FACULTY OF ENGINEERING, TECHNOLOGY & BUILT ENVIRONMENT

BEM1013

Engineering design and drawing

Portable Vending Machine

Group No: 14

Semester: May - September 2025

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PROJECT OVERVIEW & OBJECTIVES

This project focuses on the design and development of a fully functional vending machine. Vending machines provide automated access to products, making them highly convenient in modern society. Building such a machine allows us to apply principles of electrical and electronic engineering, programming, and design to create a system that is efficient, user-friendly, and reliable.

OBJECTIVE STATEMENT

To design and build an automated vending machine that dispenses products in exchange for payment, ensuring ease of access, efficiency, and minimal human involvement.

SCOPE

- **What the machine will do:**
    - Dispense selected items automatically when payment is made.
    - Operate independently without the need for staff.
    - Provide a simple, user-friendly interface for selection.
    - Provide 24/7 accessibility to customers.
    - Accept coin payment.
    - Ensure quick and efficient service.
- **What the machine will not do:**
    - Provide online or digital app-based purchasing.
    - Restock itself automatically.
    - Offer advanced features like facial recognition, smart sensors, or personalized recommendations.
    - Replace traditional retail systems entirely.

CONTEXT

This vending machine is designed with practicality and sustainability in mind. Unlike traditional retail outlets, it does not require staff, which eliminates the need for salaries and ongoing labor costs. Because the system operates automatically, it can function 24/7, providing continuous service regardless of time, holidays, or workforce limitations. Beyond cost savings, vending machines are a staple of modern convenience, offering quick access to essential products without relying on human staff. In the post-pandemic era, such automated solutions have gained greater importance by reducing unnecessary human contact and promoting hygiene in public spaces. By combining round-the-clock accessibility with enhanced efficiency and safety, the vending machine represents a reliable, cost-effective, and forward-thinking approach to product distribution in settings such as universities, workplaces, and transportation hubs.

SDG ALIGNMENT

This project aligns with **(SDG) 9: Industry, Innovation, and Infrastructure**, by promoting innovation through automated systems and contributing to accessible infrastructure in public and private spaces.
and aligns with **SDG 8: Decent Work and Economic Growth** by promoting innovation and efficiency in retail while reducing operational costs. It also supports **SDG 9: Industry, Innovation, and Infrastructure** by integrating automation into everyday services.

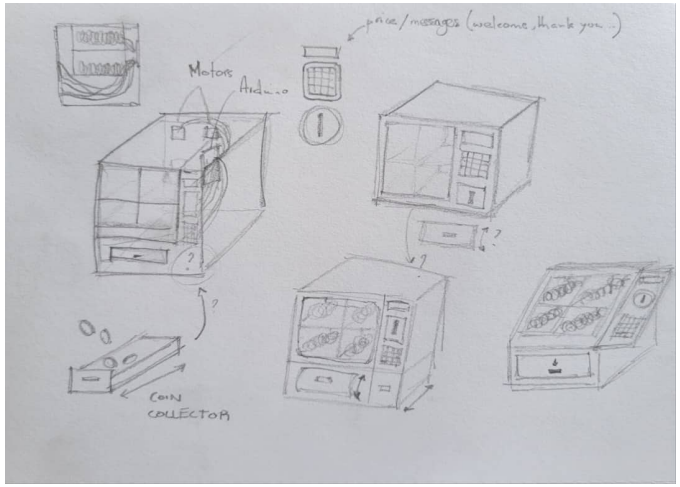


FIGURE 1. 1HAND-DRAWN OF THE EARLY CONCEPT

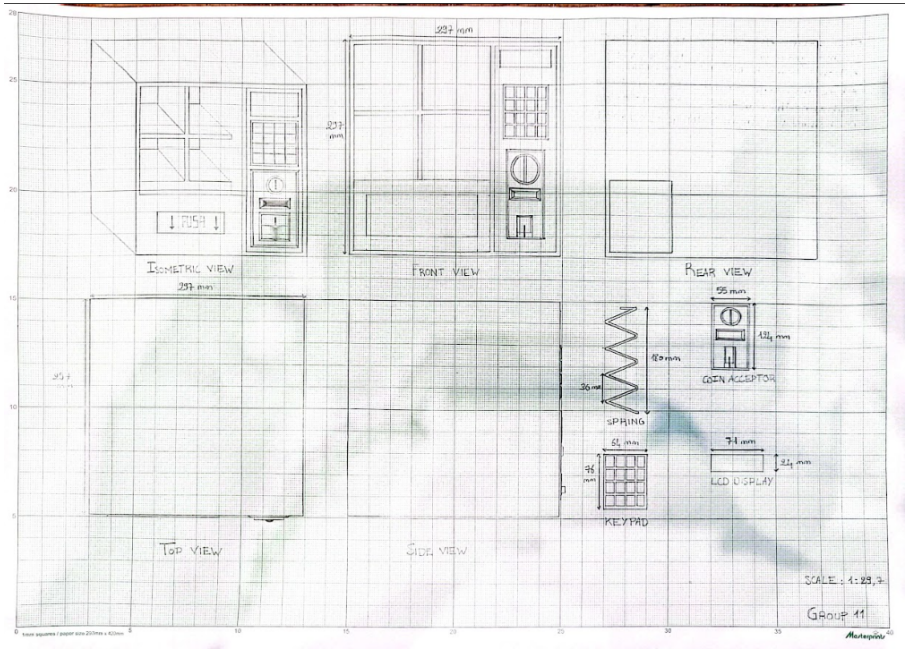


FIGURE 1. 2 HAND SKETCHES PROTOTYPE

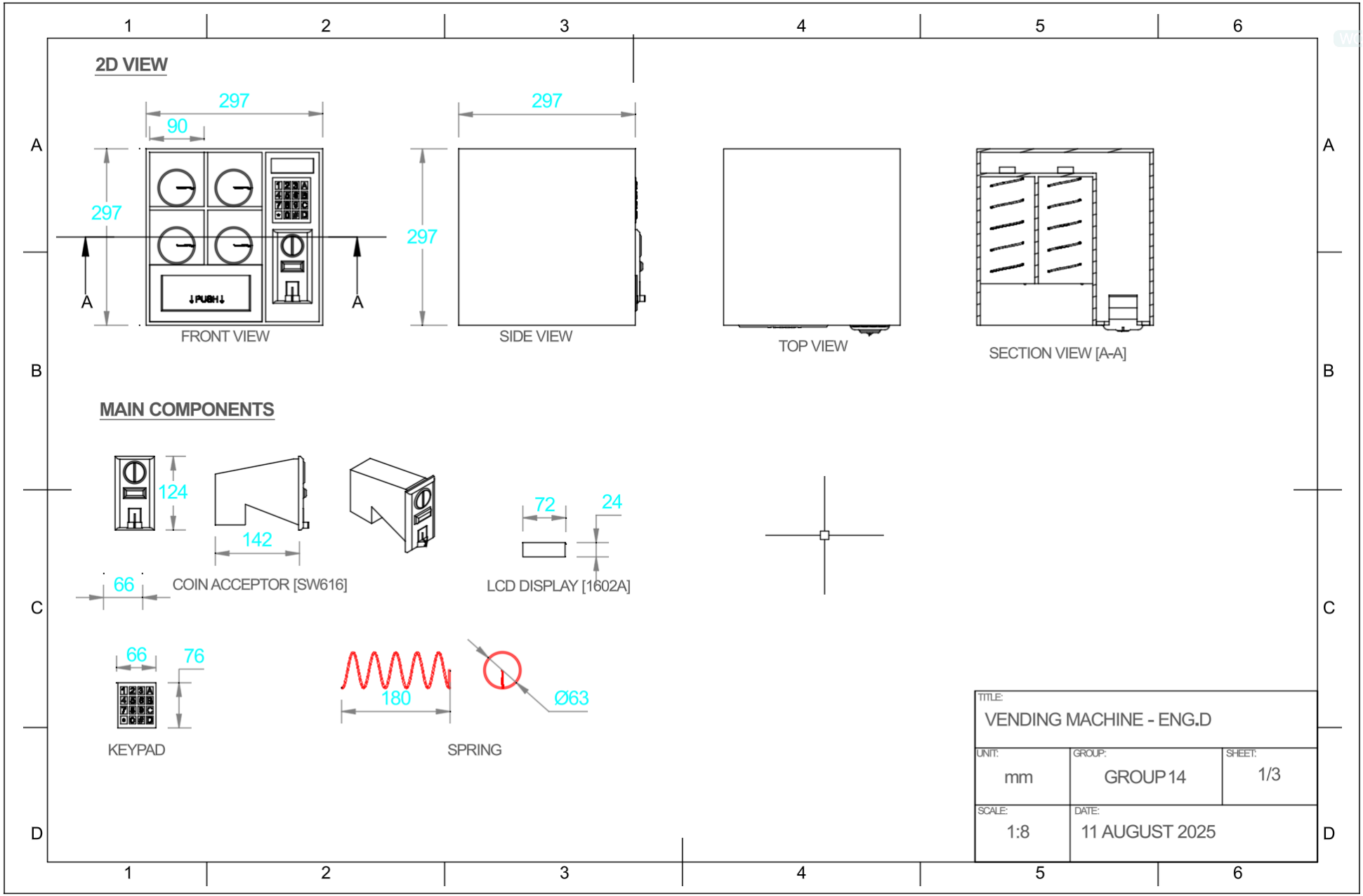
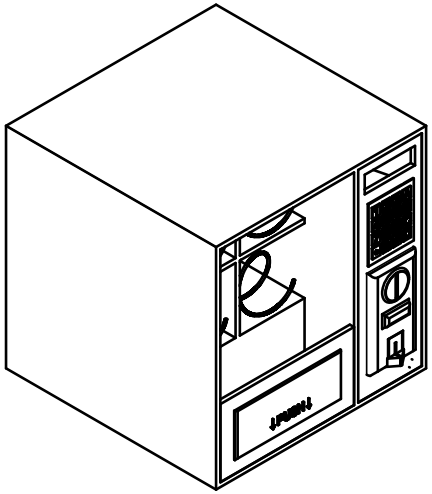
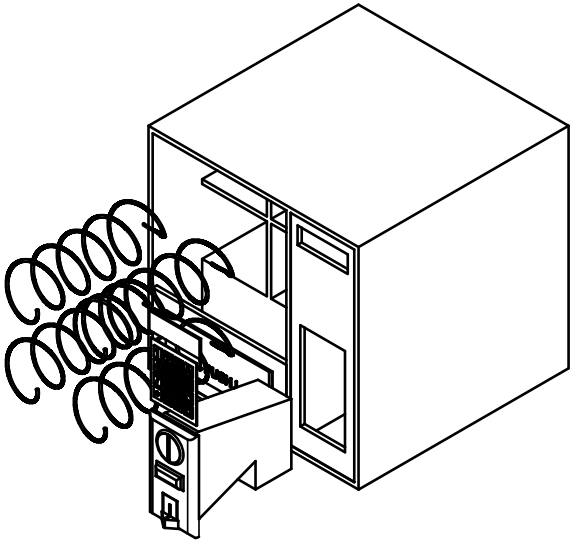


FIGURE 2. 1 2D CAD DESIGN

3D VIEW



ISOMETRIC VIEW



ISOMETRIC COMPONENT VIEW

TITLE: VENDING MACHINE - ENG.D		
UNIT: mm	GROUP: GROUP 14	SHEET: 2/3
SCALE: 1:8	DATE: 11 AUGUST 2025	

FIGURE 2. 2 3D CAD DESIGN

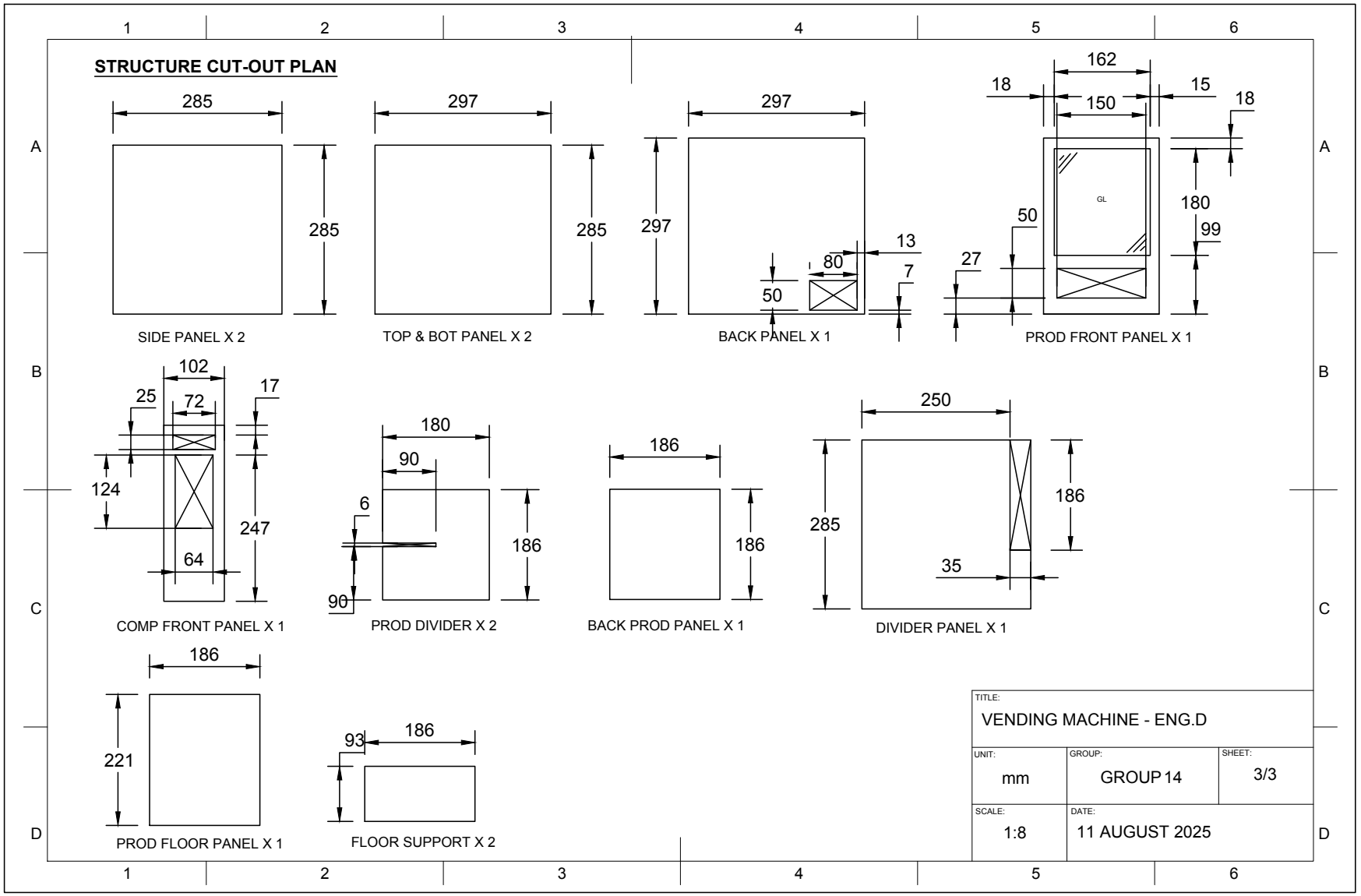


FIGURE 2. 3 STRUCTURE AND CUT-OUT

PROBLEM STATEMENT

Traditional retail outlets and kiosks require continuous human presence, which leads to high labor costs, limited working hours, and inconsistent availability of services. Customers today expect convenience, reliability, and hygienic access to products anytime. A vending machine solves these issues by eliminating the need for human staff, operating 24/7, and providing a cost-effective, automated, and user-friendly solution.

BACKGROUND RESEARCH

- **Similar vending machines on the market**
    - Standard snack and beverage vending machines (Coca-Cola, Pepsi).
    - Smart vending machines with touchscreens and cashless payments (e.g., Fuji Electric, Azkoyen).
    - Specialized vending machines (PPE during COVID-19, electronics in airports).
- **Key technical requirements**
    - **Dispensing mechanism:** Spiral coil, conveyor belt, or robotic arm system to deliver items without jamming.
    - **Payment system:** Coins, banknotes, credit/debit cards, QR code e-wallets (GrabPay, Touch ‘n Go, etc.).
    - **Size limits:** Within A3 size (~297 mm x 420 mm).
    - **Power requirements:** 220–240V standard plug, with backup battery option.
    - **Interface:** Touchscreen or button-based for product selection.
- **Standards, safety rules, ergonomic considerations**
    - Electrical safety compliance (IEC/CE certification).
    - Anti-theft lock.

- Ergonomic design: product window at eye-level and accessible.
- Food safety standards for temperature-sensitive products.

User Needs

- Must provide **24/7 service** without human supervision.
- Must **dispense reliably** without jamming.
- Must have **secure and tamper-proof design**.
- Must ensure **energy efficiency** to reduce operational cost.
- Must have **easy restocking system** for operators.
- Must comply with **safety and hygiene standards**.
- Must be **accessible to all users** (ergonomic design).

OVERVIEW OF VENDING MACHINES

- Vending machines have been widely adopted worldwide as an automated retail solution that minimizes the need for human labor (Smith, 2018).
- They are especially popular in areas with high foot traffic such as universities, airports, and hospitals.

AUTOMATION AND LABOR REDUCTION

- Studies highlight that vending machines reduce operational costs since they eliminate the need for salaries and shift schedules (Lee & Park, 2020).
- The ability to provide service 24/7 makes vending machines a highly efficient alternative to traditional shops.

TECHNICAL ADVANCEMENTS

- Modern vending machines incorporate **cashless payment systems** (cards, QR codes, e-wallets), improving user convenience and transaction speed (Nguyen, 2021).
- Improved dispensing mechanisms and sensors reduce product jams and ensure smooth delivery (Khan et al., 2019).

SAFETY, STANDARDS, AND ERGONOMICS

- Research emphasizes the importance of **ergonomic design** (easy-to-reach product slots, clear instructions) to improve accessibility for all users (WHO, 2019).
- Compliance with **electrical and fire safety standards** is critical for reliability in public spaces.

USER EXPECTATIONS AND EXPERIENCE

- Literature shows that users expect vending machines to be **fast, reliable, and accessible**, with minimal errors (Tanaka, 2020).
- Acceptance of digital payments is increasingly considered a must-have feature in the modern market.

FIGURE 3. 1 3D MODEL

FIGURE 3. 2 PROTOTYPE

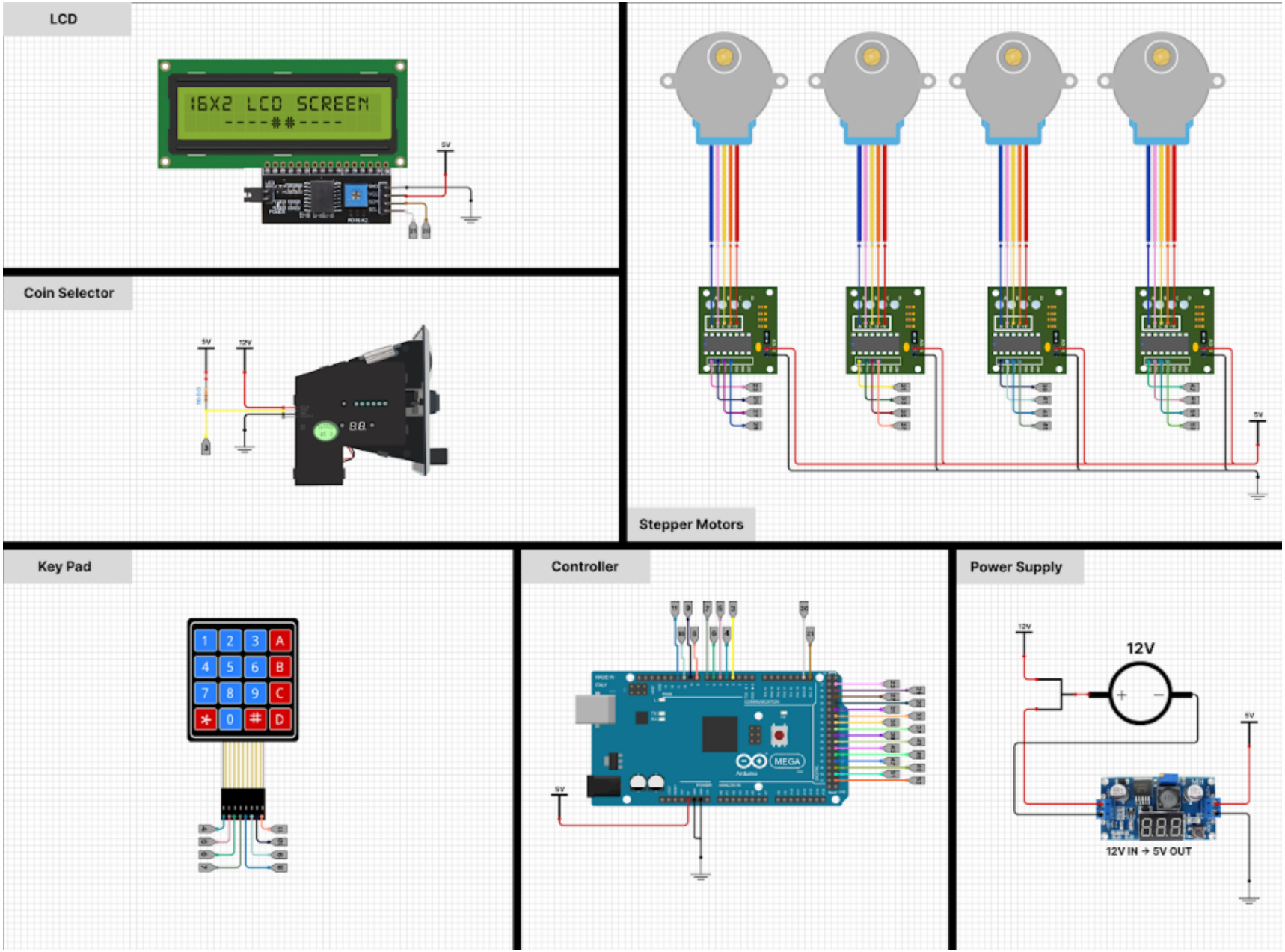


FIGURE 4. 1 CONNECTIONS SCHEMATIC

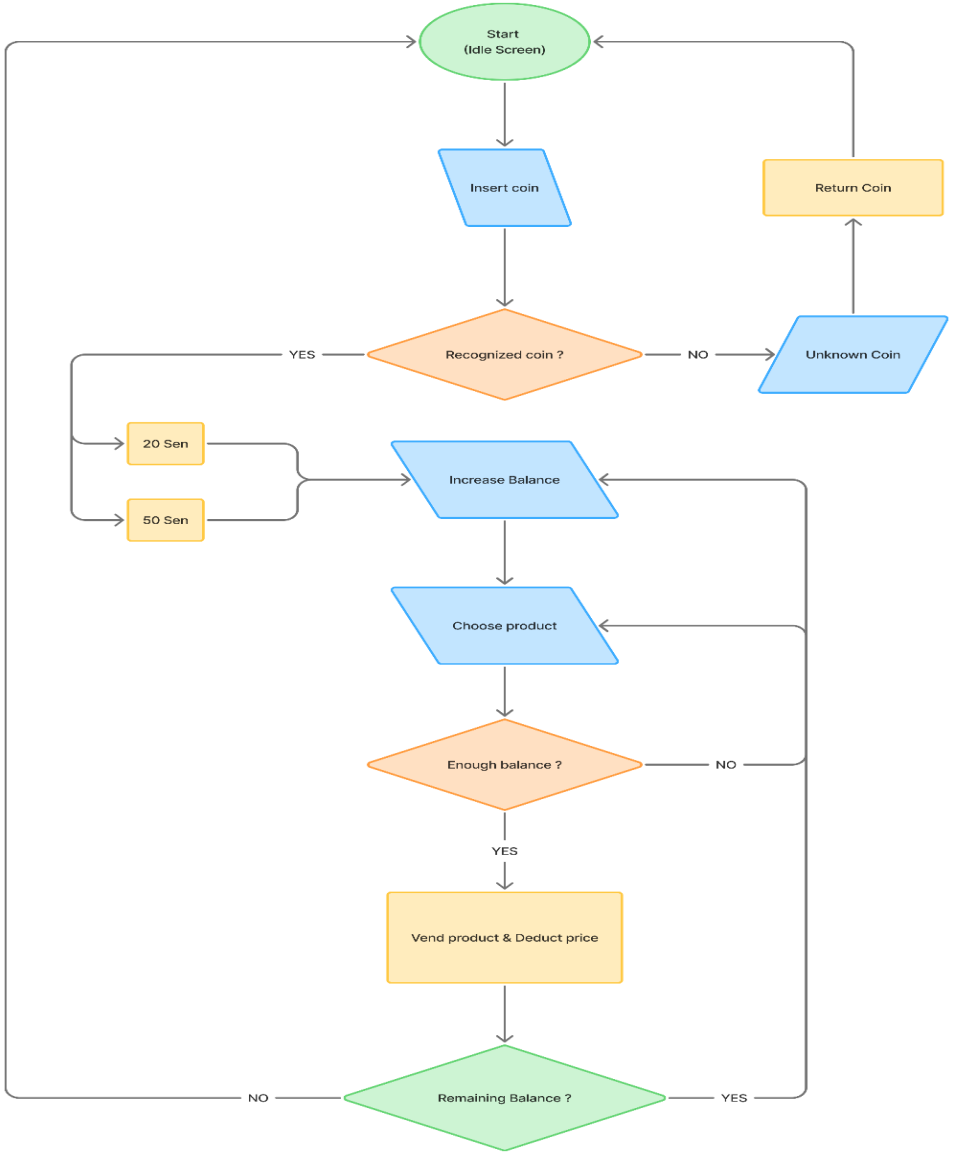


FIGURE 4. 2 LOGIC FLOW CHART

1) OVERVIEW

The System runs a 4-slot vending mechanism on an **Arduino Mega** with:

- **I²C 16×2 LCD**
- **4× ULN2003** driver boards + **28BYJ-48** steppers (one per product)
- **Coin acceptor** (open-collector pulse output)
- **4×4 keypad**

Credits & funds model

- Balances are tracked in **sen (cents)** and **credits (MYR)**.
- Coin acceptor emits **pulse bursts** per coin; pulses are **debounced** and **grouped** to detect denomination.
- Products are vended if the balance ≥ price; price is deducted before motor motion.

2) FEATURES

- Smooth **scrolling marquee** ("INSERT YOUR COIN") on the LCD bottom line.
- Clear LCD states: **idle (balance), coin accepted, unknown coin, insufficient funds, vending start, vending done**.
- Non-blocking coin recognition via **ISR + timed grouping**.
- Per-motor **direction** and **step count** tuning.
- Simple keypad mapping to products.

3) HARDWARE & WIRING

3.1 Bill of Materials

- Arduino **Mega 2560**
- LCD **16×2, I²C backpack** (PCF8574 @ 0x27)
- Coin acceptor (open-collector pulse output)

- 4× ULN2003 stepper driver boards
- 4× **28BYJ-48** steppers
- 4×4 membrane keypad

Power

- 12 V → buck → regulated **5 V rail** for Mega + LCD + keypad + ULN2003 logic
- 12 V for coin acceptor (per its spec)

3.2 Signals (Mega)

Subsystem	Pin(s)	Notes
Coin acceptor (pulse)	**D3**	`INPUT_PULLUP` with **external 10 k pull-up** recommended; INT on **FALLING**
I²C LCD	**SDA/SCL**	Mega SDA=D20, SCL=D21
Keypad rows	**D4, D5, D6, D7**	`rowPins`
Keypad columns	**D8, D9, D10, D11**	`colPins`
Motor 1 ULN2003 IN1..IN4	**D23, D25, D27, D29**	`M_PINS[0]`
Motor 2 ULN2003 IN1..IN4	**D31, D33, D35, D37**	`M_PINS[1]`
Motor 3 ULN2003 IN1..IN4	**D39, D41, D43, D45**	`M_PINS[2]`
Motor 4 ULN2003 IN1..IN4	**D47, D49, D51, D53**	`M_PINS[3]`

4) CONFIGURATION KNOBS

4.1 Coin detection

```
const uint8_t  P20 = 7;      // pulses for 20 sen
const uint8_t  P50 = 10;     // pulses for 50 sen
const uint8_t  TOLERANCE = 1;            // ±1 pulse
```

```
const unsigned long DEBOUNCE_US   = 30000UL; // 30 ms (ISR debouncing)
const unsigned long GROUP_TIMEOUT = 250UL;   // ms quiet gap to finalize a coin
```
How it works:

the ISR counts pulses; the loop "finalizes" a coin if no new pulses arrive for `GROUP_TIMEOUT` ms, then matches pulses to a denomination within `TOLERANCE`.

4.2 Products & pricing

```
const char  PRODUCT_KEYS[4]   = { '4', '5', '7', '8' };
const char* PRODUCT_NAMES[4]  = { "Product 1", "Product 2", "Product 3", "Product 4" };
int         productPrice[4]   = { 20, 50, 70, 100 }; // sen
```
Map keypad keys to slots and adjust prices (in **sen**).

4.3 Motors

```
int8_t  MOTOR_DIR[4]             = { +1, +1, -1, +1 };   // per-slot direction
unsigned VEND_STEPS_PER_MOTOR[4] = { 3072, 3072, 3072, 3072 };
```
- **Direction**: flip sign if your spiral turns the wrong way.
- **Steps per vend**: tune for your dispenser's pitch (28BYJ-48 ≈ **4076 half-steps/rev** typical; many use **2048** depending on gearbox—3072 is a safe starting point).

4.4 Step timing

```
const unsigned STEP_DELAY_MS = 1.5; // comment says ms
```
Note: `delay()` has 1 ms resolution (integer). If you want true **sub-millisecond** or microsecond timing, use `delayMicroseconds()` and adjust logic accordingly.

5) SYSTEM BEHAVIOR (HIGH-LEVEL FLOW)

Idle

- LCD line 1: Balance: MYRx.xx
- LCD line 2: scrolling "INSERT YOUR COIN"
- Keypad read is polled.

ISR **Coin inserted**

- counts pulses (debounced).
- After GROUP_TIMEOUT of quiet, loop matches denomination and increments funds.
- LCD briefly shows **"Coin accepted"** (+amount).

Vend

- Press one of PRODUCT_KEYS to select slot.
- If **balance < price** → brief **"Insufficient / Balance"** screen.
- If **balance ≥ price**:
    - Deduct price
    - LCD shows **"Vending <name> / Paid: MYRx.xx"**
    - Run stepper: 8-phase **half-step** sequence, de-energize coils at end
    - LCD shows **"<name> dispensed"** (top line scrolls) + **"Thank you!"**
    - Return to idle

Diagnostics

- Press D to print funds to Serial.

6) IMPORTANT FUNCTIONS (WHAT THEY DO)

- **`coinISR()`**
  Debounces and counts coin pulses (µs domain). Updates `lastPulseUs` and `lastPulseMs`.
- **`rotateInsertCoin()`**
  Scrolls the "INSERT YOUR COIN" message smoothly by slicing a doubled string.
- **`fmtMoneyCents()`/`fmtPriceOnly()`**
  Build `MYRw.xx` strings and price strings.
- **Funds helpers**
  `totalFundsCents()`, `setFundsFromTotal()`, `addFundsCents()`, `deductFundsCents()` keep cents/credits consistent.
- **Motor control**
  `motorHalfStep()`, `motorRotate()`, `motorIdle()` implement the 8-phase half-step sequence and safe de-energize.
- **LCD states**
  `showIdleScreen()`, `lcdShowCoinAdded()`, `lcdShowUnknownCoin()`, `lcdShowInsufficient()`, `lcdShowVendStart()`, `lcdShowVendDone()` centralize UI feedback.

7) LCD UI DETAILS

- **Address:** `0x27` (change in `LiquidCrystal_I2C lcd(0x27, 16, 2)` if your backpack differs).
- **Line fitting:** `fit16()` pads/truncates to exactly 16 chars (optionally centered) so the display never shows stale characters.
- **Marquee speed:** `ROTATE_INTERVAL` (ms) and `ROTATE_STEPS` (chars/tick).
- **Vend done:** top line scrolls product name for ~3 s while bottom line says **"Thank you!"**.

8) TIMING & CONCURRENCY NOTES

- **ISR vs loop:** The ISR only increments `pulseCount` and timestamps; grouping & denomination detection happen in `loop()` once the line is quiet for `GROUP_TIMEOUT`.
- **Debounce:** `DEBOUNCE_US` rejects spurious edges within 30 ms (adjust per acceptor).
- **Stepper timing:** `delay(STEP_DELAY_MS)` is per half-step; smaller values increase speed but reduce torque and may cause stalls. Consider supply and load.

9) CUSTOMIZATION EXAMPLES

Add a new coin (e.g., 10 sen)

1. Measure pulse count for 10 sen by watching Serial logs (it will appear as "Unknown coin: X pulses").
2. Add a constant const uint8_t P10 = <X>;.
3. In the **coin finalize** block:

```
4. if (abs(int(pulses) - P10) <= TOLERANCE) {
5.   addFundsCents(10);
6.   Serial.println("→ Detected 10 sen");
7.   lcdShowCoinAdded(10);
8. } else if (abs(int(pulses) - P20) <= TOLERANCE) { ... }
```

Change which keys vend

Update `PRODUCT_KEYS[]` with any of the keypad characters in your matrix.

Tune vend distance

Increase/decrease the matching index in `VEND_STEPS_PER_MOTOR[]` until the mechanism dispenses exactly one item.

10) SAFETY & RELIABILITY TIPS

- **Power**: Separate motor power if possible; ULN2003 boards sink current—ensure common ground.
- **Back-EMF**: ULN2003 includes flyback diodes; still route wiring cleanly.
- **Coin line**: Use shielded/short cable; maintain solid **pull-up**; ensure coin acceptor open-collector output is 5 V-safe.
- **Thermals**: Long stalls overheat steppers; keep step times reasonable and de-energize after motion (already done by `motorIdle()`).

11) TROUBLESHOOTING

- **Unknown coin often** → reduce/increase `TOLERANCE` a bit; verify `GROUP_TIMEOUT` is long enough for the coin's full pulse train; check for electrical noise.
- **Missed pulses** → increase `DEBOUNCE_US` only if there is bounce; otherwise **decrease** it (30 ms is generous).
- **Weak torque / missed steps** → increase `STEP_DELAY_MS` (slower), verify 5 V under load, check wiring order.
- **Wrong vend direction** → flip `MOTOR_DIR[slot]` sign.

TABLE 1. 1 BILL OF MATERIALS

Product name	Quantity	Price	X	y	z	Datasheet
Arduino Mega 2560 Rev3	1		100.5mm	53mm	14.05mm	Arduino Mega 2560 Rev3
LCD Display (1602A QAPASS)	1		80+-0.5mm	36+-0.5mm	17+-0.5mm	LCD Display (1602A QAPASS)
(1602A QAPASS) Front Display	1		71+-0.5mm	24+-0.5mm	4.5+-0.5mm	LCD Display (1602A QAPASS)
Full Sized breadboard	1		170mm	55mm	10mm	Breadboard
(28BYJ-48) Stepper mototr	4		28mm	31mm	29+-0.5mm	(28BYJ-48) Stepper mototr
ULN2003 Driver	4		35mm	32.5mm	13mm	ULN2003 Driver
Keypad	1		69mm	76mm	__	Keypad
Keypad Cable			20mm	88mm	__	Keypad
SW616 Coin Acceptor	1		64mm	124mm	143mm	SW616 Coin Acceptor
Total cost						

FABRICATION METHODS

For our vending machine prototype, we primarily used **wood** as the main construction material due to its affordability, availability, and ease of handling in the university workshop. The panels were measured and cut according to design specifications. The wooden body was assembled using **two hinges** to allow door movement, **nails** for structural support, and **magnets** to secure the interface in place.

For the electronic components, we performed **basic welding** (soldering) to connect wires, ensuring reliable circuits and minimizing loose connections. No advanced fabrication techniques such as 3D printing or laser cutting were required for this stage of development.

The fabrication steps included:

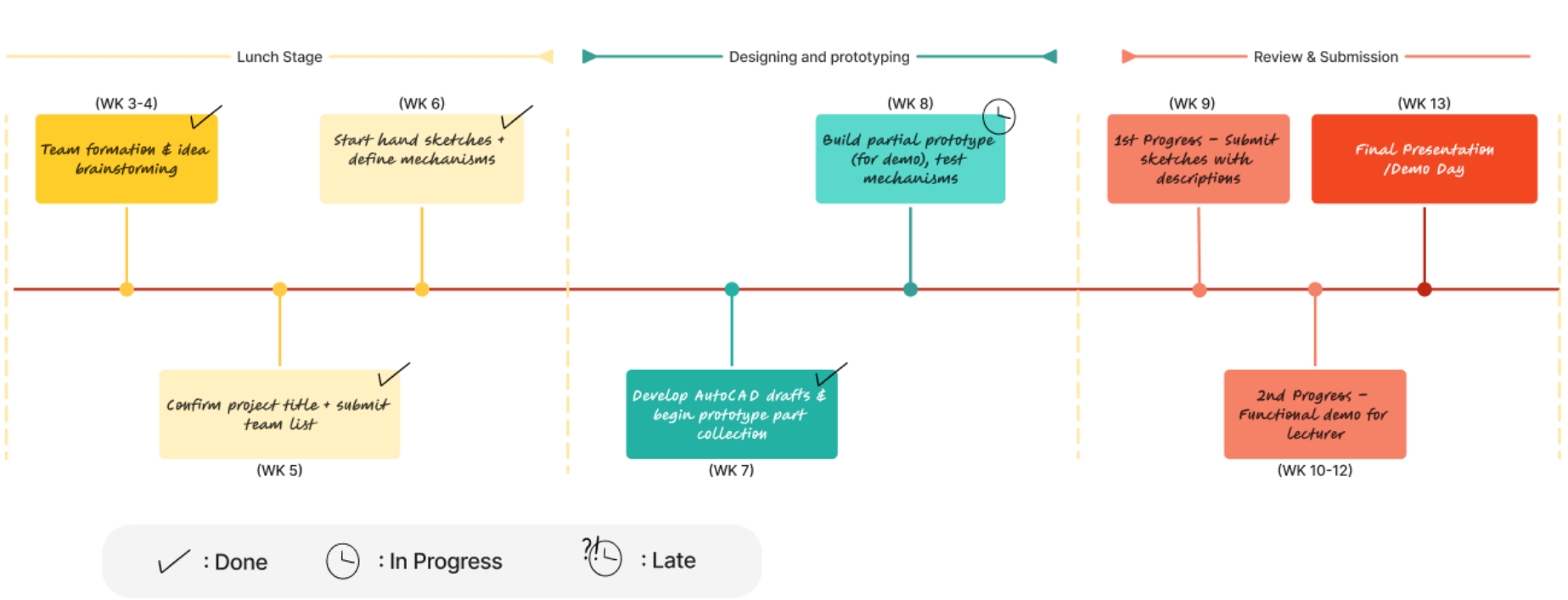
- **Wood Cutting:** The panels were cut to the required dimensions using standard workshop tools.
- **Assembly:** Two **hinges** and several **nails** were used to assemble and secure the parts.
- **Interface Fixing: Magnets** were added to allow easy opening and closing of the interface door.

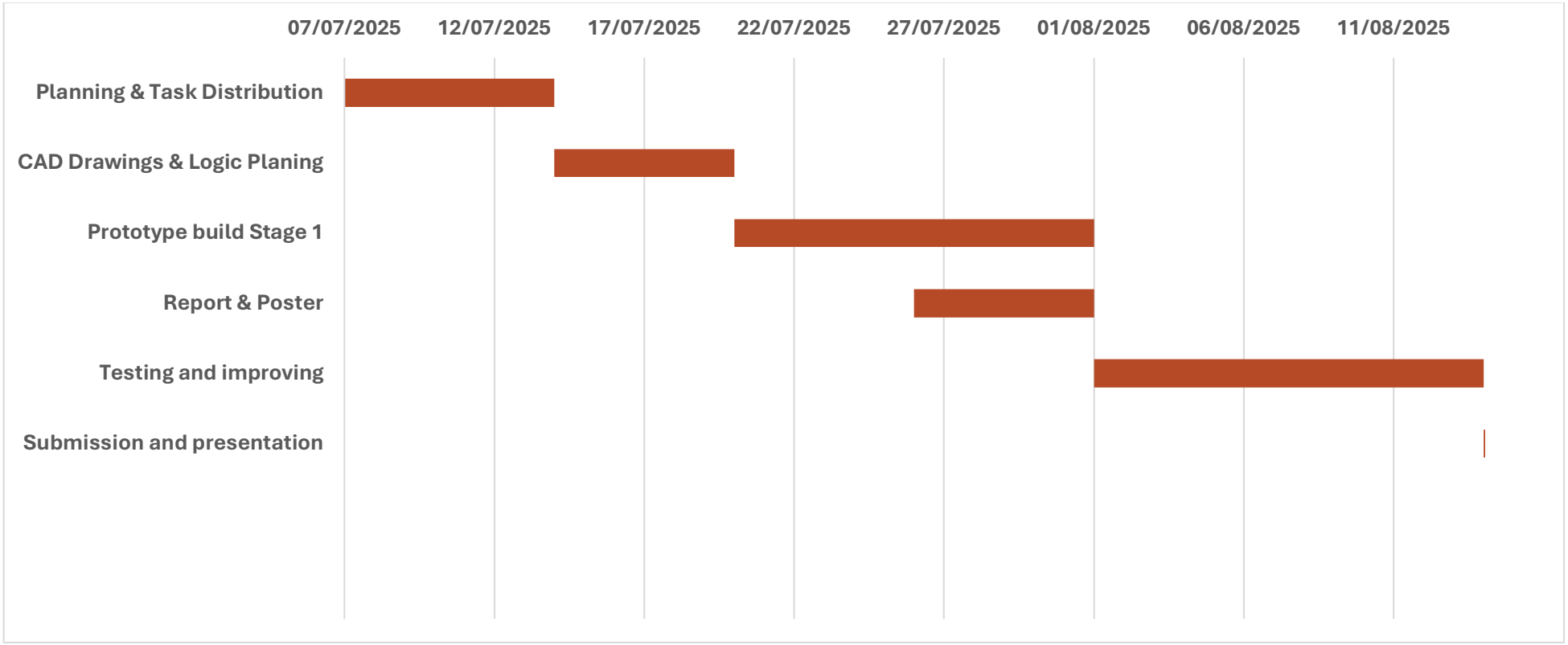
MATERIAL CHOICES:

- **Wood (body construction):** Lightweight, strong, low cost.
- **Hinges (2 pcs):** For opening/closing mechanism.
- **Nails:** To fix wooden panels securely.
- **Magnets:** To hold the interface cover neatly in place.
- **Electronic parts (with soldering):** For smooth electrical connectivity.

No advanced fabrication methods such as 3D printing, or laser cutting were required due to the simplicity of the wooden structure.

PROJECT GENERAL ROADMAP

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Planning & Task Distribution
CAD Drawings & Logic Planing
Prototype build Stage 1
Report & Poster
Testing and improving
Submission and presentation

Although each member was assigned a specific role, the project was carried out through continuous collaboration. Every team member contributed ideas, assisted in research, and supported one another in completing tasks. The roles outlined below represent the main responsibilities of each individual, but the work was achieved collectively as a team.

Team Roles & Task Distribution

Role	Member Name	Responsibility
Leader	**Aloraini**	Oversees progress, supports everyone
CAD & Drawing Specialist	**Muhannadu**	Creates all technical sketches and CAD drawings (AutoCAD)
Electronics & Logic Designer	**Aloraini**	Coin sensor setup, motor/spring logic, wiring, and testing
Prototype & Material Engineer	**Aiham**	Leads recycling material sourcing, ensures A3 and 2kg limits
Aesthetic & Ergonomics Designer	**Abdelmohsen**	Visual design (color, shape), button layout, accessibility
Marketing Poster & Demo Manager	**Salman**	Designs final poster, coordinates demo setup and team presence
Report & Design Book Writer	**Salma**	Collects input from all members and compiles the full report

WEEK 6 MEETING

Group Assignment

Minutes of Meeting

Title	General Meeting – Meeting #1	**Date**	26th June 2025
Attendees	1) Aloraini Abdulhakim 2) Abdelmohsine Smili 3) Aiham Samooh Nizaru 4) Muhannadhu Musthafa 5) Salma Yasser 6) Mohammed Salman Jalil	**Time**	5–6 PM
Absent/Late (reason)	No absence	**Venue**	MS Teams
Minutes by	Salma Yasser		

Agenda	**Action by**
1.0 Roles Assigned • Aloraini started by greeting everyone • Aloraini showed the main roles of the project and what is every role responsibility • Aloraini told everyone what they are assigned to be on charge of based on their choices on the team group before	Dr.Tina
2.0 WK6 Tasks Disruption • Aloraini showed the week 6 tasks and clarified to everyone what are their responsibilities on those tasks based on their roles • Everyone agreed that All week 6 tasks can be done by making helding a workshop	Salma & Rama
3.0 Brainstorming Workshop	

• Everyone agreed to set this workshop to do all the week tasks • 4 members voted to make the workshop on Monday 7/7 • The workshop Time will be decided later by a poll on the team WhatsApp group	Salma, Mark & Khaled

Prepared by,

_____

Salma Yasser

Approved by,

_____

ALoraini

WEEK 8 MEETING

Title	General Meeting – Meeting #1	**Date**	26th June 2025
Attendees	1) Aloraini Abdulhakim 2) Abdelmohsine Smili 3) Aiham Samooh Nizaru 4) Muhannadhu Musthafa 5) Salma Yasser 6) Mohammed Salman Jalil	**Time**	6 – 7 PM
Absent/Late (reason)	No absence	**Venue**	MS Teams
Minutes by	Salma Yasser		

Agenda	**Action by**
1.0 WK6&7 Outcomes • Completed initial sketches • Developed CAD designs and orthographic views	Aloraini

• Designed the coin system and wiring • Identified materials (MDF boards, acrylic panel) **2.0 Week8 tasks** • Mohannadu: Convert 3D files to DWG format • Aloraini: Complete coin sensor programming • Collect various 20 and 50 cent coins for sensor calibration • Build base, motor mounts, and coin slots • Salma and Abdul Masen: Plan aesthetic design • Integrate motor with spring for vending simulation	All

Prepared by,

_____

Salma Yasser

Approved by,

_____

Aloraini

REFLECTION

Working on the vending machine project was a valuable learning experience. As a team, we collaborated effectively, shared ideas, and supported one another in completing tasks. What went well was our teamwork, task distribution, and the ability to adapt when challenges came up. Some challenges we faced included limited time to test and refine the prototype, and make a nice interface design, technical issues such as the issues that came up while testing the mechanism and Electronic connections. From these challenges, we learned the importance of detailed planning, repeated testing, and systematic troubleshooting.

REFERENCES

1. Vending Machine Automation & Technology

Nilani Ratnasri & Tharaga Sharmilan (2021). *Vending Machine Technologies: A Review Article*. International Journal of Sciences: Basic and Applied Research. This paper examines both non-IoT and IoT-based vending systems and highlights the trend toward smart, automated machines (PDF) Vending Machine Technologies: A Review Article , monther,+12579-Article+Text-38178-1-6-20210602+

2. Safety Standards for Vending Machines

IEC 60335-2-75:2024 — *Safety of Commercial Dispensing Appliances and Vending Machines*. Specifies electrical safety, voltage limits, and hygiene provisions for vending machines IEC 60335-2-75:2024 | IEC , Singapore Standards

IEC 60335-2-75:2012 — Earlier edition that also covers safety for electric vending machines Review on VEND IT!- A Smart Vending Machine

3. Smart Vending Innovations

"Vend It! — A Smart Vending Machine", IJRASET. Describes a prototype that uses Raspberry Pi, IoT, predictive analytics, and remote monitoring to redefine vending experience (PDF) Technological Advancements in Vending Machines Transforming Consumer Behavior Market Trends and the Future of Automated Retail

4. Broader Trends & Consumer Behavior

“Technological Advancements in Vending Machines Transforming Consumer Behavior”, ResearchGate discussion. Offers insights on evolving user expectations and industry trends toward healthier choices

ScienceDirect — Narrative Review on Factors Influencing Vending Purchases. Investigates how product placement and choice affect consumer decisions Vending Machines: A Narrative Review of Factors Influencing Items Purchased - ScienceDirect

5. Related Safety Observations

Wikipedia — Death by Vending Machine. Highlights real-world safety concerns like tipping hazards, underscoring the need for secure vending designs Death by vending machine - Wikipedia