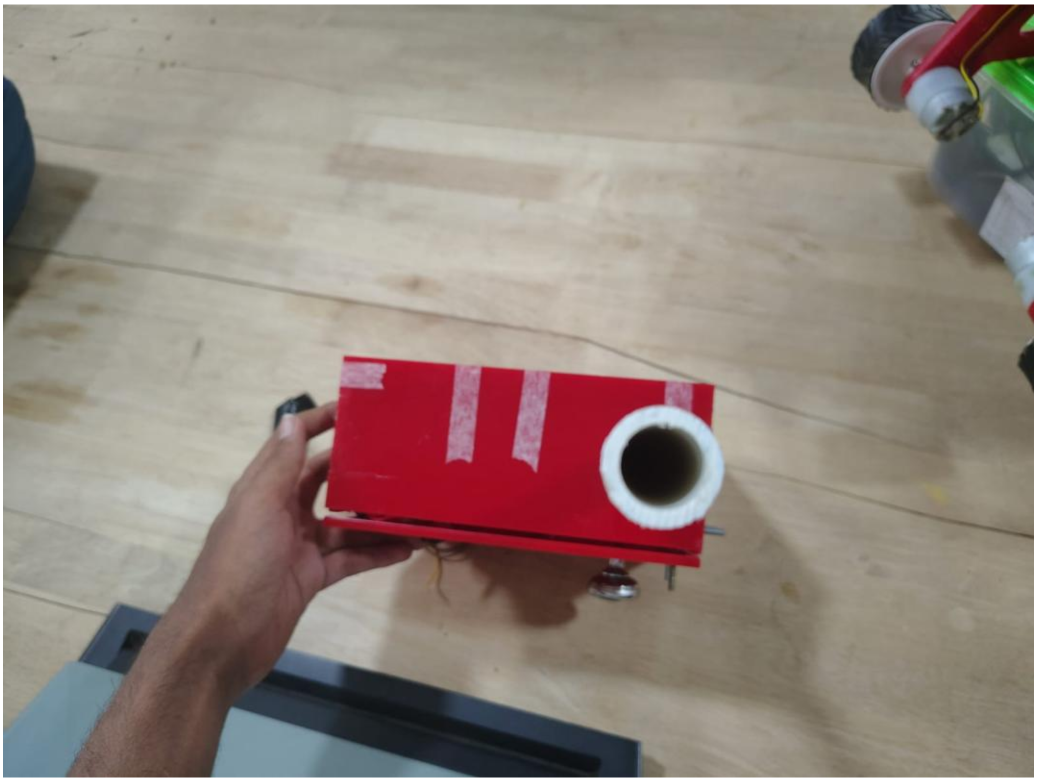

Fig 8.7 Top View of Main Control Cabinet Assembly

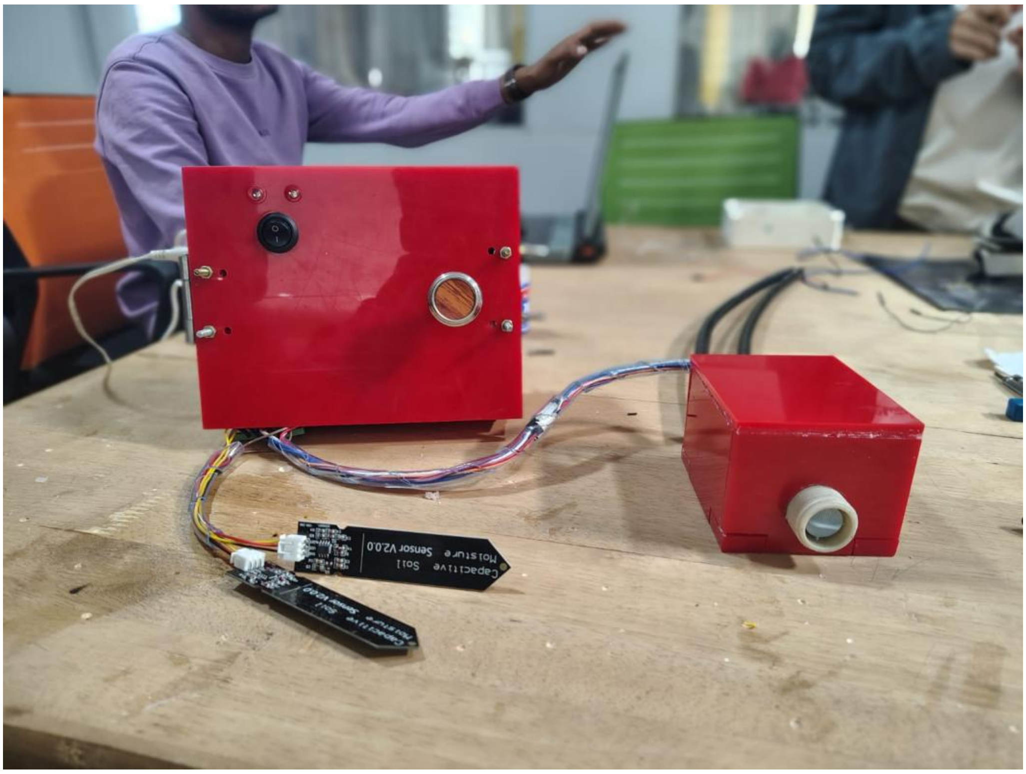

Fig 8.8 Assembly of Main Cabinet & Solenoid Box

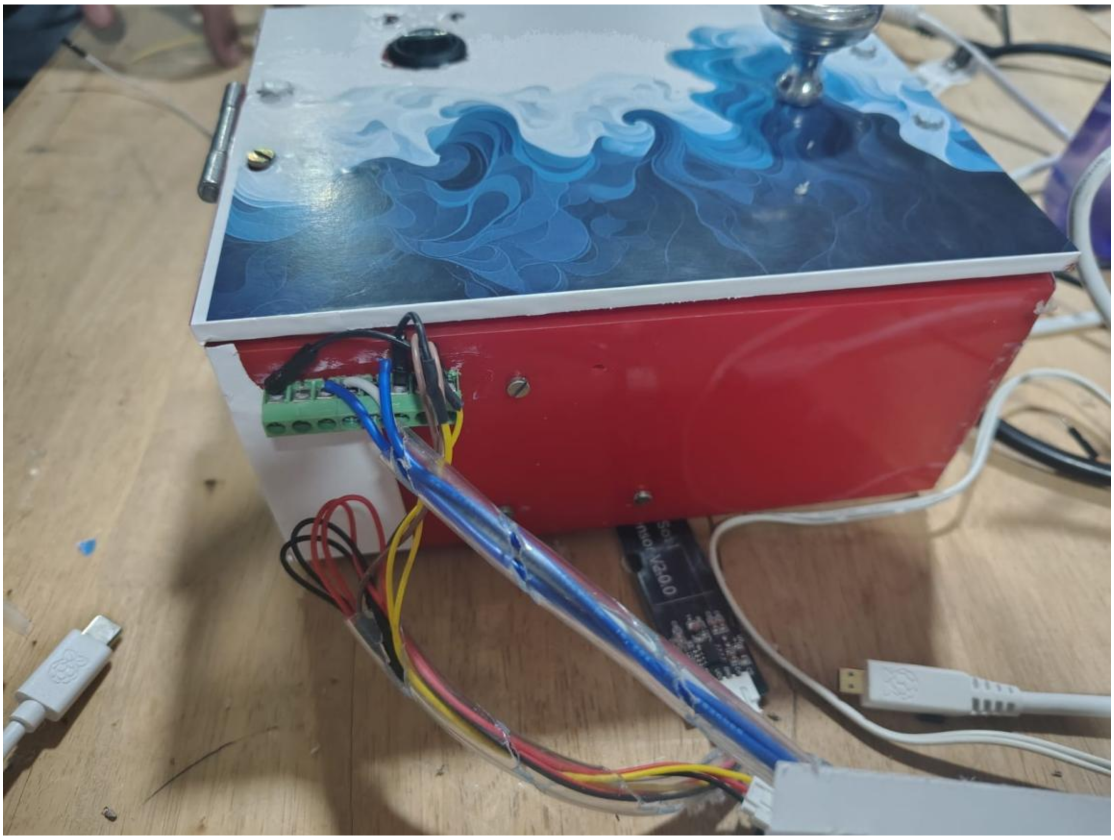

Fig 8.9 Cable sleeving of wires

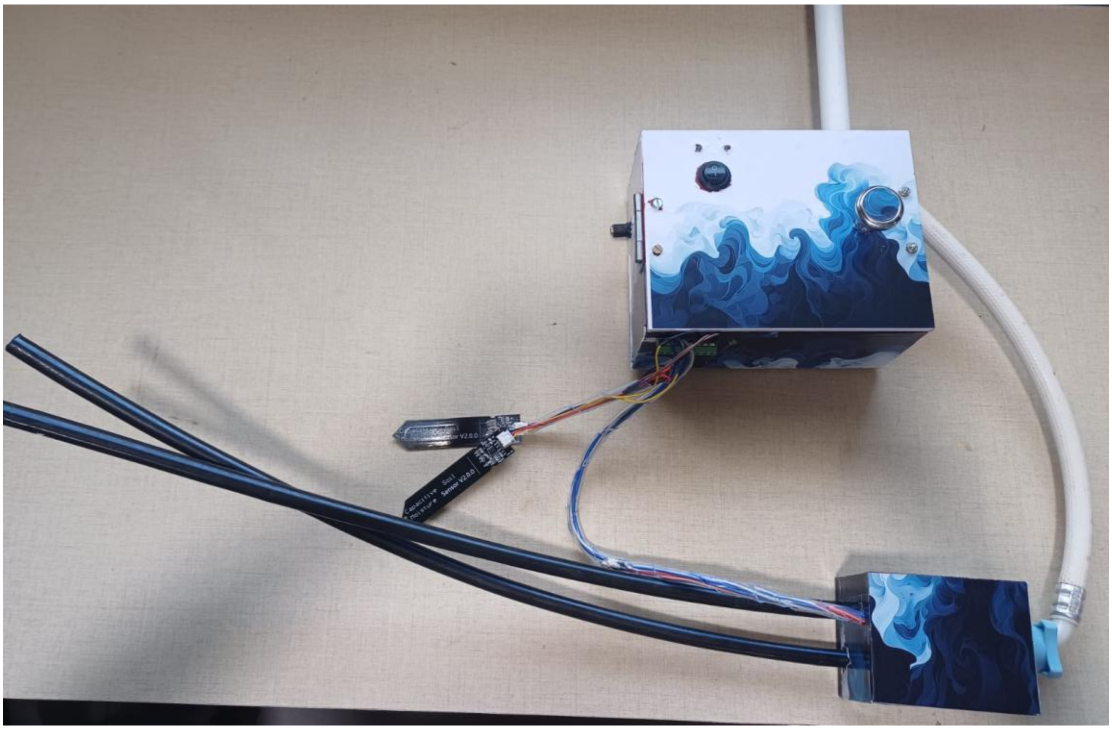

Fig 8.10 Final Integrated Prototype of the Smart Irrigation Control System

The assembly and integration of the smart irrigation system prototype were carried out in a systematic and sequential manner, as illustrated from Fig. 8.1 to Fig. 8.10. The process began with the interconnection of the pump and solenoid valve to establish controlled water flow (Fig. 8.1), followed by the connection of the capacitive soil moisture sensor to enable real-time soil moisture sensing (Fig. 8.2). Subsequently, the Raspberry Pi 5 was interfaced with all peripheral components, including sensors, actuators, and power modules, forming the core control unit of the system (Fig. 8.3). In parallel, the frontend and backend source code of the dashboard module was developed to facilitate user interaction, data visualization, and control logic execution (Fig. 8.4).

Once the electronic and software components were ready, the physical assembly phase commenced using laser-cut cabinet parts, which were assembled step by step to form the main control cabinet structure (Fig. 8.5). The completed cabinet enclosure was then integrated with internal components, resulting in the assembled main control cabinet enclosure (Fig. 8.6). A top view of the cabinet highlights the placement of ports, piping, and mounting provisions (Fig. 8.7), while the assembly of the main cabinet along with the solenoid box demonstrates system-level integration (Fig. 8.8). To ensure safety, durability, and neat organization, cable sleeving of wires was performed to protect electrical connections and improve aesthetics (Fig. 8.9). Finally, all subsystems were interconnected and tested, leading to the final integrated prototype of the smart irrigation control system, which represents a fully functional and ready-to-deploy solution (Fig. 8.10).

9. Conclusion & Learnings

The Terrace Watering System mini project successfully demonstrated the application of the Engineering Design (ED) process to solve a real-world problem in a structured and systematic manner. The primary objective of designing an automated and efficient watering system for terrace gardens was achieved by focusing on optimal water usage, simplicity of operation, and cost effectiveness. The developed system proves to be suitable for small-scale urban farming and terrace gardening applications.

By following each stage of the Engineering Design process—problem identification, stakeholder analysis, conceptual design, embodiment design, detailed design, and testing—the project ensured that both technical feasibility and user requirements were addressed effectively. This systematic approach helped in minimizing design errors, improving functionality, and enhancing overall system reliability. The final outcome is a practical and scalable solution that can be further upgraded with advanced features such as weather-based automation, mobile app control, or IoT integration.

Overall, the project highlights how structured engineering methodologies can convert simple ideas into functional solutions. The terrace watering system serves as a strong foundation for future improvements and real-world implementation, reinforcing the importance of design thinking in engineering practice.

Learning Outcomes from the Mini Project

Technical Learning:

Through this mini project, I gained practical experience in working with Raspberry Pi 5 as the central controller for the terrace watering system. I learned how to configure the Raspberry Pi operating system, manage GPIO pins, and interface external components such as sensors, relays, pumps, and solenoid valves. This helped me understand real-time control, hardware–software integration, and system-level debugging in an embedded environment.

In addition, I developed skills in web-based system development using HTML, CSS, and JavaScript to design an interactive and user-friendly control interface. HTML was used to structure the web pages, CSS to enhance visual appearance and responsiveness, and JavaScript to enable dynamic interactions such as button controls, status updates, and real-time feedback from the system.

On the backend side, I learned to use PHP to handle server-side logic, process user commands, and communicate between the web interface and the Raspberry Pi. I also implemented MySQL for data storage, which allowed logging of watering schedules, system states, and user actions. This provided exposure to database design, basic query handling, and secure data management.

Overall, this project helped me understand how embedded systems, web technologies, and databases can be integrated into a single automated solution, making it a valuable learning experience in full-stack IoT-based system development.

Engineering Design Understanding:

The project significantly improved my understanding of the Engineering Design process and its importance in developing reliable systems. I learned how design justification, iterative improvement, and proper documentation play a crucial role in achieving efficient and user-oriented solutions.

Practical Problem-Solving Skills:

Working on real constraints such as component limitations, water flow control, and system safety enhanced my analytical and problem-solving abilities. The project encouraged logical thinking and decision-making at each design stage.

Personal and Professional Skills:

On a personal level, the mini project improved my teamwork, communication, and time management skills. Coordinating tasks, meeting deadlines, and resolving design challenges collaboratively helped me develop confidence in handling engineering projects.

10. Future Scope

The Smart Terrace Watering System offers considerable scope for future development in scalability, intelligence, and user accessibility. The system can be enhanced to support multiple pots and irrigation zones by incorporating modular valve units and zone-wise scheduling, allowing efficient management of plants with different water requirements. This expansion would make the system suitable for medium and large terrace gardens.

Future improvements can also include cloud-based deployment of the dashboard and backend services, enabling remote access, real-time monitoring, secure data storage, and multi-user support. Expanding multilingual support to additional regional languages can further improve usability and adoption across diverse user groups. From an intelligence perspective, integrating machine learning techniques and weather forecast data can help optimize watering schedules by adapting to plant needs, seasonal changes, and rainfall conditions, thereby reducing water wastage.

Additional enhancements such as mobile application integration, solar-powered operation for energy efficiency, alert systems for fault detection, and advanced analytics for tracking water usage can further strengthen the system. Overall, the Smart Terrace Watering System has the potential to evolve into a comprehensive, intelligent, and sustainable solution for urban terrace farming.

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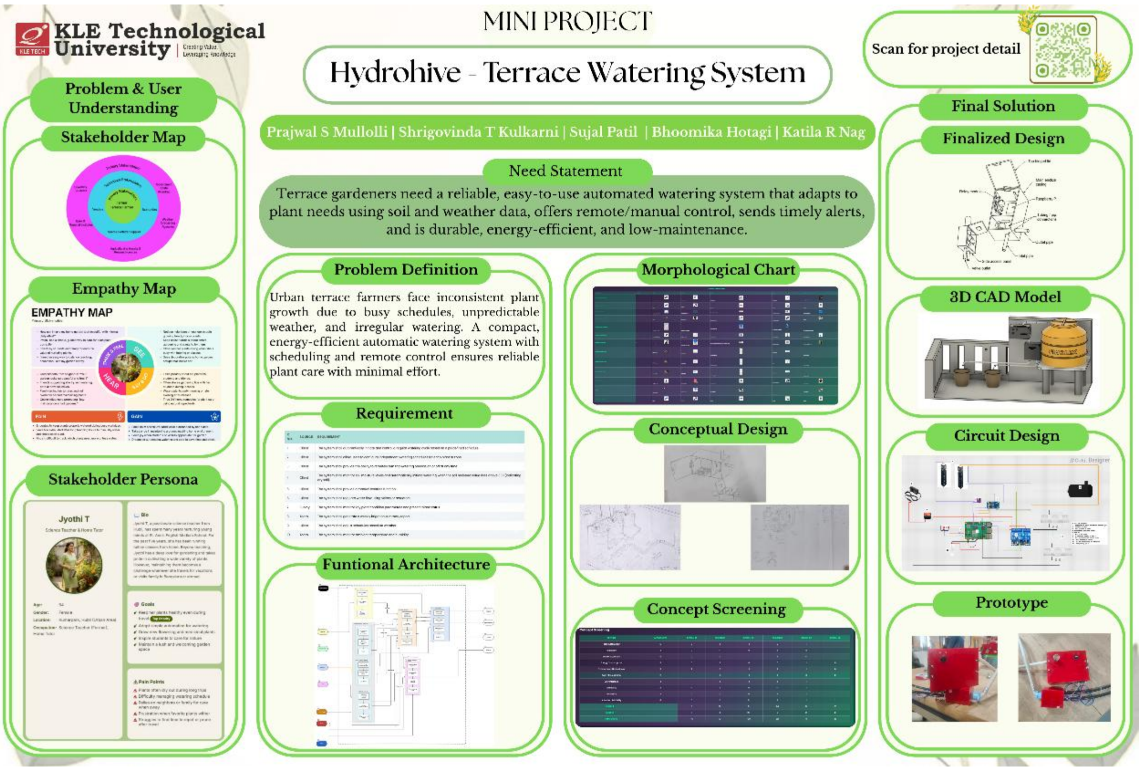
KLE Technological University
MINI PROJECT
Hydrohive - Terrace Watering System
Scan for project detail
Prajwal S Mullolli | Shrigovinda T Kulkarni | Sujal Patil | Bhoomika Hotagi | Katila R Nag
Problem & User Understanding
Stakeholder Map
Empathy Map
EMPATHY MAP
Stakeholder Persona
Jyothi T
Need Statement
Terrace gardeners need a reliable, easy-to-use automated watering system that adapts to plant needs using soil and weather data, offers remote/manual control, sends timely alerts, and is durable, energy-efficient, and low-maintenance.
Problem Definition
Urban terrace farmers face inconsistent plant growth due to busy schedules, unpredictable weather, and irregular watering. A compact, energy-efficient automatic watering system with scheduling and remote control ensures reliable plant care with minimal effort.
Requirement
Funtional Architecture
Morphological Chart
Conceptual Design
Concept Screening
Final Solution
Finalized Design
3D CAD Model
Circuit Design
Prototype

TEAM DETAILS

Member Details:

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Team Photo:

Portfolio Link: https://sites.google.com/view/team-02-arise/home?authuser=0