GNG2101

Deliverable D: Detailed Design and BOM

TEAM FLEXTECH E1.2

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1 Detailed Design and BOM

1.1 Detailed design

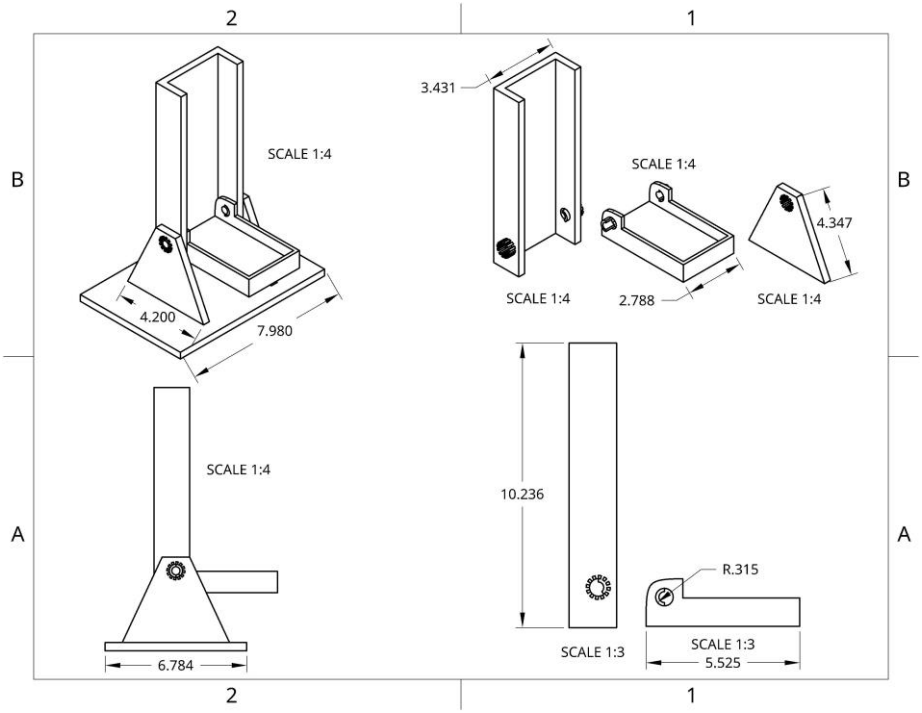
1.1.1 Summarized client feedback

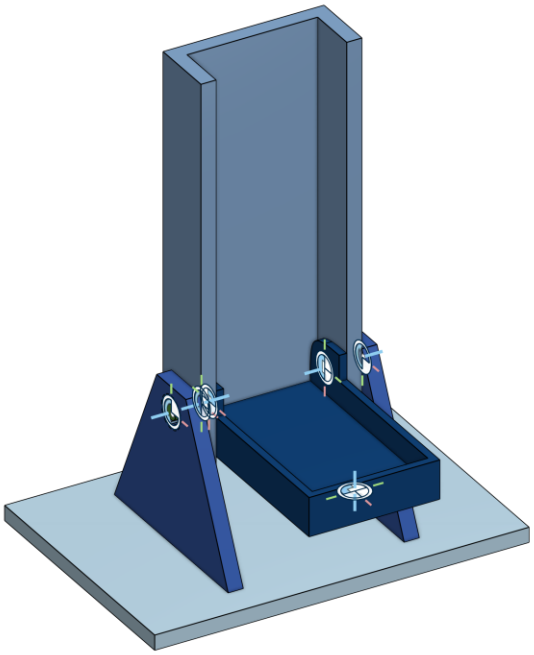
After conducting a 15-minute interview at our client's house, we received a lot of feedback and learned many new things from the client. The feedback is split into 5 main categories.

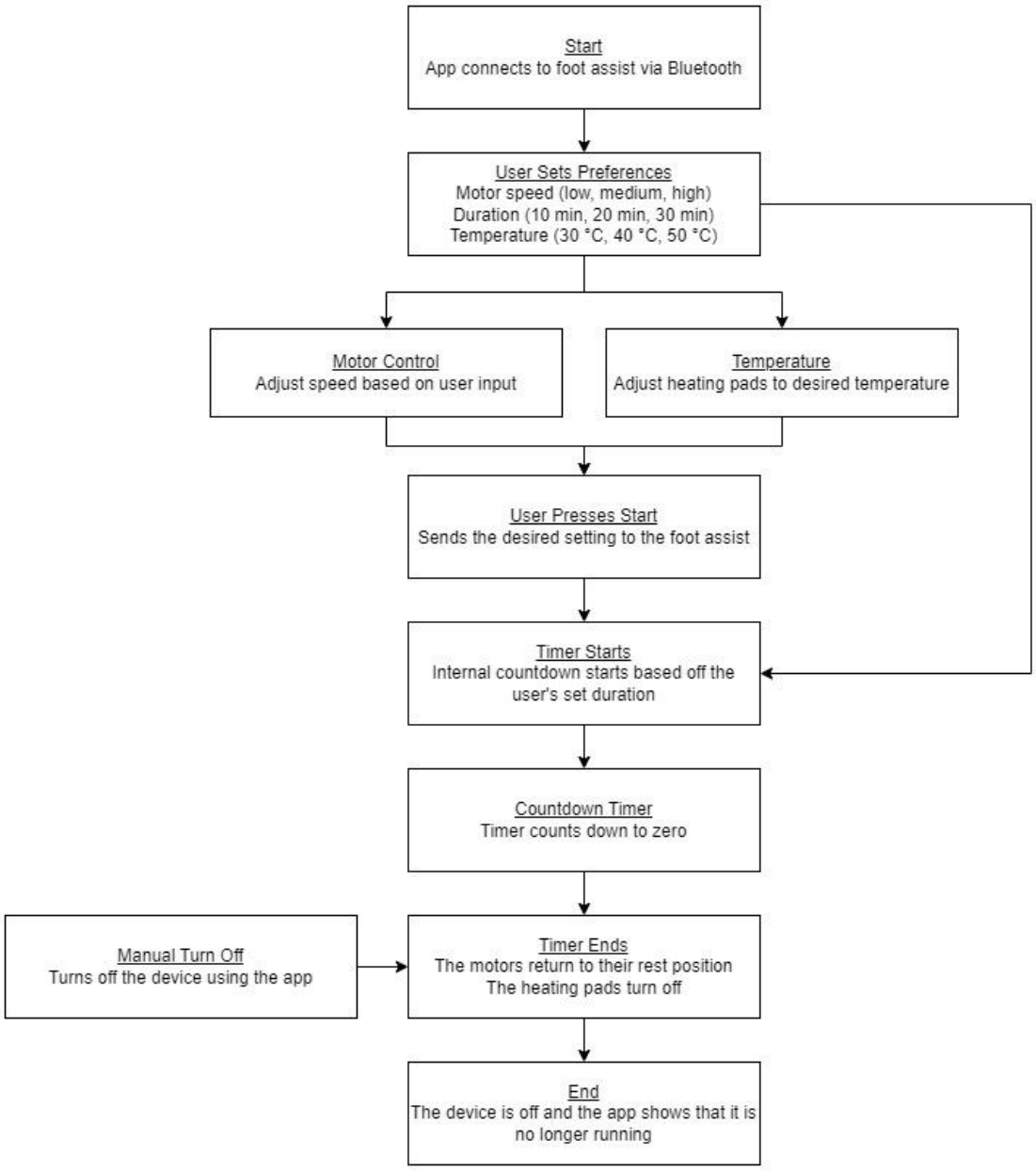
1. Portability:
    a. There is no need for portability since the client will not take the device outside of her house nor need the device for vacations/holidays.
2. Speed/Time:
    a. The raising and lowering of the dorsi/plantar flexion exercise should last 2-3 seconds for one interval, as per client request.
    b. The speed should aim to loosen the joint of the client's ankle and foot, similar to the hand machine (a device that forms our client's hand into a fist and back).
    c. The foot flex assist device will be used for half an hour; the same amount of time she uses the hand machine.
3. Current Exercises:
    a. The client uses a "ballet bar" to lean and hold on while she conducts the necessary stretches with her foot.
    b. As she leans on the bar, she presses her foot against a foam half cylinder lying flat on the ground.
    c. This stretches her calf muscles, as well as flexes her foot in the direction she needs, and can be adjusted to the range of motion.
4. Remote:
    a. The client prefers to use an app on her iPhone as the controller. The client uses many apps to automate assisting devices around the house, so she likes having her controller as a universal remote.
5. Charging:
    a. She requested a duration function for the timing and for how long the device will run.
    b. She also requested to have a rechargeable battery over single use batteries for the device (Duracell).

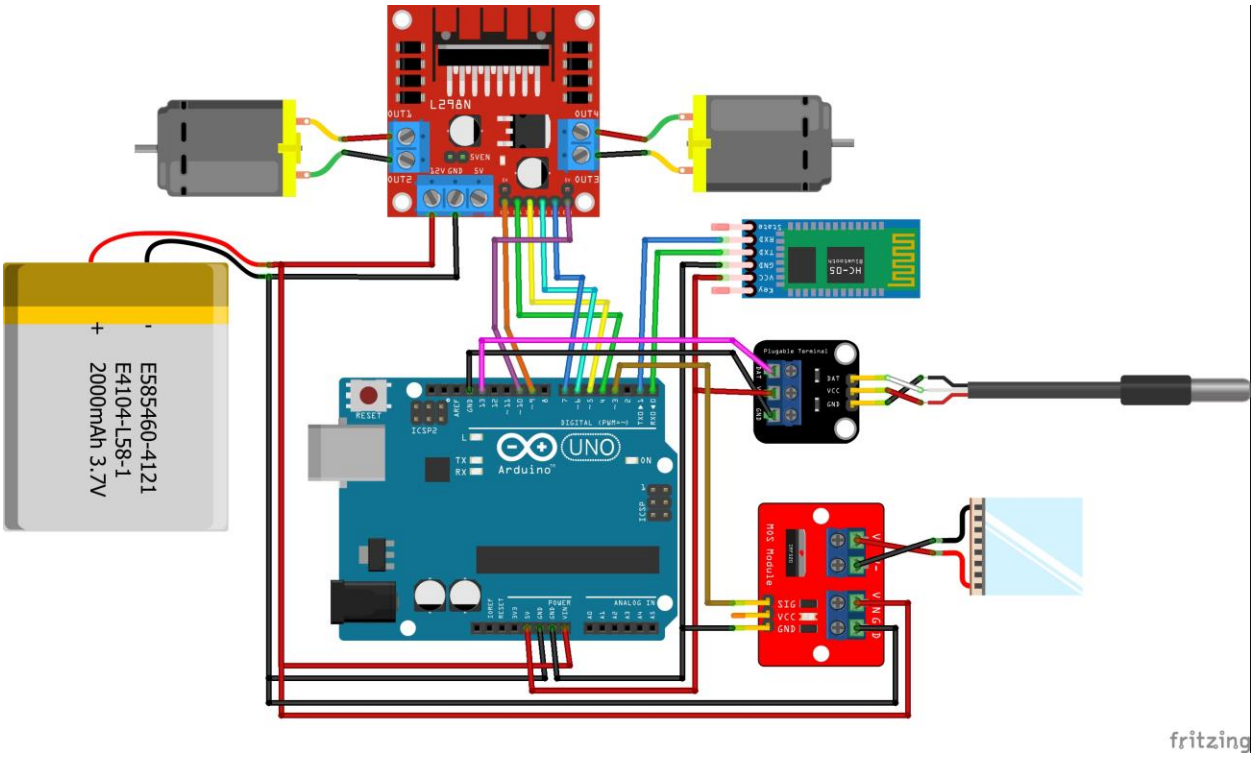
Based on our client's feedback, the new changes we need to make to our device are clear. We will have a device that is controlled from her iPhone (via Bluetooth), that can function with rechargeable batteries, and that can enable a timing function for how long the device will run, creating dorsi/plantar flexion intervals of 2-3 seconds.

1.1.2 Visual representation concepts (prototype + subsystems)






Start
App connects to foot assist via Bluetooth
User Sets Preferences
Motor speed (low, medium, high)
Duration (10 min, 20 min, 30 min)
Temperature (30 °C, 40 °C, 50 °C)
Motor Control
Adjust speed based on user input
Temperature
Adjust heating pads to desired temperature
User Presses Start
Sends the desired setting to the foot assist
Timer Starts
Internal countdown starts based off the user's set duration
Countdown Timer
Timer counts down to zero
Manual Turn Off
Turns off the device using the app
Timer Ends
The motors return to their rest position
The heating pads turn off
End
The device is off and the app shows that it is no longer running



1.1.3 Considerations to design the concept

Based on our updated detailed design, we have new considerations we must take to design our concept to meet our DFX factors. Some of which include our client's feedback such as:

- **Making our client's iPhone the remote device:** In order to Design for User Experience, Reliability and Simplicity, we want to make the remote device our client's iPhone, as she stated in a client interview that she prefers to have control of her automated devices all in one place (her iPhone). We now must design a Bluetooth component in our design that can be accessible from an iPhone. Most likely, we will use an Arduino component with a Bluetooth sensor chip that can activate our motors via a Bluetooth connection.
- **Rechargeable batteries:** In order to Design for Cost, User Experience, Reliability, and Simplicity, the device will have rechargeable batteries over one-use batteries. This was made in consideration of our client being unable to reliably change batteries in a device due to her condition.
- **Timer setting:** In order to design for User Experience, the device will have a timer setting that allows our client to set a time for how long she would like the device to last. The timer would be integrated through code and an Arduino software. As she enables the timer, the device will perform a 2-3 second interval of plantar/dorsi flexion exercise. This is the time our client requested.
- **3D printing:** In order to Design for Cost and Simplicity, the main body of the device will be constructed from 3D printing filament. We have many designs that can reduce the total amount of material used but require geometries and parts that are difficult to obtain in local stores. Therefore, we decided to use 3D printing to save on total material usage

and cost to create the base of our frame. It is lightweight and durable enough to support our client's foot, and the stresses applied on the device will be minimal enough for the filament to withstand. We will also have to create our CAD designs and print prototypes early in order to beat the rush of students who will also use the 3D printers in various design competitions.

- **Simple materials**: In order to Design for Cost, Safety, and Simplicity, we have selected simple, cheaper materials to use for a variety of reasons. Our deadline to create our first prototype is February 10, 2025, meaning we will have little time to construct and present our idea. The minimal materials will also cost less for us and the client and will be easier to obtain. Being cheaper materials, the device can also be easily dismantled should an accident occur.

Overall, the most important DFX factors would be Design for Cost and Design for User Experience. One large factor is that many of the existing devices cost hundreds of dollars and have very complex mechanisms/additional features our client does not need. By creating a cheaper alternative that is intuitively easier for our client to learn, we can address a majority of our client's needs effectively just by addressing these two DFX.

1.1.4 List of skills and resources

We have a wide range of skills at our disposal that will enable us to create our design. In order to create our physical foot flex assist design, we can leverage the following skills from our group members:

- **CAD software skills:** Jordan and Stella can utilize CAD software skills (OnShape, or SolidWorks) to produce 3D renderings of our design and create mockups/subsystems that can be 3D printed. These models also allow us to dimension the device to fit our clients' needs and foot.
- **Mechanical prototyping skills:** Jordan can create various mechanical prototypes from metal frames and motors that can demonstrate the functionality of basic subsystems, as well as advanced mechanisms of our device.
- **Programming skills:** Coming from a software engineering background, Omon has skills in programming the functionality of our device, whether that's including preprogrammed exercises, or code to activate the motors at controlled speeds or limited to a specific angular velocity.
- **3D printing skills:** Cuyler, Skylar, and Stella have created various 3D prints in the Makerspace lab, allowing our team to create the necessary 3D printed parts for our design with a CAD file.
- **Lathe skills:** Since everyone in our group has taken the basic lathe training course in our Lab 3, everyone has the skills to use the Lathe machine in order to create specific parts for our foot flex assist device.
- **Electronic/Arduino skills:** After completing Lab 5, everyone has the necessary skills to operate an Arduino and program with the IDE, allowing us to program the functionality of our device with electric motors, microcontrollers and more complex wiring.

- **Design Thinking skills:** Because everyone completed GNG 1103 (or another prerequisite to this course), everyone has experience with the design thinking process and knows what it takes to create a working prototype from problem statement to physical solution. Everyone also has experience with Design Day and knows what is expected to be delivered.
- **Critical thinking skills**: There will be many problems we will encounter during the ideation and prototyping phase. Through our university experience in our engineering course, we have all developed the ability to think like engineers and find solutions to the many small problems we will encounter, which will help our team in the long run.

We also have a wide range of resources that can be used to create our foot flex assist design:

- **3D Printing filament:** Having access to the Makerspace, we can use the 3D printing filament to design small parts such as irregular geometries, smaller intricate designs, and parts that aren't readily available in stores to construct our design.
- **Foam padding:** Foam padding will be useful for creating a cushioned environment for our client to rest her foot on the foot flex assist device. We can find this resource at a local Dollarama.
- **Velcro straps:** Velcro straps (or any other method of securing our client's leg) can help attach the device to ensure our client's foot doesn't slip out and injure her. These straps allow easy accessibility to our device with minimal effort. We can purchase this resource at Dollarama.
- **Light metal framing:** Jordan has many pieces of metal framing that can be used to construct preliminary prototypes, as well as our final prototype. The base of our device can be constructed from this lightweight, yet sturdy frame.
- **Arduino components + wiring:** Stella has access to many useful Arduino components from her STEM teaching job. This includes an Arduino board, motors, and wiring. In addition, Cuyler can provide additional wiring, along with other electronic components such as an ESP32 microcontroller, potentiometers, wire strippers, and more if necessary.
- **Bolts, screws, and other small components:** We won't have these on us, so we can find whatever small parts we need at Home Depot or we can 3D print smaller parts.
- **Heating pads:** We also do not have any heating devices on us. Therefore, we can purchase heating devices on Amazon, or look for cheaper alternatives at stores like Walmart, Dollarama, etc.

1.1.5 Realistic assessment of our time

1.1.5.1 Assessment of Timeline

1. **Material Procurement (1.5 weeks)**
    a. Can be done in parallel with other tasks (e.g., planning, designing).
    b. Delays could occur if suppliers are slow or items are out of stock.
2. **3D Printing Frame Parts (4 weeks)**
    a. A long process, so ensure designs are finalized before printing.

    b. Consider print failures and the need for reprints.
    c. This could be a bottleneck if not started early.
3. **App Development (2 weeks)**
    a. Can be worked on in parallel with printing and assembling electronics.
    b. Testing and debugging may take longer than expected.
4. **Electronics Assembly (4 days)**
    a. Feasible within lab/meeting times, provided all components arrive on time.

1.1.5.2 Key Constraints

- **Limited Work Hours**: Each member has ~3–4 hours per week outside lab/meeting times.
- **Midterm Season**: Reduced availability, so scheduling must account for lighter workloads during exams.
- **Parallel Processing**: Some tasks can run simultaneously (e.g., 3D printing while coding the app).
- **Potential Delays**: Printing failures, component shipping delays, debugging, and learning curves.

1.1.6 Other critical product assumptions

1. **Component Availability**
    a. **Assumption:** All required components (Arduino, motors, sensors, batteries) are readily available for purchase within 1.5 weeks.
    b. **Risk:** Shipping delays or stock shortages could push back assembly and testing.
    c. **Mitigation:** Order components early and find alternative suppliers and/or parts.
2. **Motor Strength & Power Requirements**
    a. **Assumption:** The selected motor can generate at least 15–20 Nm of torque to lift the ankle.
    b. **Risk:** If the motor is underpowered, it may not provide enough force, requiring a redesign or stronger motor.
    c. **Mitigation:** Test motor specs before finalizing purchase and have a backup motor option.
3. **3D Printing Feasibility**
    a. **Assumption:** Frame parts can be successfully printed within 4 weeks with minimal failures.
    b. **Risk:** Print failures, warping, or weak parts could require redesign or switching materials.
    c. **Mitigation:** Print a small test piece first
4. **Battery Life & Weight Constraints**
    a. **Assumption:** The battery will provide sufficient power for at least **1–2 hours** of continuous use without adding excessive weight.
    b. **Risk:** Short battery life could limit functionality, and heavy batteries could affect comfort/usability.

c. **Mitigation:** Select lightweight, high-capacity batteries and test power consumption early.

1.2 BOM

This BOM outlines the key components required for our Foot Flex Device, which is designed to automate foot flexing for therapy and exercise purposes. The device will be controlled via a mobile application, allowing users to adjust motor speed, duration, and temperature settings. The system is built around an Arduino UNO microcontroller.

Part	Quantity	Unit Cost	Shortcut
Microcontroller & Processing Unit			
Arduino UNO	1	$15.99	Link
Motor & Motion Control			
DC Motor	1	$21.23	Link
Motor Driver L298N	1	$16.99	Link
Power Supply			
12V DC Power Adapter (Outlet-Based)	1	$13.99	Link
Voltage Regulator LM7805	1	$0.80	Link
Wireless Communication			
Bluetooth Module (HC-05 or HM-10)	1	$9.00	Link
Structural & Mechanical Components			
¼" MDF (18”x 24”)	4	$4.00	Link
Screws	20	$0.10	Link
Gears (2:1 ratio)	1 Set	$21.99	Link
Mattress Foam Padding	1	-	-
	Total Cost =	$117.99	
Software Requirements			
Arduino IDE	1	-	Link
Mobile App (Android/iOS)	1		

MIT App Inventor / Flutter (Optional)	1		
Onshape	1	-	Link

Note: We currently already have an Arduino and a heat pack, so these will not be included in our expenses.

Extras (don't have the budget for varying temp):

Heating Element (PTC Heater)	1	$11.99	Link
Temperature Sensor (DS18B20)	1	$13.98	Link
MOSFET Module IRF520	1	$12.54	Link

1.2.1 Microcontroller & Processing Unit

- **Arduino UNO** (x1) – The central microcontroller responsible for handling motor control, temperature regulation, and communication with the mobile app.

  Estimated Cost: $25

1.2.2 Motor and Motion Control

- **DC Motor** (x2) – Provides precise angular control to flex the foot at variable speeds.
  Estimated Cost: $40
- **Motor Driver (L298N or equivalent)** (x1) – Ensures efficient power delivery and control of the servo motor.
  Estimated Cost: $5 - $10

Recommended Motor Specs:

- Type: 12V DC Gear Motor
- Torque: 5-10 Nm (to lift and hold the foot without retraction under resistance)
- Speed: 30-60 RPM (for smooth, controlled movement)
- Current: 2A - 5A (to provide enough power without overheating).

1.2.3 Power Supply

- **12V DC Power Adapter (Outlet-Based)** (x1) – Supplies power to the motor and Arduino via a standard wall outlet.
  Estimated Cost: $10 -15
- **Voltage Regulator (LM7805 or similar)** (x1) – Converts 12V down to 5V for safe operation of the Arduino and sensors.
  Estimated Cost: $2 - $5

1.2.4 Temperature Control

- **Heating Element (PTC Heater or similar)** (x1) – Provides controlled heat for therapeutic purposes.
  Estimated Cost: $10 - $25
- **Temperature Sensor (DS18B20 or similar)** (x1) – Monitors the temperature and allows app-based control.
  Estimated Cost: $2 - $10
- **MOSFET Module (IRF520 or equivalent)** (x1) – Controls power delivery to the heating element.
  Estimated Cost: $5 - $10

1.2.5 Wireless Communication

- **Bluetooth Module (HC-05 or HM-10)** (x1) – Enables communication between the Arduino and the mobile application.
  Estimated Cost: $5 - $15

1.2.6 Structural and Mechanical Components

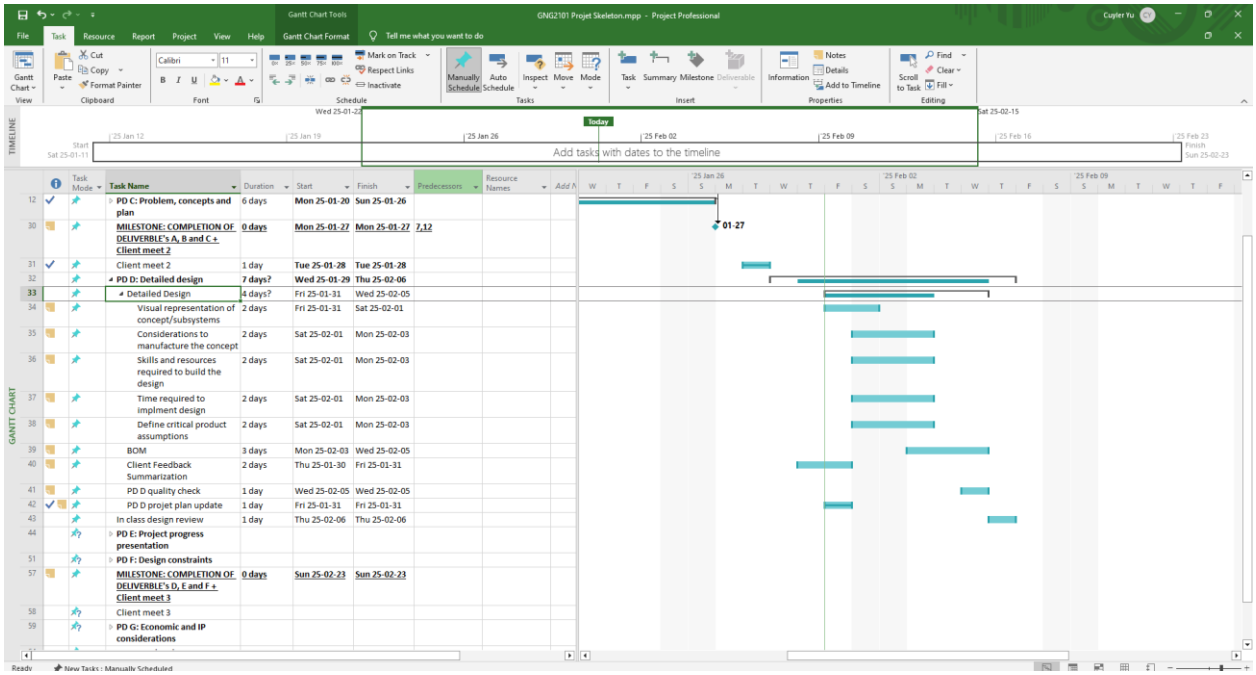
- **¼" MDF** – Provides structural support for the device.
  Estimated Cost: $10 - 20
- **Hinges & Mounting Brackets** – Allows secure movement of the foot.
  Estimated Cost: $5 - $15
- **Fasteners & Screws** – For securing all components.
  Estimated Cost: $5 - $10

1.2.7 Software Requirements

- **Arduino IDE** – Used for programming and uploading firmware.
  Free
- **Mobile App (Android/iOS)** – Custom-built for user control via Bluetooth/Wi-Fi.
  Development Cost Varies

- **MIT App Inventor / Flutter (Optional)** – Potential frameworks for mobile app development.
  Free to Low Cost

1.2.8 Summary

The Foot Flex Device integrates mechanical, electronic, and software components to provide an automated, app-controlled therapy tool. It enables adjustable motor speeds, session duration, and temperature settings for a customized user experience. The estimated total cost for the project ranges between **$80 - $100**, depending on component choices and brands which we purchase.

1.3 Project plan update