DESIGN AND IMPLEMENTATION OF A MINI ARTIFI 3D PRINTER

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Dedication

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EXECUTIVE SUMMARY

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PART-A

This part contains the concept and the project proposal as prepared on EEE400A.

Chapter 1 Project Concept and Proposal

1.1 Project introduction

Our capstone project, "Design and Implementation of a Mini Artify 3D Printer," aims to develop a printer that will produce a three-dimensional object based on any given design as input. This concept has been offered as a viable solution to a variety of modern-day problems. The next subsections cover the purpose, motivation, and applications in brief.

- **Objective:** The main target of this project is enabling design into reality. We will build a printer. It will produce 3D object as output according to the given design as input.
- **Motivation:** We can make any 3-dimensional object according to the design provided by completing this project. When students in our country are studying science, it is often difficult for them to envision and comprehend lots of topics. Different shaped materials are required in the medical industry at times, which are rarely readily available in the market. On the other side, unemployment is a significant impediment to Bangladesh's progress. All of these issues will be resolved if we can make things according to our intended design whenever we need them.
- **Applications:** A 3D printer can make a substantial positive difference in a variety of important industries such as education, medical, and so on. Some of its key applications are educational institutions, bio-medical laboratories, art and craft shops, mills and factories, and fabrication enterprises. It can also be used to recycle plastic.

1.2 Literature review

A 3D printer is a device that will enable designs into reality. We can utilize such a device in the field of engineering and product design, manufacturing, dental, health care, education, entertainment, jewelry, audiology and various other sectors. For consumer level additive manufacturing, there are currently two main methods to 3D print objects: Stereo lithography (SLA) and Fused Deposition Modeling (FDM) [1]. So, with the aim of executing our project, we have reviewed some papers with similar concepts. They are mentioned below:

- **Stereo lithography (SLA):**

  Here, according to the paper of Tyler [1], SLA method requires several steps to initiate a print operation and obtain a finished product. First, the reservoir is attached to the frame of the machine [1]. Screws and an L-brackets are used to clamp the reservoir so that it doesn't shift during printing [1]. Next, the build plate is inserted into its mounting device [1]. After these parts are assembled, the resin is prepared and poured into the reservoir [1]. Proper and careful completion of each step is required for a successful print job [1].

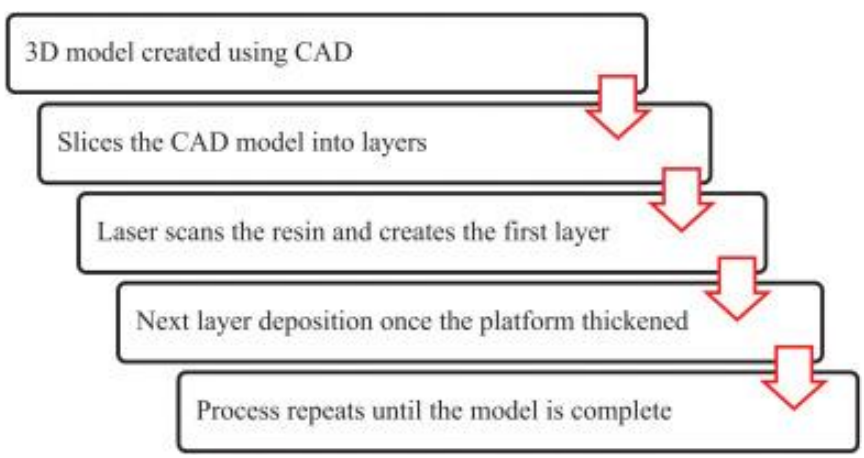


Figure 1.2.1: Basic manufacturing process in SLA method [2]

- **<u>Fused Deposition Modeling (FDM):</u>**

3D printing has a significant impact across diverse domains. Within the expansive realm of 3D printing, various methods exist to bring designs to life, with Fused Deposition Modeling (FDM) standing out as one such method. Considering this, Nitin K. Kumar Anekar et al. [3] employ a layer-by-layer deposition method in their project. Key steps are vital for successful printing. In the pre-processing stage, the 3D model undergoes slicing into layers based on a predefined design. Subsequently, this sliced model is converted into G code using software tools [3]. Following the pre-processing stage, the production phase requires essential components such as an Arduino microcontroller, print bed, extruder, hot end, end stop, stepper motor, and filament to transform the designed model into tangible reality [3].

Wilson, S., Thomas et al. [4], in their paper, explain how the microcontroller processes data and executes the movements required for printing. The stepper motor driver controls the movement in accordance with the pre-designed model. The end stop serves the purpose of defining the maximum distance the axes are supposed to move. The extruder ejects filaments into the hot end, and the hot end heats the filament, pushing it through the nozzle onto the print bed. In the final stage of post-processing, the support material is removed, rendering the printing ready for use [4]. When using FDM 3D printers, several issues may surface. Some are related to the machine and can be adequately addressed, while others are inherent to the material itself. Although the latter are often unavoidable, their impact can be assessed and mitigated. through straightforward techniques.

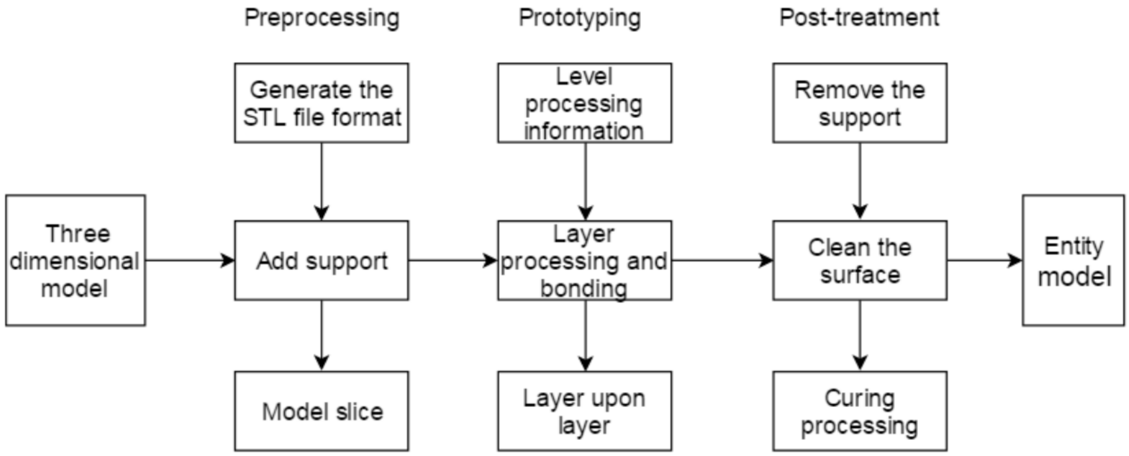


Figure 1.2.2: Process flow chart of FDM 3D printing technology [5]

1.3 Standards and codes of practices

There is no specified standards and codes of practices for this project yet. Because-

i) It is an emerging sector

ii) This industry is not properly established yet

iii) No human-safety issues

iv) No conflict with any other trade sectors

1.4 Stakeholders' expectations/requirements

There are three major types of stakeholders who shall be related to this project. They are:

1. Relevant Industry
2. Vendors
3. Users

Relevant Industry: To acquire requirements, first of all, we went to "Singer Bangladesh Limited", as they are one of the largest manufacturing companies in Bangladesh and can be one of our stakeholders. We went to their head office at Badda and contacted the PD Director (Product Development) there. He shared his valuable views on our project on behalf of the company. According to him-

- The printer should have a large actively heated chamber
- It should have complex printing capability
- A dural system is expected
- It should give design freedom
- It should have dimensional accuracy
- There should be low maintenance cost
- It should offer high reliability
- There should be an option for re-productibility
- Proper safety and monitoring systems should be installed
- Finally, the platforms should be open

Vendors: Firstly, we discussed with 'Singer' to manufacture our 3D printer. 'Singer' assured us they would be a possible vendor if we could fulfill their requirements. Now we talked with 'MK Electronics'. If they want to sell a 3D printer then what would be their requirements after we asked them the answer they had is written below.

- **Cost effect:** they are willing to sell our 3D printer if we can minimize the cost of our 3D printer without much difference from the existing 3D printer.
- **Brand value:** if any big and famous companies which manufacture their product in Bangladesh like ‘Singer’, ‘Walton’, ‘Panasonic’, etc. manufacture our 3D printer then they are willing to sell this 3D printer.
- **Parts and Accessories:** According to them, if the accessories that need to be changed can be provided free of charge for two times, then it is very good and also attractive for the buyers.
- **Guarantee/Warranty:** More guarantee and warranty facilities than the existing competitor companies.

Users: Normally a 3D printer is not an essential product for mass people. SO, we are aiming education sector, medical sector, art and craft sector, industrial fabrication sector as our main users. We have talked to a teacher as a probable user representing a reputed private university from our country. According to him, his requirements are-

- It shall be produced in smaller scale
- It should be capable of making small 3-dimensional objects sized 1mm to 5mm
- Materials should be environment friendly
- Should be recyclable
- Cost should be lower than other available products
- Durability of the printer should be high
- Structure of the printer should be strong
- Expected price range is from 20,000tk – 30,000tk

1.5 Project requirements

After the overviews taken from the stakeholders, we have got to know about several mostly expected functional requirements. Among them, the requirements that we wish to meet are:

1. **Complex printing capability:** By implementing customizable hotent and variable layer height, it will be able to create output according to given design irrespective of complexity.
2. **Design freedom:** Users will be able to enable any design into reality within the specified size.
3. **Dimensional accuracy:** Dimensional accuracy in 3D printing refers to how closely the measurements in our CAD design match those of the parts once it's printed. It's a key consideration if our components need to fit together precisely or if our manufacturing sizable assemblies. In case of our project, the printed object will match the size and specifications of the given design to maintain dimensional accuracy.
4. **Ensuring user-friendly interface:** Our printer will have easily accessible functions like operation, design input and other instructions. Not only the interface but also the whole product as well as the operation procedure will be easily usable.

1.6 Project Management

1.6.1 *Project plan*

A project plan is a work plan. Basically, this is a blueprint of the goals, objectives, and tasks which our team needs to accomplish for the project. Our project plan should include information about our project schedule, scope, due dates, and deliverables for all phases of the project lifecycle.

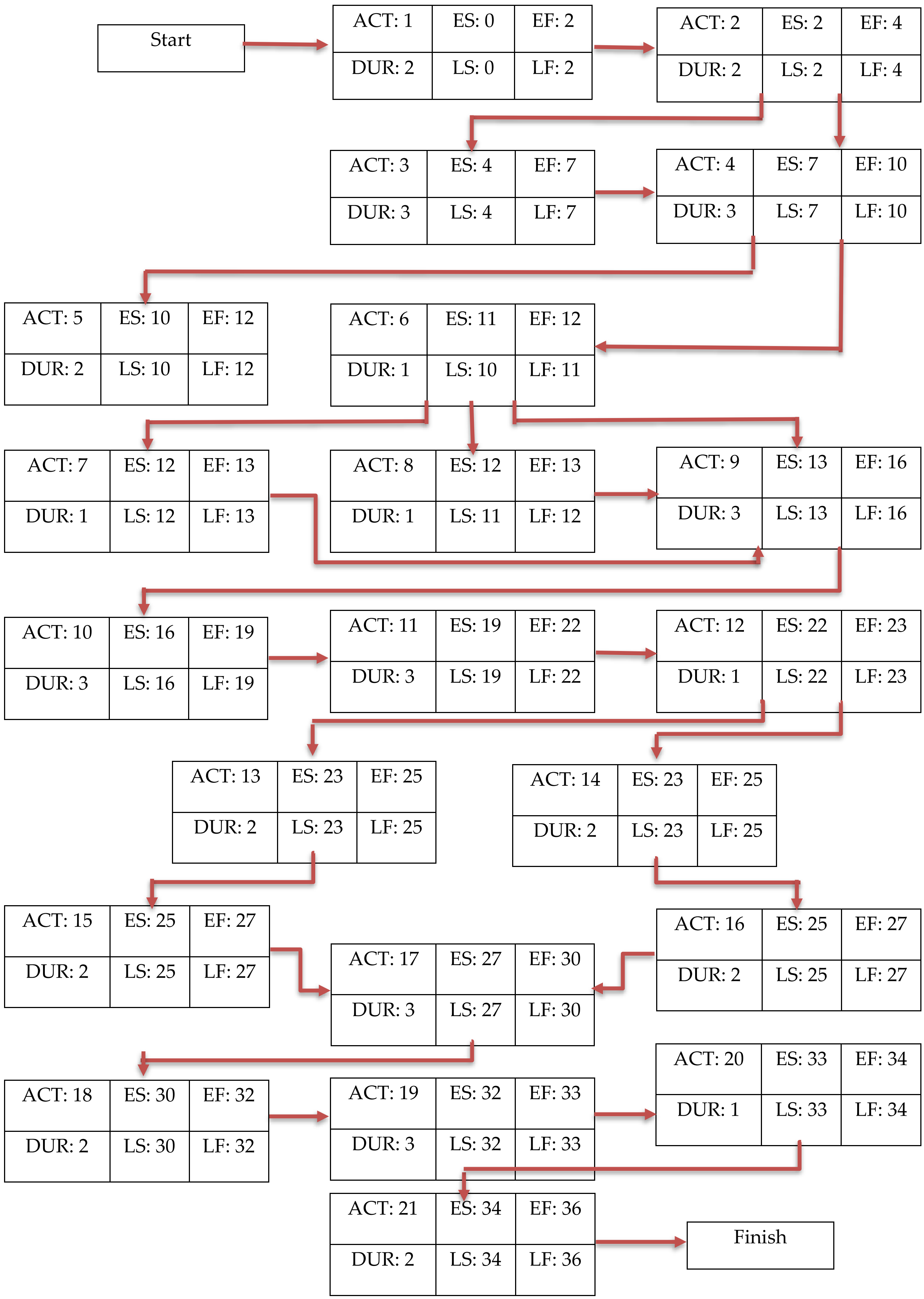
Table 1.6.1.1: Project Timeline

Activity No.	Activities	Duration [Week]	Predecessor	No. of Worker
1.	Topic selection	**2**	**-**	**4**
2.	Approving the topic idea from the supervisor	**2**	**1**	**4**
3.	Prove of social relevance, complex engineering and design problem (Milestone - 1)	**3**	**2**	**4**
4.	Literature Review, Identify the stakeholders and prepare questionnaires for the stakeholders	**3**	**2&3**	**4**
5.	Proceeding with the stakeholder survey and finalizing the requirements (Milestone - 2)	**2**	**4**	**4**

6.	Identification of impact of project on society, Identification of effect of project on environment, sustainability, health and safety issues & Reviewing standards and codes of practice	**1**	**4**	**4**
7.	Project plan and Risk management	**1**	**6**	**4**
8.	Identifying required resources and budget and Analysis project product lifecycle (Milestone - 3)	**1**	**5&6**	**4**
9.	Preparing Project concept and Proposal report (Milestone - 4) 400A	**3**	**6,7&8**	**4**
10.	Preliminary design of the system	**3**	**9**	**4**
11.	Analysis of alternate solution and verify the preliminary design (Milestone - 5)	**3**	**10**	**4**
12.	Cost Optimization	**1**	**11**	**4**
13.	Preparing Report (Milestone - 6) 400B	**2**	**12**	**4**

14.	Find out equipment availability	**2**	**12**	**4**
15.	Preparation of draft design	**2**	**13**	**4**
16.	Purchase equipment	**2**	**14**	**4**
17.	Implementation	**3**	**15,16**	**4**
18.	Performance evaluation of the system	**2**	**17**	**4**
19.	Finalization of design based on performance evaluation (Milestone - 7)	**1**	**18**	**4**
20.	Demonstration of the working product And Bill of materials cost of solution and Economic analysis	**1**	**19**	**4**
21.	Preparing final report and presentation (Milestone - 8)	**2**	**20**	**4**

Now, we will design the Critical Path Method (CPM) diagram. This will allow us to determine the scheduling flexibilities of the necessary tasks. Critical path indicates the longest path required to maintain to finish the project on time. The rest of the project will be delayed if critical tasks are delayed.


Start
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ACT: 5 ES: 10 EF: 12 DUR: 2 LS: 10 LF: 12
ACT: 6 ES: 11 EF: 12 DUR: 1 LS: 10 LF: 11
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ACT: 8 ES: 12 EF: 13 DUR: 1 LS: 11 LF: 12
ACT: 9 ES: 13 EF: 16 DUR: 3 LS: 13 LF: 16
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ACT: 20 ES: 33 EF: 34 DUR: 1 LS: 33 LF: 34
ACT: 21 ES: 34 EF: 36 DUR: 2 LS: 34 LF: 36
Finish

Critical Path: ACT:1 – ACT:2 – ACT:3 – ACT:4 – ACT:6 – ACT:8 – ACT:9 – ACT:10 – ACT:11 – ACT:12 – ACT:13 – ACT:15 – ACT:17 – ACT:18 – ACT:19 – ACT:20 – ACT:21

The Project Completion Time: 36 Weeks

The CPM diagram also contains Forward Pass and Backward Pass diagram, which has_

ES - Early Start

EF – Early Finish

LS – Late Start

LF – Late Finish

Act - Activity

Dur – Duration (Week)

A Gantt chart is an excellent tool for visualizing when each project task will be completed. This could be viewed as a brief visual representation of the timeline. Below is a Gantt chart of our capstone project.

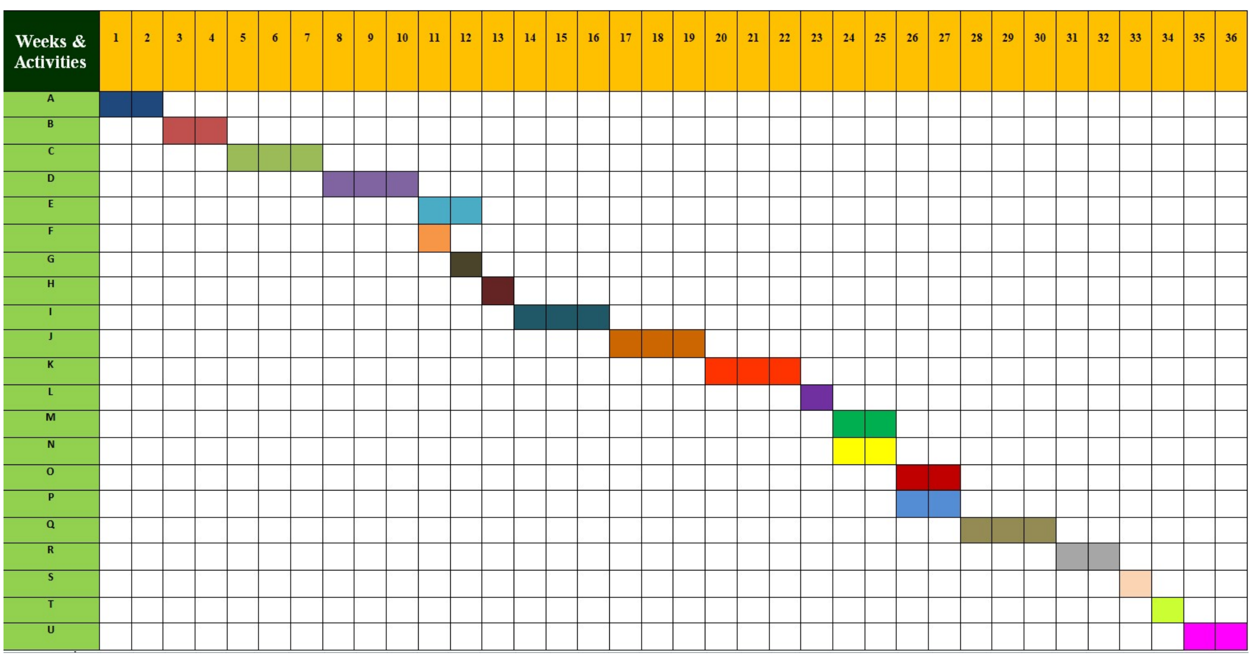


Figure 1.6.1.1: Gantt Chart

1.6.2 *Risk management*

- **Unavailability of equipment:** We need the necessary equipment in order to successfully finish the project on time. But it is a very common problem that all the equipment's are not always available in the market. As a result of which we have to face various problems to finish the project and it can be delay the project's time.

- **Over budget problem:** Many times, we make an initial budget for the project. But if the costs of any equipment's are increases during the project, then it will have a bad effect on the budget of the project. If there is no equipment, we have to manage alternative equipment. That could also increase our costs.

- **Mitigation Plan:** Our big challenge is to complete the project on time at any cost. So, we have to mitigate the risks that were addressed to finish the project on time. If any equipment is not in the market, we may have to buy other alternative equipment. Even it may be that we need to buy equipment from other countries. The situation of the international market is not so good because of Russia-Ukraine & Palestine-Israel war. Due to which the price of equipment is likely to increase. We need to keep an eye on this kind of problem so that it does not become a big obstacle for us. Also, during the project, we may have communication gap because not everyone in the group is always available. So, to make our communication stronger we can hold meetings online when we need. During the project, we may have many small and big problems may come, we can have different plans like 'Plan-A, Plan-B, Plan-C' to overcome them.

- **<u>Contingency Plan:</u>** If the mitigation plan does not work for us then we have to go to another plan, which is the contingency plan. If we see that a part is not available anywhere, then we can do without it or plan it in another way. Also, we can all share our works. We can set a team leader who understands all these things better than us. We can share a different milestone of each other's work. Hopefully, if we go through like this, then we can successfully overcome all the obstacles of our project and complete it.

1.6.3 Required resources and budget.

To finish the project, we need to figure out how much money and resources are required. It's hard to give an exact number because the project is only in stage 400A. So, we'll have to guess and estimate since there are still many things we don't know.

Resources

- **Computer** (Equipped with decent requirements for running all the software)
- **Software:**
    - Arduino IDE
    - AutoCAD
    - Marlin 3D printer Firmware
    - Cura 3D Printing Slicing Software

- **Hardware:**
    - Arduino Mega
    - Ramps
    - Power supply
    - SD Card

- Logic Wire
- Stepper Motor
- Mechanical End Stops
- Smart full graphic display from discount RepRap
- Three Prong Wall Cord and Connector
- Male to Female Wire
- Ring Crimp Connector
- Large Gauge wire
- logic wire
- Electrical tape
- Tape, Velcro, or other cable management solutions

➢ **Tools:**

- Soldering iron
- Solder
- Wire strippers
- Crimpers

Table 1.6.3.1: Project Budget

Name of Equipment/Service	Unit Price (BDT)	Quantity/Amount	Total (BDT)
Arduino Mega	1895	1	1895
Ramps	2000	1	2000
Power supply	1400	1	1400
SD Card	600	1	600
Stepper Motor	1300	5	6500

Mechanical End Stops	180	6	1080
Smart full graphic display from discount RepRap	1800	1	1800
Wire, connectors other cable management solutions	-	-	1000
Extruder	1200	1	1200
Body	-	-	2000
Stepper Motor driver with heatsink	200	5	1000
Travel	-	-	1000
Others	-	-	1000
Total			22475

1.7 Projected product lifecycle

To start with, we have the initial advantage in our country because there is currently no existing 3D printer locally. As a result, our first priority will be to make sure that our 3D printer is helping educational purposes, the medical sector and art and craft industries. After that, we will make sure that our 3D printer is easy for the user's access. Furthermore, we will make sure that we are using recycled plastic which will help to reduce global warming.

However, if this product is to be mass-produced and for the business to be sustainable, we must introduce new functionalities to the 3D printer and ensure the smooth operation of the manufacturing process. Among the factors that are critical to continue the smooth running of the business and ensure a long product life cycle are new features to keep the users interested and adequate after-sales service which include customer service and technical support. As a result, we have developed our strategies for addressing these facts and our strategies for addressing these facts, along with other planned new features, are described below:

1. **<u>After-sales Service</u>**
   - **Customer Service:** Our primary customers would be the art and craft industries who buy our 3D printer and we will see the recycled plastic waste. We will hire sales professionals to make sure that they can understand the qualities of our product with respect to the normal 3D printers which are on the market.
   - **Technical Support:** We will ensure technical support to our customers in the circumstance that the 3D printer is not working successfully or malfunctioning in any way. Moreover, it will be made sure that there is a smooth integration of the existing 3D printer of art and craft industries with the network of our 3D printer.
2. **<u>Marketing Campaigns</u>**

   In the future, we can launch online marketing campaigns to increase people's awareness of our product. As a result of this, people will recognize our 3D printer and they will want to experience using it.
3. **<u>Implementation in other sectors</u>**

   Depending on our success we can try to implement the product in the medical sector and industrial fabrication.

1.8 Impacts of the project

1.8.1 *Impacts on society*

Bangladesh, in South Asia, is at a crucial point where old ways meet new. As the country moves forward in the 21st century, 3D printing can make a big difference in how things work, both socially and economically. This groundbreaking technology, usually seen in developed countries. It brings exciting possibilities and sparks new ideas in different areas, opening doors for progress and innovation.

Our project "Design and Implementation of Mini Artifi 3D printer " will have the following impact on our society:

- **Empowering Local Industries:** In Bangladesh, a global textile and garment industry leader, the advent of 3D printing is poised to bring about significant transformations. This advanced technology is ready to revolutionize the industry, bringing with it a range of benefits that go beyond just textiles. Unlike the old-fashioned ways that use a lot of resources and take a long time, 3D printing allows for quick and detailed creation of textile designs and prototypes. This means a faster and more efficient way of doing things that can push the industry forward. The impact of 3D printing is not confined to the textile sector alone; various industries such as toy manufacturing, showpiece production, automobile manufacturing, and architectural firms are poised to reap benefits as well. The technology facilitates swift prototyping, efficient design implementations, and streamlined mass production processes across these diverse sectors.

  Furthermore, the introduction of 3D printing can pave the way for the establishment of standalone companies dedicated to this technology. These enterprises can potentially give rise to an entirely new industry within Bangladesh, generating employment opportunities and contributing to economic growth. The implications of 3D printing extend far beyond the textile industry, opening doors for innovation, efficiency, and economic diversification across multiple sectors in the country.

- **Revolutionizing Healthcare Access:** Bangladesh faces challenges in healthcare, 3D printing is expected to make big changes. The issues include not having enough resources and problems accessing specialized medical services. But 3D printing has the potential to help. In a sense, 3D printing will revolutionize healthcare by making personalized and affordable medical solutions. This might mean creating custom-made prosthetics and making dental implants that more people can afford, breaking down barriers to important healthcare services.

- **Educational Transformation:** In the future of education in Bangladesh, using 3D printing will make learning super cool and helpful. It lets students touch and see things in a special way, especially in subjects like science and math. With 3D printing, students can make real models of things they're learning about, making it much more interesting. This new way of learning fits well with STEM education, which is all about science, technology, engineering, and math. It helps students be creative and solve problems by letting them design and create their own projects. In technical and job-related classes, 3D printing is like a magic tool. Students can turn their ideas into real things they can touch, helping them learn how things are designed and made. Even in places with fewer resources, like remote areas, schools can use 3D printing to make custom tools and models for teaching. Adding 3D printing to the school lessons also encourages students to think like entrepreneurs. They can use their creativity to make things and maybe even start their own small businesses.

In the medical field, 3D printing helps students studying medicine by creating models of the human body. This makes it easier for them to learn about complicated body parts. So, with 3D printing in schools, Bangladesh will be preparing students for an awesome future. They'll learn cool things, be creative, and maybe even start their own businesses.

- **Localized Production and Economic Resilience:** By using 3D printing Bangladesh can make its economy more resilient and self-sufficient. This technology allows local businesses to produce goods on-site, reducing dependence on distant suppliers. By adopting 3D printing, companies can manufacture products closer to home, which is a smart strategy to navigate any global market challenges. Localized production through 3D printing is not just a vision; it's a practical solution for Bangladesh. It offers the potential to create jobs and new business opportunities. This technology enables entrepreneurs to start their ventures and contribute to the local economy. Moreover, relying on 3D printing for manufacturing ensures that Bangladesh has a reliable supply of essential goods, even in the face of disruptions in the usual supply chain. In essence, 3D printing is a tangible tool for economic empowerment, job creation, and securing the country's needs. It's a realistic approach to building resilience and self-sufficiency within Bangladesh, ensuring a more robust and adaptable economy for the challenges ahead.

- **Waste reduction:** Bangladesh, 3D printing can be a green game-changer. Traditional manufacturing often creates a lot of waste, but 3D printing builds things layer by layer, cutting down on material waste. Also recycling materials then using them in 3D printer can be very effective and efficient. It also lets us make things close to where they're needed, reducing the pollution from transporting goods. Plus, 3D printing can use eco-friendly materials that are better for the environment. This technology allows us to customize products, making them last longer and reducing the need for replacements. As we focus on saving energy, 3D printing is becoming more energy-efficient too. In Bangladesh, where proper waste management is a challenge, 3D printing offers a smart way to make things while caring for our environment.

1.8.2 *Effects on environment and sustainability*

Implementing the project on a large scale to address a critical societal issue comes with unavoidable environmental consequences. While the project's focus on addressing societal concerns is commendable, it's crucial not to overlook the environmental impact. Therefore, it becomes imperative to introduce and implement effective mitigation measures to counteract these environmental consequences.

3D printing is pretty amazing, but we need to think about how it affects the environment. Let's break it down to understand the possible environmental concerns.

First off, the stuff used for 3D printing, like plastic filaments, usually comes from fossil fuels. That's not great for the environment because getting and processing these materials can lead to pollution and greenhouse gas emissions. Also, the energy used by 3D printers can be a problem, especially if it comes from non-renewable sources like coal. So, the whole process might be adding to the carbon footprint.

Now, let's talk about waste. Sometimes, 3D prints don't turn out right, or there are leftover support structures that need to be removed. This creates plastic waste, and if we don't handle it properly, it could end up causing pollution. Figuring out what to do with this waste is important to keep our environment clean.

When 3D printers do their thing and melt plastic filaments, it can release chemicals into the air. These chemicals, called volatile organic compounds (VOCs), might not be great for us to breathe, so that's another thing to consider.

When it's time to say goodbye to 3D-printed stuff, throwing it away can be a puzzle. If it's not recycled properly, it might end up in landfills, and that's not good for the environment. So, finding smart ways to handle the end-of-life phase of 3D printed items is crucial.

Now, if we switch gears to metal 3D printing, handling the metal powders used in the process can be risky for both people and the environment.

To make 3D printing friendlier to the environment, we need to think about using materials that are kinder to the Earth, being wise about how we use energy, and figuring out smart ways to deal with the waste. As 3D printing keeps getting better, it's crucial to find ways to make it eco-friendlier and more sustainable for a healthier planet.

1.8.3 *Health and safety issues*

We will address some of the health and safety issues regarding our project below:

- **<u>Heat and Fire Hazards</u>**
  - **Heat Surface:** 3D printers don't have any hot components, such as heated beds and Extruders. Users should avoid touching these parts during operation.
  - **Fire Risk:** if the printer has not been properly maintained then the heating component of a 3D printer has a fire risk. Never leave a 3D printer unattended during operation.

- **<u>Electrical Hazard</u>**

  Faulty wiring and damaged electrical components can pose electrical hazards. Regularly inspect the printer's electrical components.

- **<u>Maintenance Risk</u>**

  Regular maintenance is circular to keep the 3D printer in good working condition. Follow the manufacturing guideline for maintenance and reduce the safety risk.

- **<u>Training and Supervision</u>**

  Proper training and supervision are essential for users, especially those new to 3D printing.

1.9 Instructions on how to use this template.

This section provides instructions on how to use this template. This section should be deleted while writing the project report.

Equation example (**<u>recommended</u>**)

$$y = x^2 + c \tag{1.1}$$

The equation is done inside a 3-column table. To see the invisible lines of all the tables, put cursor in the table or equation, go to 'Layout' tab and select 'View Gridlines'. Always copy-paste this table to write another numbered equation so that the equation number is automatically updated. Cross-referencing can be done through 'References' tab > 'Cross-reference'.

Below is an example of a table. Whenever you have a new table, copy-paste the caption so that the numbering is automatically updated. Cross-referencing can be done through 'References' tab > 'Cross-reference'.

Table 1.1 Appropriately write your caption

Below is an example of a figure with caption. Whenever you have a new figure, copy-paste the caption so that the numbering is automatically updated. Cross-referencing can be done through 'References' tab > 'Cross-reference'. Do not damage the aspect ratio in your figures.

Fig. 1.1 Your figure caption goes here.

Referencing should be done in IEEE format using Zotero, Mendeley, EndNote, etc. Manual citations are not allowed. Example citation: "Meta-surfaces provides the means to bend light to our will through flat-optics [1], [2]. A review by Walia *et al*. summarizes recent work in meta-surface designs [3]."

PART-B

This part includes the design, analysis and optimization of the project as prepared in EEE400B.

Chapter 2 Project Design

2.1 Functional design

Revising project objectives & motivation-

1. The main target of this project is to enable design into reality.
2. It will produce 3D object as output according to the given design as input.
3. The impact of use cases for 3D printers on the mass public is transformative, influencing various aspects of daily life, industry, and innovation. As our main target is the public, our primary goal is to make manufacturing more accessible to everyone. By enabling individuals to create customized, on-demand products, 3D printing empowers people to turn their ideas into physical objects without the need for extensive manufacturing infrastructure. This shift fosters creativity and entrepreneurship, allowing small businesses and hobbyists to compete with larger companies. Such use cases are:

   - **Medical Sector:** 3D printing is increasingly utilized in the medical field for custom implants, prosthetics, surgical tools, anatomical models, and bioprinting tissues. It enables patient-specific customization and has been instrumental in complex surgeries.
   - **Automotive Sector:** Additive manufacturing has revolutionized the automotive industry by producing lighter, stronger, and safer products quickly. It's used for lightweight parts, replacement parts, and prototypes, minimizing material waste and reducing time and cost for testing new designs.
   - **In the electronics industry:** 3D printing makes it easier to create intricate and useful items. This technology is pushing forward developments in wearable electronics, soft robots, and interfaces between humans and

machines. Engineers are even making electronics that can stretch, bend, and be put into other materials. Additionally, 3D printers can now make printed circuit boards (PCBs), which are essential components in many electronic devices.

- **Food Sector:** 3D printing in the food industry allows for the creation of nutritious meals, personalized nutrition, and various shapes and sizes of food items. Techniques include extrusion-based printing, inkjet printing, and binder jetting.
- **Maintenance and Repair:** Additive manufacturing is beneficial for producing or repairing parts quickly in industries like aerospace. It's used for prototyping, manufacturing specialized tools, and creating high-performance components without traditional tooling.
- **Education Sector:** 3D printing enhances learning by providing tangible objects for hands-on experiences, promoting creativity, understanding, and collaboration among students.
- **Jewellery Industry:** 3D printing expands design possibilities in jewellery production, incorporating diverse materials alongside traditional precious metals. Methods include Investment Casting and Direct Printing, both starting with CAD design.
- **Fabric and Fashion Sector:** 3D printing is merging with fashion, offering benefits like reduced supply chain costs and on-demand customization. It's used for creating unique designs in clothing, shoes, and accessories.
- **Eyewear Sector:** Customization capabilities of 3D printing benefit the eyewear industry, resulting in comfortable, high-quality glasses at lower costs, with minimal waste.

- **Model Making:** 3D printing makes detailed miniatures and scale models more affordable and achievable, benefiting businesses focused on custom modeling and aiding fields like forensic reconstruction and paleontology.
- **Micro fluidics:** In microfluidics, 3D printing, specifically fused deposition modeling (FDM), offers a cost-effective, simple, and quick method for creating microfluidic devices from CAD models. This technology drastically reduces the time from design to practical experimentation, accelerating research and development from weeks to hours. However, standard 3D printers typically can't produce fluidically sealed devices. Dolomite Microfluidics addresses this with the Fluidic Factory, an innovative tool enabling FDM printing of sealed microfluidic devices using a biocompatible polymer (COC). This advancement streamlines microfluidic prototyping, enhancing efficiency and accessibility in research and development.

Beyond these sectors, 3D printing holds promise for applications in housing and construction, space travel, and historical artifact recreation. It also opens new job opportunities in design, manufacturing, maintenance, product development, and sales.

As 3D printing technology expands, there's a growing demand for skilled workers and opportunities for entrepreneurs to establish small-scale businesses offering customized products and services.

Revising project requirements-

1. Complex printing capability: By implementing customizable hotent and variable layer height, it will be able to create output according to given design irrespective of complexity.
2. Design freedom: Users will be able to enable any design into reality within the specified size.

3. Dimensional accuracy: Dimensional accuracy in 3D printing refers to how closely the measurements in our CAD design match those of the parts once it's printed. The printed object will match the size and specifications of the given design to maintain dimensional accuracy.
4. Ensuring user friendly interface: Our printer will have easily accessible functions like operation, design input and other instructions. Not only the interface but also the whole product as well as the operation procedure will be easily usable.

Revising Standards & codes of practices-

1. In this case, we have found out that, in our country, there are not any set standards or regulations for how a 3D printer shall be made. However, the production of commercial 3D printers in China, one of the countries that are sitting on the leading positions in this industry, is typically governed by a combination of domestic standards, international standards, and industry best practices. Here are some key aspects:
    - **International Standards**: Chinese manufacturers often adhere to international standards developed by organizations such as ISO (International Organization for Standardization) and ASTM International. These standards provide guidelines for aspects like terminology, material properties, testing methods, and safety requirements applicable to 3D printing.
    - **CE Marking**: While CE marking is a European requirement, many Chinese manufacturers producing 3D printers intended for export to the European market ensure compliance with CE directives and standards, particularly related to safety and electromagnetic compatibility.

- **Quality Management Systems**: Chinese manufacturers may implement quality management systems based on ISO 9001 standards to ensure consistent product quality and adherence to regulatory requirements.
- **Industry Best Practices**: Chinese companies producing 3D printers often adopt industry best practices and guidelines established by organizations such as ASTM International, America Makes, and the Additive Manufacturing Consortium to ensure product quality, safety, and performance.
- **Customs and Import Regulations**: Chinese manufacturers exporting 3D printers to other countries must comply with the import regulations and standards of the destination countries. This may involve ensuring that the products meet specific technical requirements and safety standards applicable in those markets.

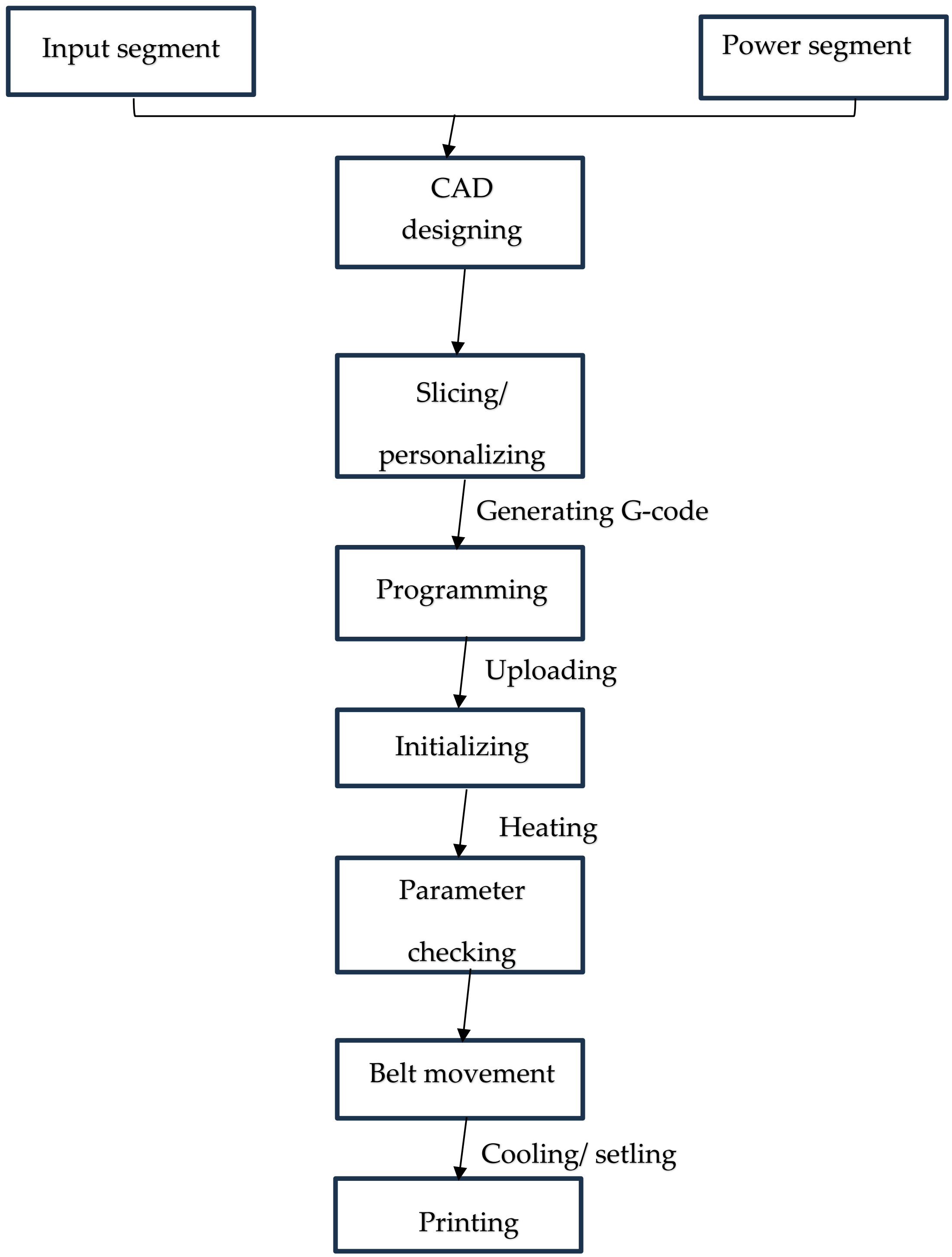
As there are not any specific "standard codes and practices" exclusively for producing commercial 3D printers in Bangladesh, we are planning to follow these standard codes and practices while building our project with a view to following a combination of domestic regulations, international standards, and industry best practices to ensure the quality, safety, and compliance of our products for both domestic and international markets.

2. There are many types of materials that are used to create objects using a 3D printer. Among them, some common materials are: metal, plastic, semiconductor, **Polydimethylsiloxane** (PDMS), Ceramics, Resins, COC Polymer etc. But we will use plastic in our project as basic material.
3. Industrial 3D printers are large in size and expensive in cost. But our aim is to make it available for mass people. So, this consumer product will be smaller and compact in size.

Revising effects on environment & health issues

1. One of the purposes of this project is to reduce harm to the environment by recycling plastic.
2. Careful steps about using recycled plastic can reduce the damage of nature to great extent.
3. We should also be careful about throwing the components of this product into environment as it would contain various chemicals and toxic substance that can harm the ecosystem.
4. Professionals may be needed to reduce the product defects.

By considering all the requirements, the functional block diagram will be as follows-



2.2 Analysis of alternate solutions

Since we're tackling an open-ended problem, we've selected two different approaches to build our system. While both are based on practical implementation, only one of them meets the specific requirements we outlined.

Alternate Solution in terms 3D printer:

To compare the solution, we have selected two parameters.

Which are

1. Accuracy
2. Cost Analysis

From literature review we have found two alternate solutions that can be implemented to our project. Which are FDM and SLA Method

Accuracy:

FDM Method

The machine parameters for Fused Deposition Modeling (FDM) 3D printing include bed leveling and nozzle size. The process parameters encompass nozzle temperature, bed temperature, extrusion width, and raster orientation. [6]

FDM printing uses a nozzle to deposit material on the build platform in a precise layer-by-layer manner. Consistent nozzle-to-bed distance is crucial for quality prints; poor calibration can cause warping or collisions. Nozzle size impacts print speed and detail, with larger diameters providing faster production but potentially lower precision. [6]

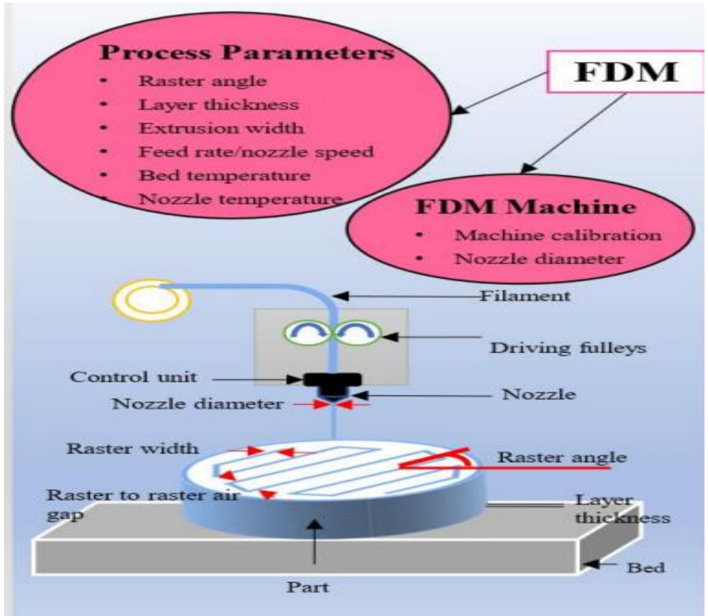


Figure 2.2.1: Overview of the process parameters of FDM [6]

FDM systems can be divided into two types. The Bowden setup has an extruder separated from the moving hot end, with filament transported through a Bowden tube. This design makes the print head smaller and lighter but can lead to issues with flexible filaments due to compression and friction in the tube. Using a tube with tighter tolerances can help mitigate these problems. [7]

The Direct-drive setups position the extruder on top of the print head, providing a short and direct path for filament to the hot-end. This design is ideal for flexible filaments, reducing compression and kinks. A fully constrained filament path from the drive gear to the hot end helps prevent filament slippage or escaping during printing. [7]

The filament can be transported in two possible ways to the hot end. By a Bowden setup (a), where the extruder is decoupled from the hot end, and a direct-drive (b), where the extruder is mounted on the hot-end. Fully constraining the filament path (as shown right) prevents tangling of the filament. [7]

Increasing nozzle diameter has been shown to improve part quality and mechanical properties in FDM 3D printing. Ambient temperature is a key factor that affects part warpage. Studies report that PLA warpage rates are about 50%, 30%, and 10% at ambient temperatures of 10 °C, 15 °C, and 20 °C, respectively.

Several process parameters impact the properties of parts in FDM, including raster angle, extrusion width, extrusion rate, bed temperature, nozzle temperature, and nozzle speed. The raster angle is the angle between the nozzle's direction and the x-axis (or y-axis) of the printing platform. Extrusion rate defines how quickly filament extrudes from the nozzle onto the build platform. [6]

From literature we got Bed temperature is crucial for maintaining adhesion between the build platform and the printed part, reducing warpage. Nozzle temperature is the heat level at which the filament melts for extrusion. It significantly affects the mechanical properties and microstructure of printed parts. For example, relative density in PEEK increased from 89.9% to 92.8% when nozzle temperature rose from 370 °C to 390 °C. [6]

Nozzle speed refers to how quickly the nozzle moves during printing. It influences dimensional accuracy, with faster speeds reducing print time but potentially affecting wall thickness. For example, a wall thickness increase from 2.00 mm to 2.17 mm was reported when nozzle speed rose from 30 mm/s to 90 mm/s. [6]

A tensile test in 3D printing is vital for assessing the mechanical properties and performance of 3D-printed materials and parts. It determines key metrics like tensile strength, yield strength, elongation at break, and Young's modulus, aiding in material characterization. This test supports quality assurance by ensuring consistent mechanical properties, helping to verify design strength and flexibility, and guiding process optimization through optimal printing parameters. Tensile testing also allows comparative analysis between different materials and printing techniques. It's crucial for safety and compliance, especially in industries like education, medical, and contributes to research and development, facilitating the advancement of 3D printing technology.

Form literature two equation are used to get the tensile test results,

$$\Delta L = \varepsilon . L . \frac{1}{100\%} \tag{1}$$

$$F_{max} = E . A . \frac{\Delta L}{L} \tag{2}$$

The maximum displacement, ΔL, was calculated using Equation (1), where ε represents the nominal strain at break, and L is the initial distance between grips. Additionally, the maximum force at break, F_{max}, was determined using Equation (2). In this equation, E denotes Young's modulus, A is the smallest cross-sectional area, ΔL is the maximum displacement, and L is the initial grip separation distance. [8]

Case	Specimen Code	Tensile Strength σ [MPa]	Strain ε [%]	Nominal Strain at Break ε_{tB} [%]	Young's Modulus E [MPa]
Case 1	1A_30	19.423	2.11	2.51	1376.824
	2A_30	19.756	2.15	3.13	1138.182
	3A_30	19.545	2.14	2.42	1409.644
	4A_30	18.911	2.22	2.76	1278.181
	5A_30	19.912	2.17	2.54	1400.937
	Average (St. Dev.)	19.509 (0.384)	2.16 (0.04)	2.67 (0.28)	1320.754 (114.695)
Case 2	1A_100	26.715	2.33	4.75	1730.422
	2A_100	28.635	2.26	3.22	1831.286
	3A_100	27.187	2.28	3.09	1751.838
	4A_100	27.545	2.13	3.11	1920.691
	5A_100	26.925	2.20	3.92	1788.691
	Average (St. Dev.)	27.401 (0.756)	2.24 (0.08)	3.62 (0.72)	1804.586 (75.380)

Figure 2.2.2: FDM 3D-printed ABS tensile-tested specimens: test results [8]

Here, Case 1 denotes tensile test outcomes for FDM 3D-printed ABS samples with a 30% in fill density and Case 2 denotes tensile tests for ABS samples with a 100% in fill density. [8]

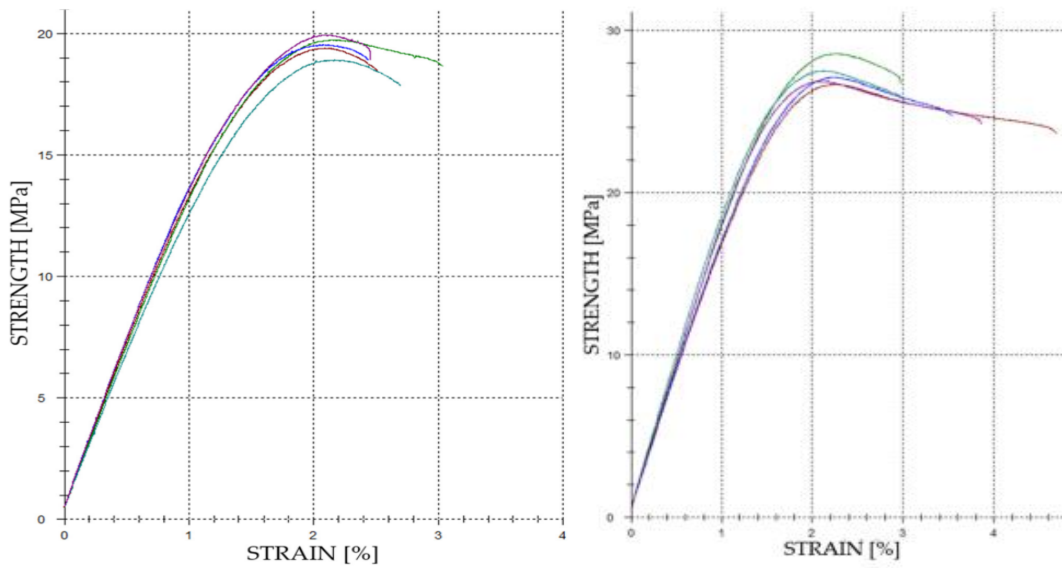


Figure 2.2.3: The tensile strength–strain curves for ABS specimens produced using FDM 3D printing with a 30% infill density (left) 100% infill density (right) [8]

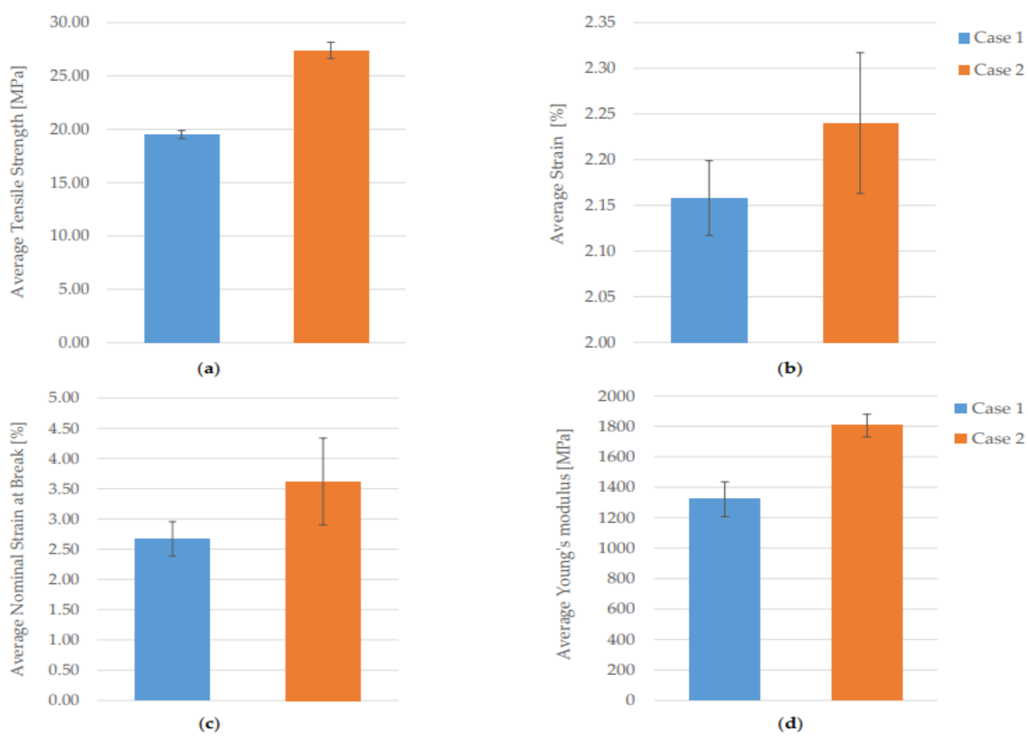


Figure 2.2.4: The mechanical parameters of ABS 3D-printed specimens using FDM were tested under tensile loading conditions at two different infill densities: 30% (Case 1) and 100% (Case 2): (a) average tensile strength, (b) average strain, (c) average nominal strain at break, (d) average Young's modulus [8]

The average strain in FDM 3D-printed ABS material specimens with 100% infill density was 3.57% higher compared to those with 30% infill density (refer to Figure 2.2.2 and Figure 2.2.4b). The impact of infill density on ABS specimens produced via FDM 3D printing is evident when examining the average nominal strain at break and the average Young's modulus, as illustrated in Figure 2.2.4. [8]

The average nominal strain at break for FDM 3D-printed ABS specimens with 100% infill density was 26.24% higher than that for specimens with 30% infill density (Figure 2.2.4c). Likewise, Young's modulus followed a similar trend, indicating that it was 26.81% lower in specimens with 30% infill density compared to those with 100% infill density (Figure 2.2.4d). [8]

Using tensile test data from Figure 2.2.2 and applying Equations (1) and (2), the maximum force at break and the maximum displacement were calculated for FDM 3D-printed ABS specimens subjected to tensile testing. Figure 2.2.5 and Figure 2.2.6 present the respective average maximum displacement and average maximum force at break for these specimens.

Case	Specimen Code	Max. Displacement ΔL [mm]	Max. Force at Break F_{max} [N]
Case 1	1A_30	2.89	794.750
	2A_30	3.60	822.497
	3A_30	2.78	817.702
	4A_30	3.17	771.801
	5A_30	2.92	825.025
	Average (St. Dev.)	3.07 (0.33)	806.355 (22.729)
Case 2	1A_100	5.46	1177.557
	2A_100	3.70	1217.823
	3A_100	3.55	1198.283
	4A_100	3.58	1194.612
	5A_100	4.51	1181.455
	Average (St. Dev.)	4.16 (0.83)	1193.946 (15.922)

Figure 2.2.5: The calculated value of mechanical parameters for FDM 3D-printed ABS tensile test specimens. [8]

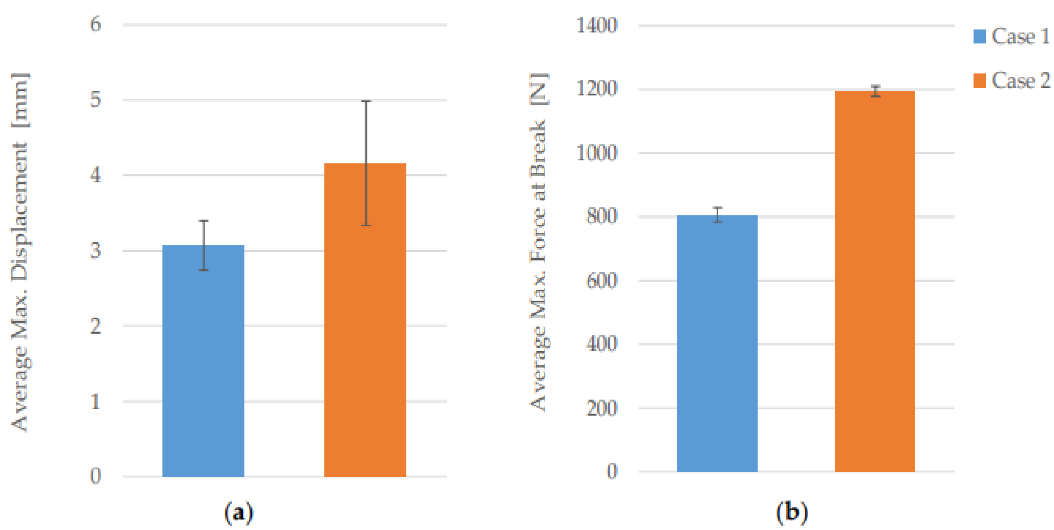


Figure 2.2.6: The calculated average value of mechanical parameters for FDM 3D-printed ABS tensile- tested specimens: (a) average maximal displacement and (b) average maximal force at break. [8]

According to the data in Figure 2.2.5, FDM 3D-printed ABS specimens with 100% infill density showed a 35.51% increase in average maximum displacement compared to specimens with 30% infill density. Additionally, the average maximum force at break increased by 26.29%. [8]

According to the manufacturer's specifications for ABS filament from Figure 2.2.7(a), the tensile strength of FDM 3D-printed ABS specimens with 100% infill density is approximately 63.72% of the original filament's tensile strength. [8]

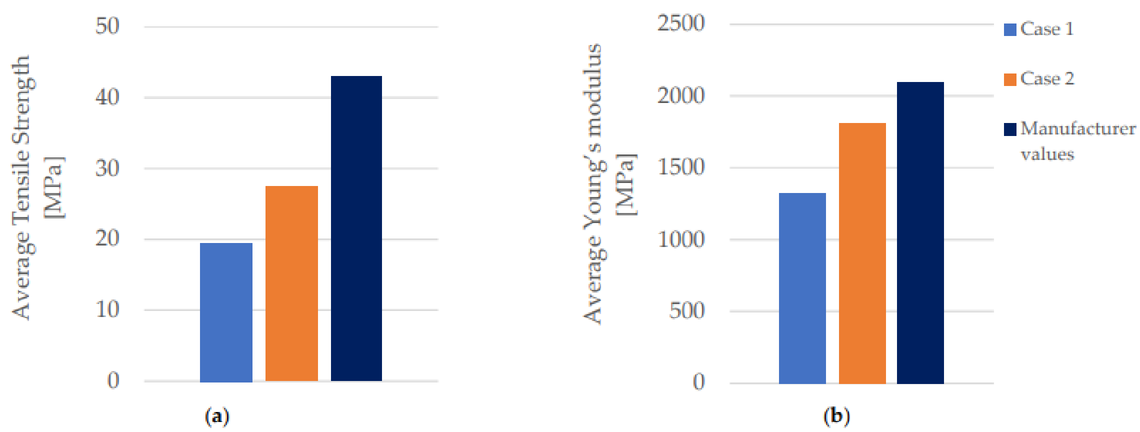


Figure 2.2.7: Comparison between tensile strength and Young's modulus of FDM 3D-printed ABS specimens post-tensile testing and manufacturer-specified filament values: (a) average tensile strength, (b) average Young's modulus. [8]

Similarly, when analyzing Young's modulus, a comparison between the results for FDM 3D-printed ABS specimens with 100% infill density and the manufacturer-specified values for ABS filament reveals that the FDM-printed specimens achieve about 85.92% of the filament's designated values, according to figure 2.2.7(b).

SLA Method:

SLA functions through photopolymerization, a process where a liquid resin solidifies due to the light-triggered initiation of a chemical reaction. As the photocurable resin absorbs light, it hardens, enabling the formation of three-dimensional objects. [6]

Photopolymerization utilizes light rays to trigger a chain polymerization process, leading to the photo-crosslinking of existing macromolecules. The crosslinker bonds polymer chains together through covalent or ionic bonds. This process solidifies a pattern within the resin layer, facilitating adhesion between subsequent layers. A photoinitiator or photoinitiator system is necessary to convert photolytic energy into reactive species (radicals or cations) for chain growth. The molar attenuation coefficient measures the light attenuation by a chemical species at a specific wavelength. Photoinitiators with high molar attenuation coefficients at short wavelengths (UV < 400 nm) are commonly used to initiate photochemical reactions. [6]

In SLA 3D printing, a computer-controlled laser beam illuminates a specific pattern on the surface of a resin, causing the resin to solidify where the beam strikes. This process is repeated layer by layer to create a three-dimensional object. The thickness of each layer is determined by the energy of the light source and the exposure time. [6]

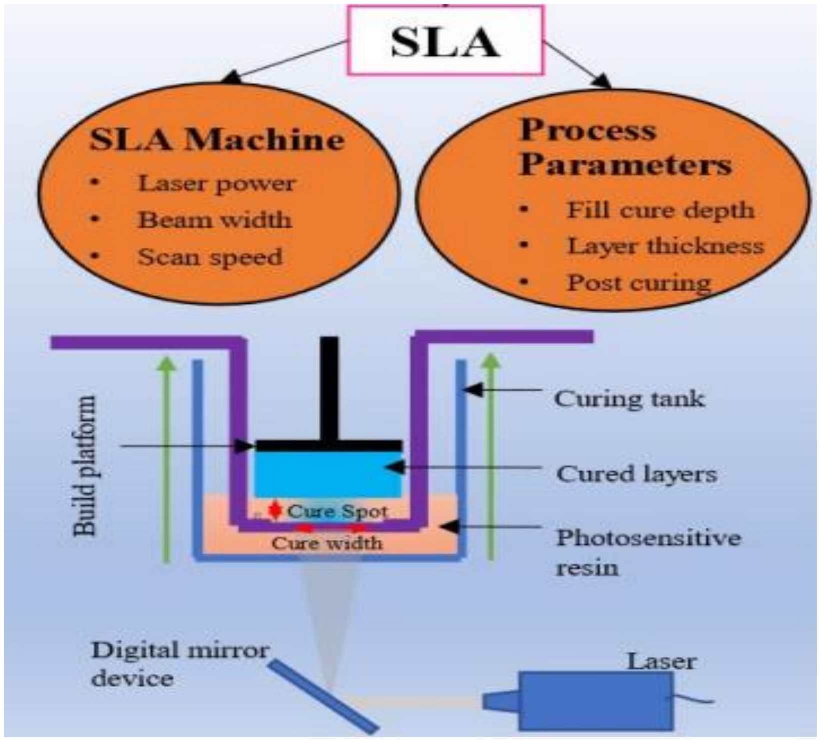


Figure 2.2.8: Overview of the process parameters of SLA [6]

The quality of SLA-printed parts is influenced by several key process parameters, including cure depth, layer thickness, and post-curing. Cure depth is determined by the energy of the light exposed to the resin, which is controlled by laser power and exposure time. A high enough cure depth ensures efficient fabrication, while avoiding excessive polymerization that could compromise resolution and detail. However, if the cure depth is too high, parts may be over-cured, resulting in poor quality and low precision. Cure depth (Cd) is calculated using an equation derived from the Beer–Lambert law:

$$Cd = Dp\ log\frac{E}{E_C}$$

In SLA 3D printing, cure depth (Dp) is influenced by light exposure (E, in J/m²) and critical light exposure (E_C, in J/m²). The penetration depth (Dp) is a function of light exposure, and the wavelength of the laser used plays a significant role, typically ranging from 300 nm to 400 nm. To ensure optimal mechanical properties, SLA-printed parts often require post-curing. This additional curing process enhances the durability and strength of the printed objects. For example, post-curing dental parts like crowns and bridges can take between 60 to 90 minutes to achieve desired mechanical characteristics. [6]

Case	Specimen Code	Tensile Strength σ [MPa]	Strain ε [%]	Nominal Strain at Break ε_{tB} [%]	Young's Modulus E [MPa]
Case 3	1S_30	33.312	3.01	3.07	1698.081
	2S_30	25.658	2.36	2.36	1340.203
	3S_30	35.591	3.27	3.31	1787.256
	4S_30	33.018	2.59	2.61	1783.058
	5S_30	30.008	4.28	4.33	1434.025
	Average (St. Deev.)	31.517 (3.830)	3.10 (0.75)	3.14 (0.76)	1608.525 (207.890)
Case 4	1S_100	45.621	4.53	5.66	2050.024
	2S_100	45.468	4.56	5.81	2043.581
	3S_100	42.915	3.91	6.25	2202.640
	4S_100	44.694	3.34	3.33	2073.162
	5S_100	48.010	4.42	4.91	2059.801
	Average (St. Dev.)	45.342 (1.839)	4.15 (0.52)	5.19 (1.15)	2085.842 (66.237)

Figure 2.2.9: SLA 3D-printed ABS-like resin tensile-tested specimens: test results [8]

Here Case 3 denotes tensile test outcomes for SLA 3D-printed ABS samples with a 30% fill density and Case 4 denotes tensile tests for ABS samples with a 100% fill density,

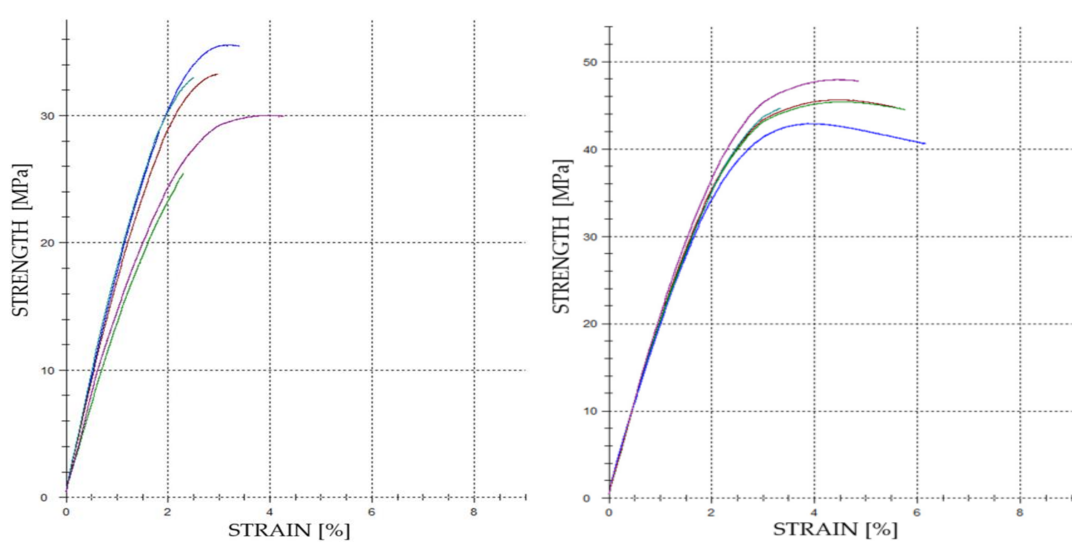


Figure 2.2.10: The tensile strength–strain curves for ABS-like resin specimens produced using SLA 3D printing with a 30% infill density (left) and 100% infill density (right) [8]

Figure 2.2.9 summarizes the tensile testing data for all ABS-like resin specimens fabricated with SLA 3D printing. The graphical representations of tensile strength and strain for these specimens are shown in Figures 2.2.10. Figure 2.2.10 illustrates the tensile test results for SLA 3D-printed ABS-like resin specimens with a 30% fill density (Case 3) and shows the results for ABS-like resin specimens with a 100% fill density (Case 4). These figures provide a visual comparison of tensile strength and strain for each fill density case. [8]

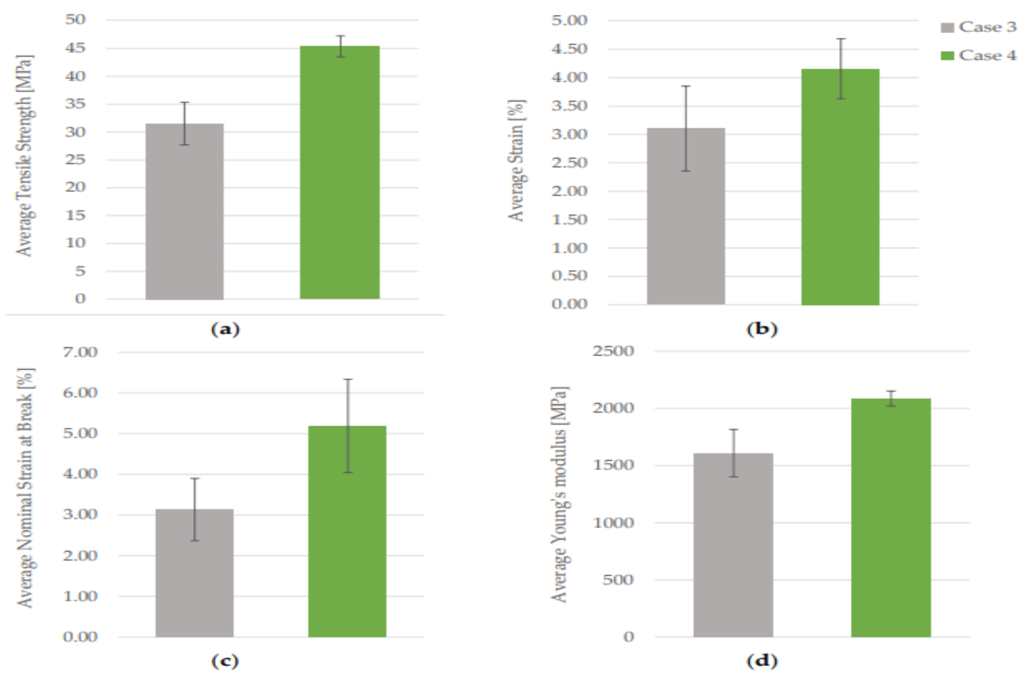


Figure 2.2.11: The mechanical parameters of SLA 3D-printed ABS-like resin tensile-tested specimens with 30% (Case 3) and 100% (Case 4) infill density: (a) average tensile strength, (b) average strain, (c) average nominal strain at break, (d) average Young's modulus. [8]

An in-depth analysis of the data presented in Figures 2.2.10 reveals a clear trend: ABS-like resin specimens produced through SLA 3D printing with 100% infill density show significant improvements in both tensile strength and nominal strain at break. This finding highlights the effectiveness of SLA 3D printing in manufacturing high-strength ABS-like resin components, suggesting its potential for applications that require superior mechanical properties. [8]

Specifically, the average tensile strength of SLA 3D-printed ABS-like resin specimens with 100% infill density experienced a substantial 30.49% increase compared to specimens with lower infill densities (as shown in Figure 2.2.11a). This notable rise in tensile strength reflects the capability of SLA 3D printing to enhance the mechanical performance of ABS-like resin components, making them not only stronger but also more robust and reliable in various engineering and manufacturing contexts. [8]

Such an increase in tensile strength allows for broader applications where parts must endure substantial loads and stresses. This enhanced robustness can foster new design opportunities for creating durable parts with greater confidence in their structural integrity. The increased tensile strength and reliability of SLA 3D-printed ABS-like resin components can lead to their adoption in demanding industries, including automotive, aerospace, and medical, where durability and strength are critical. This breakthrough provides a solid foundation for further exploration and innovation in 3D printing technology. [8]

Case	Specimen Code	Max Displacement ΔL [mm]	Max Force at Break F_{max} [N]
Case 3	1S_30	3.53	1374.599
	2S_30	2.71	1047.965
	3S_30	3.81	1433.605
	4S_30	3.01	1347.233
	5S_30	4.98	1238.802
	Average (St. Dev.)	3.61 (0.88)	1288.441 (151.859)
Case 4	1S_100	6.51	1845.802
	2S_100	6.67	1812.359
	3S_100	7.19	1709.733
	4S_100	3.83	1806.313
	5S_100	5.65	1924.241
	Average (St. Dev.)	5.91 (1.32)	1819.689 (77.36)

Figure 2.2.12: The calculated value of mechanical parameters for SLA 3D-printed ABS-like resin tensile tested specimens. [8]

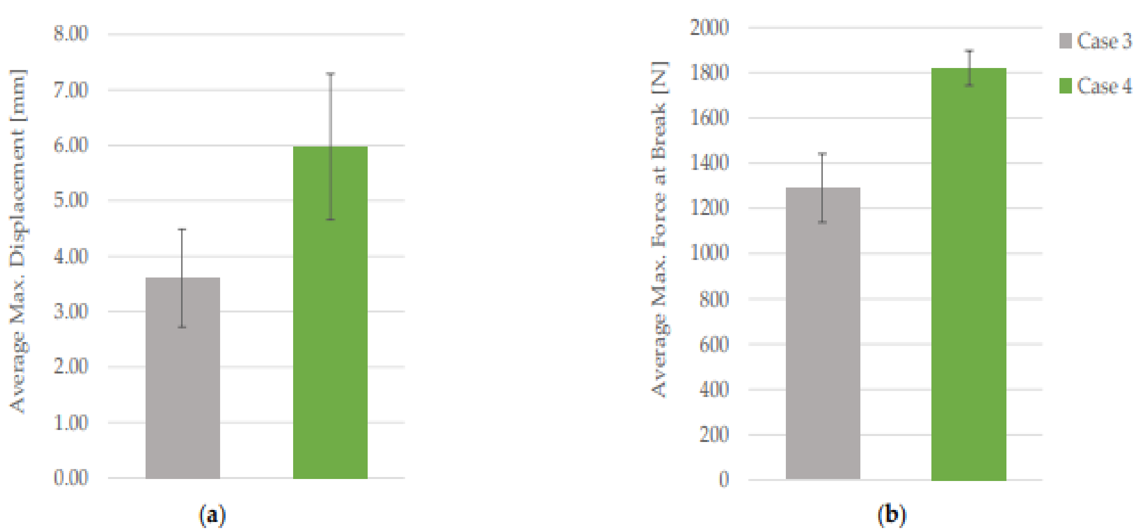


Figure 2.2.13: The calculated average value of mechanical parameters for SLA 3D-printed ABS-like resin tensile-tested specimens: (a) average maximal displacement and (b) average maximal force at break. [8]

The average strain value of SLA 3D-printed ABS material specimens with 100% infill density showed a 25.30% increase compared to those with 30% infill density, as indicated in Figure 2.2.9 and Figure 2.2.11b. This 25.30% increase in nominal strain at break, highlighted in Figure 2.2.11c, points to greater flexibility and durability in SLA 3D printing when using higher infill densities. This improvement has significant implications for applications where materials need to withstand deformation and stress without structural failure. Higher infill density leads to greater resilience, allowing components to endure more strain, which broadens their potential use in engineering and design. [8]

The same trend is observed with the average Young's modulus, depicted in Figure 2.2.11d. SLA 3D-printed ABS-like resin specimens with 30% infill density had an average Young's modulus 22.88% lower than those with 100% infill density. A higher Young's modulus in specimens with 100% infill density suggests increased stiffness, which is beneficial for parts requiring higher rigidity. [8]

Using data from figure 2.2.9 and applying Equations (1) and (2), the maximum displacement and maximum force at break for SLA 3D-printed ABS-like resin specimens were calculated. These results are presented in Figure 2.2.12 and Figure 2.2.13. The observed increases in strain, stiffness, and tensile strength indicate that SLA 3D printing with 100% infill density produces stronger, more flexible, and more durable parts, making them suitable for a wider range of demanding applications, from engineering components to customized consumer goods. [8]

According to the data in Figure 2.2.9 and Figure 2.2.13, SLA 3D-printed ABS-like resin specimens with 100% infill density exhibited a significant increase in average maximum displacement, rising by 38.92% compared to those with 30% infill density (as illustrated in Figure 2.2.13a). However, the average maximum force at the point of break showed a decrease of 22.88% in Case 4 (100% infill density) compared to Case 3 (30% infill density), as highlighted in Table 2.2.11 and Figure 2.2.13b. This contrasting trend indicates that while SLA specimens with 100% infill density allow for greater displacement before breaking, they tend to require less force to reach the breaking point compared to those with lower infill density. [8]

Figure 2.2.14a shows that SLA 3D-printed ABS-like specimens with 100% infill density have an average tensile strength about 0.76% higher than the manufacturer's recommended values for ABS-like resin. [8]

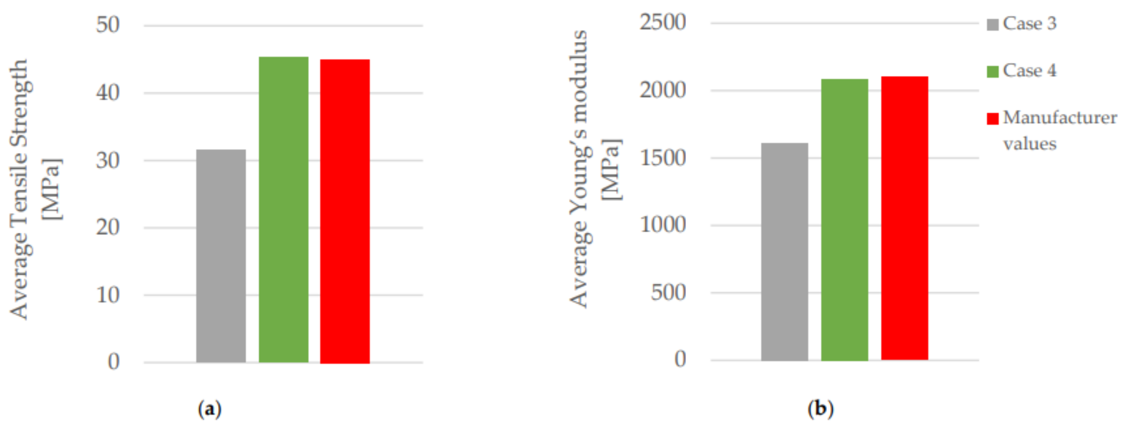


Figure 2.2.14: Comparison of the tensile strength and Young's modulus of the SLA 3D-printed ABS-like tensile-tested specimens with those of the resin (manufacturer values): (a) average tensile strength, (b) average Young's modulus [8]

When looking at Young's modulus and comparing the manufacturer's values for ABS-like resin with the results from SLA 3D-printed ABS-like specimens with 100% infill density, a clear pattern emerges. The SLA 3D-printed specimens reach 99.33% of the manufacturer's stated values (Figure 2.2.14b). This shows that SLA 3D printing is remarkably accurate and consistent in making ABS-like parts that almost meet industry standards, suggesting it's a good choice for applications that need reliable and high-performance materials. [8]

Comparison:

Figure 2.2.15 breaks down the mechanical parameters for ABS and ABS-like tensile-tested specimens made using both FDM and SLA 3D printing methods, while Figure 2.2.16 provides a visual representation of this comparison.

Material	Case	Average Tensile Strength σ [MPa]	Average Strain ε [%]	Average Nominal Strain at Break ε_{tB} [%]	Average Young's Modulus E [MPa]	Average Maximal Displacement ΔL [mm]	Average Maximal Force at Break F_{max} [N]
ABS (filament)	Case 1 (St. Dev.)	19.507 (0.384)	2.16 (0.04)	2.67 (0.28)	1320.754 (114.695)	3.07 (0.33)	806.355 (22.729)
	Case 2 (St. Dev.)	27.401 (0.756)	2.24 (0.08)	3.62 (0.72)	1788.691 (75.380)	4.16 (0.83)	1093.946 (15.922)
ABS-like (resin)	Case 3 (St. Dev.)	31.517 (3.830)	3.10 (0.75)	3.14 (0.76)	1608.525 (207.890)	6.51 (5.65)	1288.441 (151.859)
	Case 4 (St. Dev.)	45.132 (1.839)	4.15 (0.52)	5.19 (1.15)	2085.842 (66.237)	5.91 (1.32)	1924.241 (77.360)

Figure 2.2.15: Comparison of mechanical parameters in tensile-tested ABS (filament) and ABS-Like (resin) specimens manufactured via FDM and SLA 3D printing. [8]

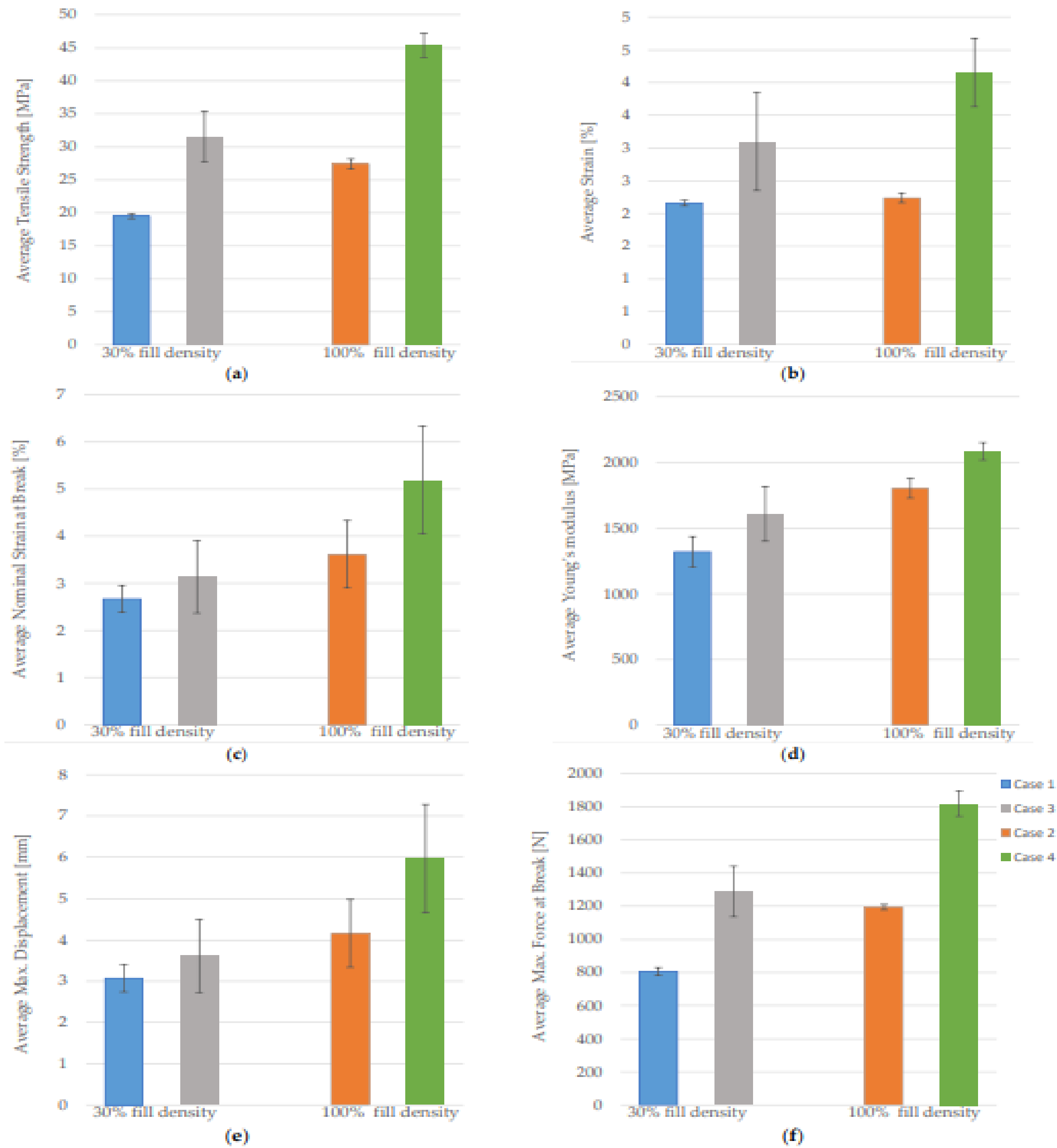


Figure 2.2.16: Graphical comparison of mechanical parameters between ABS filament and ABS-like resin [8]

In figure 2.2.16(a) denotes as average tensile strength, (b) as average strain, (c) as average nominal strain at break, (d) as average Young's modulus, (e) as average max. displacement, (f) as average max. force at break [8]

Figure 2.1.15 highlights a clear pattern—SLA 3D-printed ABS materials show better performance in specific mechanical parameters like tensile strength, Young's modulus, and displacement. According to Figure 2.2.16a, SLA-printed ABS-like specimens with 30% infill density have a 38.11% higher average tensile strength compared to FDM-printed specimens with the same infill density. For SLA-printed specimens with 100% infill density, this difference increases to 39.57% over their FDM equivalents. [8]

In terms of displacement, Figure 2.1.16 shows that SLA-printed specimens with a 30% infill density have a 14.96% higher average maximum displacement than FDM-printed ABS with the same infill density. When SLA specimens have a 100% infill density, the increase in displacement compared to FDM is 30.32%. [8]

Regarding Young's modulus, figure 2.2.16d indicates a 17.89% increase for SLA-printed specimens with 30% infill density compared to FDM-printed ABS. For specimens with 100% infill density, the SLA-printed ones are 13.48% stronger in Young's modulus than FDM-printed ones (Figure 2.2.16c). These findings suggest SLA printing provides better mechanical properties, regardless of infill density. [8]

However, when it comes to resistance to deformation, Figure 2.1.16b shows that increasing infill density in FDM doesn't offer much improvement. FDM-printed ABS specimens with 30% infill density have an average strain of 2.16%, while those with 100% infill density show a slightly higher strain of 3.1%. In contrast, SLA-printed ABS-like specimens with 30% infill density have an average strain of 2.24%, but those with 100% infill density have a much higher strain of 4.15%. [8]

Looking at nominal strain at break, Figure 2.2.16c reveals that FDM-printed specimens with 30% infill density have an average strain of 2.67%, while those with 100% infill density reach 3.62%. In contrast, SLA-printed specimens with 30% infill density show a strain at break of 3.614%, but those with 100% infill density show a higher value of 5.19%. This suggests that higher infill density in SLA printing significantly improves the material's resistance to breakage, indicating that the choice of infill density is crucial when using SLA printing for high-performance applications. [8]

This comparison gives us important insights into the mechanical properties of 3D-printed ABS filament and ABS-like resin specimens. The focus was on two key 3D printing technologies, FDM and SLA, and how they affect key mechanical properties: tensile strength, Young's modulus, and maximum displacement.

When ABS samples were tested with 100% infill density, the average tensile strength of FDM-printed specimens increased by 28.81%. For SLA-printed ABS-like resin specimens, the increase was even greater, at 30.49%. The maximum displacement also saw notable increases—35.51% for FDM-printed ABS specimens, and 38.92% for SLA-printed ABS-like resin specimens, both with 100% infill density. This shows that SLA technology offers better mechanical performance compared to FDM. [8]

Young's modulus also showed significant gains with 100% infill density: FDM-printed ABS specimens saw a 26.81% increase, while SLA-printed ABS-like specimens had a 13.48% increase. These differences underscore the advantages of SLA in achieving stiffer, more durable materials. [8]

The results show a clear difference in the mechanical properties of specimens printed with FDM and SLA technologies. SLA consistently outperforms FDM, demonstrating significant improvements in key metrics like tensile strength, maximum displacement, and Young's modulus. [8]

Cost Analysis:

FDM Method: Here's a basic breakdown of the parts we will need for an FDM 3D printer along with approximate costs:

1. Frame:

- Aluminum Extrusions or Acrylic Sheets
- Cost: 6000 - 18000 BDT [10]

2. Print Bed:

- Borosilicate Glass or Aluminum Plate
- Cost: 1000 - 3000 BDT [9]

3. Extruder Assembly:

- Extruder Motor
- Hotend Assembly
- Bowden Tube
- Cost: 3000 – 8000 BDT [9]

4. Electronics:

- Motherboard
- Stepper Motor Drivers
- Power Supply
- Wiring, Connectors, and End stops
- Cost: 4000 – 10000 BDT 10]

5. Movement System:

- NEMA motor, stepper motors (X, Y, Z axis)
- Belts, Pulleys, and linear Rods
- Linear Bearings
- Cost: 4000 -10000 BDT [9]

6. Control Interface:
- Display monitor
- Control Knob
- Cost: 1000 – 3000 BDT [10]

7. Heating and Cooling:
- Heated Bed
- Cooling Fans (Hot end and Electronics)
- Cost: 1000 – 3000 BDT [10]

8. Miscellaneous:
- Fasteners (Screws, Nuts, Bolts)
- Cable Management
- Lubricants and Adhesives
- Cost: 1000 – 3000 BDT [9]

Total Cost: 21000 - 58000 BDT

It should be noted that these are approximate costs, and the actual cost can vary depending on the quality and brand of the components we choose, as well as any additional features one may want to add to the printer. Additionally, it is needed to consider the cost of filament and any tools required for assembly.

SLA Method: For an SLA 3D printer, the parts list and costs are a bit different:

1. Frame:
 - Aluminum Frame or Acrylic Enclosure
 - Cost: 15000 – 40000 BDT [9]

2. Build Platform:
 - Platform Assembly
 - Cost: 8000 - 20000/ BDT [9]

3. Resin Tank:
 - Resin Tank Assembly
 - FEP Film
 - Cost: 8000 – 20000 BDT [9]

4. Light Source:
 - UV LED Array or Laser Module
 - Cost: 10000 – 25000 BDT [9]

5. Optics:

- Mirrors, Galvanometers (for laser SLA)
- Cost: 10000 – 25000 BDT [9]

6. Control Electronics:

- Mainboard (e.g., Arduino Mega, RAMPS)
- Stepper Motor Drivers
- Power Supply
- Cost: 8000 – 15000 BDT [10]

7. Z-axis System:

- Stepper Motor and Lead Screw
- Cost: 8000 – 15000 BDT [9]

8. Cooling System:

- Cooling Fans
- Cost: 2000 – 6000 BDT [10]

9. Resin:

- UV-Curable Resin (varies based on type and color)
- Cost: 8000 – 15000 BDT per liter [9]

10. Miscellaneous:

- Fasteners (Screws, Nuts, Bolts)

- Cable Management
- Lubricants and Adhesives
- Cost: 3000 – 6000 BDT [9]

Total Cost: 82000 – 187000 BDT

Again, these are approximate costs, and the actual cost can vary depending on the quality and brand of the components you choose, as well as any additional features you may want to add to your printer. Additionally, you may need to consider the cost of post-processing equipment and materials.

Comparison:

We are calculating two alternate solutions for our 3D printer. We have seen the calculation of power consumption, accuracy, and cost analysis for our 3D printing technology method. If we summarize it, then we get:

Table 2.2.1 Comparison of Alternate Solutions

Alternative Solution	Cost analysis (BDT)
FDM method	21000 – 58000
SLA method	82000 – 187000

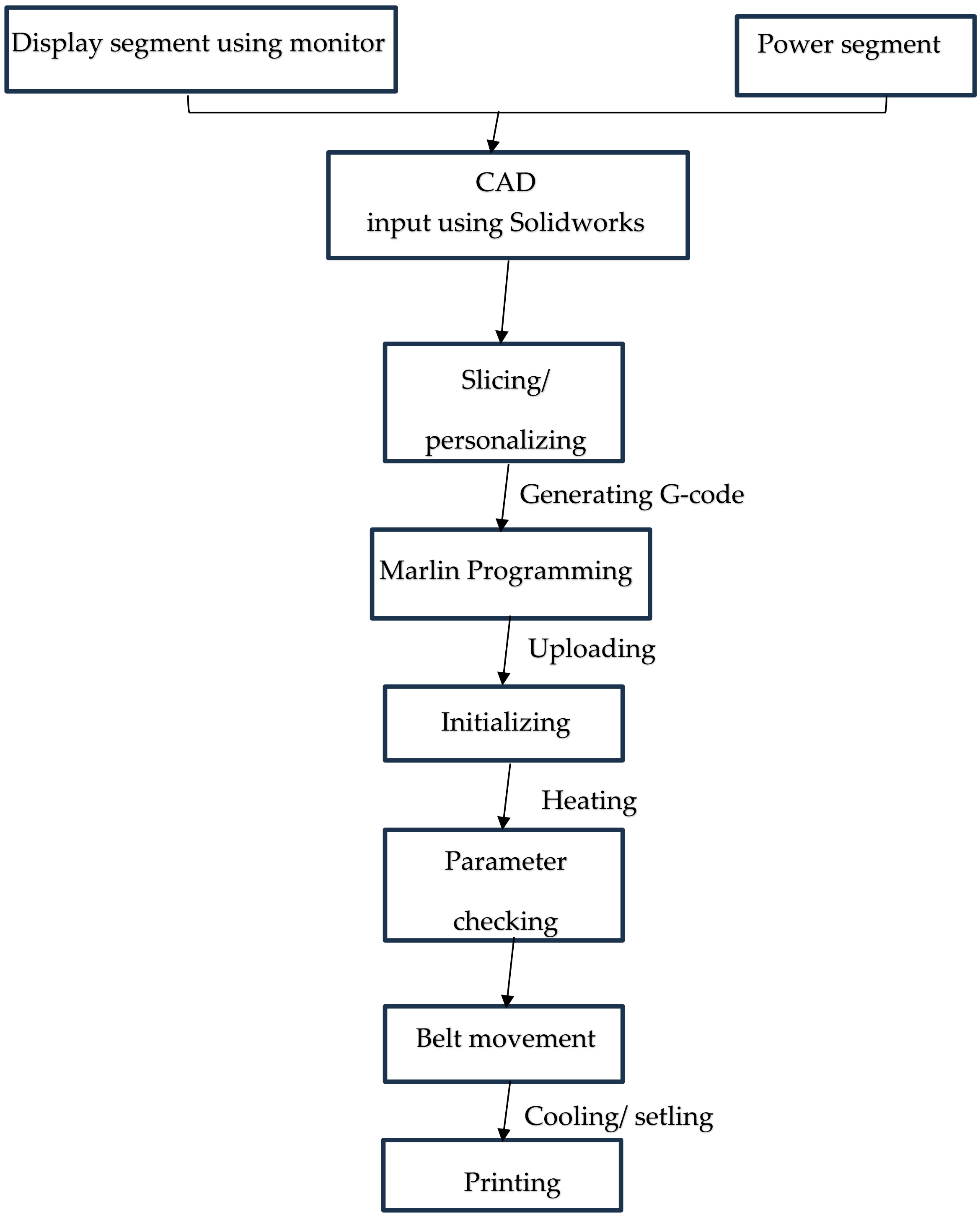
While FDM and SLA both have their advantages and disadvantages, the choice between them depends on various factors such as budget, desired print quality, material properties, and the specific requirements of the application. FDM is generally more cost-effective for rapid prototyping and producing functional parts with moderate detail, while SLA is better suited for applications requiring high precision and intricate detail. But our main objective or goal is cost minimization, so we have selected FDM method over SLA method for our project.

2.3 Refined design

We are designing an Artify 3D printer to enable design into reality. Our main purpose of the project is to minimize the cost and to build it in a user-friendly manner. So, we will be using components that will help to build such a project with expected functionalities as well as to ensure the user-friendliness of the project.

We have planned our design accordingly. We will place a motherboard which will be connected to all the main components. It will convert main design (which will be given input through monitor) into G-code. After that, the G-code will be converted into appropriate commands according to the programming commands set by MARLIN. Then, by synchronizing with the linear rods and all the motors, the nozzle will move accordingly in the X,Y,Z-axes. Then according to the prepared programming set-up, raw material will be melted while passing through the extruder and by falling on the heat bed layer after layer, it will create appropriate design.

The functional block diagram will be as follows -



Technical Specification:

1. **Micro-Controller:** In 3D printer, we will require a microcontroller to act as the brain of the device and for the coordination of all the components. We will use Arduino for our purpose as we require very high number of Input/Output pins for our device.

2. **Motor Driver:** A motor driver is a mechanical system that include an electric motor and drives the machine. Generally, it controls the speed, torque, direction. When we need to control the motor using a controller, we need a motor driver. [11]

3. **Extruder:** The 3D printer extruder is a series of parts that handle the moving and processing of plastic filament. The extruder is responsible for how much and at what speed 3D printer pushes filament into the hotend. [12]

4. **Stepper Motor:** Stepper motors are brushless DC motors that achieve a high level of precision in small movements and impart full torque at low speeds. Stepper motors drive the movement of the print head along the X, Y and Z axes of the 3D printer. Each axis is equipped with its own stepper motor, allowing independent control of movement in each direction. [12]

Figure 2.3.1: Stepper motor

5. **Filament Path:** the filament path must be carefully designed and maintained to prevent issues such as filament jams, clogs, or misalignment, which can result in failed prints or printed malfunction. [12]

Figure 2.3.2: This plastic lever arm, tension spring, and plastic gear exert pressure on filament as it travels

6. **Nozzle:** the nozzle itself has a chamber where molten filament pools, pressure builds, and extrudes through a taper into the nozzle's opening and out onto your

printer's build plate. The nozzle opening is a precise diameter, which is the measure by which you purchase it. Most desktop 3D printers ship with 0.4-mm nozzles as standard, but there are many other sizes available. [12]

Figure 2.3.3: Nozzle

7. **Heat bed:** A heated bed is an essential component of a 3D printer that can significantly improve the quality of the prints. Its ability to improve adhesion, reduce warping and curling, and allow for the use of a wider range of materials make it an indispensable tool for any 3D printing enthusiast. [13]

PART-C

This part includes the implementation, finalized design, and analysis of economic viability of the project.

Chapter 3 Demonstration of Implemented Solution and Finalization of Design

3.1 Development of the prototype

We have brought certain changes to the design we made for EEE400C. In EEE 400B, we chose FDM method to add the recycling feature to our design. There were two main features for the printer. One was to print and another one was to recycle. During evaluating our design for the 3D printer in 400C, we have realized the need for adding a separate compartment for the recycling feature. This is because, unless the filament input is not continuous, then at first filament shall be made, and after producing the filament, one side of the filament shall be given as the input. So, there will be one extra compartment in our new design for recycling.

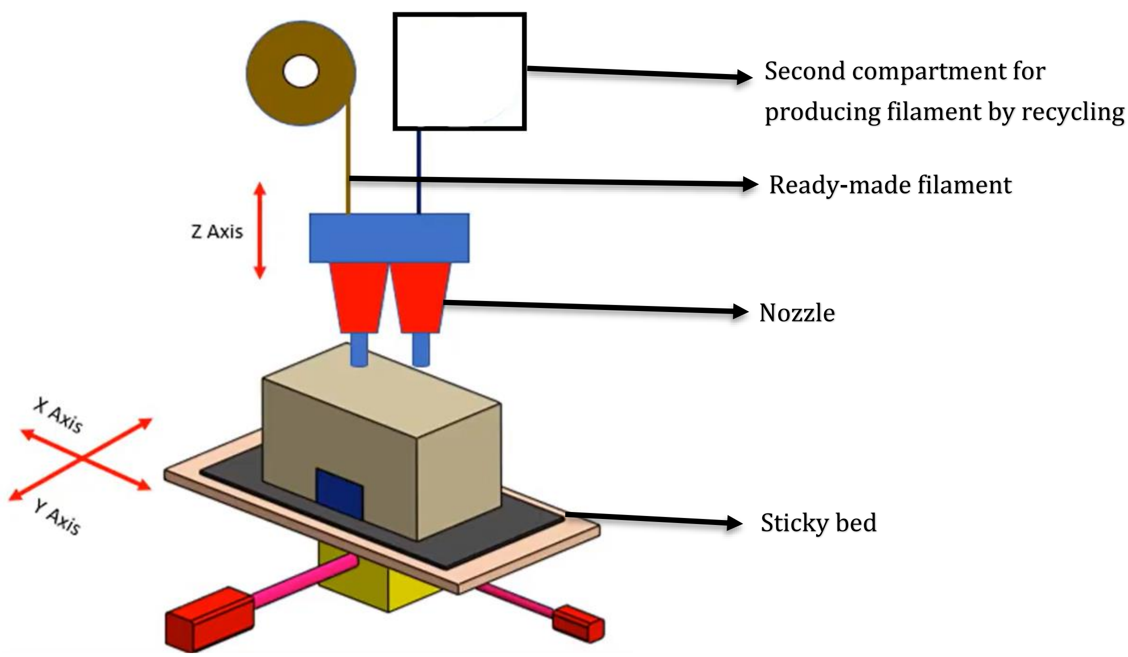


Figure 3.1.1: Fundamental design of prototype

On the above figure we can see the change in design. There will be 2 compartments as shown. People have to put one side of the PET plastic of any random bottle (which will be recycled) to the first compartment. Then filament will be produced from that PET plastic. Then, this filament will be given as input into the main compartment of the printer. On the other hand, design of the expected object will be created by FreeCAD software. Thus, after generation of G-code by Ulticura, our selected host software Pronterface will operate stepper motors and all other components via our choosen microcontroller Arduiono. Finally the output will be created layer by layer in the heat bed on the above shown position on the figure 3.1.1. Thus the output will be created. For the prototype, we will build the frame of the device first. We will build an aluminium extrusion frame. For this, we will be using 2040 V-slot aluminium linear rails. Thus we have prepared the frame.

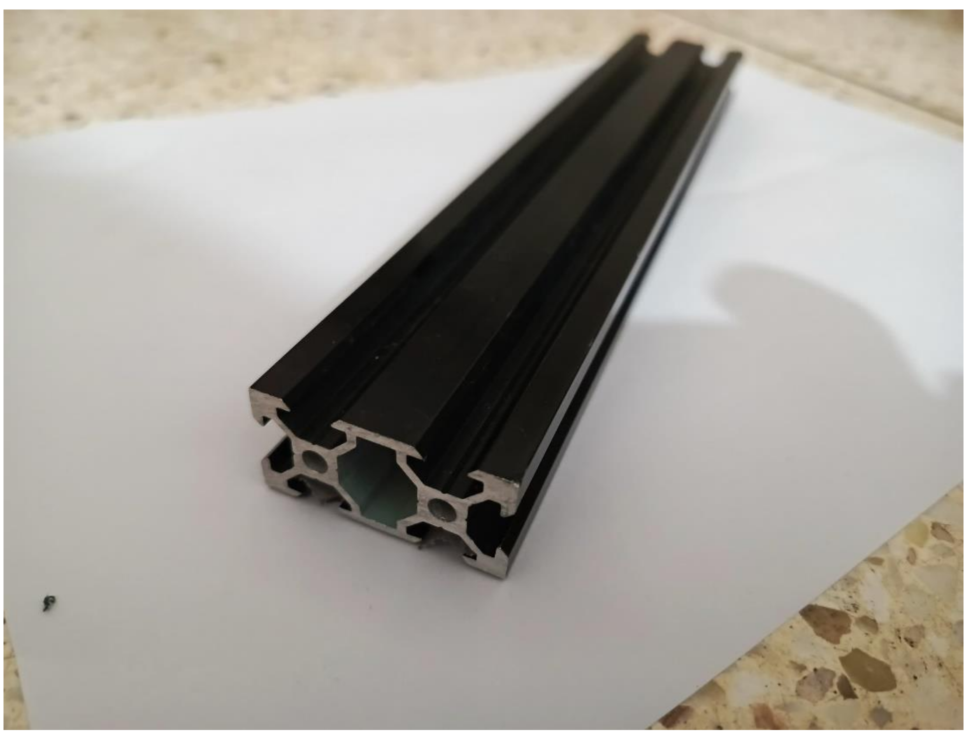


Figure 3.1.2: 2040 V-slot aluminium

One stepper motor will be used for controlling the movement of the nozzle in the z-axis. So, we have connected a stepper motor with a coupler and a T-8 nut and then adjusted it with the aluminium rail for moving along the z-axis.

Figure 3.1.3: X and Z axis

We have connected the bed with the Y axis rail through 4 T-nuts. Then we have attached it with XZ axis as demonstrated in figure 3.1.5.

Figure 3.1.4: Preparing Y axis

Figure 3.1.4: Y axis rail with anoth
stepper motor, timing belt, pully
and bed

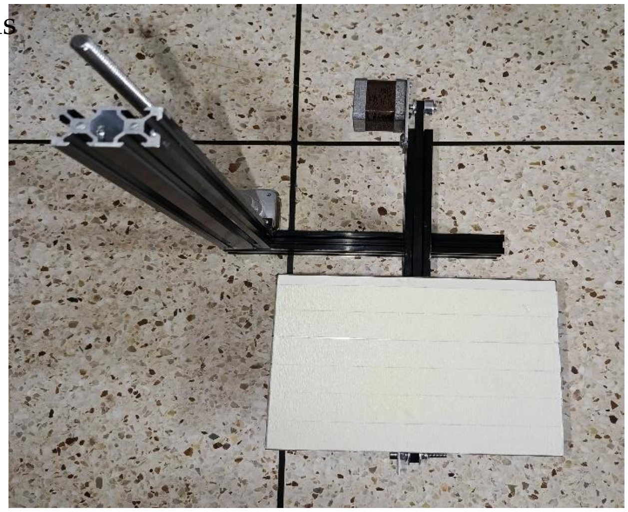


Figure 3.1.5: Main frame

Then we have prepared another X axis rail that will move along the Z axis. This will carry the heat sink, heat block, the nozzle and the cooler. These altogether develop the hotend. After that, the hotend has been connected to the extruder through PETG tube as demonstrated in figure 3.1.6.

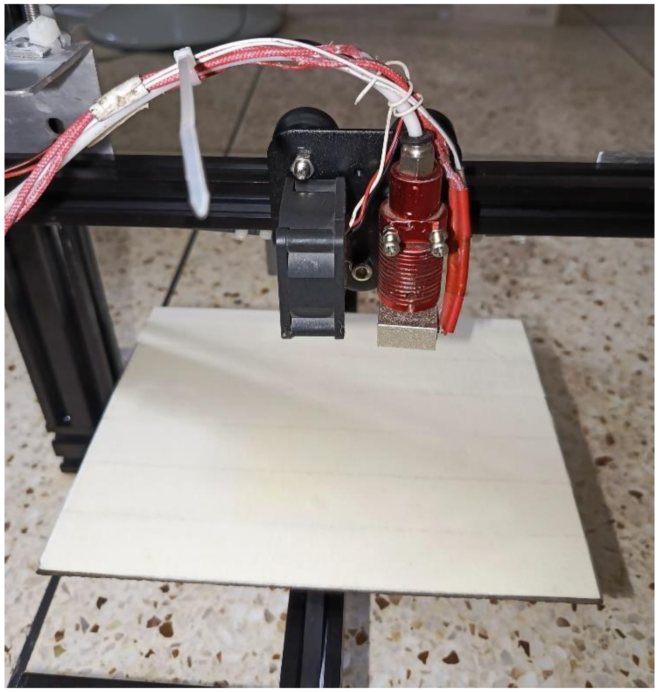


Figure 3.1.6: Actual X axis controller trail with hotend

Other end of the PETG tube will be connected to the extruder.

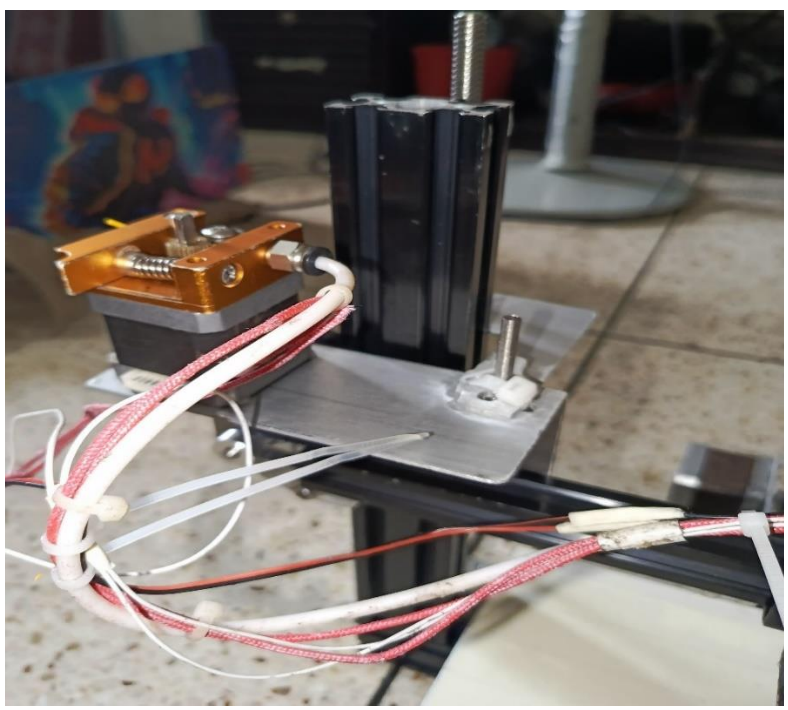


Figure 3.1.7: Extrudenr for melting the filament

That is how, the hardware part is done. After finishing up to this, now the setup will look as shown in figure 3.1.8.

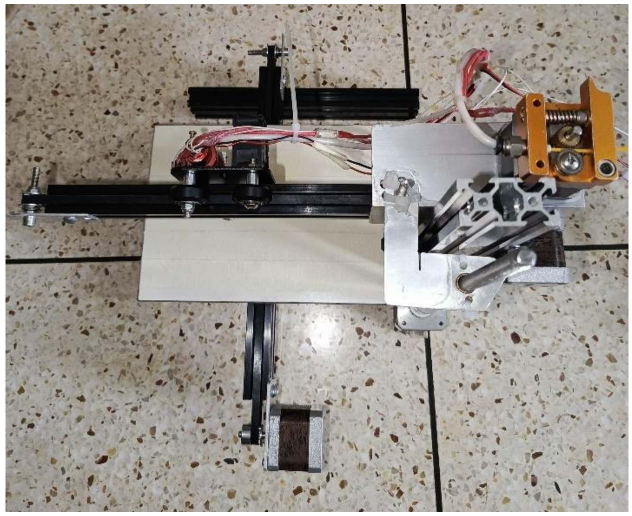


Figure 3.1.8: Total mechanical part

Then we have created connection among Arduino Mega, RAMPS and stepper drivers to control Nema stepper motors as shown in figure 3.1.9. RAMPS interfaces with the powerful Arduino MEGA platform and has plenty room for expansion. The modular design controls the movement of the 3D printer, extruders, hotend and a heated bed while sensing the temperature of the hotend and heated bed. The necessary Arduino code for this purpose is available for being open source.

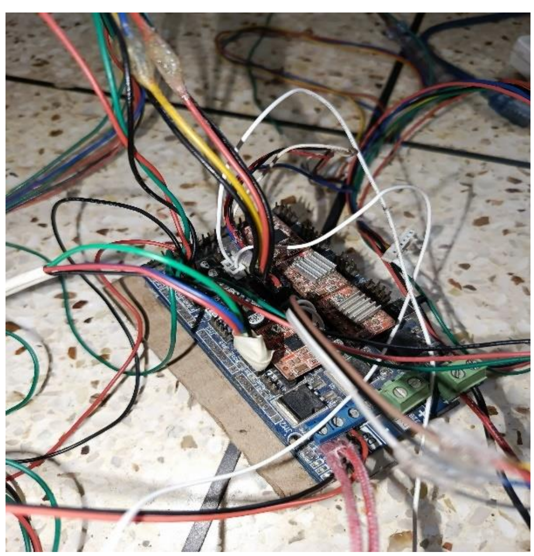


Figure 3.1.9: Arduino Mega, RAMPS, necessary wirings

A mechanical endstop is a simple mechanical switch positioned to trigger when a RepRap's axis reaches the end or start of its motion. We have used these endstops to control the movement of the heat bed and hotend.

Figure 3.1.10: Mechanical endstops

Finally, we will need a power supply for running the printer.

Figure 3.1.11: Power supply

Then after necessary wire connections, our first compartment has been prepared.

The task of the first and main compartment is done. Now the remaining job is to build the second compartment. It will mainly do the work of recycling. For this work, we need three components. They are-

i) Voltage regulator

ii) Incubator

iii) Heat block

The voltage regulator will keep rotating the bobbin where the transformed filament will be stored. The main task will be performed by the incubator. We will use Incubator W1209. This is a high-precision temperature control module. Through this, we will heat a heat block up to a certain temperature. When the PET plastic will pass through the block, it will get melted and transform into our desired filament and will be stored in the bobbin.

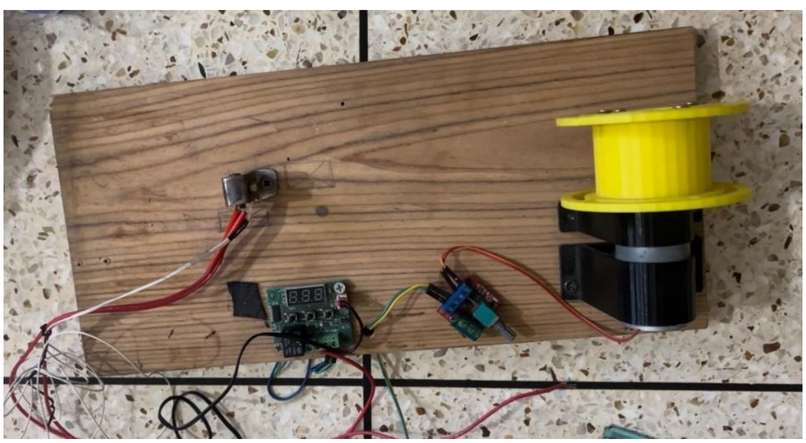


Figure 3.1.12: Second compartment for recycling

Figure 3.1.13: Incubator W1209

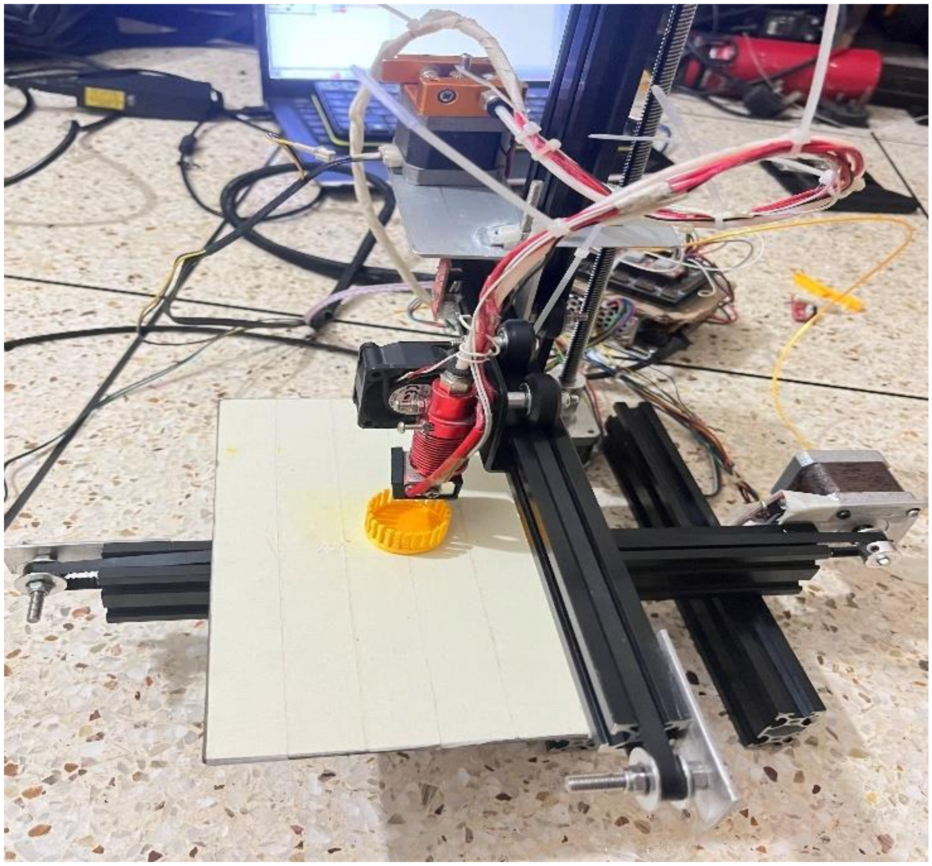


Figure 3.1.14: Developed Prototype

3.2 Performance evaluation of implemented solution against design requirements

We had some project requirements which have been mentioned in EEE 400A part. We will analyze the requirements one by one. As a result, we will find out which requirements have been fulfilled and which ones have not been.

- **Complex printing capability:** In 400 A, our first concern and target were to be able to create output according to any given design irrespective of complexity. For this purpose, we are using Pronterface. Pronterface is a simple graphical user interface that provides users with the ability to monitor and control their printer from a USB-connected computer. With it, we can directly move stepper motors, control bed and nozzle temperatures, send G-code commands directly via a terminal or console window, and much more. In our prepared prototype, we have created many critical designs using Pronterface and enabled those designs into reality. As a result, we can say that we have achieved this project requirement in our project.

Figure 3.2.1: Output product

Figure 3.2.2: Given design

- **<u>Design freedom:</u>** For creating designs, we will use FreeCAD. FreeCAD is an open-source parametric 3D modeler made primarily to design real-life objects of any size. That is how, our project will give a user design freedom. Thus, our project has met this requirement as well.

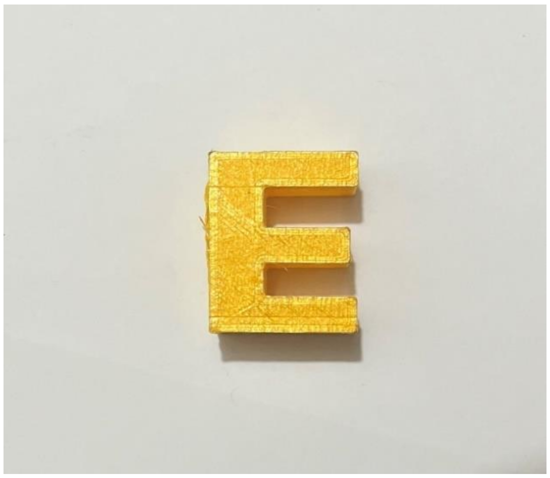


Figure 3.2.3: A letter as desired output

Figure 3.2.4: Mechanical channel

- **<u>Dimensional accuracy:</u>** High dimensional accuracy is crying need here, because it guarantees that the printed parts fit together correctly and perform as intended, dimensional accuracy is essential. This is particularly crucial in sectors where accurate measurements can make the difference between success and failure, such as aerospace, automotive, and healthcare.

However, in our case, we have printed several designs to examine the design freedom. From those outputs, dimensional accuracy of our prototype is as follows:

Table 3.2.1: Dimensional accuracy

Credentials		Fig 3.2.1	Fig 3.2.3	Fig 3.2.4
Length	Digital model	4 cm	3 cm	8 cm
	Printed model	4.2 cm	3.1 cm	8 cm
	Accuracy	**95%**	**96.67%**	**100%**
Width	Digital model	4 cm	2 cm	7 cm
	Printed model	4.2 cm	2.1 cm	7 cm
	Accuracy	**95%**	**95%**	**100%**
Height	Digital model	0.5 cm	1.5 cm	0.5 cm
	Printed model	0.45 cm	1.5 cm	0.5 cm
	Accuracy	**90%**	**100%**	**100%**

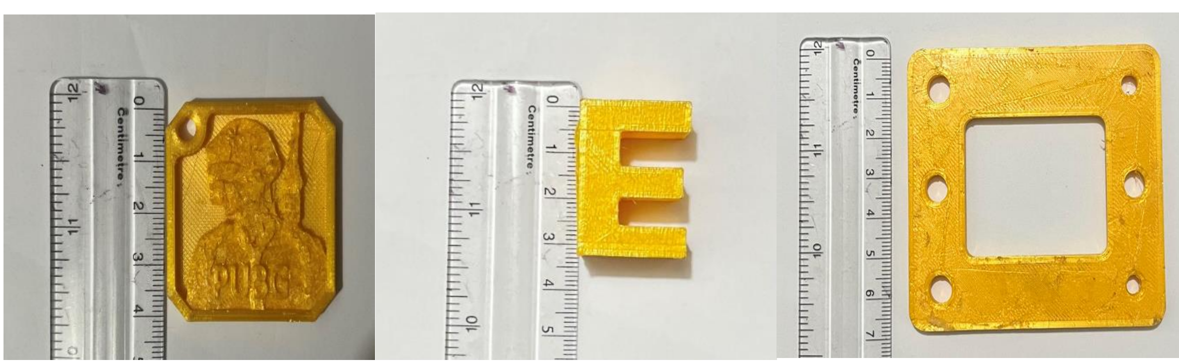


Figure 3.2.5: Dimensional parameters

The numbers clearly indicate that, we have achieved a high dimensional accuracy.

- **Ensuring user friendly interface**: The 3D printer features an intuitive and user-friendly interface designed to streamline the printing process for users of all skill levels. It is designed in such a way that anyone will be able to access all essential functions, including file selection, print settings and real-time monitoring with his own computer or laptop just by having that three necessary software. With its simple navigation and straightforward controls, users can effortlessly set up and start prints with minimal training. Additionally, the interface includes helpful prompts and feedback to guide users through each step, ensuring a smooth and hassle-free printing experience. This thoughtful design minimizes complexity and maximizes efficiency, making advanced 3D printing accessible and convenient.

- **Innovative recycling technology:** In 400 A, one of our main motives behind this project was to make a positive impact on the environment by recycling plastic. Our 3D printer incorporates a recycling technology that transforms used plastic materials into high-quality print filaments. This innovative approach not only reduces waste by diverting plastic from landfills but also significantly lowers the environmental footprint of the printing process. By reusing discarded plastics, the printer contributes to a circular economy, minimizing the demand for new raw materials and reducing overall resource consumption. This sustainable technology aligns with our commitment to environmental responsibility, offering a greener solution for 3D printing while supporting efforts to combat plastic pollution and conserve natural resources.

3.3 Finalization of design

In our performance evaluation from the perspective of dimensional accuracy, we found a satisfying accuracy of the prototype. We have designed our system consisting of two separate compartments- one for printing and the other one for preparing filament by recycling. To make the device more user-friendly, we can design only one compartment where the user will put their used PET bottle and the device will print according to the design directly. For this, a more sophisticated framing is needed where there will be a narrow path through which, the PET plastic will be able to reach the heat block by itself, and then through another separate narrow path, the produced filament will directly travel to the extruder.

3.4 Use of modern engineering tools

In the process of executing the mini Artifi 3D printer project, we utilized a variety of modern engineering tools. The following section outlines how each tool was employed.

- **FreeCad: We use FreeCad, a widely used 3D modeling software, to create detailed 3D models for our projects. The software offers a variety of tools for designing complex shapes, textures, and animations. FreeCad's user-friendly interface and wide range of features make it easy for us to create detailed models with both precision and creativity. Once the 3D models are complete, they can be exported in various file formats compatible with 3D printing software like Ultimaker Cura. This capability enables us to seamlessly transition from digital design to physical objects, allowing to produce high-quality prints that accurately reflect our original concepts**
- **Ultimaker Cura:** We use Ultimaker Cura, a powerful and popular 3D printing software, to prepare models for our 3D printer. The software is highly user-friendly, giving us greater control over the printing process. It works by

converting a 3D model into layers and generating a file that the printer can understand. Specifically, Cura translates the design into G-code, which can then be used with other software to execute the printing. This allows for precise customization of print quality and speed, ensuring optimal results for our printer.

- **Pronterface:** We use Pronterface, dependable and easy-to-use software, to handle our 3D printing. It has a straightforward interface that lets us send commands to the printer, adjust settings, and keep an eye on the print's progress. With Pronterface, we can manage everything from temperature and movement to extrusion, ensuring our designs come out just right. After preparing a 3D model in software like Ultimaker Cura and converting it into G-code, Pronterface takes over, communicating with the printer and making the whole printing process smooth and efficient. This setup helps us produce our projects with accurate details and high quality.

Chapter 4 Review of Milestone Achievements and Revision of Schedule

Table 4.1: Revised project plan

Activity No.	Activities	Duration [Week]	Predecessor	On Time/ Delay
1	**Topic selection**	**2**	**-**	**On Time**
2	**Approving the topic idea from the supervisor**	**2**	**1**	**On Time**
3	**Prove of social relevance, complex engineering and design problem (Milestone - 1)**	**3**	**2**	**On Time**
4	**Literature Review, Identify the stakeholders and prepare questionnaires for the stakeholders.**	**3**	**2&3**	**On Time**

5	**Proceeding with the stakeholder survey and finalizing the requirements (Milestone - 2)**	**2**	**4**	**On Time**
6	**Identification of impact of project on society, Identification of effect of project on environment, sustainability, health and safety issues & Reviewing standards and codes of practice**	**1**	**4**	**On Time**
7	**Project plan and Risk management**	**1**	**6**	**On Time**
8	**Identifying required resources and budget and Analysis project product lifecycle (Milestone - 3)**	**1**	**5&6**	**On Time**
9	**Preparing Project concept and Proposal**	**3**	**6, 7&8**	**On Time**

	report (Milestone - 4) 400A			
10	**Preliminary design of the system**	**3**	**9**	**On Time**
11	**Analysis of alternate solution and verify the preliminary design (Milestone - 5)**	**3**	**10**	**On Time**
12	**Cost Optimization**	**1**	**11**	**On Time**
13	**Preparing Report (Milestone - 6) 400B**	**2**	**12**	**On Time**
14	**Find out equipment availability**	**2**	**12**	**On Time**
15	**Preparation of draft design**	**2**	**13**	**On Time**
16	**Purchase equipment**	**2**	**14**	**Delay**
17	**Implementation**	**3**	**15&16**	**Delay**
18	**Performance evaluation of the system**	**2**	**17**	**Delay**

19	**Finalization of design based on performance evaluation (Milestone - 7)**	**1**	**18**	**On Time**
20	**Demonstration of the working product And Bill of materials cost of solution and Economic analysis**	**1**	**19**	**On Time**
21	**Preparing final report (Milestone - 8)**	**2**	**20**	**On Time**

Purchase Delay: The project encountered setbacks due to difficulties in acquiring necessary components. These issues arose from supplier problems, extended delivery times, and the unavailability of certain parts. Additionally, some components had to be sourced from outside the country, further complicating the timeline. These delays affected the overall progress, as work could not continue until all required materials were secured.

Implementation delay: During the 400C phase of the project, the implementation of the Mini Artifi 3D printer took longer than anticipated. Initially, we encountered issues with some of our NEMA motors burning out and problems with the extruder. We spent a significant amount of time troubleshooting these issues, including verifying the connections between the motors and the extruder with the Arduino, and

ensuring that the material was being properly extruded. Additionally, the delay was compounded by the extra time required to procure replacement motors.

Performance evaluation delay: Since we have built a 3D printer, we needed a good amount of time to evaluate its performance. We organized our time keeping that in mind so that we could evaluate its performance well. But recently we could not leave our house due to unstable environment prevailing in Bangladesh. A curfew was imposed across the country. Not only that, but there was also no internet connection in our country.

Chapter 5 Cost of Solution and Economic Analysis

5.1 Bill of materials cost of solution

The cost of our prototype design is given below

Table 5.1.1 Cost of the prototype.

Equipment	Quantity/Size	Per metric/Unit price (BDT)	Total Price (BDT)
2020 aluminum extrusion frame	280mm	1.3214	370
2040 aluminum extrusion frame	800mm	1.75	1400
2020 Aluminum Corner Bracket	2	30	60
M4 slide T Nut	12	15	180
V-slot gantry plate	1	900	900
V-slot Wheel / POM wheel	10	137	1370
X axis gantry plate	1	760	760
Z axis gantry plate	1	1200	1200
Eccentric spacer nut	6	45	270
Aluminum Spacer Bore Eccentric spacer nut	4	18	72

GT2 Idler Pulley 20 Teeth	2	115	230
Gt2 pulley 20 teeth	2	125	250
T8 Lead Screw Rod	300mm	1.8	540
T8 Lead Screw Nut	1	150	150
M5 SS Screw	12	15	180
M5 SS lock Screw	2	15	30
M5 SS hex screw	15	7.34	110
M4 SS screw	12	7.5	90
Y axis motor holder	1	200	200
Gt2 timing belt	1300mm	0.1307	170
NEMA 17 stepper motor	4	700	2800
Arduino Mega 2560 R3	1	1300	1300
Ramps 1.6	1	680	680
A4988 Stepper Motor Driver	4	195	780
12V 5A (SMPS) power supply	1	450	450
PTFE tube	300mm	0.176	53
Mk8 Extruder	1	730	730
CR 10s pro hot end	1	750	750

Others		1000
Total		17075

Our prototype is capable of printing 3D models up to 180×180×180 mm, which is a scaled-down version of our main design. While the prototype's cost provides a rough baseline, the actual cost of the final consumer-grade FDM printer is expected to be higher. This increase is due to additional expenses that were not accounted for during the prototype phase. Below is the estimated cost for the complete system.

Table 5.1.2 Cost of the proposed design.

Equipment	Quantity/Size	Per metric/Unit price (BDT)	Total Price (BDT)
2020 aluminum extrusion frame	280mm	1.3214	370
2040 aluminum extrusion frame	800mm	1.75	1400
2020 Aluminum Corner Bracket	2	30	60
M4 slide T Nut	12	15	180
V-slot gantry plate	1	900	900
V-slot Wheel / POM wheel	10	137	1370
X axis gantry plate	1	760	760

Z axis gantry plate	1	1200	1200
Eccentric spacer nut	6	45	270
Aluminum Spacer Bore Eccentric spacer nut	4	18	72
GT2 Idler Pulley 20 Teeth	2	115	230
Gt2 pulley 20 teeth	2	125	250
T8 Lead Screw Rod	300mm	1.8	540
T8 Lead Screw Nut	1	150	150
M5 SS Screw	12	15	180
M5 SS lock Screw	2	15	30
M5 SS hex screw	15	7.34	110
M4 SS screw	12	7.5	90
Y axis motor holder	1	200	200
Gt2 timing belt	1300mm	0.1307	170
NEMA 17 stepper motor	4	700	2800
Arduino Mega 2560 R3	1	1300	1300
Ramps 1.6	1	680	680
A4988 Stepper Motor Driver	4	195	780

12V 5A (SMPS) power supply	1	450	450
PTFE tube	300mm	0.176	53
Mk8 Extruder	1	730	730
CR 10s pro hot end	1	750	750
Acrylic enclosure	-	-	4323
Others			1000
Total			21398

To implement our main design, we will need 21,398 BDT.

5.2 Economic analysis

Below is an estimate of the monthly operating and maintenance expenses for our system.

Table 5.2.1 Operational Cost

Designation	No. Of Employee	Salary Month (BDT)	Salary Per Year (BDT)
Manager	1	35,000	4,20,000
Marketing Executive	4	80,000	9,60,000
Engineer	3	75,000	9,00,000
Technician (Assemble)	7	49,000	5,88,000
Accountant	1	10,000	1,20,000
Cleaner	2	14,000	1,68,000
Total			31,56,000

The plan is to establish an office, two service centers and a manufacturing center in Dhaka to operate the business with a total of 18 employees. The office and manufacturing center will be located at Tongi and will have an area of 1000 square feet and 2000 square feet respectively. The first service center will be located at Badda while the second service center will be located at Jurain. Each service centers will have an area of approximately 500 square feet. For marketing, we will initially run Facebook ads. The average cost per click (CPC) for Facebook ads targeting users interested in "Bangladesh" 5-30 BDT, and the average cost per action 50-500 BDT impressions (CPM) 50-300 BDT. [14] We will also run television ads.

Table 5.2.2 Utility Cost

Description	Unit	Expenditure per month (BDT)	Expenditure per year (BDT)
Office Rent	1	15,000	1,80,000
Manufacturing Centre	1	40,000	4,80,000
Service Centers	2	20,000	2,40,000
Utility Bills	-	10,000	1,20,000
Marketing Cost	-	10,000	1,20,000
Refreshments	20	3000	36,000
Others	-	2000	24,000
Total			1,200,000

Considering our initial plan is to manufacture 5000 units annually.

Total annual expenditure = Production cost of 5,000 pieces + O&M Cost

= 12838.80 x 5,000 + 12,00,000 + 31,56,000

= 6,85,50,000 BDT

We surveyed almost 1 year ago. Since then, the price of electronic components and others have increased drastically. Considering that we have set our unit selling price.

Unit Selling Price = 25,500 BDT

Annual sale = 5,000 units × 22,500 BDT = 11,25,00,000 BDT

Discount Rate, d = 8.52%

Interest Rate, i = 11%

Considering all the basic elements, we calculated the average lifetime of the device and determined it to be 5 years.

n = 5 Years

Present Value Function, PVF (d, n) = $\frac{(1+d)^n-1}{d(1+d)^n}$

$= 3.94$

Capital Recovery factor, CRF(i, n) = $\frac{i(1+\mathrm{i})^n}{(1+\mathrm{i})^n-1}$

= 0.27

Annual expenditures, P = 6,85,50,000 BDT

Annual loan Payment, A = P × CRF(i, n)

= 6,85,50,000 BDT × 0.27

= 1,85,08,500 BDT

Annual Savings Without Tax,

ΔA′ = Annual sale - Annual Loan Payment - Total annual expenditure

= 11,25,00,000 – 1,85,08,500 – 6,85,50,000 = 2,54,41,500 BDT

In Bangladesh, the rate of tax imposed on corporations is 30%.

Annual savings after paying tax,

ΔA = ΔA′ x 0.7

= 25441500 × 0.7

= 1,78,09,050 BDT

Initial first cost, ΔP = 6,85,50,000 BDT

Net Present Value, NPV = ΔA × PVF (d, n) – ΔP

= (1,78,09,050× 3.94) – 6,85,50,000

= 16,17,657 BDT

Simple payback period = $\frac{\Delta P}{\Delta A}$

= $\frac{6{,}85{,}50{,}000}{1{,}78{,}09{,}050}$

= 3.85 Years

= 3 Years 10 Months 4 Days

Figure 5.2.1 IRR Estimation Chart. [15]

Number of Years	Interest Rate per Year														
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%
1	.990	.980	.971	.962	.952	.943	.935	.926	.917	.909	.901	.893	.885	.877	.870
2	1.970	1.942	1.913	1.886	1.859	1.833	1.808	1.783	1.759	1.736	1.713	1.690	1.668	1.647	1.626
3	2.941	2.884	2.829	2.775	2.723	2.673	2.624	2.577	2.531	2.487	2.444	2.402	2.361	2.322	2.283
4	3.902	3.808	3.717	3.630	3.546	3.465	3.387	3.312	3.240	3.170	3.102	3.037	2.974	2.914	2.855
5	4.853	4.713	4.580	4.452	4.329	4.212	4.100	3.993	3.890	3.791	3.696	3.605	3.517	3.433	3.352
6	5.795	5.601	5.417	5.242	5.076	4.917	4.767	4.623	4.486	4.355	4.231	4.111	3.998	3.889	3.784
7	6.728	6.472	6.230	6.002	5.786	5.582	5.389	5.206	5.033	4.868	4.712	4.564	4.423	4.288	4.160
8	7.652	7.325	7.020	6.733	6.463	6.210	5.971	5.747	5.535	5.335	5.146	4.968	4.799	4.639	4.487
9	8.566	8.162	7.786	7.435	7.108	6.802	6.515	6.247	5.995	5.759	5.537	5.328	5.132	4.946	4.772
10	9.471	8.983	8.530	8.111	7.722	7.360	7.024	6.710	6.418	6.145	5.889	5.650	5.426	5.216	5.019
11	10.37	9.787	9.253	8.760	8.306	7.887	7.499	7.139	6.805	6.495	6.207	5.938	5.687	5.453	5.234
12	11.26	10.58	9.954	9.385	8.863	8.384	7.943	7.536	7.161	6.814	6.492	6.194	5.918	5.660	5.421
13	12.13	11.35	10.63	9.986	9.394	8.853	8.358	7.904	7.487	7.103	6.750	6.424	6.122	5.842	5.583
14	13.00	12.11	11.30	10.56	9.899	9.295	8.745	8.244	7.786	7.367	6.982	6.628	6.302	6.002	5.724
15	13.87	12.85	11.94	11.12	10.38	9.712	9.108	8.559	8.061	7.606	7.191	6.811	6.462	6.142	5.847
16	14.72	13.58	12.56	11.65	10.84	10.11	9.447	8.851	8.313	7.824	7.379	6.974	6.604	6.265	5.954
17	15.56	14.29	13.17	12.17	11.27	10.48	9.763	9.122	8.544	8.022	7.549	7.120	6.729	6.373	6.047
18	16.40	14.99	13.75	12.66	11.69	10.83	10.06	9.372	8.756	8.201	7.702	7.250	6.840	6.467	6.128
19	17.23	15.68	14.32	13.13	12.09	11.16	10.34	9.604	8.950	8.365	7.839	7.366	6.938	6.550	6.198
20	18.05	16.35	14.88	13.59	12.46	11.47	10.59	9.818	9.129	8.514	7.963	7.469	7.025	6.623	6.259
25	22.02	19.52	17.41	15.62	14.09	12.78	11.65	10.67	9.823	9.077	8.422	7.843	7.330	6.873	6.464
30	25.81	22.40	19.60	17.29	15.37	13.76	12.41	11.26	10.27	9.427	8.694	8.055	7.496	7.003	6.566

Number of Years	Interest Rate per Year														
	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%
1	.862	.855	.847	.840	.833	.826	.820	.813	.806	.800	.794	.787	.781	.775	.769
2	1.605	1.585	1.566	1.547	1.528	1.509	1.492	1.474	1.457	1.440	1.424	1.407	1.392	1.376	1.361
3	2.246	2.210	2.174	2.140	2.106	2.074	2.042	2.011	1.981	1.952	1.923	1.896	1.868	1.842	1.816
4	2.798	2.743	2.690	2.639	2.589	2.540	2.494	2.448	2.404	2.362	2.320	2.280	2.241	2.203	2.166
5	3.274	3.199	3.127	3.058	2.991	2.926	2.864	2.803	2.745	2.689	2.635	2.583	2.532	2.483	2.436
6	3.685	3.589	3.498	3.410	3.326	3.245	3.167	3.092	3.020	2.951	2.885	2.821	2.759	2.700	2.643
7	4.039	3.922	3.812	3.706	3.605	3.508	3.416	3.327	3.242	3.161	3.083	3.009	2.937	2.868	2.802
8	4.344	4.207	4.078	3.954	3.837	3.726	3.619	3.518	3.421	3.329	3.241	3.156	3.076	2.999	2.925
9	4.607	4.451	4.303	4.163	4.031	3.905	3.786	3.673	3.566	3.463	3.366	3.273	3.184	3.100	3.019
10	4.833	4.659	4.494	4.339	4.192	4.054	3.923	3.799	3.682	3.571	3.465	3.364	3.269	3.178	3.092
11	5.029	4.836	4.656	4.486	4.327	4.177	4.035	3.902	3.776	3.656	3.543	3.437	3.335	3.239	3.147
12	5.197	4.988	4.793	4.611	4.439	4.278	4.127	3.985	3.851	3.725	3.606	3.493	3.387	3.286	3.190
13	5.342	5.118	4.910	4.715	4.533	4.362	4.203	4.053	3.912	3.780	3.656	3.538	3.427	3.322	3.223
14	5.468	5.229	5.008	4.802	4.611	4.432	4.265	4.108	3.962	3.824	3.695	3.573	3.459	3.351	3.249
15	5.575	5.324	5.092	4.876	4.675	4.489	4.315	4.153	4.001	3.859	3.726	3.601	3.483	3.373	3.268
16	5.668	5.405	5.162	4.938	4.730	4.536	4.357	4.189	4.033	3.887	3.751	3.623	3.503	3.390	3.283
17	5.749	5.475	5.222	4.990	4.775	4.576	4.391	4.219	4.059	3.910	3.771	3.640	3.518	3.403	3.295
18	5.818	5.534	5.273	5.033	4.812	4.608	4.419	4.243	4.080	3.928	3.786	3.654	3.529	3.413	3.304
19	5.877	5.584	5.316	5.070	4.843	4.635	4.442	4.263	4.097	3.942	3.799	3.664	3.539	3.421	3.311
20	5.929	5.628	5.353	5.101	4.870	4.657	4.460	4.279	4.110	3.954	3.808	3.673	3.546	3.427	3.316
25	6.097	5.766	5.467	5.195	4.948	4.721	4.514	4.323	4.147	3.985	3.834	3.694	3.564	3.442	3.329
30	6.177	5.829	5.517	5.235	4.979	4.746	4.534	4.339	4.160	3.995	3.842	3.701	3.569	3.447	3.332

The simple payback period is 3.85 years, which is close to the value of 3.89 shown in Figure 5.2.1. According to the same chart, for a period of 5 years, the approximate value of the internal rate of return (IRR) is 9%.

After analyzing the relevant financial metrics of the project, we can observe that the Net Present Value (NPV) is positive, indicating that the project's future cash inflows will exceed the initial investment and generate a profit. Additionally, we can note that the Internal Rate of Return (IRR) is approximately 1.06 times higher than the discount rate, implying that the project will deliver an attractive return on investment. These results suggest that the project is a financial investment that is likely to yield positive outcomes.

Chapter 6 Conclusion

6.1 Verification of complex engineering problem

The 3D printer satisfied 4 complex engineering problems. In this section of 400C, we will now verify them,

- **P1: Depth of Required Knowledge**
  - **K4 (Engineering Specialist Knowledge):** in our 3D printer, we required a microcontroller to integrate the sensors.
  - **K5 (Engineering Design Knowledge):** In our circuit we have designed a custom circuit layout which is suitable for our purposes. We have also custom designed the interior of the 3D printer so that we can move our components in the x, y and z axis.
  - **K6 (Knowledge of Modern Engineering Tools):** We used modern engineering tools in the execution process of the 3D printer. For our 3D printer we use "cura" software for slicing our input models. The 3D printer prototype's outlook, interior, inside compartments, and positioning of sensors and modules were all designed using freecad. The circuit's schematic layout was made using Proteus.
  - **K8: (Research Knowledge):** During the completion of this project, we have had to use research knowledge every step of the way. From deciding on the material of printing to deciding what sensors and mechanisms could be used to separate the 3D printer we have had to go through several research papers to understand and implement this project. Furthermore, we have also had to evaluate alternate solutions of how to improve output "object" look. And how to improve the tensile strength from research papers and decide on the one that we think works for our project the best.

- **<u>P3: Depth of Analysis Required</u>**

When we were implementing the project, we found multiple methods of executing this project. In those methods, we had to find a cost analysis of each solution and decide whether that method was feasible or not. Other than the cost analysis, we had to evaluate the performance and the quality of the sensors, and many mechanical instruments strength that we were going to use in our 3D printer and choose the ones that were suitable for our project.

- **<u>P6. Extent of Stakeholder Involvement and Conflicting Requirements</u>**

For our 3D printer the main stakeholders are educational institutions. School, collage, university that use 3D printers for teaching and reacheres purposes. They are stakeholders in terms of how the technology is integrated into educational programs and research projects. 3D printers are increasingly used in science and technology, engineering, and mathematics programs to prove hands on experience with technology and design. Researchers use 3D printers to create prototypes, conduct experiments, and develop new technologies.

In the other sense, we can say manufactures, suppliers, distributors and retailers are also the stakeholders. These kinds of stakeholders do all the work for our 3D printer, they can manufacture on a large scale, and supply many ways in the marketplace. In our country "singer", "walton" and many other companies manufacture and supply all over the bangladesh. We are talking with "singer" as a manufacturing company and "MK electronics" as a local vendor. We are also talking with the general users.

Conflicting Requirements: Main conflicting part of our project is cost. When talking with a manufacturing company, they say they are not focusing on the cost, they are only focusing on the product's durability, easy of access, product quality, and most important the product work function. And the vendors and users commonly say they need a 3D printer with the best quality at a cheaper price.

- **P7: Interdependence**

In the implementation of our project, we have a lot of processes which are interdependent on each other. These are:

1. Raw material selection
2. Transfer technology of materials
3. 3 dimensional location control

In our project, raw material is an important factor. For that reason, we have selected plastic as raw material. However, technology may vary according to the material. On the other hand, 3 Dimensional locational control also depends according to the specified technology.

6.2 Meeting the project objectives

Our main motive of this project is to enable designs into reality. These printed objects are helping teachers to teach many difficult things that are not understood by 2D view. We are also trying to update the learning process of students. Our 3D printer can print many external parts of many objects like broken showpieces, any part of broken sunglasses and so on. On the other hand, 3-dimensional locational control also depends according to the specified technology. Most importantly it can be used for printing prosthetics for medical science. We have built a prototype of 3D printer that costs around 17075 BDT. Initially we have set a unit selling price of 25500 BDT. Thus, our 3D printer is a user-friendly and cost-effective solution to the problem of various problems and can help to understand the learning of something which is difficult to understand in 2D view.

To conclude, we can say it satisfies all the project objectives.

APPENDIX A. ACTIVITY CHART

Part-A

Date	Participants	Activity Description	Approx. hrs. spent

Part-B

Date	Participants	Activity Description	Approx. hrs. spent

Part-C

Date	Participants	Activity Description	Approx. hrs. spent

APPENDIX B. OTHER TECHNICAL DETAILS

APPENDIX C. JUSTIFICATION OF COMPLEX ENGINEERING PROBLEM

This table prepared in EEE400A justifies the proposed project as a complex engineering problem

Attribute	**Complex Engineering Problems** have characteristic P1 and some or all of P2 to P7:	**Covered in the project? (Y/N)**	**Explain/justify**
Depth of knowledge required	P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach		
Range of conflicting requirements	P2: Involves wide-ranging or conflicting technical, engineering and other issues		
Depth of analysis required	P3: There is no obvious solution, and abstract thinking and originality in analysis are required to formulate suitable models		
Familiarity of issues	P4: Involves infrequently encountered issues		
Extent of applicable codes	P5: Are outside problems encompassed by standards and codes of practice for professional engineering		
Extent of stakeholder involvement and conflicting requirements	P6: Involves diverse groups of stakeholders with widely varying needs		
Interdependence	P7: High level problems including many component parts or sub-problems		

APPENDIX D. JUSTIFICATION OF COMPLEX ENGINEERING ACTIVITIES

This table prepared in EEE400C describes the complex engineering activities in the project

Attribute	**Complex activities mean (engineering) activities or projects that have some or all of the following characteristics:**	**Covered in the project? (Y/N)**	**Explain**
Range or resources	A1: Involves the use of diverse resources (for this purpose, resources include people, money, equipment, materials, information and technologies)		
Level of interaction	A2: Requires resolution of significant problems arising from interactions among wide-ranging or conflicting technical, engineering, or other issues		
Innovation	A3: Involves creative use of engineering principles and research-based knowledge in novel ways		
Consequences for society and the environment	A4: Has significant consequences in a range of contexts; characterized by difficulty of prediction and mitigation		
Familiarity	A5: Can extend beyond previous experiences by applying principles-based approaches		

APPENDIX E. RUBRICS

Rubrics for EEE400

Table 1: Rubrics for assessment of PO9 (Individual work and teamwork)

Performance indicators	Outstanding (9 – 10)	Good (7 – 8)	Satisfactory (6)	Unsatisfactory (0 – 5)
Individual skills	Actively participates in group discussions and decision making, contributes useful ideas, completes assigned responsibilities thoroughly on time	Participates in group discussions and decision making, contributes ideas, completes assigned responsibilities mostly on time	Somewhat participates in group discussions and decision making, sometimes contributes ideas, completes some of the assigned responsibilities on time	Does not participate in group discussions and decision making, does not contribute relevant ideas, does not complete assigned responsibilities on time
Team skills	Always collaborates with others, always promotes constructive team atmosphere, always identifies and responds to conflicts promptly and positively	Usually collaborates with others, usually promotes constructive team atmosphere, usually identifies and responds to conflicts positively	Sometimes collaborates with others, sometimes promotes constructive team atmosphere, sometimes identifies and responds to conflicts positively	Does not collaborate with others, does not promote constructive team atmosphere, does not identify and respond to conflicts
Leadership skills	Always provides direction to achieve goals, always respects and listens to other members, always plans for improvement, always motivates others	Usually provides direction to achieve goals, usually respects and listens to other members, usually plans for improvement, usually motivates others	Sometimes provides direction to achieve goals, sometimes respects and listens to other members, sometimes plans for improvement, sometimes motivates others	Does not provide direction to achieve goals, does not respect and listen to other members, does not plan for improvement, does not motivate others
Multidisciplinary activities	Fully understands and appreciates the multidisciplinary nature of the project activities, shows interests and participates in activities in disciplines outside of own	Mostly understands and appreciates the multidisciplinary nature of the project activities, participates in activities in disciplines outside of own	Somewhat understands and appreciates the multidisciplinary nature of the project activities, participates in some activities in disciplines outside of own	Does not understand or appreciate the multidisciplinary nature of the project activities, does not participate in activities in disciplines outside of own

Table 2: Rubrics for assessment of PO8 (Ethics)

Performance indicators	Outstanding (9 – 10)	Good (7 – 8)	Satisfactory (6)	Unsatisfactory (0 – 5)
Equity	Always approaches situations with consideration of equity, always behaves inclusively	Mostly approaches situations with consideration of equity, mostly behaves inclusively	Sometimes approaches situations with consideration of equity, Sometimes behaves inclusively	Does not approach situations with consideration of equity, does not behave inclusively
Accountability	Always understands about accountability and personal responsibility, always assumes responsibility of own actions	Mostly understands about accountability and personal responsibility, mostly assumes responsibility of own actions	Sometimes understands about accountability and personal responsibility, sometimes assumes responsibility of own actions	Does not understand about accountability and personal responsibility, does not assume responsibility of own actions
Proper use of others' works	Always recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and acts accordingly	Mostly recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and mostly acts accordingly	Sometimes recognizes the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and sometimes acts accordingly	Does not recognize the need for due acknowledgment of others' works, intellectual property and copyrighted materials, and does not act accordingly
Professionalism	Fully understands the role of the engineer in protecting public interests, fully understands and is aware of relevant codes of ethics	Mostly understands the role of the engineer in protecting public interests, mostly understands and is mostly aware of relevant codes of ethics	Somewhat understands the role of the engineer in protecting public interests, somewhat understands and is somewhat aware of relevant codes of ethics	Does not understand the role of the engineer in protecting public interests, does not understand or is not aware of relevant codes of ethics

Rubrics for EEE400A

Table EEE400A: Rubrics for assessment of the project concept and proposal

Performance indicators	Outstanding (9 – 10)	Good (7 – 8)	Satisfactory (6)	Unsatisfactory (0 – 5)
PCP_PI1: Able to identify a suitable complex engineering design problem (1a) [sec-1.1, Appendix C] **(CO1/PO12, P1)**	Demonstrates an ability to explore a topic thoroughly, and to identify a suitable complex engineering problem	Demonstrates an ability to explore a topic, and to identify a reasonably suitable complex engineering problem	Demonstrates an ability to somewhat explore a topic, and to identify a somewhat suitable complex engineering problem	Demonstrates minimal or no ability to explore a topic, or to identify a suitable complex engineering problem
PCP_PI2: Engages to stay up to date on the relevant topic (2b) [sec-1.2] **(CO1/PO12, P1)**	Demonstrates thorough engagement to stay up to date on the relevant topic	Demonstrates engagement to stay up to date on the relevant topic	Demonstrates some engagement to stay up to date on the relevant topic	Demonstrates minimal or no engagement to stay up to date on the relevant topic
PCP_PI3: Identifies the regulatory requirements, standards, and codes of practice (2a) [sec-1.3] **(CO2/PO3, P5)**	Identifies all the relevant regulatory requirements, standards, and codes of practice	Identifies most of the relevant regulatory requirements, standards, and codes of practice	Identifies some of the relevant regulatory requirements, standards, and codes of practice	Does not identify any of the relevant regulatory requirements, standards, and codes of practice
PCP_PI4: Explains the objectives, project requirements and constraints of the solution considering the expectations of the stakeholders (2c) [sec-1.4, 1.5] **(CO2/PO3, P2, P6)**	Clearly explains the objectives, project requirements and constraints taking into account all the expectations of the stakeholders	Explains the objectives, project requirements and constraints taking into account most of the expectations of the stakeholders	Somewhat explains the objectives, project requirements and constraints fully taking into account some the expectations of the stakeholders	Does not explain the objectives, project requirements and constraints and/or does not take into account any expectation of the stakeholders
PCP_PI5: Prepares project management plan, setting up milestones and considering risks and contingencies (2d) [sec-1.6.1, 1.6.2] **(CO3/PO11)**	Prepares a comprehensive project management plan, clearly sets up milestones, thoroughly considers risks and contingencies	Prepares a project management plan, sets up milestones, considers risks and contingencies	Prepares a project management plan, sets up a few milestones, attempts to considers risks and contingencies	Prepares a unclear/incomplete project management plan, does not set up milestones, does not consider risks and contingencies
PCP_PI6: Identifies required resources and prepares a realistic budget (2e, 2g) [sec-1.6.3] **(CO3/PO11)**	Identifies all resources and prepares budget that covers all applicable areas of the project including room for contingency	Identifies most resources and prepares budget that covers most applicable areas of the project including room for contingency	Identifies some resources and prepares budget that covers some applicable areas of the project	Cannot identify resources and cannot prepare a budget addressing major applicable areas of the project
PCP_PI7: Explains how to sustain and maintain the product/service in business if the solution is successfully commercialized. (2h) [sec-1.7]	Clearly explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Somewhat explains how to sustain and maintain the product/service in business if the solution is successfully commercialized.	Does not explain how to sustain and maintain the product/service in business if the solution is successfully commercialized.

PCP_PI8: Considers the impact of the solution on society including health, safety, cultural, and legal issues (2f) [sec-1.8.1, 1.8.3] **(CO4/PO6)**	Considers all the impacts on society including health, safety, cultural and legal issues	Considers most of the impacts on society including health, safety, cultural and legal issues	Considers some of the impacts on society including health, safety, cultural and legal issues	Does not consider any impact on society including health, safety, cultural and legal issues
PCP_PI9: Considers the impact of the solution on environment and sustainability over the entire product life cycle. Proposes mitigating solution if needed. (2f) [sec-1.8.2] **(CO5/PO7)**	Considers all the impacts on environment and sustainability. If necessary, proposes solutions to mitigate negative impact	Considers most of the impacts on environment and sustainability. If necessary, identifies impacts which need mitigation	Considers some of the impacts on environment and sustainability	Minimal or no consideration of impacts on environment and sustainability

P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach

P2: Involves wide-ranging or conflicting technical, engineering and other issues

P4: Involves infrequently encountered issues

P6: Involves diverse groups of stakeholders with widely varying needs

Rubrics for EEE400B

Table 1: Rubrics for assessment of the Design Report

Performance indicators	Outstanding (9 – 10)	Good (7 – 8)	Satisfactory (6)	Unsatisfactory (0 – 5)
DR_PI1: Develops a functional design considering applicable standards, codes of practice, health, safety, and environmental considerations. (1a) [sec-2.1] **(CO2/PO3, P2, P7)**	Appropriately partitions the problem into sub-problems, considers all relevant engineering standards and codes where applicable, involves all health, safety, and environmental issues in design	Partitions the problem into sub-problems, considers most relevant engineering standards and codes where applicable, involves major health, safety, and environmental issues in design	Partitions the problem into sub-problems to some extent, considers some relevant engineering standards and codes where applicable, involves some health, safety, and environmental issues in design	Does not usefully partition the problem into sub-problems, does not consider relevant engineering standards and codes, health, safety, and environmental issues not involved in design
DR_PI2: Formulates and evaluates alternate solutions (1b) [sec-2.2] **(CO1/PO2, P1, P3)**	Effectively formulates multiple solutions that functionally meet most requirements, compares and evaluates alternate solutions, extracts valid conclusions	Formulates multiple solutions that functionally meet most requirements, partially compares and evaluates alternate solutions, conclusions in line with analysis	Formulates multiple solutions that functionally meet some requirements, attempts to compare and evaluate alternate solutions, conclusions somewhat in line with analysis	Does not formulate multiple solutions, no attempt to compare and evaluate alternate solutions, conclusions not based on analysis
DR_PI3: Prepares and refines design with analysis and/or simulation of the system for implementation (1c, 1d) [sec-2.3] **(CO2/PO3, P1)**	Performs all design calculations, produces detailed design, analyzes and/or simulates to verify that the design satisfies all requirements. Design is skillfully refined to facilitate implementation.	Performs most design calculations, produces design with some details, analyzes/simulates to verify that the design satisfies most requirements. Design is refined to facilitate implementation.	Performs some design calculations, produces design with a few details, attempts to analyze/simulate the design to verify satisfaction of requirements. Design is somewhat refined to facilitate implementation.	Does not perform design calculations, detailed design not produced, analysis/simulation not done to verify satisfaction of requirements. Design is not refined to facilitate implementation.

P1: Cannot be resolved without in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6 or K8, which allows for a fundamentals-based, first principles analytical approach

P2: Involves wide-ranging or conflicting technical, engineering and other issues

P3: There is no obvious solution, and abstract thinking and originality in analysis are required to formulate suitable models

P7: High level problems including many component parts or sub-problems

Rubrics for EEE400C

Table 1: Rubrics for Final report of EEE400C

Performance indicators	Outstanding	Good	Satisfactory	Unsatisfactory

	(9 – 10)	(7 – 8)	(6)	(0 – 5)
FR_PI1: Discusses how the prototype of the solution is developed. [sec 3.1]	Comprehensively discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Somewhat discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams	Poorly discusses how the prototype of the solution is developed with the help of appropriate figures, photos and diagrams
FR_PI2: Evaluates performance of the developed system as per requirements. Finalizes design based on performance evaluation (1a and 1b) [sec 3.2, sec 3.3] **(CO1/PO4, CO3/PO3)**	System meets all requirements or the students can identify and explain clearly when deviation from requirements occurs. Revises design with appropriate technical analysis if necessary to achieve compliance with all specification and requirements	System meets major requirements. Students can identify and explain most deviations from requirements. Revises design with technical analysis if necessary to achieve compliance with most specification and requirements	System meets some requirements. Students can identify and explain some deviations from requirements. Revises design with some technical analysis if necessary to achieve compliance with some specification and requirements	System does not meet most requirements. Students cannot identify and explain most deviations from requirements. Design not revised to achieve compliance.
FR_PI3: Finalizes design based on performance evaluation (1c) [sec 3.3] **(CO3/PO3)**	Revises design with appropriate technical analysis to achieve compliance with all requirements finalized in 400B	Revises design with technical analysis to achieve compliance with most requirements finalized in 400B	Revises design with some technical analysis to achieve compliance with some requirements finalized in 400B	Does not revise design with technical analysis to achieve compliance with any requirement finalized in 400B
FR_PI4: Selects and uses appropriate modern engineering tools for modeling, simulation and/or performance evaluation throughout the project (EEE400 A, B, C) [sec 3.4] **(CO2/PO5)**	Carefully selects and skillfully uses modern engineering tools knowing all the relevant limitations of the tools	Selects and uses modern engineering tools with some degree of care and skill knowing major relevant limitations of the tools	Selects and uses modern engineering tools knowing some relevant limitations of the tools	Selected and used modern engineering tools are mostly not appropriate. No knowledge of relevant limitations of the tools
FR_PI5: Achieve the milestones set in the project proposal or revises the schedule appropriately to complete the project within the deadline (EEE400 A, B, C) [Chapter 4] **(CO4/PO11)**	All milestones are reached on time or corrective measures are appropriately taken to revise the schedule to complete the project within deadline	Most milestones are reached on time or corrective measures are taken to revise the schedule to complete the project within deadline	Milestones are somewhat reached on time or some corrective measures are taken to revise the schedule to complete the project within deadline	Milestones are mostly not reached on time. Corrective measures are not taken to revise the schedule to complete the project within deadline
FR_PI6: Prepares the bill of materials and estimates the cost of the system [sec 5.1] **(CO5/PO11)**	Prepares bill of materials considering all the project components and/or parts and the cost is accurately estimated	Prepares bill of materials considering most the project components and/or parts and the cost is estimated	Prepares bill of materials considering major project components and/or parts and the cost is reasonably estimated	Prepares bill of materials ignoring important project components and/or parts and the cost is not reasonable
FR_PI7: Performs economic analysis to calculate suitable economic parameter(s)	Evaluates the financial prospect of the project through detailed and	Evaluates the financial prospect of the project through	Evaluates the financial prospect of the project through analysis.	Does not evaluate the financial prospect of the project through analysis

to evaluate the economic prospect of the proposed project [sec 5.2] **(CO5/PO11)**	thorough analysis. Interpretation is clear	analysis. Provides interpretation		

Table 2: Overall rubrics on report writing

Communicates the main ideas in written form [Overall] **(CO8/PO10)**	Communicates the main ideas clearly and to the point	Communicates the main ideas	Communicates the main ideas to some extent	Does not communicate the main ideas
Uses illustrations (graphs, tables, diagrams) to support ideas, analysis and interpretation [Overall] **(CO8/PO10)**	Skillfully uses illustrations to support ideas. Illustrations enhance comprehension of analysis and interpretation	Uses illustrations to support ideas. Illustrations somewhat enhance comprehension of analysis and interpretation	Uses illustrations which are related to analysis and interpretation	Either does not use illustrations or illustrations used are not relevant to ideas, analysis and interpretation
Uses citations and references [Overall] **(CO8/PO10)**	Citations and references are effectively used to duly acknowledge prior art and other people's works	Citations and references are used to acknowledge prior art and other people's works	Citations and references are used to somewhat acknowledge prior art and other people's works	Citations and references are not used or prior art and other people's works are not acknowledged
Uses a language which is mechanically (punctuation, spelling and grammar) correct [Overall] **(CO8/PO10)**	The report is free from mechanical errors	The report contains a few mechanical errors	The report contains some mechanical errors	The report contains several mechanical errors

Table 3: Rubrics for oral presentation

Performance indicators	Outstanding (9 – 10)	Good (7 – 8)	Satisfactory (6)	Unsatisfactory (0 – 5)
Communicates appropriately targeting the society at large **(CO8/PO10)**	Communication is skillfully tailored to appropriately suit the level of target audience	Communication is tailored to suit the level of target audience	Communication is somewhat tailored to suit the level of target audience	Communication is not tailored to suit the level of target audience
Focusses on the creative aspects of the solution with clarity **(CO8/PO10)**	Creative aspects are clearly articulated and emphasized. Presentation is logically and skillfully structured	Creative aspects are articulated and emphasized. Presentation structure is logical	Creative aspects are somewhat articulated and emphasized. Presentation structure is somewhat logical	Creative aspects are not articulated or emphasized. Presentation structure is not logical
Above two PIs will assess the sales pitch part of the presentation. Following PIs are for the technical part				
Designs and integrates visual aids (illustrations, demonstrations, props, etc) to support and focus presentation **(CO8/PO10)**	Visual aids are creatively designed, skillfully used and seamlessly integrated to enhance and focus presentation	Visual aids are designed, used and integrated to enhance and focus presentation	Visual aids are designed, used and integrated to enhance and focus presentation to some extent	Visual aids are not designed, used or integrated to enhance and focus presentation
Completes presentation within the allotted time **(CO8/PO10)**	Finishes the presentation as prepared within time without rushing or skipping content	Finishes the presentation as prepared within time with rushing or skipping content occasionally	Finishes the presentation as prepared within time with rushing or skipping content a few times	Does not finish the as prepared presentation within time or skips major contents to finish within time
Listens to the questions and answers appropriately **(CO8/PO10)**	Carefully listens to the questions, answers concisely transitioning skillfully between presentation and Q/A	Listens to the questions, answers to the point transitioning well between presentation and Q/A	Listens to the questions, answers somewhat to the point transitioning between presentation and Q/A in an acceptable manner	Does not listen to the questions, answers not to the point transitioning between presentation and Q/A not in an acceptable manner

REFERENCES

[1] Finnes, T. (n.d.). *High Definition 3D printing – Comparing SLA and FDM printing technologies*. Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. https://openprairie.sdstate.edu/jur/vol13/iss1/3/

[2] A. Golebiowska, H. S. Kim, G. Camci-Unal, and S. P. Nukavarapu, "Integration of technologies for bone tissue engineering," in *Elsevier eBooks*, 2019. doi: 10.1016/b978-0-12 -801238-3.11063-3.

[3] Anekar, N. (2020b). Design and Analysis of FDM based 3D Printer. Mitpune. Retrieved from https://www.academia.edu/44259284/Design_and_Analysis_of_FDM_based_3D_Printer

[4] Wilson, S., Thomas, R., Mary, N., Bosco, E. T., & Gopinath, A. (2021b). Development and fabrication of fused deposition modelling 3D printer. IOP Conference Series, 1132(1), 012019. https://doi.org/10.1088/1757-899x/1132/1/012019

[5] Hao, B., & Lin, G. (2020). 3D printing technology and its application in industrial manufacturing. IOP Conference Series, 782(2), 022065. https://doi.org/10.1088/1757-899x/782/2/022065

[6] A. Kafle, E. Luis, R. Silwal, H. M. Pan, P. Shrestha, and A. K. Bastola, "3D/4D printing of polymers: fused deposition Modelling (FDM), selective laser sintering (SLS), and stereolithography (SLA)," *Polymers*, vol. 13, no. 18, p. 3101, Sep. 2021, doi: 10.3390/polym13183101.

[7] Schouten, M., Wolterink, G., Dijkshoorn, A., Kosmas, D., Stramigioli, S., & Krijnen, G. (2021, June 1). *A Review of Extrusion-Based 3D Printing for the Fabrication of Electro- and Biomechanical Sensors*. IEEE Sensors Journal. https://doi.org/10.1109/jsen.2020.3042436

[8] Hozdić, E. (2024, January 12). *Characterization and Comparative Analysis of Mechanical Parameters of FDM- and SLA-Printed ABS Materials*. Applied Sciences. https://doi.org/10.3390/app14020649

[9] AliExpress - Affordable Prices on Top Brands with Free Shipping. (n.d.). AliExpress. https://www.aliexpress.com/

[10] Online Shopping in Bangladesh: Order Now from Daraz.com.bd. (n.d.). https://www.daraz.com.bd/

[11] *Motor driver*. (n.d.). https://store.roboticsbd.com/17-motor-driver

[12] Mensley, M. (2023, July 27). *3D printer Extruder – All you need to know*. All3DP. https://all3dp.com/2/3d-printer-extruder-guide/

[13] Alhamed, A. (2023, April 4). *Heated beds and 3D printing: what you need to know*. Cytron Technologies. https://www.cytron.io/tutorial/why-your-3d-printer-needs-a-heated-bed#:~:text=A%20heated%20bed%20is%20an%20essential%20component%20of%20a%203D,for%20any%203D%20printing%20enthusiast.

[14] Akib, A. A. (2024, June 10). Facebook Advertising Cost in Bangladesh: A Comprehensive Guide. *Medium*. https://medium.com/@akaeid786/facebook-advertising-cost-in-bangladesh-a-comprehensive-guide-b705fcda5401#:~:text=Average%20Costs%20in%20Bangladesh&text=Cost%20Per%20Click%20(CPC)%3A%20Typically%20ranges%20from%20BDT%205,on%20the%20action%20and%20industry.

[15] Unknown. (n.d.). *How to calculate Internal Rate of Return (IRR)? (Critical Review)*.

https://hoileongchan.blogspot.com/2012/08/how-to-calculate-internal-rate-of.html