TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS

INDUSTRIAL ATTACHMENT AT DEPARTMENT OF DESIGN (IIT ROORKEE, INDIA)

SUBMITTED BY

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AN INDUSTRIAL ATTACHMENT REPORT TO THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE BACHELOR'S DEGREE IN MECHANICAL AND AEROSPACE ENGINEERING

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ABSTRACT

Sugarcane is one of the major cash crop of India where 58% of the population is involved in farming. It contributes significantly for the economy of the farmers and whole nation while also providing other byproducts like ethanol (bio fuel), molasses, and bagasse. But the farmers who have small landholding ($<$ 10 - 15 biggas) face numerous challenges in sugarcane cultivation mainly in planting due to extensive labor requirements, high cost of mechanization in planting, drudgery and health related issues. Also, existing sugarcane planters in the market are often expensive and designed for large-scale farming, making them impractical for small-scale farmers. This project aims to address this gap by developing an affordable, ergonomic and frugal sugarcane planter tailored for small landholders. The methodology for the project included whole design thinking process from direct interviews with farmers, a detailed field visit to observe current practices, an analysis of their needs and wants to design implementation. The problem was identified and a prototype focusing on single sugarcane dropping mechanism was designed and fabricated. Our project was successful in developing a cost-efficient, ergonomically suitable sugarcane planter for the farmers. The single dropping mechanism was successful in dropping sugarcane at the desired gap during planting and the overall planter showed potential for easing the manual burden on farmers and improving planting efficiency. However, the limited sample size of interviews, tight time constraints, not fully tested in field and no user feedback from the farmers were some implication for the project.

Keywords: Sugarcane, Planter, Small-scale, Ergonomic, Frugal

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CHAPTER 1:
INTRODUCTION

1.1. Organization Background

Indian Institute of Technology, Roorkee (abbreviated IIT Roorkee) is a technical university located in Roorkee, Uttarakhand, India. It is the oldest engineering institution in India. IIT Roorkee has 23 academic departments covering engineering, architecture and planning, sciences, humanities social sciences, and management programmes. The Department of Design was established in Indian Institute of Technology Roorkee in 2021. The Department of Design currently offers three programs: **Bachelor in Design (B. Des.)**, **Masters in Design (M. Des. Industrial Design)** and **Masters in Innovation Management (MIM)** focused on the broad theme of innovation and product design. B. Des. program is designed with a unique fusion of creative thinking, design methodology, computing, engineering, and manufacturing. M. Des. Industrial Design program focuses on the concepts and principles leading to a successful product design. The Masters in Innovation Management program provides students with exposure to products and process innovation, services innovation, market and marketing innovation and organizational innovation.

Figure 1.1.1: Department of Design

The Department of Design at IIT Roorkee has become a hub for fostering creative ideas and solving technical problems due to the increase in design and innovation in India. It is created with the goal of combining technology with design concepts, and the department strives to develop designers capable of addressing actual problems by incorporating beauty, practicality, and usefulness. The Department of Design utilizes a variety of

Figure 1.1.2: Building of Department of Design

Figure 1.1.3: IIT Roorkee

disciplines, including product design, user experience design, system design, and sustainability. The department's curriculum gives students a comprehensive knowledge of design practices, tools, and modern technologies, preparing them for various careers in fields like industrial design and digital interfaces.

1.2. Scope of the internship

During the internship, we had the opportunity to work on a design tasks that helped us develop both my technical and professional skills. We gained hands-on experience by applying theoretical knowledge to real-world problems, which improved our problem-solving abilities and adaptability. The focus area of the internship included designing a sugarcane planter adhering to design thinking principles, giving us exposure to industry standards and workflows. We also explored innovative approaches, connected with experienced professionals, and gained valuable insights into design thinking, which will be invaluable for our future career. Position: Design Intern Working Duration: 31 days

Working hours: [Non-specific working time, accessed on the basis of progress] Location: Department of design, IIT Roorkee Internship Supervisors: Dr. Bibhuti Ranjan Bhattacharya Internship Guidance Counselor: Mr. Hiranmaya Barik

1.3. Specific Objectives

1. To understand about the concepts of design thinking and implement them in practical situations.

2. To utilize design tools/software.

3. To learn methods for user research, prototyping, and usability testing.

4. To gain knowledge of sustainable,innovative and ergonomics in design.

5. To understand the workflow and collaborative dynamics within an organization.

1.4. Limitations of Internship

1. Limited exposure to the organization and projects due to the academic nature of the internship.

2. Restricted access to certain facilities and resources during the internship period.

3. Constraints on time to explore a broader range of design domains and tools.

1.5. Design Thinking

Design thinking encompasses a range of cognitive, strategic, and practical processes that designers use during the design process, as well as the body of knowledge about how people reason when solving design challenges. It is also linked to methodologies for innovating products and services in business and social contexts. Originating in the 1950s and 1960s, design thinking has roots in the study of design cognition and methods. It is often described as ”designerly ways of knowing, thinking, and acting” or simply as ”designerly thinking.” Research into design cognition and activity, both in controlled settings and real-world scenarios across various design fields, has helped identify many fundamental concepts and features of design thinking. The term has been applied in multiple ways: as a cognitive approach that involves thinking like a designer, a broad theory explaining how designers operate, and a set of teaching tools to help organizations or novice designers tackle complex problems with a design-oriented mindset. These diverse interpretations have led to some ambiguity in the term’s usage.

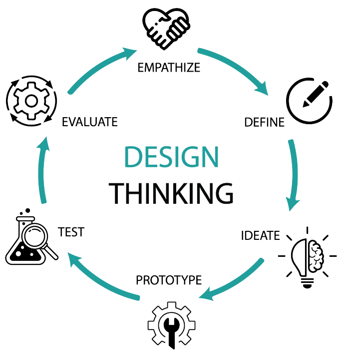


Figure 1.5.1: Design Thinking

1.5.1. Empathize

The Empathize stage is the foundation of design thinking, where the focus is on understanding the users deeply. This involves researching the problem, consulting experts, and observing the users to connect with their experiences and motivations. You might even immerse yourself in the users' environment to gain firsthand insights. By setting aside personal assumptions, you can uncover the real issues and needs your users face. This stage is essential for creating meaningful, human-centered solutions.

1.5.2. Define

In the Define stage, you organize and analyze the insights gathered during the Empathize stage. This step helps you pinpoint the central problems in a way that focuses on the users' needs, not just business goals. A well-crafted problem statement shifts the perspective from "What do we want to achieve?" to "What do users need?" This clarity allows you to outline features and solutions that directly address users' challenges and prepare for the next phase: ideation.

1.5.3. Ideate

The Ideate stage is where creativity flourishes. Armed with a deep understanding of your users and a clear problem statement, you brainstorm innovative ideas. By exploring multiple perspectives, you can challenge assumptions and expand the range of potential solutions. Techniques like Brainstorming, SCAMPER, or even coming up with the ”Worst Possible Idea” help generate a broad set of ideas. Towards the end of this stage, you narrow down the most promising solutions to move forward.

1.5.4. Prototype

The Prototype stage involves creating simple, inexpensive models of your solutions. These prototypes can range from sketches to basic physical models and are meant to test specific features or ideas. The goal is to experiment, gather feedback, and refine your concepts. By testing these prototypes with users or within your team, you can identify what works, what needs improvement, and what should be discarded. This stage helps clarify how users interact with your solution and highlights any limitations.

1.5.5. Test

In the final stage, you test the prototypes with real users to evaluate their effectiveness. This rigorous testing provides deeper insights into how users think, feel, and behave with the product. The results often lead to refinements or even revisiting earlier stages to address new problems or improve existing solutions. Testing ensures the solution aligns with users' needs and paves the way for a polished, user-centric product.

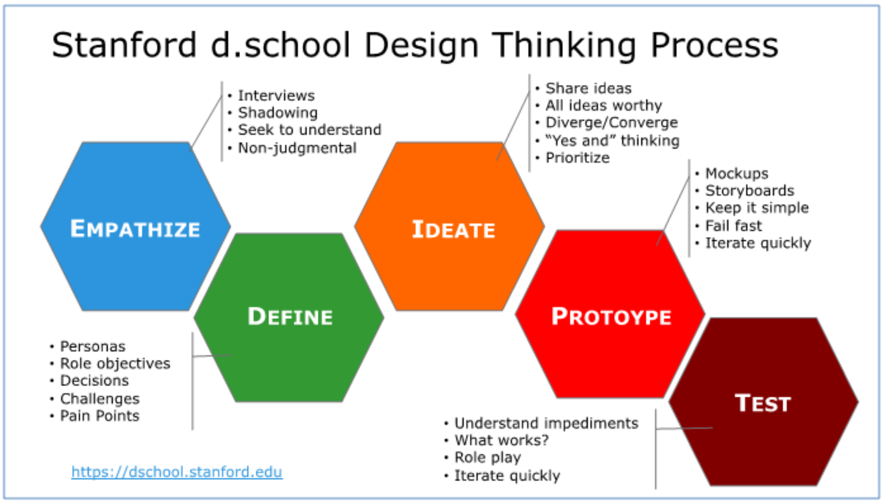


Figure 1.5.2: Design Thinking Process

1.6. Quadruple Helix Model

Working together, academic institutions, industries, communities, and governments play a key role in turning design ideas into real, useful products. Universities drive creativity and innovation by conducting research and developing new approaches. Industries provide practical skills, funding, and the ability to turn ideas into products people can use. Communities share important feedback to make sure the designs meet real needs and are user-friendly. Governments support this process by creating policies, funding projects, and encouraging teamwork between different groups. By combining their strengths, these partners create a system that connects ideas with practical results. Design thinking helps guide this process, focusing on understanding users, testing ideas, and working together. This teamwork leads to better solutions, faster innovation, and products that benefit society and the economy.

The Quadruple Helix Model is an innovative framework that explains how collaboration among four key sectors—government, universities, industry, and civil society—drives knowledge creation and economic growth. This model builds on the earlier Triple Helix Model, which focused on interactions between universities, industries, and government. By adding civil society as a fourth pillar, the Quadruple Helix Model acknowledges the importance of public participation and societal input in fostering innovation and addressing modern challenges. It was developed by Elias G. Carayannis and David F.J. Campbell, this model highlights how these four sectors overlap and interact to create knowledge and transform it into products, services, and technologies. It introduces the concept of a ”media-based democracy,” where governments must communicate their innovation policies effectively to the public and civil society. This communication fosters public support for strategies that drive economic and social progress. Similarly, industries involved in research and development (R&D) need to align their public relations efforts to shape perceptions through media and build trust.

The Quadruple Helix Model emphasizes that innovation is not only about technological advancements but also about how knowledge circulates and transforms within society. Universities play a critical role by generating research and developing new ideas. Governments create policies and provide funding to support innovation. Industries apply knowledge to create products and services, while civil society provides feedback and ensures that innovations are relevant and beneficial. These interactions form a dynamic and adaptive ecosystem where innovation thrives.

One of the significant advantages of this model is its flexibility and relevance to modern challenges. For instance, it can be applied to address issues like climate change and sustainable development. By integrating socio-ecological perspectives, the model promotes innovations that are environmentally sustainable and socially inclusive. It encourages stakeholders to consider the impact of their actions on the natural environment and work toward solutions that benefit future generations.

The Quadruple Helix Model is particularly relevant in regions where innovation is crucial for economic growth and competitiveness. For example, in the Middle East and North Africa (MENA) region, adopting this model has led to initiatives that promote digital transformation, cultural awareness in schools, youth empowerment, and support for tech start-ups. These efforts have helped boost creativity and innovation among entrepreneurs and the wider public, demonstrating how the model can drive regional and national competitiveness.

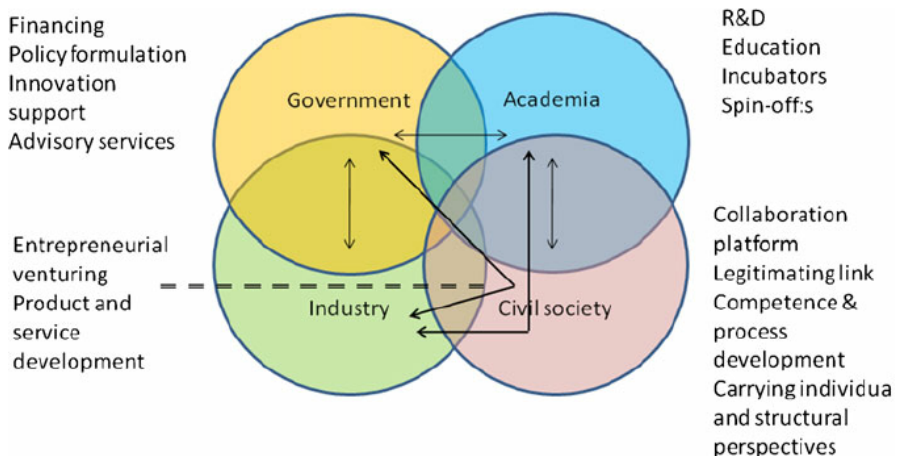


Figure 1.6.1: Quadruple Helix Model

CHAPTER 2:
MANAGEMENT OVERVIEW

2.1. Organizational Profile

The department started its graduate program in 2021 and the undergraduate program in 2023. Currently, there are 60 students, comprising 20 undergraduate students, 34 master's students, and 6 PhD scholars. The department has 15 faculty members and 5 non-teaching staff members. Dr. Apurbba Kumar Sharma currently serves as the Head of Department.

The department has been actively organizing various events and workshops since its inauguration. It recently hosted the international symposium IDEAS-2024 from 19th to 20th October 2024, jointly with Queen's University Canada, focusing on relationship between design, engineering, and resource constraints. During our internship tenure, we were able to attend this program and gain valuable insight into design thinking and innovation.

Figure 2.1.1: IDEAS-2024 Event Attendance

2.2. Organizational Structure

The department is led by the head of the department and supported by faculty members. We were given access to the department and its resources for the month of October 2024. We were provided with an Internship ID Card, which need to be shown for access to various resources. The internship card was also valid outside the department to access certain facilities provided at the IIT Roorkee Campus.

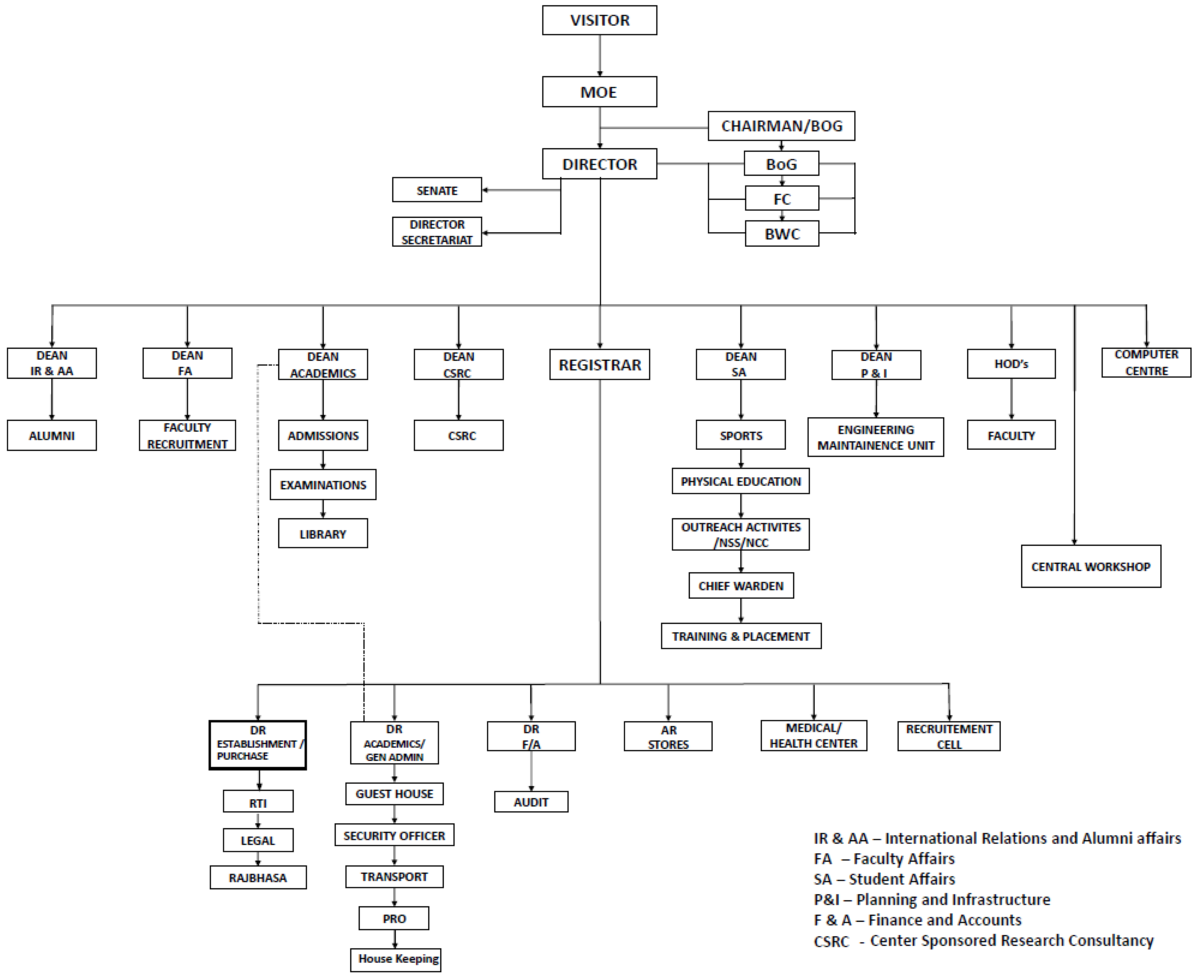


Figure 2.2.1: Organizational Structure

CHAPTER 3:
INFRASTRUCTURES AND EQUIPMENTS

3.1. Infrastructures

The Department of Design in located opposite the Thomason Building (Administration Office) of IIT Roorkee. The department is just 2km from the main Gate 1 of the campus.

Figure 3.1.1: Entrance of Department of Design

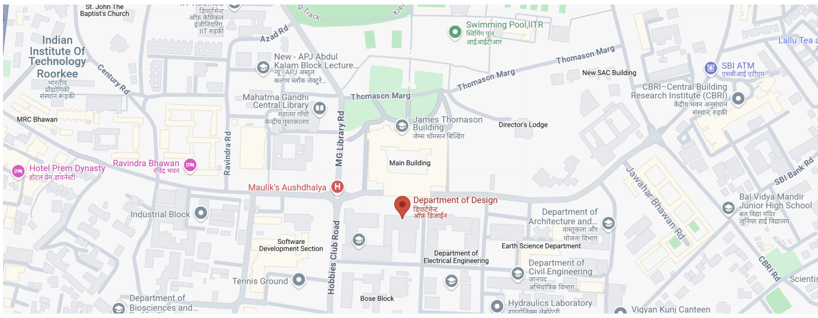


Figure 3.1.2: Department of Design on map

The department is facilitated with a discussion lobby, a meeting hall, faculty rooms, administration rooms, and five different workspace rooms.

The department has a discussion lobby where students, faculty, and visitors can discuss ideas as well as rest comfortably for brainstorming. The department also has a meeting room where most meetings, discussions, seminars, virtual webinars, and student classes are conducted. The workspace rooms are provided with cubicles where students can work on their projects.

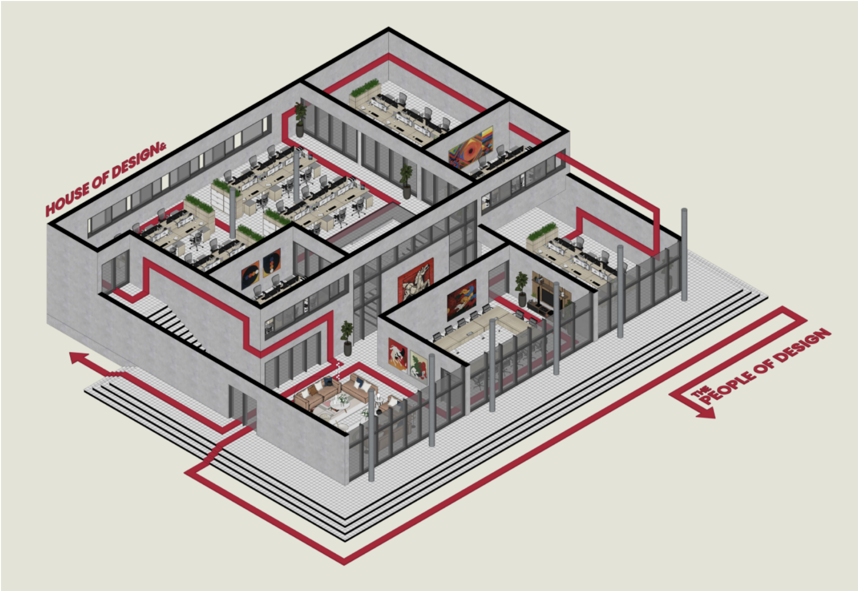


Figure 3.1.3: Floor Plan of the Department

Figure 3.1.4: Outdoor Discussion Lobby

Figure 3.1.5: Meeting Room

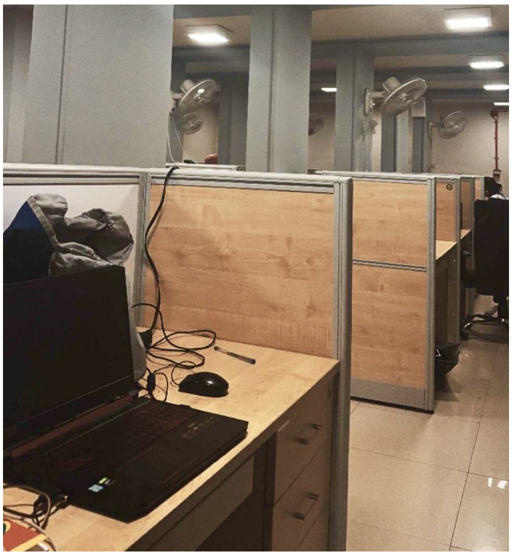


Figure 3.1.6: Workspace

3.2. Equipments

The Department is equipped with state-of-the-art utilities like advanced 3D printers, comprehensive toolkits, and a wide range of art and craft accessories such as scissors, cutters, and more. There are also design boards, where scholars can brainstorm and plan their ideas in creative manners and planning techniques.

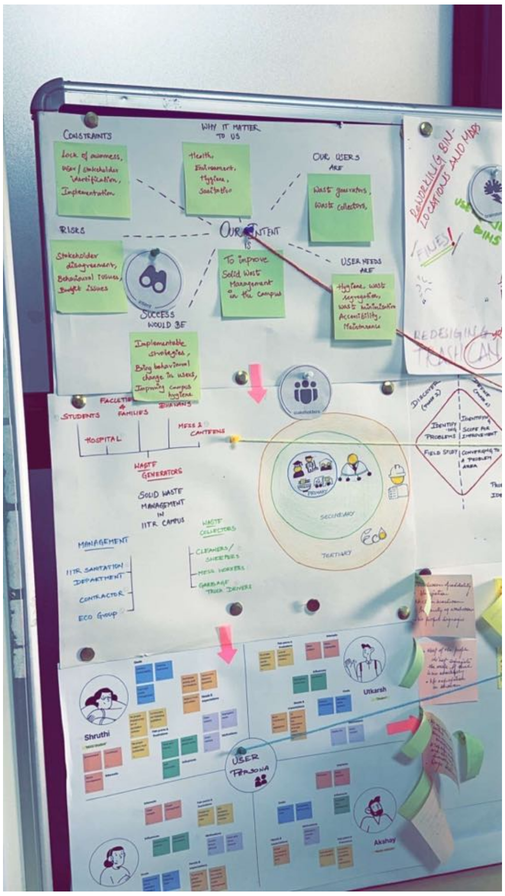


Figure 3.2.1: Design Board

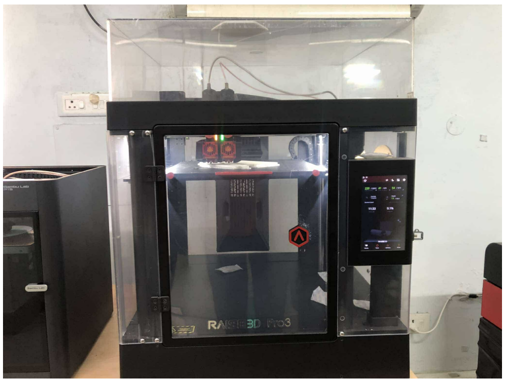


Figure 3.2.2: 3D Printer

The Building of the Department of Design also hosts an advanced in-house facility called the Tinkering Lab, which scholars within the department can also access. This lab is equipped with cutting-edge manufacturing utilities, including 3D printers, lathes, cutters, laser cutters, and other essential machinery for fabrication. Scholars can utilize these resources for their projects by pre-registering their work and waiting for their turn to use the machines.

For 3D printing, users must provide their designs to the operator. The operator then allocates the design to one of the available 3D printers, which include Bambu, Raise3D, and other modern printers. Once the printing is complete, the finished product is placed on the collection desk, from where users can collect their model.

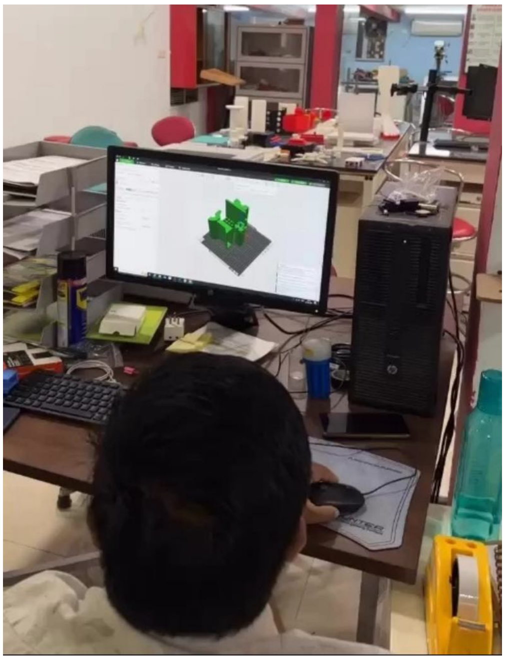


Figure 3.2.3: 3D Printing Operator

Figure 3.2.4: 3D Models Collection Desk

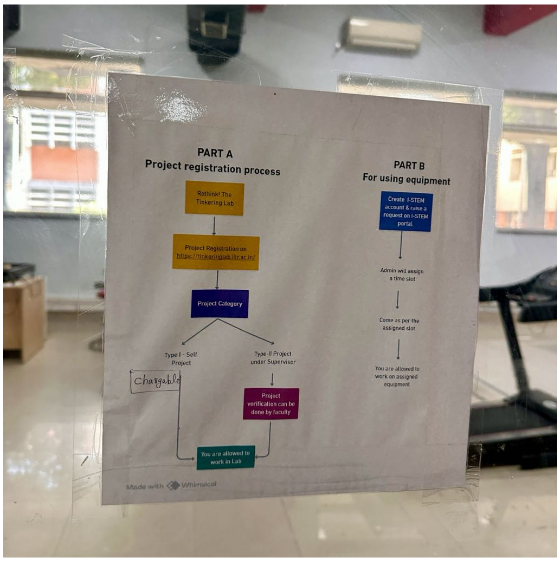


Figure 3.2.5: Lab Equipment Access Procedure

CHAPTER 4:
INTERNSHIP PROJECT

4.1. INTRODUCTION

4.1.1. Background

Sugarcane, *(Saccharum officinarum)*, is a perennial grass of the family Poaceae, cultivated for extraction of its juice which serves as a basis for sugar processing (Yamane, 2024,). Sugarcane grass is varies within 2 – 5 m height with stout, with jointed fibrous stalks (CIRAD, 2023,). In addition to sugar, the other byproducts of sugarcane are ethanol (bio fuel), molasses (used to make wine and food), and bagasse (used to generate energy in sugar mills). Around 110 countries of the world produce sugar with 80% coming from sugar and remaining 20% from sugar beet (Yamane, 2024,). Asia is the largest sugar producing region yielding almost 60 million metric tons of sugar - largest contributors being India, China and Thailand (Yamane, 2024,).

In India, where agriculture plays a pivotal role in its economy, about 58% of the population is engaged in agriculture; sugarcane is considered one of the main crash crop (Devanathan et al., ,). Given that millions of farmers, laborers, and workers in sugar mills and related industries rely on sugarcane for their livelihoods, its economic importance is exceptionally high. It stems from high possibility for financial gains(Solomon, 2014,). It's known for its multipurpose use in producing sugar, ethanol, molasses, and bagasse, and is essential not only as a source of food but also as an industrial raw material. In India, sugarcane is predominantly cultivated in tropical and subtropical regions, with northern states such as Uttar Pradesh, Haryana, and Punjab playing a crucial role in national sugarcane production. Uttar Pradesh, in particular, stands as one of the largest sugarcane-producing states, contributing over 40% to the country's total output. The crop's robust presence in the northern regions has made it an economic staple, supporting a large segment of the population and sustaining a significant agro-industrial network. The sugarcane industry contributes significantly to India's economy, employing millions of farmers directly and supporting numerous associated industries. Sugar mills, ethanol plants, and paper and bio-fuel manufacturers depend heavily on sugarcane by-products. The industry also contributes to energy production by utilizing bagasse (sugarcane residue) as a renewable source for power generation, thereby supporting the country's energy infrastructure. Ethanol derived from sugarcane juice serves as a bio-fuel that aids in reducing India's dependence on fossil fuels, aligning with government initiatives promoting sustainable energy sources. The sugarcane industry supports rural economies, creates jobs, and contributes to the national GDP, making it an important part of India's agro-economic scenario.

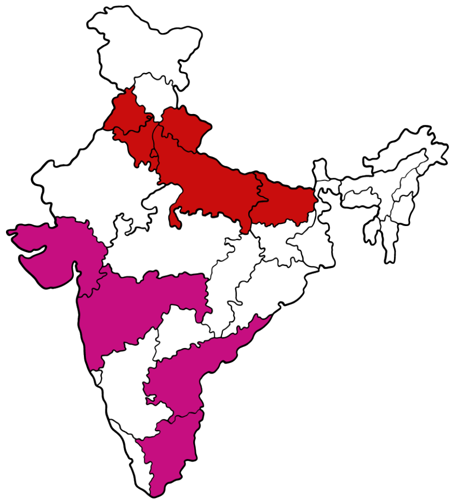


Figure 4.1.1: Sugarcane Producing States

Cultivating sugarcane is a highly labor-intensive and time-consuming process as planting requires about 350 man-hour/ha with the cost of INR 3987 in conventional system of planting, whilst 20 man-hour for mechanized planting with the cost of INR 2200/ha (?, ?). The need for mechanization of planting process stems from the quest for improved cost & time reduction planting techniques, while minimizing drudgery (Ali, 2015,). In the traditional cultivation method of sugarcane, farmers rely on vegetative propagation by using setts—stem cuttings with at least one bud—placed manually in prepared furrows. Once the setts are placed, they are covered with soil, and subsequent watering, fertilization, and weed control are carried out. This method, while well-practiced, is heavily labor-intensive and requires consistent maintenance to optimize yield. The manual planting of sugarcane involves significant labor in tilling, spacing, and planting, making it both time-consuming and costly. Additionally, because sugarcane crops have a long growing season of about 10 to 16 months, they require intensive irrigation and field maintenance, increasing the labor demand even further. Among these challenges, smallholder farmers, who make up a significant segment of the sugarcane farming community, often struggle to access modern technology and machinery. Many of these farmers operate on limited landholdings, typically ranging from 15 to 20 bighas, and are heavily reliant on manual labor for essential agricultural operations. This dependence on manual labor results in labor-intensive practices that pose significant challenges. Farmers engaged in manual labor face physically demanding tasks, such as bending, lifting heavy loads, and performing repetitive motions, which can lead to musculoskeletal disorders and chronic health issues (Leite et al., 2018,). Additionally, exposure to harmful pesticides during manual weeding and pest management further exacerbates the health risks associated with these labor-intensive farming practices.

Consequently, smallholder farmers frequently endure considerable physical strain, and their limited access to healthcare services leaves them vulnerable to health complications arising from their labor-intensive work (Mohanaselvan et al., 2024,) . To effectively address the challenges faced by small farmers, need exists for the development of cost-effective, frugal, & locally designed machinery tailored to their operational requirements. Unlike their large-scale counterparts, small farmers require affordable and efficient equipment that enhances agricultural productivity without imposing an onerous financial burden. The primary aim of this research is to engage directly with local farmers in Roorkee to gain a deeper understanding of their specific needs and challenges. Through this interactive approach, the research seeks to identify the critical problems faced by these farmers and to develop tailored equipment that effectively addresses their requirements. Given aforementioned challenges, the mechanization of sugarcane planting has emerged as a promising solution to reduce labor dependency and increase efficiency. A mechanized sugarcane planter offers the ability to automate the placement of setts at consistent depths and intervals, resulting in uniform growth and healthier crops. Mechanization also accelerates the planting process, reducing labor requirements and associated costs, making sugarcane farming more sustainable and profitable. Mechanized planters can enhance efficiency, lower labor expenses, and support larger-scale farming while maintaining crop yield and quality. In this report, we discuss the iterative design process of a sugarcane planter aimed at enhancing performance, ease of use, and adaptability. By following essential design principles, including simplicity, durability, and cost-efficiency, our design aims to address the core challenges faced by farmers in northern India, supporting the long-term sustainability of the sugarcane industry.

4.1.2. Problem statement

Sugarcane farming involves extensive use of human labor complemented with repetitive drudgery. Alongside putting labors vulnerable to musculoskeletal disorders like back pain, muscle strain, joint issues, it accounts for significant portion of the overhead. The drudgery directly contributes to increased work time, but the work time can be optimized - but against overhead costs. While these issues are addressed for large scale farmers, mid to small scale farmers are still reliant on antique tools and methods for plantation. Ergo, a solution measure incorporating repair-ability, convenience, modular & frugal design is proposed and scrutinized for viability.

4.1.3. Field Visit

On October 6, 2024, we conducted a field visit to three to four farms located approximately 5 kilometers from the campus. Our objective was to gather insights into the problems faced and method employed by farmers. Our visit was facilitated by one of the PhD scholars who is already involved with the farmer. We prepared a questionnaire addressing the needs of farmers, specifically focusing on the types of equipment they feel they require or desire. In field visit, topic like Labor Force and work schedule observations, wage and gender disparities, equipment and tools usage, planting process observations, health and safety concerns, and farmer Preferences and equipment needs we discussed and observed. Our field visit helped in providing valuable insights into the agricultural practices and challenges faced by sugarcane farmers in Uttarakhand. It showed us the need for proper ergonomically designed and efficient machine for small-medium farms and machine which are cost effective and requires less labor in their farming. These are the issues which are to be tackled in order to enhance farmers' productivity while safeguarding their health and well-being.

Figure 4.1.2: Assessing Farming Accessories

Figure 4.1.3: Farming Accessory

4.1.4. Objectives

The following set of objectives were identified and defined for addressing aforementioned problem statement:

4.1.4.1. Main Objective

- Design of sugarcane planter with adherence to frugal design principles

4.1.4.2. Specific Objective

- Study of different mechanism for planting procedure.
- Study of variation among sugarcane billets.
- Analysis and Design definition based on mechanism and billet dimension.
- Design of sugarcane planting machine
- Test and Analysis of dropping mechanism

4.2. LITERATURE REVIEW

4.2.1. Frugal Design

Frugal innovation is defined as the products, services, systems, and business model which are (re)designed in order to remove complexity and total lifecycle costs, and enhance functionality, while providing high user value(Leliveld and Knorringa, 2018,). The products and services developed by frugal innovation should be significantly less expensive, retain (technical) functionality, be accessible to low-income clients, and work in contexts with limited resources(Bhatti, 2012,). The frugal innovation philosophy incorporates products and services which are highly targeted and fits resource-constrained environment to address the unmet needs of Bottom of the Pyramid (BoP) (Bhattacharjya et al., 2023,). BoP include those people living on less than US $ 2 a day, an estimated 4 billion people worldwide(Prahalad and Hart, 2002,).

4.2.2. Cultivation Process

4.2.2.1. Land Preparation

Sugarcane crop requires well prepared seed bed. In sugarcane production tillage is done with the help of mould board plough, disc plough, heavy disc harrow, duck foot tillers , rotavators, sub soiler ,cultipeckers/ clod crushers, blade tracers, land planer, bund former, trencher, ridger, furrower and other local tillage tools . Introduction of tractor operated rotavators have been found quite effective in cane cultivation. Land preparation and stool removal in sugarcane production can be a major contributor to overall production costs. Conventional tillage system has been implicated in yield decline over the long term and therefore yield benefits are envisaged together with cost savings. A study analysis showed that minimum tillage with mechanical stool removal and machine planting gave the best economic returns, being 29.3more profitable than the conventional and no tillage treatments respectively (Grange et al., 2004,)

4.2.2.2. Sugarcane planting

Sugarcane planting involves a series of steps aimed at establishing a healthy crop for optimal growth and yield. The process typically begins with land preparation, which involves plowing, leveling, and sometimes adding organic matter to condition the soil. Planting methods vary and are often selected based on local conditions, climate, and soil type. Common methods include:

1. Seed planting: Seed planting is often used for developing new varieties of sugarcane.

2. Billet planting: Billet planting is used for producing the sugar. (Hoy et al., 2006,

,)

Each planted billets has 3 to 5 nodes at each one the billets buds appear and grow as stalk. So, a 10 to 15 cm overlapping will result in a more uniform crop coverage after germination.(Hoy et al., 2011,) The numbers of billets planted depend on various factors, including planting methods, environmental conditions, variety, rate and method of irrigation. They may be 15 to 20 thousands billets per hectare. (Johnson et al., 2011,) The billet length is a very important factor which has considerable effects on planting process and mechanical damage to the billets. Damage to the billets with an average length of 50 cm in manual planting is reported to be 11.4. For higher lengths, in mechanized planting, the damage will increase.(Johnson et al., 2011,)

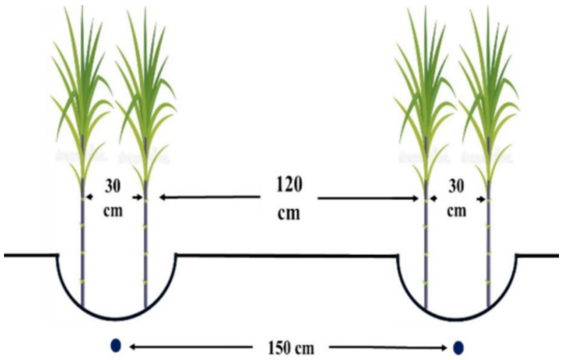


Figure 4.2.1: Typicall Planting Dimension (Anjaly et al., 2024,)

4.2.2.3. Weeding

In order to prevent weeds from competing with the crop for vital nutrients, water, and sunlight, weeding is an essential part of sugarcane farming. Several tactics are usually needed to effectively manage weeds in sugarcane fields: Manual Weeding: Farmers have historically pulled weeds by hand or with basic implements. Although labor-intensive, this approach works well for small farms or certain trouble spots. Mechanical Weeding: In larger fields, weeds are removed using a variety of cultivators and weeders that are pulled by tractors or by animals. Although mechanical weeding is effective, rows must be spaced apart to allow for machine access. Chemical Control: To keep weeds under control, herbicides are frequently sprayed both before and after emergence. While cautious application is required to prevent environmental effects, selective herbicides kill weeds without damaging sugarcane plants. Mulching: Covering the sugarcane with organic mulch

4.2.2.4. Sugarcane Harvesting

Manual harvesting of sugarcane is vogue in India. Different types of sugarcane harvesting knives of different size, shape and weight are being used for sugarcane harvesting at different places. Sugarcane harvesting involves base cutting of sugarcane ,stripping and retracing of sugarcane, detopping, bundle making and finally transport of sugarcane to the sugar mills (Grange et al., 2004,) The available sugarcane harvesting systems can be grouped into: 1. Whole stalk linear windrowing 2. Whole stalk transverse windrowing 3. Whole stalk bundling machine 4. Hand controlled self propelled harvester 5. Chopper type cane harvesters. (Grange et al., 2004,)

4.2.3. Recent Studies

Various literature from multiple sources associated with the relevancy to the topic was reviewed thoroughly. According to (Nalawade et al., 2018,), the sugarcane planting process involves harvesting, sett cutting, seed treatment, transport to the planting area, and planting. The planting is done either completely powered (tractor) or partially powered (bullock, human) (Nalawade et al., 2018,). The implementation of mechanized planting technology in India is crucial as it may mitigate labor shortages, lower expenses, and enhance productivity in sugarcane farming(Kumar and Singh, 2012,). Another paper (Yadav et al., 2003,) also talks about how mechanization in sugarcane cultivation is currently low in India, necessitating urgent development and adoption of modern machinery to enhance efficiency, reduce labor, and improve productivity.In India, research and development of agricultural machinery have been going in considerably but the adoption of these machine have not been to the desired level. There remains mechanization gap especially in the area of sugarcane planting, interculture, plant protection, harvesting and as a result, focused efforts must be made to adopt, develop, and popularize sugarcane machinery(Ali, 2015,).

Sugarcane planting is indeed one of the most labor-intensive stages of cultivation, making it both costly and time-consuming. Mechanization in this phase presents a substantial opportunity for increasing productivity while significantly reducing labor and time requirements. There different types of existing deign for sugarcane planter which are being developed and used for sugarcane planting. (Vaibhav, 2011,) developed an innovative device that cuts sugarcane, feeds it into a furrow, and sprays insecticide and fertilizer. And after all procedures, a leveler distributes soil onto sugarcane pieces in the furrow. Many sugarcane planters have been created using cutting mechanisms, and they save money compared to planting by hand, needing only 2 or 3 people to operate(Yadav et al., 2020,). IISR has developed semi-automatic, automatic and cane cutter-planter. Sugarcane cutter planter is most adopted by the farmers and performs the work of sett cutting and planting simultaneously. A tractor mounted multipurpose sugarcane planter has also been developed at IISR.

From recent studies we can classify existing design for sugarcane planter as follow:

1. Full-stalk planters : The full-stalk sugarcane planters place the sugarcane setts into the sugarcane loading container. Then, the planter is employed to mechanized all sugarcane sets into the ditch.(zha, ,)

2. Real-time cutting(Cutter Planter) planters : The real-time cutting planters cut the entire sugarcane stalks and drop it into the opened groove.(Singh and Singh, 2017, ,)

3. Pre-cut planters(Billet Planter): The pre-cut planters cut sugarcane into seg ments. Sugarcane planting is then followed via the planting procedures.(zha, ,)

   Compared with the first two planting machines, the pre-cut sugarcane planting machine is characterized by an improved planting efficiency and budding rate. (zha, ,) used a U-groove hooking device to achieve uniform seeding of sugarcane segments. Ravindra et al. (2013) employed belt elevators to complete seed storage and achieve seed metering through belt conveyors. However, roller-type automatic seed metering device was used to achieve an orderly arrange ment of sugarcane seeds and effectively prevent mutual influence between sugarcane seeds ((Naik et al., 2013,)

Figure 4.2.2: Full stack Planter

Figure 4.2.3: Cutter and Planter

Large-scale cultivation is the main focus of the sugarcane planter designs currently in use, whether they are for pre-cut or real-time cutting. Although these machines are strong and effective for planting in large fields, they are not appropriate for small to medium-sized fields or individual use due to their high manufacturing costs and complicated maintenance and repair requirements.

Figure 4.2.4: Pre cut planter

A frugal design of sugarcane planter for small and medium-scale production has been developed to overcome these constraints. Farmers with limited resources can use this design because it is less expensive and simpler to fix. By cutting labor and time costs, the frugal planter not only saves money but also preserves the advantages of mechanization, increasing production and facilitating effective sugarcane planting on a smaller scale.

4.3. METHODOLOGY

This section includes all the activities that were done from the beginning of our project. A thorough overview is shown in the flowchart as shown in Figure 4.3.1.

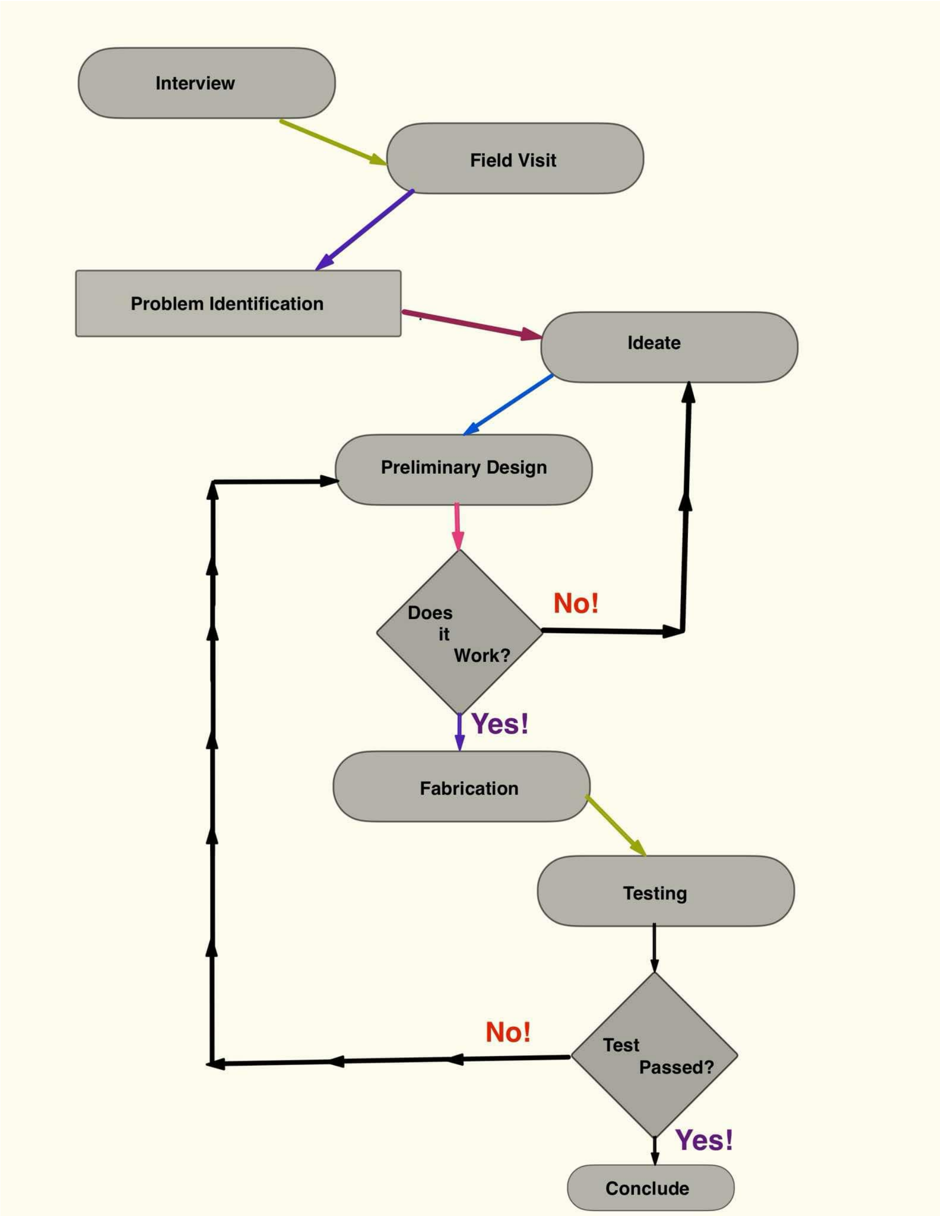


Figure 4.3.1: Workflow of the project

4.3.1. Problem Identification

First step in the methodology is the problem identification. In problem identification initial discussion with local farmers were to be carried out to understand their primary concerns, current practices, and needs. Second in problem identification is the planning of conducting field visit to observe the entire process.

4.3.2. Field Visit

Field visit is conducted to gather insights into the problems faced and method employed by farmers. Our visit was facilitated by one of the PhD scholars who is already involved with the farmer. We prepared a questionnaire addressing the needs of farmers, specifically focusing on the types of equipment they feel they require or desire. In field visit, topic like Labor and work schedule observations, wage and gender disparities, equipment and tools usage, planting process observations, health and safety concerns, and farmer Preferences and equipment needs were discussed and observed.

4.3.3. Problem Selection

With problem identification and field visit done, a problem was selected to address. This problem was based on the analysis of the data from the field visit. Also with weeder already made diverse range of sugarcane farming equipment to be designed and developed was also kept in mind.

4.3.4. Preliminary Research & Design

After selecting the problem statement, preliminary research was done . This means extensive literature review and online research to thoroughly understand existing developments related to sugarcane planting machinery. Academic databases like Google Scholar, Web of Science, and Science Direct were utilized to gather relevant research papers and technical reports (Anroedh et al., 2024,). Context-specific study was done, particularly designs and technologies that have been developed and manufactured in India and are currently in use in the Indian agricultural market. Additionally, papers featuring designs and innovations from other major sugarcane-producing countries like Brazil, Thailand, and the USA were reviewed. This approach to research lays a strong foundation for the conceptual and CAD design phases that followed.

4.3.5. CAD Design

With the preliminary study and interviews done, the next phase is the CAD. Through CAD, rapid prototyping can be done easily. First of all rough sketches were done in copy. Then, those ideas and sketches were designed in CAD software. The important parameter for proper dimension of the design was the furrow height, plantation gap, wheel diameter, no of sugarcane carried by hand, hopper volume, etc. Each individual component was modelled separately for eg wheel, frame, hopper, dropping mechanism. This was done for easiness during the reiteration of the design. Finally all the individual parts were brought together to create the full assembly of the machine in CAD. Design was adjustment based on the feedback.

4.3.6. Fabrication

Given the project's time and resource constraints, the methodology focused on selectively prototyping the sugarcane planter's dropping mechanism instead of the entire machine. The dropping mechanism was prioritized as the essential component for ensuring accurate placement of sugarcane cuttings, a critical function for planting efficiency. Testing of the prototype will validate its functionality, demonstrating consistent dropping performance. This will help in assessing planter's core functionality.

4.3.7. Testing

When the entire machine will be fabricated then testing will be conducted in farm. Farmers will be invited to review the machine's performance and provide feed. Their concerns and recommendations will be noted and taken into account for the upcoming design iterations. This iterative process ensures that the final design is not only technically effective but also aligns with the practical requirements like ergonomics, preferences of the end users, and acceptability.

4.4. RESULTS AND DISCUSSION

4.4.1. Field Visit

The farms typically spans about a total area of 15 bighas, equivalent to approximately 809 square meters. This diverse agricultural landscape includes various crop types, such as sugarcane, wheat, maize,and vegetables like potatoes. Different crops were planted throughout the year for maximizing farm efficiency and productivity. Sugarcane were planted seasonally primary from October to March. During our observations, we noted that the farm typically employs a daily labor force of 6 to 7 workers, with the potential to scale up to 10 to 15 workers during peak seasons. These workers usually arrive early in the morning, around 7 to 8 AM, to avoid the midday heat. Farmers pay male workers approximately INR 500 per day, while female workers earn around INR 350. This wage discrepancy highlights the prevailing gender biases within the agricultural labor market. The differences in wages according to the farmers is working capacity between males and females, underscoring the need for machinery that can support female workers and address the existing pay disparity.

The farmers primarily relied on traditional tools and equipment, such as sickles, for most of their tasks. However, they also utilized a few powered machines, including tractors equipped with attachments like cultivators and ploughs to facilitate tillage and planting. Additionally, tractors were used for transporting harvested sugarcane.

During our visit, the farmers demonstrated their planting process, illustrating the various steps involved in establishing sugarcane crops. They first utilized tractors and tiller machines to prepare the land, creating furrows for planting. The furrows typically measured approximately 7 cm in depth, were spaced 100 centimeters apart at the top, and had a width of around 75 centimeters.

After preparing the land, the farmers cut the sugarcane stalks each containing two buds, removed unnecessary leaf blades, and prepared the cuttings. The prepared cuttings are then placed in the furrows horizontally, with each cutting spaced approximately 4 cm apart. Typically, they carry around 30 shoots at a time in their arms for planting, with each bundle weighing approximately 1 to 1.5 kilograms. This weight poses a strain on their bodies, particularly when bending or sitting to plant the sugarcane buds. The ergonomic challenges associated with these tasks can lead to musculoskeletal disorders, including lower back pain and other related health issues. The farmers exhibited a lack of awareness regarding the potential health risks associated with their farming practices. They seemed indifferent to the long-term effects of cuts and other injuries, likely due to their adaptation to these conditions over time.

After planting, the farmers performed essential post-plantation care activities, including applying insecticides and fertilizers, as well as irrigating the crops. They primarily managed these tasks themselves, with support from family and nearby village members, thereby eliminating the need for additional hired labor.

We prepared a questionnaire addressing the needs of farmers, specifically focusing on the types of equipment they feel they require or desire. Interestingly, one of the farmers preferred using manual tools for cultivation, while the other favored motorized tools. Both farmers expressed a willingness to invest between INR 10,000 and INR 40,000 in a compact planter machine that could attach to their tractors. They acknowledged the advantages of machinery in enhancing efficiency and reducing manual labor. Due to the relatively small size of their farms, the farmers preferred small-sized compact equipment over larger farming machinery. This preference for compact tools aligns with their operational needs and space constraints, allowing them to maximize productivity without the burdens associated with larger equipment.

Figure 4.4.1: Direct Interview

Figure 4.4.2: Field Visit

4.4.2. Design Process and Design Iteration

Iterative design is a methodology that follows a repetitive cycle of prototyping, testing, analyzing, and improving a product or process. The design iteration process for our sugarcane planter followed the methodical approach starting with an initial conceptual design. This initial design served as a foundation, which resulted in rejection of multiple designs after scrutinized analysis based on visualization of how the planter would operate in real-world conditions. Special attention was given to the cylindrical hopper and billet-feeding mechanism to ensure seamless operation without billet jamming, which could compromise planting speed and accuracy. Feedback from design through analysis, provided insights into potential issues like uneven billet separation, potential jamming areas. With this feedback, we refined key aspects of the design, such as modifying the cylindrical hopper to improve flow, adjusting the feeding mechanism to prevent billet overlap, and optimizing the planter's speed to enhance precision. After multiple cycles of visualization and refinement, the design reached an acceptance state, meeting performance criteria.

4.4.2.1. Metering Mechanism Iteration

A metering mechanism is a system designed to control the rate and spacing at which sugarcane billets are placed into the soil. We need to ensure that each billet is planted at consistent intervals, optimizing the distribution across the field for uniform crop growth. The metering mechanism exists to improve crop density and overall yield potential, which is critical for reducing manual labor, as it eliminates the need for workers to manually position each billets, thus increasing the efficiency. The following are the metering mechanism subjected to detailed study for design: Spiked Rotor & Tapered Spiked Rotor The initial design for the metering mechanism featured a cylindrical rotor with evenly spaced spikes, intended to control the placement of sugarcane billets. A variant with tapered spikes was also developed in parallel. However, after closer examination, it was identified that the design would likely encounter clogging issues if billets entered the mechanism at an angle or vertically, leading to interruptions in the planting process. Additionally, the tapered spike version presented manufacturing challenges that could significantly increase production costs. A further drawback was the lack of modularity—if individual spikes failed, the entire rotor would need replacement, impacting both cost and repairability. Henceforth, this design was deemed unsuitable and was ultimately rejected.

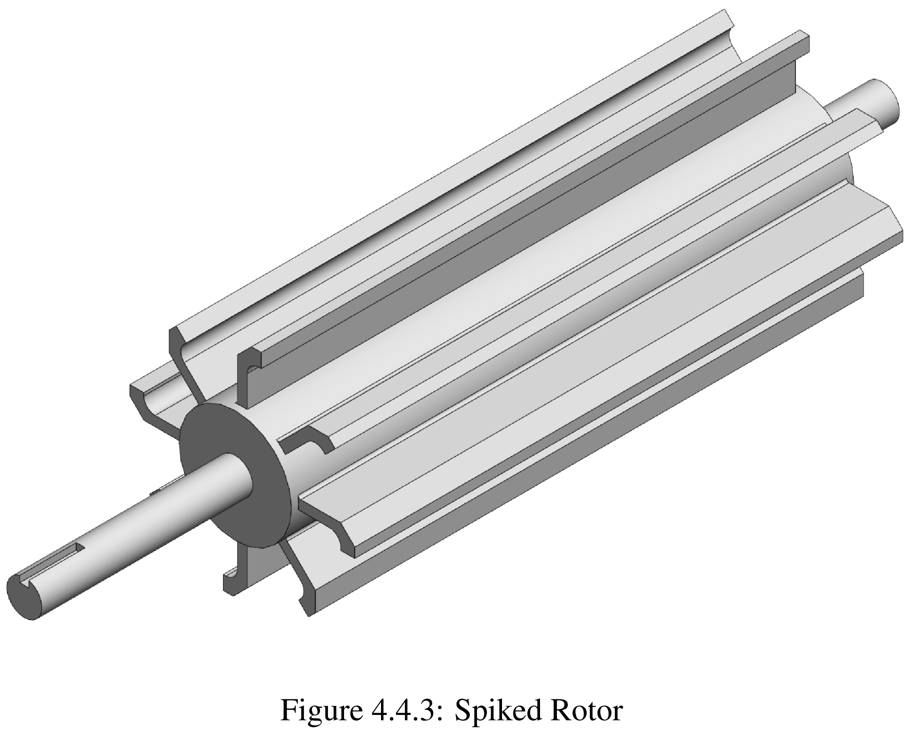


Figure 4.4.3: Spiked Rotor

Reduced Volume Rotor After the rejection of the initial spiked rotor design, a new metering mechanism was developed featuring a cylindrical rotor with pocket along its surface. In this setup, sugarcane billets from the hopper are directed into the pocket on the cylinder, where they rest securely as the planter moves forward. As the planter's wheel rotates, it drives the cylindrical rotor, which in turn rotates the billets containing rotor. Once each billet reaches the appropriate discharge point, it falls from the pocketed cylinder into a chute, guiding it smoothly into a prepared furrow in the field below. This design improves the consistency and accuracy of billet placement, reducing the risk of clogging seen in the earlier design and enhancing efficiency of the plantation process. The pocket-cylinder approach is a reliable method for automated billet placement.

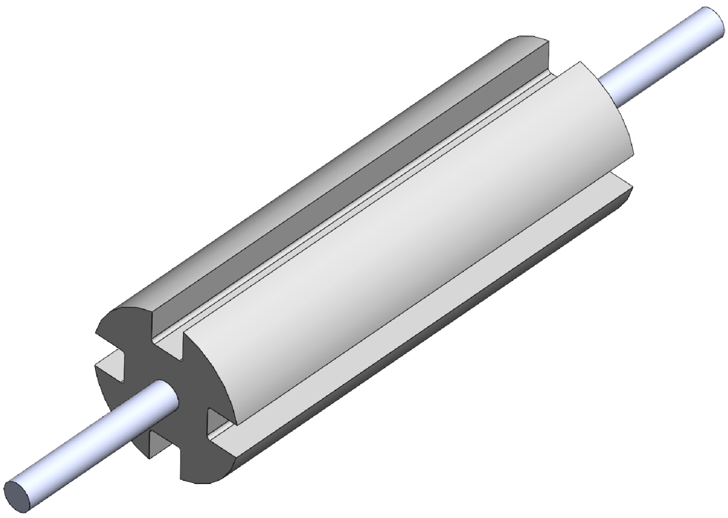


Figure 4.4.4: Reduced Volume Rotor

4.4.2.2. Hopper Iteration

A hopper is a component designed to hold and manage a steady supply of sugarcane billets before they are fed into the metering mechanism. They serve as a reservoir, where it ensures that billets are available in the right quantity, preventing interruptions and allowing for smooth, continuous operation. It is responsible for regulating the flow of billets. Its presence also reduces manual labor, as workers do not need to continuously load individual billets, making the planting machine more efficient and effective for operations. Rectangular Tapered Hopper Initially, a rectangular, tapered hopper design was developed for the reservoir in our sugarcane planting machine, aimed for controlled material feeding into the metering mechanism. However, this design faced significant issues with clogging and jamming, which compromised its functionality. To address this, variations in the tapered angle were tested, alongside a three-sided tapered design. With greater insights from analysis and visualization, the clogging susceptibility remained unresolved, ultimately leading to the rejection of this design approach. Single

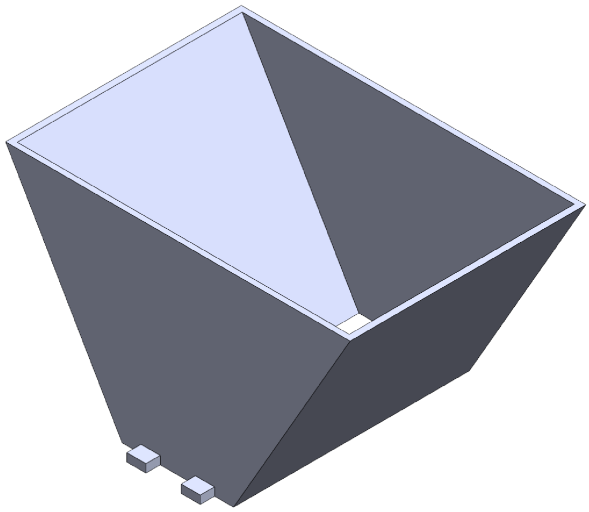


Figure 4.4.5: Rectangular Tapered Hopper

Stack, Single Drop Hopper After multiple iterations and a return to the drawing board, slender, single-stack, single-drop hopper design was developed and thoroughly analyzed. In this configuration billets was allowed to descend one at a time through gravity into the metering mechanism. When the rotor's pocket section aligned with the hopper, feeding was momentarily halted; as the pocketed section rotated back into place, billets dropped into the pocket, continuing the cycle. This design effectively resolved previous issues and was ultimately selected for implementation.

4.4.3. Chute Iteration

The hopper was equipped with a sliding mechanism designed to direct sugarcane billets into the planting furrow. This slider, constructed from an aluminum sheet, allowed billets to fall in a controlled manner, ensuring precision in their placement. Billets were collected in the opening of the hopper, where they were separated individually by a rotary separation mechanism. From there, the billets would fall through the slider, which guided them towards the furrow with minimal deviation. Positioned 10 cm above the furrow, the slider provided an efficient pathway that reduced potential misalignment, allowing billets to be placed accurately in the field.

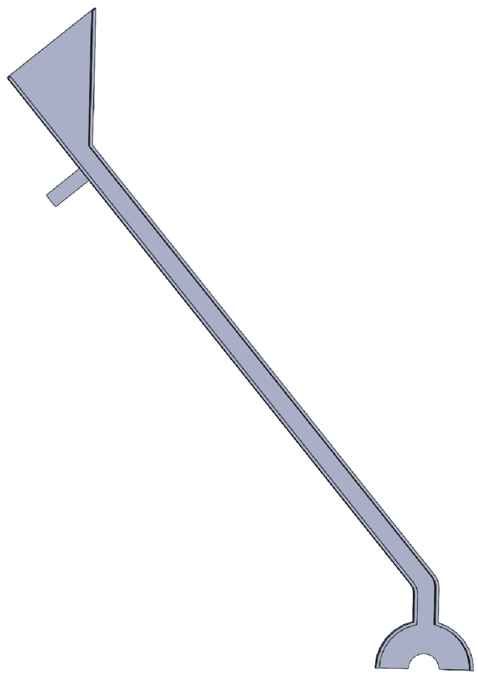


Figure 4.4.6: Simple Inclined

4.4.3.1. Simple Inclined Chute

A simple inclined design was made for the slider. The individual billets would drop from the separation rotor, and fall the slider, the slider would fix their orientation in a fixed space, and allow the billet to fall on the furrow. The billets would then fall on the furrow in horizontally in furrow. The billets would be placed lined by line in the furrow gorge with a distance of 2.5 cm between each billet.

4.4.3.2. Guide Vaned Chute

This iteration was made by implementing slight modifications to the simple inclined slider. Guide vanes were also added inside the slider. This was to improve the accuracy of the billet orientations. The guide vanes were small extrusion made inside the slider. Upon striking with the extrusions, the billets would rotate and orientation according the slider space and the required orientation of the billet for proper placement in the furrow.

4.5. Power Transmission

The rotary motion of the wheel was also used to power the dropping mechanism. Different power transmission mechanisms were needed to be used for different design iterations.

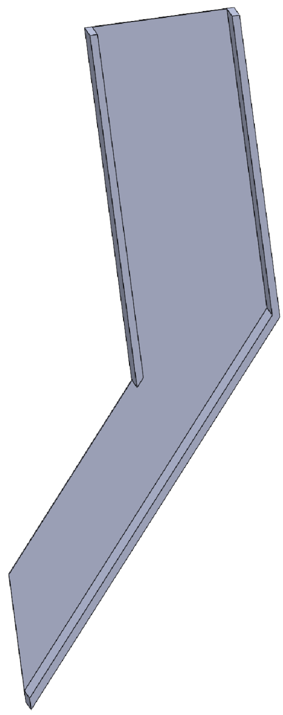


Figure 4.4.7: Simple Inclined Slider

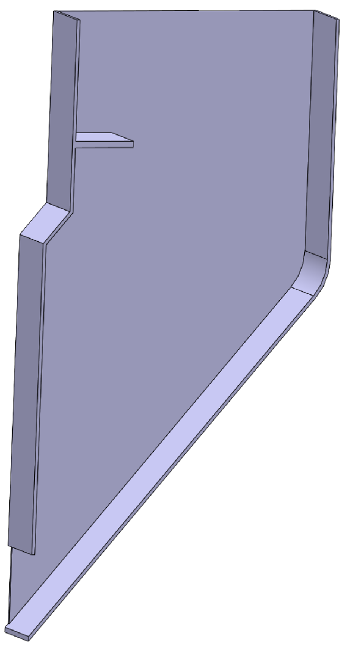


Figure 4.4.8: Slider with Guide Vane

4.5.0.1. Gear (Bevel)

Bevel Gear were to be used for the design where the direction of the rotation of wheel and the rotor were perpendicular to each other. Bevel gear was used to transmit the power as well as change the direction of motion. The design seemed to be make the planter much more complex. The complexity would decrease the frugality of the machine and also make it difficult for maintenance purposes.

4.5.0.2. Chain Sprocket

Chain Sprocket design was preferred for most of the design iterations. The chain sprocket design is simpler, as well as easy availability of sprocket and chains would make it easier for maintenance purposes. The length of the chain was determined to be 300cm. The sprockets used were of diameter 20cm and 40 cm respectively. This would give gear ratio of 1:3.

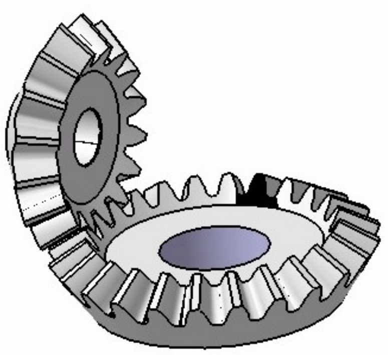


Figure 4.5.1: Gear (Bevel) Transmission

Figure 4.5.2: Chain Sprocket Transmission

4.5.0.3. Cross-belt

Cross-belt mechanism was also though of for the power transmission purpose when the plane of axis of rotations were different. The cross belt seemed to be less effective due to reduction in power transmission efficiency and also due to fast wear.

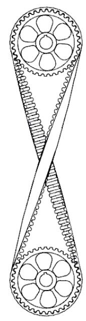


Figure 4.5.3: Cross-belt

4.5.0.4. Direct

Directly connecting the wheel shaft with the rotor shaft was also thought of in the design iterations. The major drawback of this system would be maintaining the rotation ratio, which would require very much precise designing of the designs and the rotors. This design would also be less difficult for making immediate changes and maintenance purposes.

4.5.1. Wheels

The wheels for the planter were to be made up of mild-steel. The planters were designed to be used by application of manual force .i.e external power sources like motors or engines were not provided to keep the design frugal. Spiky grooves were made around the circumference of the wheel to provide better grip for the wheel on the rough and uneven surfaces of the farmland.

4.5.1.1. Two Wheeler

Initially, two-wheeler design was made for the planter machine,with each wheel having diameter of 150 cm. Only having two wheels reduced the weight of the planter, as well as material required. This in-turn help reduced the fabrication cost of the planter. The design seemed to be bit difficult to be used in the field because it required bit more experience for balancing the wheels and requirement of higher pushing force.

4.5.1.2. Three Wheeler

To overcome the shortcomings of the two-wheeler design, an extra small sized wheel was added to the front of the planter. The diameter of the smaller wheel was kept 50 cm. This helped increase the stability of the design and also reduce the pushing force. The three wheeler design also seemed to be much more effective in the uneven and rocky soil of the farmlands.

4.5.2. Design Selection

The design selection process is a systematic approach for evaluating and choosing the most suitable design from different available options. It begins with defining clear requirements and constraints such as performance specifications, cost limits, usability, and durability, which serve as a benchmark for evaluating each option. Multiple design concepts are then generated, with an initial screening phase to eliminate options that fail to meet basic requirements.

4.5.2.1. First Iteration Design

The first design iteration features a rotor axis perpendicular to the wheel axis. This design requires a cross-belt mechanism to drive the rotor, making the driving mechanism slightly complex. In this setup, billets drop into the furrow parallel to the furrow's direction. The chute in this iteration is kept simple to facilitate straightforward delivery of billets into the furrow.

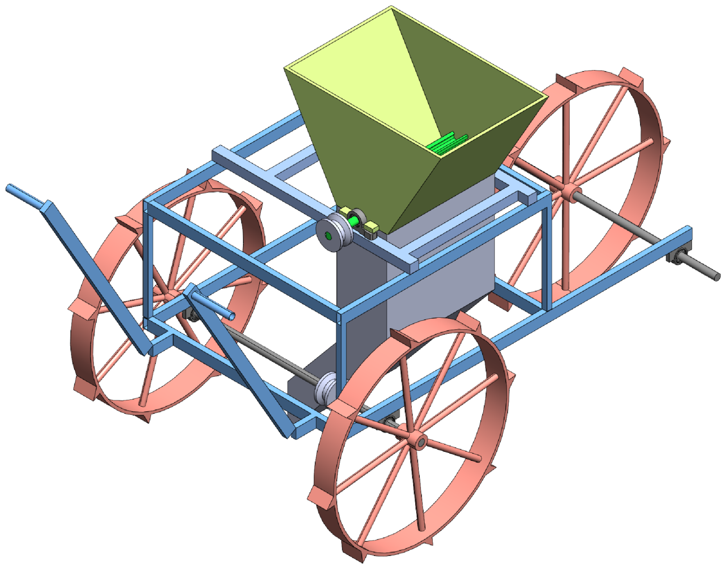


Figure 4.5.4: First Design

4.5.2.2. Second Iteration Design

In the second design iteration, the rotor axis is parallel to the wheel axis. Power transmission is achieved with a simple chain-sprocket mechanism, but the transmission process is somewhat complicated. Here, billets drop perpendicular to the furrow, necessitating a chute that realigns the billets by 90 degrees to make them parallel to the furrow. This added alignment adjustment increases the chute's complexity.

4.5.2.3. Third Iteration Design

The third design iteration returns to a rotor axis perpendicular to the wheel axis, with a somewhat complex driving mechanism. Billets drop parallel to the furrow, similar to the first iteration. To manage power, bevel gears with a ratio of 1:1.5 are incorporated, which offers a reliable transmission solution. This design also includes a simple chute and an inclined hopper capable of holding up to 30 sugarcane billets.

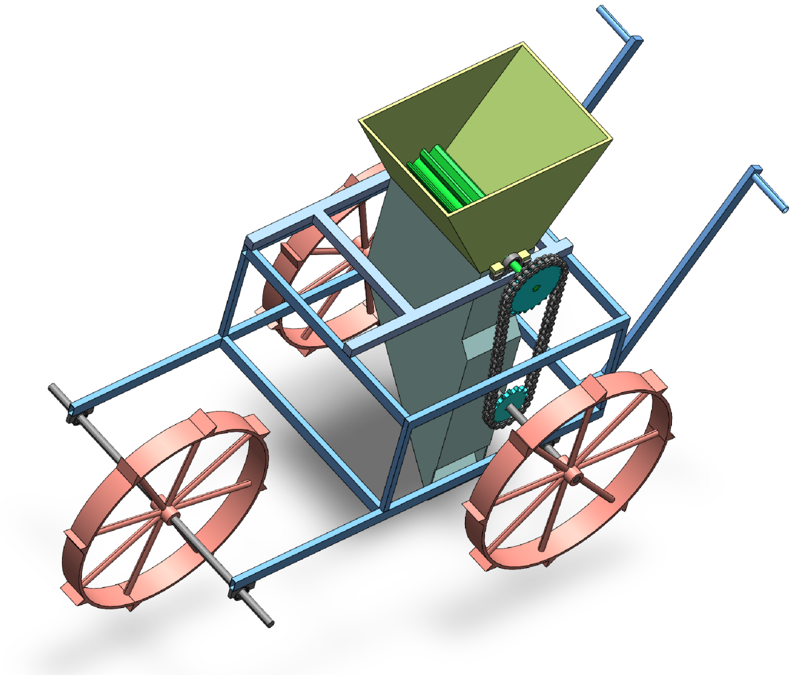


Figure 4.5.5: Second Design

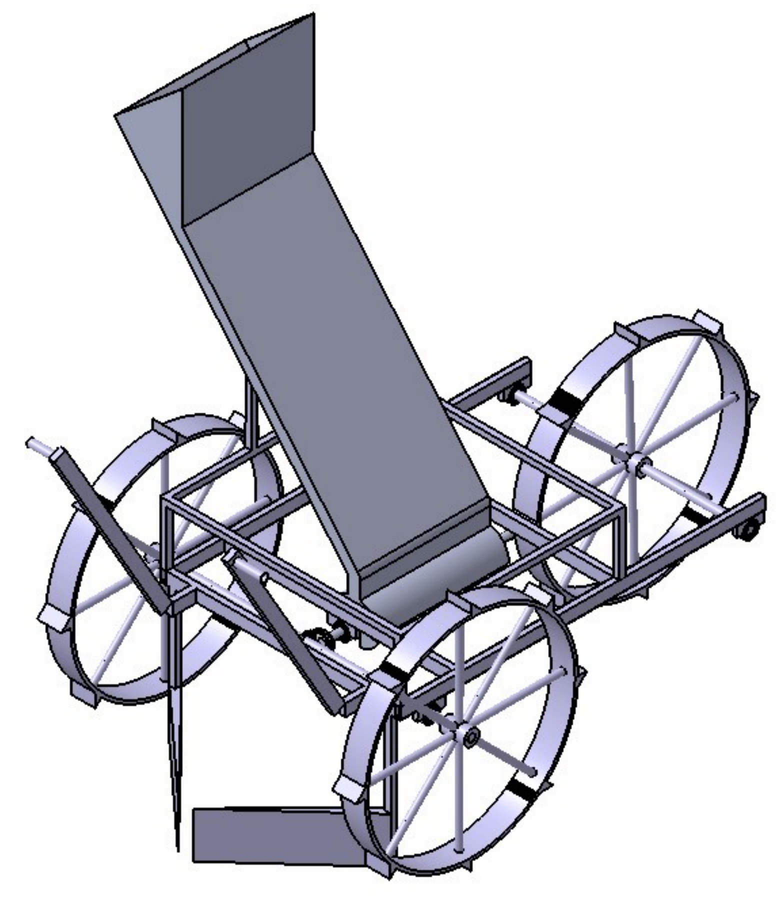
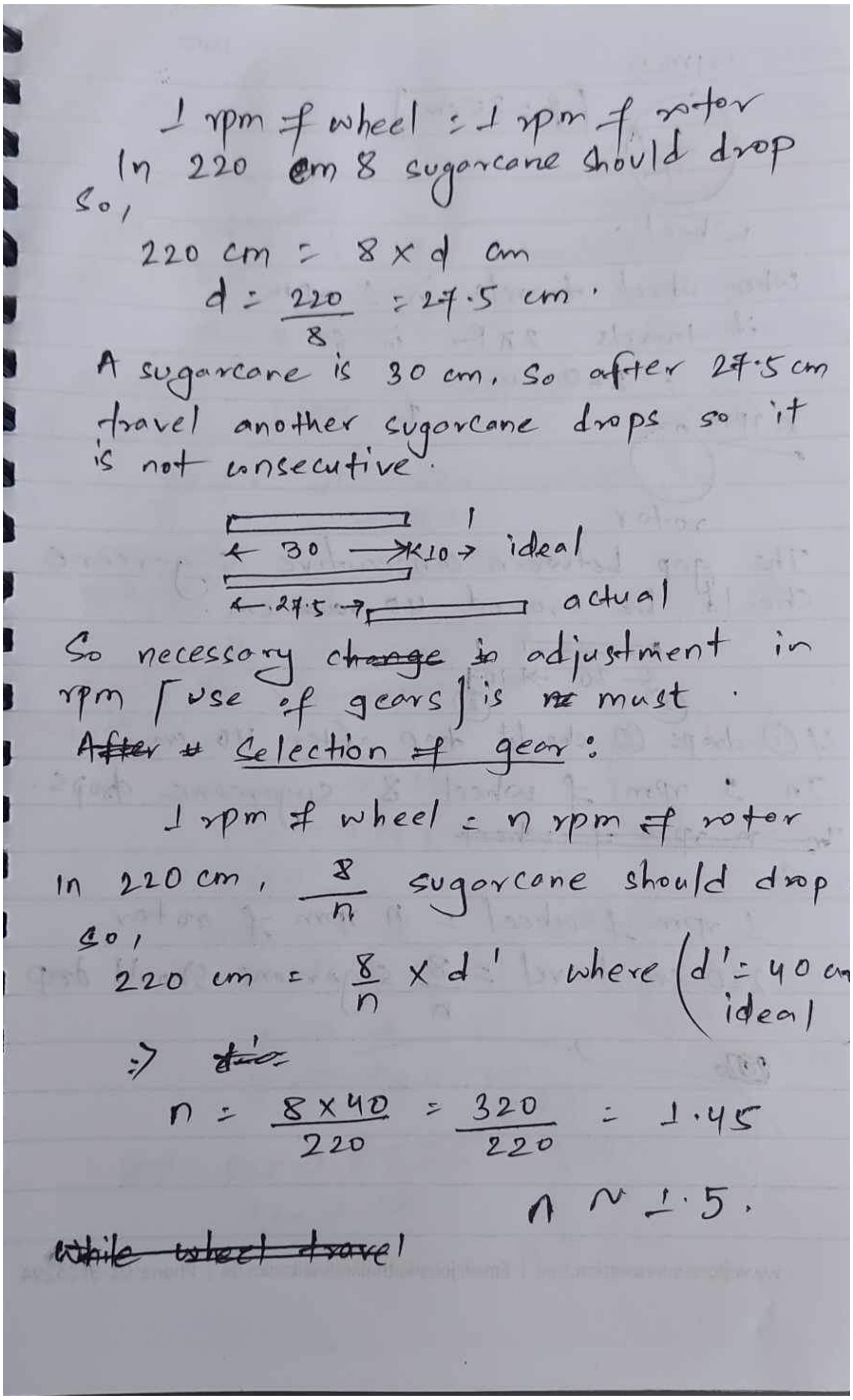


Figure 4.5.6: Third Design

4.5.3. Technical Specifications of the developed planter

S.N.	Particular	Detail
1.	Framework	Square pipe 40 mm × 20 mm × 10 mm
	Length	1200 mm
	Width	790 mm
2.	Hopper	Inclined surface and straight vertical surface joined together
	Nature	Single stack single drop hopper
	Slot length	420 mm
	Slot width	35 mm
	Thickness	5 mm
	Inclination angle	50 degrees
	Capacity	30
3.	Rotor	Square pocket rotor
	Rotor diameter	140 mm
	Orientation	Parallel to the furrow
	Pocket dimensions	400 mm × 25 mm × 20 mm
	Capacity in one revolution	4
4.	Furrow coverer	Two furrow coverers attached to the frame just beneath the handle to cover the sugarcane billets
	Angle of inclination	46 degrees
5.	Power transmission	One set of bevel gears
	Number of teeth in gear	24
	Gear diameter	25 mm
	Number of teeth in pinion	16
	Pinion diameter	15 mm
6.	Wheels	Spike wheels
	Number of wheels	3
	Number of spikes	8
	Wheel diameter	700 mm
	Rim width	80 mm
7.	Overall dimensions	
	Length	2002 mm
	Width	1310 mm
	Height	1450 mm



1 rpm of wheel = 1 rpm of rotor

In 220 cm 8 sugarcane should drop

So,

$$220 \text{ cm} = 8 \times d \text{ cm}$$

$$d = \frac{220}{8} = 27.5 \text{ cm.}$$

A sugarcane is 30 cm, so after 27.5 cm travel another sugarcane drops so it is not consecutive.

So necessary ~~change~~ ~~in~~ adjustment in rpm [use of gears] is must.

~~After~~ Selection of gear:

1 rpm of wheel = n rpm of rotor

In 220 cm, $\frac{8}{n}$ sugarcane should drop

So,

$$220 \text{ cm} = \frac{8}{n} \times d' \quad \text{where } (d' = 40 \text{ cm ideal}$$

$$\Rightarrow n = \frac{8 \times 40}{220} = \frac{320}{220} = 1.45$$

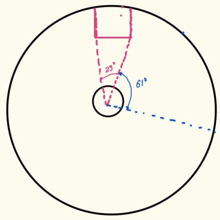
$$n \sim 1.5.$$

~~While wheel travel~~

Figure 4.5.7: Gear ratio calculation during initial design iteration

From the afore-displayed calculation, it was found that the wheel should rotate with 1.5 times the angular velocity of the rotor. Also, from the gear ratio formulae, it is known that the diameter of the wheel gear must be 1.5 times the diameter of the rotor gear.

Rotor Diameter = 140 mm



Sugarcane Billet spacing = 7.5 cm
= 75 mm

For billet spacing,

$l = \theta_1 r$

$\Rightarrow 75 = \theta_1 70$

$\Rightarrow 75/70 = \theta_1$

$\therefore \theta_1 = 1.071 \ (61.363^\circ)$

$\boxed{\therefore \theta_1 \sim 61^\circ}$

Slot dimension $\Rightarrow$ length = 35 mm

$l = \theta_2 r$

$\Rightarrow 35 = \theta_2 70$

$\therefore \theta_2 = 0.5$

$\boxed{\therefore \theta_2 = 28.65^\circ \sim 29^\circ}$

Now, total angle $= \theta_1 + \theta_2$

$= 61 + 29$

$= 90^\circ$

Again, Number of billet slots $= \dfrac{360}{\theta_1 + \theta_2}$

$= \dfrac{360}{90}$

$= 4$

Figure 4.5.8: Number of Billet housing calculation

4.5.4. 3D Printing

Before the final prototype could be fabricated, 3D model of the planter design is to be printed and tested for analyzing the efficiency and working of the planter mechanism. The scaled model is then to be tested for visualization of their performance in real working scenario. Here, only the billet dropping mechanism was printed to check their working efficiency. If the mechanism was working properly, then they could be easily fitted into any frames of the planter with slight modification. This would reduce the time for model analysis, by identification of the problem to a specific area which could then be addressed.

Figure 4.5.9: Designing Work

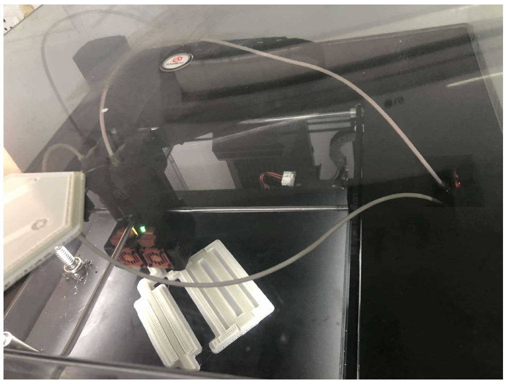


Figure 4.5.10: 3D Printing of Mechanism Prototype

4.5.4.1. Testing of 3D printing prototype

Following the completion of the overall design process, a prototype of the dropping mechanism was developed. To accommodate the available 3D printer at the Tinkering Lab, the prototype was scaled down, adhering to the printer's maximum build volume of 35 x 35 x 65 cm. PLA was selected as the printing material for its strength and availability while the model was scaled down. The design also took into account for the dimensions of a 7.8 mm bearing which influenced the prototype's overall scale and structural parameters. Sample sugarcane buds were also printed, each with a diameter of 9 mm and a length of 10 cm to test the mechanism's functionality. The prototype included a handle to simulate the rotor's movement, mimicking the wheel and gear rotation in the actual mechanism. A viewing slot was incorporated into the base/dropper to observe the precise placement and dropping of the sugarcane buds. The CAD model and corresponding 3D-printed prototype are displayed in figure 4.5.11 below, illustrating the design's practicality and alignment with the project's objectives.

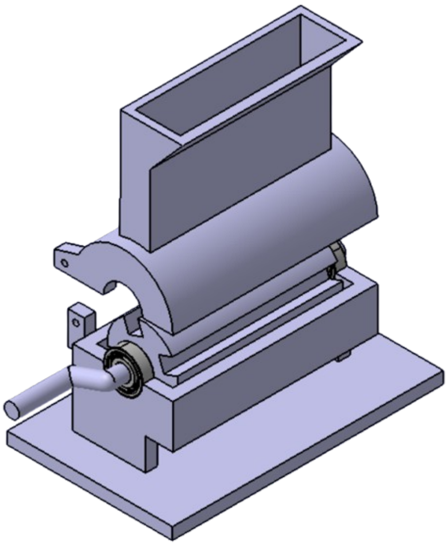


Figure 4.5.11: 3D CAD model

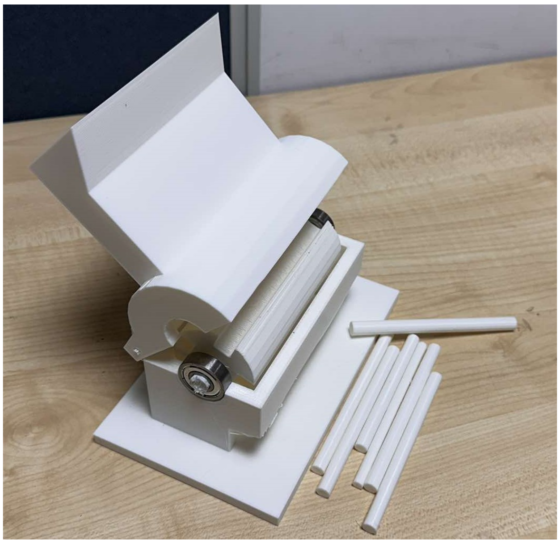


Figure 4.5.12: 3D scaled model

4.6. MATERIALS REQUIRED

To successfully complete our project, we have outlined a budget that includes expenses for both new and existing resources.

Table 4.6.1: Budget Estimation

SN	Description	Quantity	Estimated Cost(INR)
1	Mild Steel Pipe	10 kg	1200
7	Mild Steel Plate	3 kg	300
5	Sheet Metal	5 kg	1500
2	Wheel	3	2500
3	Sprocket	2	800
4	Chain	2	500
6	Ball Bearing	2	400
8	Miscellaneous		3,000
Total			10,200

The project will require total budget of INR 15,200. This budget makes sure we can receive all the resources we need while making the most of what we have, to cut costs wherever we can.

4.7. WORK TIMELINE

The project schedule was maintained adhering to the following gantt chart:

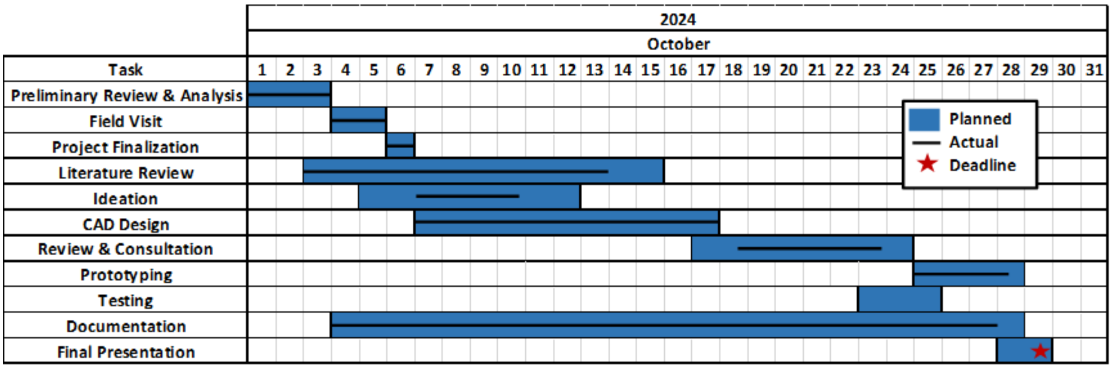


Figure 4.7.1: Gantt Chart showing project timeline

- **Preliminary Review & Analysis**: Planned from October 1–3, with actual completion on October 3.
- **Field Visit**: Scheduled for October 4–5, with actual completion on October 5.
- **Project Finalization**: Planned from October 5–6, matching the actual completion date.
- **Literature Review**: Scheduled from October 3–15, with actual progress slightly ahead of plan.
- **Ideation**: Planned from October 5–12, with actual progress overlapping the planned timeline.
- **CAD Design**: Scheduled from October 7–17, with minor deviations in actual completion.
- **Review & Consultation**: Planned from October 17–24, with no marked deviations.
- **Prototyping**: Scheduled from October 25–28, with actual work beginning as planned.
- **Testing**: Planned from October 23–25, following the prototyping phase.
- **Documentation**: Scheduled from October 4–28, running concurrently with other tasks.
- **Final Presentation**: Set for October 29 as the project's final deadline.

4.8. OUTCOME AND FUTURE DIRECTIONS

4.8.1. Limitations

The following are the limitations encountered during our project:

- Limited working timescale for the project constrained many stages from taking place.
- Data biases might have highly influenced the design, as only one set of data form localized area was used for design iteration.
- Though a prototype was developed, full testing and validation of the machine could not be completed within the project timeline.
- Limited experience in agricultural machinery may have impacted the depth of technical solution explored.

4.8.2. Future Enhancements

We strongly believe that the project can be further enhanced and following suggestions are listed for future undertake:

- Large project with requirement for design, prototyping, testing, and fabrication demands considerable allocation of time. Henceforth, time scale of at least 4 months is encouraged.
- Development of a standard machine necessitates plethora of data, which can only be achieved by increasing sample size i.e. number of data from the farms from varying geographical locations must be comparatively high.
- Prototyping and Testing should be extensive and rigorous process including simulation or replication of performance in harshest scenario to ensure the robustness of the machinery.
- Design principle like that of quadruple helix stipulating the joint collaboration among, community, academia, government and industry should be prioritized as it helps inclusion of traditional practices into the model which can be rectified.

4.9. Design Presentation

On 29th October 2024, we presented our designs, and 3D printed mechanism prototype to our internship supervisor Dr. Bibhuti Ranjan Bhattacharjya in the meeting hall. The presentation was also attended by present scholars within the Department. We were provided with necessary feedback and project continuation recommendations. The department has planned to continue the project and research in the coming days.

4.10. Reporting

All the works related to the given project were documented to prepare a report, including all the iterations, the result from the 3D printed mechanism, and necessary

Figure 4.9.1: Project Presentation

recommendations for the designs, and submitted to the Department of Design.

INDIAN INSTITUTE OF TECHNOLOGY
ROORKEE

DESIGN AND DEVELOPMENT OF FRUGAL SUGARCANE PLANTER

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AN INTERNSHIP REPORT TO THE DEPARTMENT OF DESIGN IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE BACHELOR'S DEGREE IN MECHANICAL AND AEROSPACE ENGINEERING

DEPARTMENT OF DESIGN
IIT Roorke, Uttarakhand

October, 2024

Figure 4.10.1: Project Report

CHAPTER 5:
CONCLUDING REMARKS

The design and development of the sugarcane planter mark an important step toward creating agricultural machinery that is efficient, user-friendly, and sustainable. The project focused on key aspects like making the machine modular and easy to repair, ensuring it would be adaptable and practical for long-term use. While the main focus was on building and testing the dropping mechanism, the results were encouraging, as the mechanism performed well within the desired specifications for accurate billet placement.

However, the project had its challenges. The limited timeline meant there wasn't enough time to explore additional design iterations or carry out comprehensive testing of the machine's overall performance. Another issue was the reliance on data from just one localized area, which may have introduced biases and affected how broadly the design could be applied. Additionally, the team's limited experience with agricultural machinery might have prevented them from exploring more advanced technical solutions.

Future efforts should focus on addressing these challenges. Using a broader range of data will help refine the design to suit different agricultural settings. Gaining more experience in designing agricultural machines and thoroughly testing prototypes will also be essential to create a well-rounded, validated solution that meets the needs of modern farming.

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