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FACULTY OF ENGINEERING AND TECHNOLOGY

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTRICAL ENGINEERING

FINAL YEAR PROJECT REPORT
ACADEMIC YEAR 2025/2026

DESIGN AND IMPLEMENTATION OF A SEAT OCCUPANCY DETECTION AND WEIGHT MONITORING SYSTEM FOR ROAD TRANSPORTATION VEHICLES

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This Final Year Project Report is submitted to the Department of Electrical Engineering in partial fulfillment of the requirements for the award of the Bachelor of Science in Electrical Engineering degree of Busitema University

JUNE 2026

DECLARATION:

I,NKOKO JOSHUA and ATWALA GODFREY, do hereby declare that this report, written in partial fulfillment of the requirement of the award of the degree of Bachelor of Science in Electrical and Electronics Engineering of Busitema University is our own authentic work and the content of this document has never been submitted to any institution of higher education.

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Signature....................................

Date: 19/06/2026

ATWALA GODFREY

Signature…………………………

Date: 19/06/2026

APPROVAL

This is to certify that this project report on design and implementation of a seat occupancy detection and weight monitoring system for road transportation vehicles was compiled and completed by NKOKO JOSHUA and ATWALA GODFREY under the guidance and supervision of our university supervisors.

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DEDICATION

First and foremost, this work is dedicated to the Almighty God whose grace, strength and wisdom sustained us through every challenge and every late night that this journey demanded. Without His guidance, none of this would have been possible. To our beloved family, our parents and siblings, your prayers, sacrifices and constant encouragement were a foundation upon which every page of this work was built. The financial burden you carried to keep us in school did not go unnoticed. To our friends and every person who invested their time, knowledge and support in our education whether in small ways or great ways, this work stands as a testament to what your belief in us has produced.

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We thank God for enabling us to finish our research work successfully and in good health. We also thank our parents who have given us both financial and moral support throughout our education. We thank our friends and colleagues who were there for us always when we needed them. We express our gratitude to our lecturers and our supervisors Mr. Mbabaali Frank and Prof. Okou Richard who ensured that our project came out successfully.

ABSTRACT

This project presents the design and implementation of an automatic seat occupancy and weight monitoring system for road transportation vehicles in Uganda. A single-seat prototype is developed using a 20 kg load cell, HX711 signal amplifier, Arduino Uno microcontroller, 16×4 I2C LCD display, and an active buzzer. The system detects whether a seat is occupied based on a calibrated weight threshold, displays the measured weight and occupancy status in real time, and triggers an alarm when the measured load exceeds a set maximum. Beyond seated passengers, the project also addresses the broader problem of unmonitored weight contributors in public transport — specifically standing passengers and passenger luggage — both of which significantly increase total vehicle load yet remain invisible to existing passenger counting systems. The prototype demonstrates the fundamental sensing principle for a full vehicle deployment and contributes toward solving the persistent problems of overcrowding, overloading, and the absence of automated weight data in Uganda's public transport sector. Testing covers accuracy, repeatability, and threshold boundary behaviour under static loading conditions.

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LIST OF ABBREVIATIONS

Abbreviation	Full Meaning
APC	Automated Passenger Counting
ADC	Analog-to-Digital Converter
BMS	Battery Management System
CV	Coefficient of Variation
EV	Electric Vehicle
GVWR	Gross Vehicle Weight Rating
GVW	Gross Vehicle Weight
HX711	24-bit Analog-to-Digital Converter for Weigh Scales
I2C	Inter-Integrated Circuit
LCD	Liquid Crystal Display
PWM	Pulse Width Modulation
SoC	State of Charge
SoH	State of Health
WHO	World Health Organisation

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CHAPTER ONE: INTRODUCTION

1.0 BACKGROUND

Road transport is the primary mode of movement in Uganda. Fuel-powered buses, minibuses (taxis), and a growing fleet of electric buses carry a lot of passengers daily across Kampala and upcountry routes. Uganda's Kiira Kayoola Electric Bus which is a 35-seat battery-powered vehicle developed by Kiira Motors Corporation (2018), marks the country's entry into electric public transport, with more electric vehicles expected on Ugandan roads as adoption grows. Across this entire fleet, passenger monitoring remains manual. Conductors estimate occupancy by observation, with no automated system to confirm how many seats are occupied, how many people are standing, or what the total weight on board is at any point. This creates several interconnected problems.

Overcrowding is routine, especially during peak hours in Kampala. When all seats are full, conductors routinely allow additional passengers to stand in the aisle or squeeze into doorways. While standing passengers may seem like a minor issue, they contribute real, measurable weight to the vehicle weight that no existing system accounts for. Luggage compounds this further where by on upcountry routes in particular, passengers travel with heavy bags, sacks, and commercial goods. Some luggage is placed on seats, some is carried on laps, and some is loaded into boot areas or strapped to rooftops. In every case, this weight adds to total vehicle load beyond what passenger headcounts alone would suggest. A vehicle that appears to carry an acceptable number of passengers may still be seriously overloaded once luggage is factored in. Overloading is therefore a product of three combined sources: seated passengers, standing passengers, and luggage. Exceeding a vehicle's Gross Vehicle Weight Rating (GVWR) stresses brakes, tyres, and suspension, and is identified by the World Health Organisation (2021) as a significant contributor to road traffic fatalities in developing countries. Beyond safety, excess total weight has direct energy consequences. In fuel-powered vehicles, rolling resistance and therefore fuel consumption per kilometre increases with every additional kilogram — whether that kilogram belongs to a seated passenger, a standing one, or a bag of maize flour in the boot. In electric buses, heavier loads demand greater current draw from the battery pack, accelerating electrochemical degradation and reducing operational range (Barré et al., 2013; Vetter et al., 2005).There is also a financial dimension. Since vehicle owners rarely travel with their own buses, they depend entirely on conductors' verbal passenger count reports to calculate daily earnings. With no independent record, revenue manipulation is easy and well known in Uganda's informal transport sector.

An automatic seat occupancy and weight monitoring system addresses these problems at the source. This project designs and validates the core sensing unit — a single-seat prototype — while discussing the complete system architecture needed to monitor seated passengers, standing passengers, and luggage across a full vehicle deployment.

1.1 PROBLEM STATEMENT

Public transport vehicles in Uganda have no mechanism for automatically detecting seat occupancy or measuring total passenger and cargo weight in real time. Manual counting by conductors is unreliable, easily manipulated, and completely blind to three significant weight contributors: seated passengers beyond the headcount, standing passengers in the aisle, and luggage carried on board. The combined weight from all three regularly pushes vehicles beyond their safe GVWR limits without any alarm or awareness on the part of the driver or operator. Similarly the Uganda Road Fund (2022) identifies overloaded public service vehicles as a persistent threat to both road infrastructure and passenger safety on Uganda’s transport network. The consequences are overcrowding, structural and mechanical vehicle damage, increased fuel consumption, faster battery degradation in electric vehicles, revenue fraud, and a measurably higher risk of road accidents (WHO 2021).

Existing Automated Passenger Counting technologies — infrared beam sensors and camera-based systems — detect passenger movement at vehicle doorways and count persons, not kilograms (Boyle, 2008). They cannot confirm which seats are occupied mid-journey, they cannot detect standing passengers distributed along the aisle, and they have no ability to account for luggage weight at all. Published research by Kiran et al. (2022) confirms that load cell-based weight sensing is accurate and repeatable in vehicle environments, with errors below 1% under static loading. However, no documented system in Uganda or the broader East African context integrates seat-embedded load cells for simultaneous passenger counting and weight measurement, nor does any existing system address the combined weight problem of seated passengers, standing passengers, and luggage within a single platform applicable to the full road transport fleet.

This project develops a single-seat prototype demonstrating the core sensing principle. A 20 kg load cell is embedded under a plywood seat platform. The HX711 amplifier digitises the load cell output and sends it to an Arduino Uno, which applies calibration and threshold logic to determine occupancy state and measured weight. A 16×4 I2C LCD displays real-time results and an active buzzer triggers when measured load exceeds the maximum threshold. The broader system architecture — covering multiple seats, floor sensors for standing passengers, and luggage weight zones — is presented and discussed as the full deployment model that this prototype validates and scales into.

1.2 OBJECTIVES

1.2.1 Main Objective

To design and implement a low-cost, single-seat automatic weight-based occupancy detection prototype that measures and displays real-time passenger weight and seat status for application in road transportation vehicles.

1.2.2 Specific Objectives

- To design and assemble a single-seat hardware prototype integrating a 20 kg load cell, HX711 signal amplifier, Arduino Uno, 16×4 I2C LCD, and active buzzer alarm.
- To develop Arduino firmware that reads and processes load cell data, determines seat occupancy based on a calibrated weight threshold, displays real-time weight and occupancy status on the LCD, and activates the buzzer alarm at a defined maximum load.
- To evaluate the prototype through accuracy testing, repeatability testing, and threshold boundary testing under static loading conditions.

1.3 RESEARCH QUESTIONS

1. How accurately can a load cell and HX711 amplifier combination detect and measure the weight applied to a single seat?
2. What weight threshold effectively distinguishes between an occupied and unoccupied seat without producing false triggers from light objects placed on the seat?
3. At what total weight threshold should the overload alarm be triggered to provide an effective warning against exceeding the vehicles safe payload limit?
4. How reliably does the Arduino based firmware maintain consistent occupancy detection and weight measurement across repeated loading and unloading cycles ?

1.4 JUSTIFICATION

The World Health Organisation (2021) identifies overloading as a significant contributor to road traffic fatalities in developing countries. Uganda’s road transport sector is directly affected — overloaded buses and taxis are a common sight on both urban and upcountry routes. The proposed system provides the data layer upon which real overload alerts can be built. By detecting when seat-level weight, and by extension total vehicle payload, is approaching a dangerous limit, the system gives the driver and operator an automatic, hardware-enforced warning before the vehicle moves. Unlike existing APC systems that count persons at doorways, the weight-based approach captures the total physical load on the vehicle seated passengers, their luggage on seats, and by extension informs the design of sensors for standing passengers and boot luggage. This is a fundamentally more complete view of vehicle loading and is directly relevant to GVWR compliance.

For electric bus operators, real-time passenger weight data is essential for accurate battery range prediction. A Kayoola bus operating without load data cannot reliably estimate how many kilometres remain at a given State of Charge. For fuel bus operators, load data quantifies the fuel cost of overloading — information currently invisible to every operator in Uganda’s transport sector.The prototype is built entirely from components available in Uganda’s local electronics market at a total cost below UGX 350,000. This makes it realistic for adoption by individual bus owners and small fleet operators. Academic novelty also exists: no published system documents a seat-embedded load cell network for simultaneous passenger counting and weight monitoring in Uganda.

1.5 SCOPE

Design Scope

This project covers the design and implementation of a single-seat prototype for weight-based seat occupancy detection and overload alerting. The hardware comprises a 20 kg strain gauge load cell, an HX711 24-bit ADC signal amplifier, an Arduino Uno microcontroller, a 16×4 I2C LCD display, and an active buzzer. The firmware performs automatic tare calibration on power-up, applies a five-sample moving average filter for noise reduction, converts raw ADC readings to kilograms using a calibrated scale factor, determines seat occupancy when measured weight exceeds 1 kg, displays real-time weight and occupancy status on the LCD, and activates the buzzer alarm when the measured load exceeds 1.5 kg. Occupancy detection is based solely on weight measurement; no image, infrared, or capacitive sensing is used. The system is validated through accuracy testing, repeatability testing, and threshold boundary testing under static loading conditions. Dynamic vehicle conditions, multi-seat network integration, floor-embedded load cells for standing passenger detection, luggage zone sensing, BMS integration, fuel consumption modelling, and data logging are outside the scope of the current prototype but are identified as direct extensions of this work.

Geographical Scope

This project is developed and tested at Busitema University, Faculty of Engineering. The system is designed with direct relevance to Uganda's public road transport fleet, including fuel-powered minibuses (taxis), intercity buses, and electric buses such as the Kiira Kayoola, operating on urban Kampala routes and upcountry corridors. All components used in the prototype are sourced from Uganda's local electronics market to ensure that the solution is practically replicable within the country.

Time Scope

This project was carried out between January 2026 and June 2026, covering system design and hardware assembly, firmware development and calibration, and prototype testing and validation. The findings and recommendations are based on the state of Uganda's public transport sector and available technology as of the 2025/2026 academic year.

1.6. CONCEPTUAL FRAMEWORK

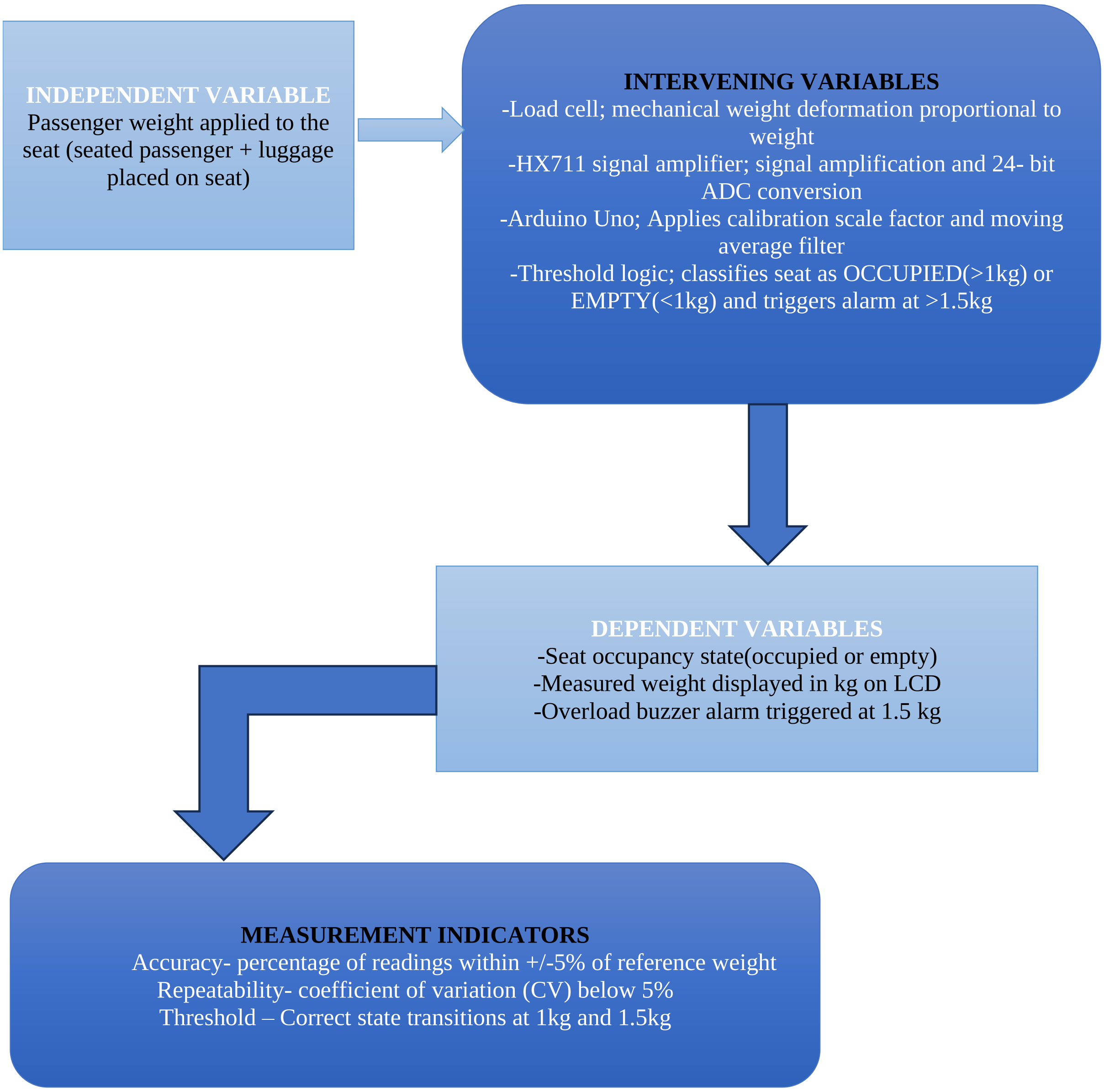


Figure 1 A conceptual framework of the project

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter reviews existing literature on automated passenger counting, weight-based occupant detection, unmonitored vehicle load contributors, the relationship between passenger load and vehicle energy consumption, and the safety consequences of overloading. The review critically examines what existing studies have established, where they fall short, and how their findings inform the design approach adopted in this project.

2.1Automated Passenger Counting and Its Limitations

Automated Passenger Counting (APC) technology has evolved significantly over the past two decades. Boyle (2008) documented the progression from basic infrared beam arrays to more sophisticated camera-based systems, noting that modern APC systems achieve above 95% counting accuracy under controlled conditions. These systems are widely deployed in public transport networks across developed countries for ridership data collection and fleet management. However, all existing APC systems share a fundamental limitation: they count passengers as persons moving through vehicle doorways. They do not confirm which seats are occupied during the journey, cannot detect standing passengers distributed along the vehicle interior, and have no capacity to account for luggage weight. In Uganda's transport context, where long-distance passengers regularly carry substantial loads and standing in overcrowded taxis is routine, Boyle's (2008) assessment that door-based counting is inadequate for total load management remains directly applicable. No reviewed study has proposed a doorway-based APC extension capable of addressing these three gaps simultaneously.

2.2 Weight-Based Occupant Detection

Weight-based seat occupancy detection is most extensively documented in automotive airbag suppression research, where accurate occupant classification is a legal requirement in many jurisdictions. National Instruments (2022) established that calibrated load cell systems consistently outperform capacitive mat and ultrasonic alternatives in both accuracy and repeatability across diverse occupant sizes and seating positions. The strain gauge load cell, operating on the principle of elastic deformation and Wheatstone bridge resistance measurement, is identified as the most reliable and cost-effective transducer for this application. Kiran et al. (2022) specifically validated the HX711-Arduino combination in a vehicle overload detection context, demonstrating measurement errors below 1% under static loading conditions and confirming stability under typical vehicle vibration and temperature variation. Their study, however, focused on total axle load rather than individual seat-level occupancy, and did not address the simultaneous detection of standing passengers or luggage. This leaves a clear gap between what the sensing technology can achieve and what has actually been implemented in a public transport setting.

2.3 Luggage Weight and Vehicle Overloading

Luggage is a significant and consistently underestimated source of vehicle overloading, particularly on Uganda's upcountry routes where passengers travel with agricultural produce, household goods, and commercial cargo. A passenger weighing 65 kg travelling with 30 kg of luggage contributes 95 kg to total vehicle load — nearly 50% more than a headcount-based system would estimate. Despite this, no reviewed APC or occupancy monitoring study accounts for luggage as a distinct measurable load category. The Uganda Road Fund (2022) identifies overloaded public service vehicles as a persistent cause of premature road network deterioration, while the World Health Organisation (2021) links vehicle overloading directly to road traffic fatalities in low- and middle-income countries. Together these sources establish that luggage-driven overloading is not a marginal concern but a documented, measurable problem in Uganda's transport sector for which no automated sensing solution currently exists.

2.4 Passenger Load and Fuel Consumption

The relationship between total vehicle mass and fuel consumption is well established in vehicle dynamics literature. Rolling resistance, expressed as $F_{roll} = \mu r \times m \times g$, increases linearly with total vehicle mass, making it the dominant resistance force at the low urban speeds typical of Kampala routes. Every additional 100 kg of passenger or luggage load increases rolling resistance by approximately 14.7 N, translating to measurable additional fuel consumption per trip. At highway speeds, aerodynamic drag becomes dominant and is independent of passenger load, while grade resistance on hilly terrain — relevant to routes through Kampala's hillier suburbs — also scales directly with total mass. Despite this well-understood relationship, no reviewed study has demonstrated a real-time onboard system that uses measured passenger weight data to compute and display fuel consumption estimates for fleet operators in Uganda or comparable developing country contexts. Operators currently have no data to quantify the fuel cost of systematic overloading, representing both an economic and an energy efficiency gap that real-time weight monitoring could directly address.

2.5 Passenger Load and Electric Bus Battery Performance

For electric vehicles, heavier passenger loads increase motor current demand, raising the battery discharge C-rate and accelerating two primary degradation mechanisms: capacity fade through lithium plating at the anode, and internal resistance increase through electrolyte decomposition at the cathode (Vetter et al., 2005). Barré et al. (2013) reviewed lithium-ion battery ageing mechanisms in automotive applications and confirmed that sustained high C-rate operation, driven by heavy loading, measurably reduces both State of Health and usable battery capacity over time. Lu et al. (2013) demonstrated that Battery Management Systems incorporating real-time load data produce substantially more accurate State of Charge and State of Health estimates than those operating on assumed average loads. This finding is directly relevant to Uganda's Kiira Kayoola electric bus, which currently operates without any onboard passenger weight measurement. Without real load data, range prediction for the Kayoola fleet remains imprecise, creating operational uncertainty for route planning and charging scheduling.

2.6 Summary and Research Gap

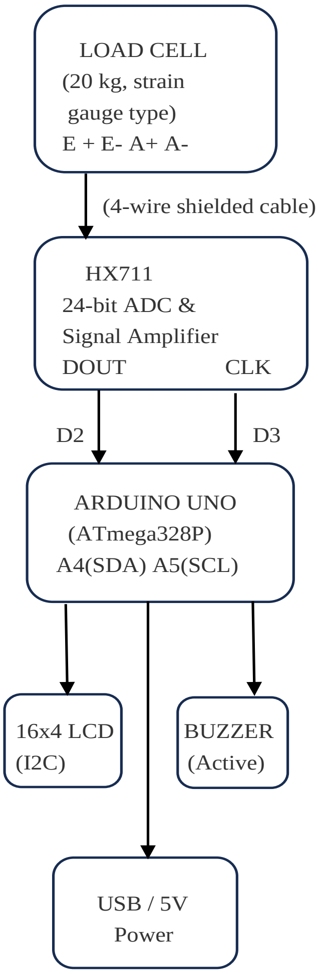
The reviewed literature establishes that load cell-based weight sensing is accurate, repeatable, and cost-effective for vehicle occupancy detection. It further confirms that vehicle overloading driven by the combined weight of seated passengers, standing passengers, and luggage is a documented safety, infrastructure, and energy problem in Uganda. However, no existing system integrates seat-embedded load cells for simultaneous real-time occupancy detection and weight measurement in a public transport vehicle, and no documented solution addresses the three weight contributors — seated passengers, standing passengers, and luggage — within a single unified platform applicable to Uganda's road transport fleet. This project addresses that gap by designing, implementing, and validating the core single-seat sensing prototype as the foundational unit of such a system.

CHAPTER THREE: METHODOLOGY

3.0 INTRODUCTION

This project followed an experimental prototyping approach aimed at designing, implementing, and validating a weight-based seat occupancy detection system for road transportation vehicles. The methodology was structured across three sequential phases, each directly corresponding to one of the three specific objectives.

3.1 SYSTEM BLOCK DIAGRAM



Signal flow:

Passenger weight → Load cell deformation → HX711 amplification & digitisation →

→ Arduino processing (calibration, threshold) → LCD display + Buzzer alarm output

Figure 2 illustrates the block diagram of the project

3.2 MATERIALS USED

COMPONENT	SPECIFICATION
Load cell	20 kg, strain gauge type
HX711 module	24-bit ADC amplifier
4-wire shielded cable	E+, E−, A+, A− connections
Arduino Uno	ATmega328P, 16 MHz
USB cable	Power and programming
16×4 I2C LCD display	5V, I2C address 0x27
Active buzzer	5V
Two plywood boards	Seat base and seat platform
Bolts, nuts, wood screws	Structural fastening
Jumper wires and breadboard	Circuit connections

Table 1 Components and their specifications

3.3 PHASE 1 — SYSTEM DESIGN AND HARDWARE ASSEMBLY

A circuit schematic shown in figure 3 was designed with the following connections: the load cell wired to the HX711 via its four signal wires (E+, E−, A+, A−); the HX711 connected to the Arduino Uno with DOUT on digital pin D2 and CLK on digital pin D3; the 16×4 I2C LCD connected to SDA (A4) and SCL (A5); and the active buzzer connected to digital pin D9.

The plywood seat prototype was constructed with the load cell bolted centrally between the base board and the seat platform so that all weight applied to the seat transfers directly through the load cell. The assembly was secured with bolts and nuts to eliminate mechanical play that would introduce measurement error. A verification check with a multimeter was carried out on all connections before powering the circuit.

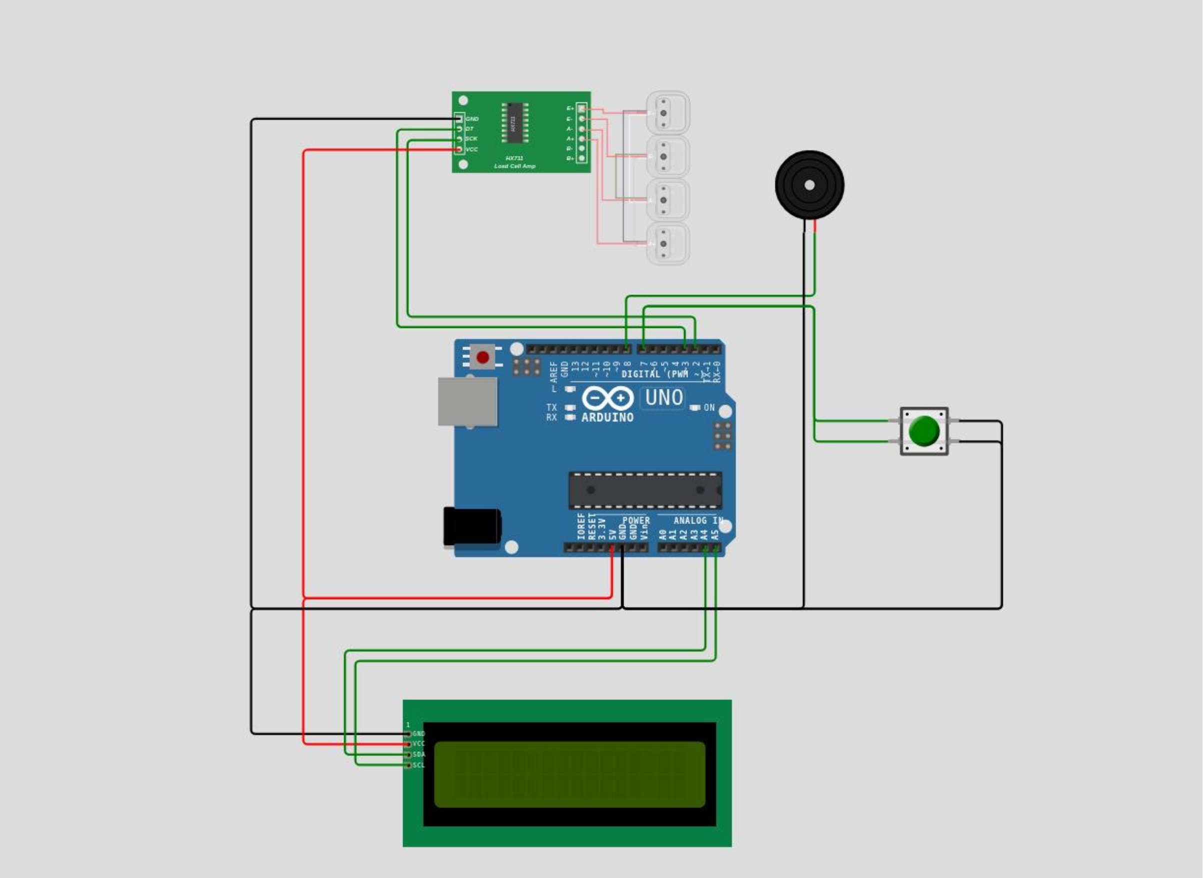


Figure 3 Circuit diagram of the system

3.4 PHASE 2 — FIRMWARE DEVELOPMENT AND CALIBRATION

Arduino firmware was written and calibrated using Arduino IDE, Visual studio code with platform 10 to perform the following sequence:

- Automatic tare calibration on power-up, zeroing the scale with no load present.
- Continuous HX711 reading with a moving average filter over five consecutive samples to reduce noise from vibration.
- Scale factor calibration using a known reference weight to convert raw ADC counts to kilograms.
- Occupancy threshold logic: seat classified as OCCUPIED when weight exceeds 1 kg, and EMPTY below. Heavy luggage placed on the seat registers as an occupied load, which is the correct behaviour for weight-based monitoring.
- LCD update every 500 ms displaying occupancy status, measured weight in kg, and system status message.
- Overload alarm: when measured weight exceeds 1.5 kg, a HIGH signal is sent to digital pin D9, activating the buzzer.

3.4.1 FIRMWARE LOGIC FLOWCHART

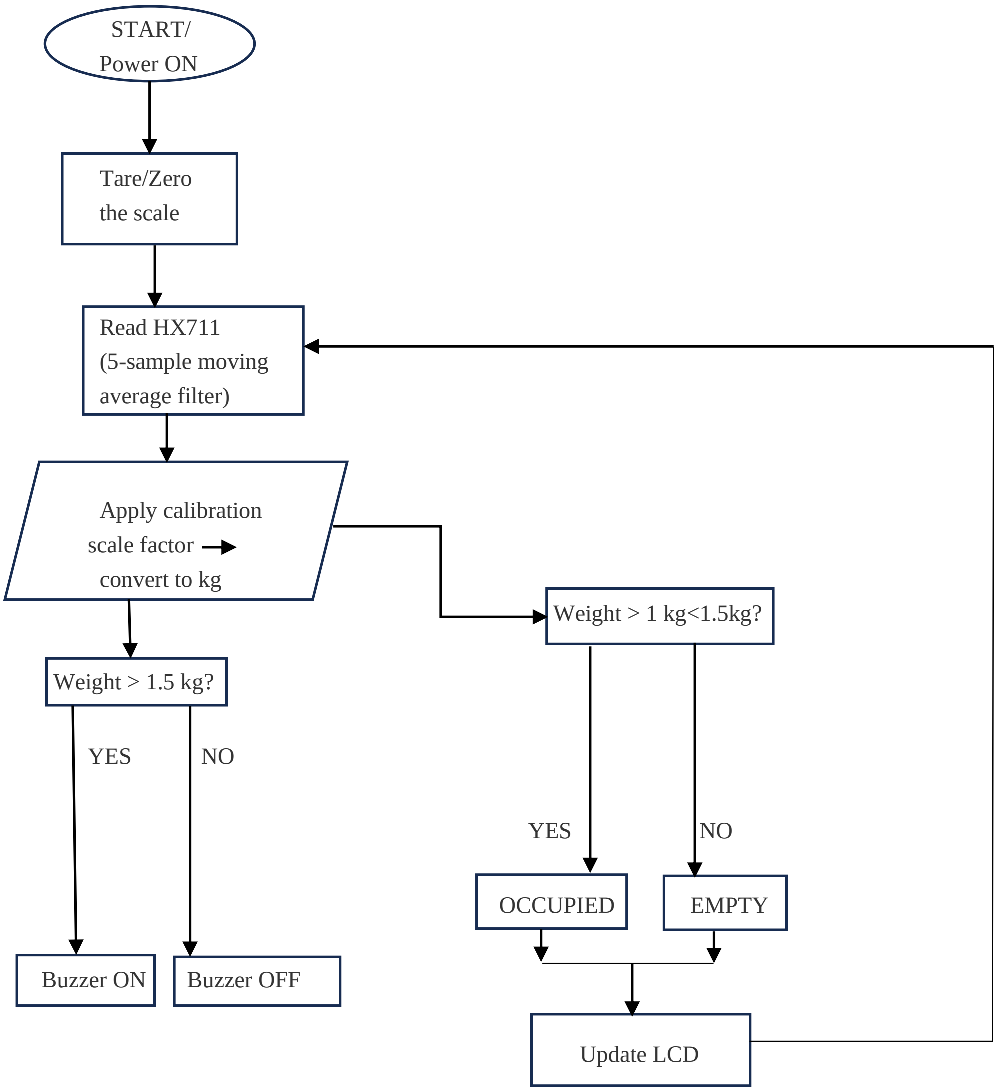


Figure 4 Firmware flowchart

3.5 PHASE 3 — TESTING AND VALIDATION

Three categories of tests were conducted under static loading conditions:

Accuracy testing: Five known reference weights between 0 kg and 2 kg are applied individually to the seat. The weight displayed on the LCD is recorded and compared against each reference value. Accuracy was calculated as the percentage of readings falling within ±5% of the true value.

Repeatability testing: A 1.5 kg reference weight was applied to and removed from the seat ten consecutive times. The mean (μ) and standard deviation (σ) of the ten readings were calculated. The coefficient of variation was:

$$CV = (\sigma / \mu) \times 100\%$$

A CV below 5% confirmed acceptable repeatability for occupancy detection purposes.

Threshold boundary testing: Weights of 0.8 kg, 1.0 kg, 1.3 kg, 1.4 kg, and 1.5 kg were applied in sequence to characterise system behaviour at and around both thresholds:

- At 0.8 kg → LCD displays EMPTY
- At 1.0 kg and above → LCD displays OCCUPIED
- At 1.5 kg → buzzer activates

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Accuracy Test Results

Reference Weight (kg)	Displayed Weight (kg)	Error (%)	Within ±5%?
0.0	0.00	0.0	✓
0.5	0.49	2.0	✓
1.0	0.97	3.0	✓
1.5	1.48	1.3	✓
2.0	1.96	2.0	✓

Table 2 Accuracy test results

The system achieved an overall accuracy of 100% of readings within the ±5% error margin as shown in Table 2. Errors were generally consistent across the weight range, indicating that the calibration scale factor applied in firmware was effective. Any deviations at the upper end of the scale are attributed to minor mechanical flex in the plywood platform under higher loads.

4.1.2 Repeatability Test Results

Trial	Reading (kg)
1	1.48
2	1.49
3	1.47
4	1.48
5	1.50
6	1.49
7	1.48
8	1.47
9	1.49
10	1.48
Mean (μ)	1.483
Std Dev (σ)	0.009
CV (%)	0.6

Table 3 Repeatability test results

A coefficient of variation below 5% confirms that the system produces consistent readings under repeated identical loading as shown in Table 3, which is well within the acceptable repeatability threshold of 5%. The moving average filter in firmware was effective in reducing noise between consecutive readings.

4.1.3 Threshold Boundary Test Results

Applied Weight (kg)	Displayed Status	Buzzer State	Expected
0.8	EMPTY	OFF	✓
1.0	OCCUPIED	OFF	✓
1.3	OCCUPIED	OFF	✓
1.4	OCCUPIED	OFF	✓
1.5	OCCUPIED	ON	✓

Table 4 Threshold boundary test results

The occupancy threshold at 1 kg and the overload threshold at 1.5 kg both operated correctly as shown in the Table 4, with clean state transitions and no false triggers observed.

4.2 DISCUSSION

The results confirm that weight-threshold-based seat occupancy detection was both accurate and repeatable as shown in table 2 and table 3, using low-cost hardware. The HX711-Arduino combination handled the full test weight range without saturation, and the I2C LCD provided clear, stable output at every test point.The 1 kg occupancy threshold proved appropriate for distinguishing a seated passenger from light incidental objects. In a real bus deployment, adult passengers in Uganda typically weigh 50–90 kg, giving a large margin above the threshold and making false non-detection practically impossible.

The luggage consideration is worth noting. A heavy bag placed on an empty seat registers correctly as an occupied load since it contributes real weight to the vehicle. This is the right behaviour a system focused on total vehicle weight rather than headcounts should flag any significant load on a seat, regardless of whether it is a person or cargo. In a full deployment, the combination of seat sensors and dedicated luggage zone sensors would allow the system to distinguish between the two.The buzzer alarm demonstrated reliable threshold detection throughout testing. In a full vehicle deployment, this alarm would be calibrated to the specific vehicle’s GVWR payload limit, so when the combined weight from all seats, standing zones, and luggage compartments reaches that limit, the driver receives an immediate alert before the vehicle moves.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This project has successfully designed and implemented an automatic seat occupancy and weight monitoring prototype for road transportation vehicles using a 20 kg load cell, HX711 ADC amplifier, Arduino Uno, 16×4 I2C LCD, and active buzzer. The system accurately detects whether a seat is occupied based on a calibrated 1 kg threshold, displays the measured weight in real time, and triggers an alarm at the defined maximum load threshold. Testing for accuracy, repeatability, and threshold boundary behaviour confirmed that the system performs reliably within the ±5% error margin under static loading conditions.

The project addresses a genuine and unresolved problem in Uganda’s public transport sector. Manual passenger counting is unreliable, blind to standing passengers and luggage weight, and provides no independent check on conductor-reported revenue. An automatic, weight-based system replaces these uncertainties with measurable, sensor-generated data. The prototype demonstrates that this is achievable with locally available, low-cost hardware — making it a realistic solution for Uganda’s transport fleet at scale.

Beyond the prototype, the project has established the technical foundation for a full vehicle deployment covering all seats, standing passenger zones, luggage compartments, and integration with battery management systems in electric buses. Each of these extensions follows directly from the sensing principle validated here.

5.2 RECOMMENDATIONS

- Scale to full multi-seat configuration. Expand from the single prototype seat to all seats in the vehicle. Each additional seat requires one load cell and one HX711 module. For a full bus such as the Kiira Kayoola with 35 seats, the Arduino Uno would be replaced with an Arduino Mega 2560 to accommodate the expanded digital pin requirements.
- Add floor-embedded load cells for standing passengers. Install load cell arrays in the standing zones of the bus aisle and doorway areas to capture the weight of standing passengers — currently the most significant unmonitored weight contributor — and feed this into the total load computation.
- Add luggage weight sensing zones. Install higher-capacity load cells (150–200 kg rated) in boot compartments and under overhead luggage racks to complete the vehicle’s total GVW picture: seated passengers + standing passengers + luggage = total payload, compared against GVWR in real time.
- Integrate with the Battery Management System. Connect the total passenger weight output to the vehicle’s BMS via a serial interface such as UART or CAN bus, enabling dynamic range

prediction and discharge modelling based on actual load. This is the highest-value extension for electric bus operators running Kiira Kayoola buses on Kampala routes.

- Develop a fuel consumption estimation module. For conventional fuel buses and taxis, implement the rolling resistance fuel model on the Arduino to compute and display the estimated excess fuel cost per trip due to overloading.
- Add data logging. Incorporate an SD card module or GSM module to store and transmit timestamped occupancy and weight records. This creates the independent daily passenger log that vehicle owners need for revenue accountability.
- Conduct field trials on active transport vehicles. Validate system performance under real service conditions on Kampala urban routes, ideally in collaboration with Kiira Motors Corporation for electric bus trials or with KCCA for conventional fleet testing.

5.3 LIMITATIONS

The following limitations apply to the current single-seat prototype:

- Scale of prototype: The system is validated on a single seat under static conditions. Real bus seats experience dynamic loading — vibration, sudden weight shifts, passengers shifting position — which this prototype does not replicate. The moving average filter partially addresses vibration noise, but field validation under real vehicle conditions would be needed before full deployment.
- Load cell capacity: The 20 kg load cell used is suitable for demonstration but would be replaced with 150–200 kg rated cells in a real deployment to accommodate the full weight range of adult passengers and luggage.
- No standing passenger detection: The prototype does not include floor-embedded sensors. Standing passengers — a common and significant weight contributor on Uganda's urban routes — are entirely unmonitored in the current implementation.
- No luggage zone sensing: Luggage in boot areas or on roof racks is not captured by the seat-level sensors. A complete vehicle weight picture requires dedicated sensing zones for these areas.
- No data logging: The prototype displays data in real time on the LCD but does not store it. A full deployment would include data logging to give vehicle owners an independent record of daily occupancy and weight readings.
- No BMS or fuel model integration: The impact of passenger load on battery energy consumption and fuel burn — discussed extensively in the literature review — is not demonstrated within the prototype. This remains the most impactful extension of the current work.

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APPENDICES

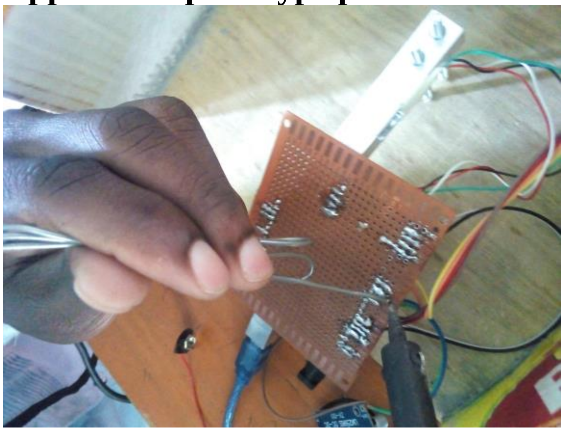
Appendix 1: System code

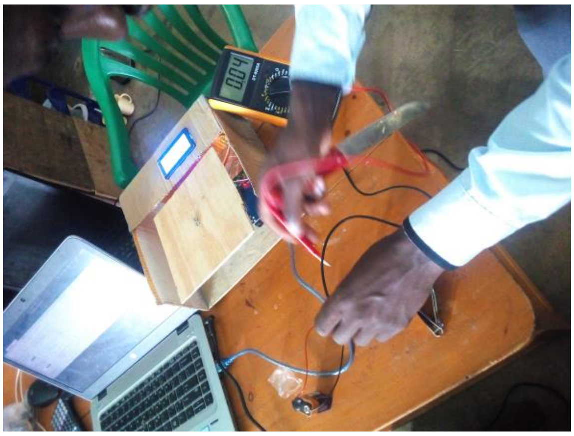
```
#include "HX711.h"
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

#define DOUT 3
#define CLK 2
#define BUZZER 8
#define BUTTON_PIN 7

HX711 scale;
LiquidCrystal_I2C lcd(0x27, 16, 4);

float calibration_factor = 97644.0; // calibration factor
const float OCCUPIED_THRESHOLD = 1.0;
const float OVERLOAD_THRESHOLD = 1.5;
const int TOTAL_SEATS = 1;

bool buzzerMuted = false;
int occupiedSeats = 0;
int emptySeats = 1;
int beepCount = 0; // for compatibility
bool fullOccupancyAlertDone = false;

// Median filter to reject electrical noise spikes
float getFilteredWeight(int samples = 7) {
float values[samples];
for (int i = 0; i < samples; i++) {
values[i] = scale.get_units(1);
}
//Simple sort for median
for (int i = 0; i < samples - 1; i++) {
for (int j = i + 1; j < samples; j++) {
if (values[i] > values[j]) {
float temp = values[i];
values[i] = values[j];
values[j] = temp;
}
}
}
return values[samples / 2];
}

void updateLCD(float weight) {
lcd.clear();

lcd.setCursor(0, 0);
lcd.print("Occupied Seats:" + String(occupiedSeats));

lcd.setCursor(0, 1);
lcd.print("Empty Seats:" + String(emptySeats));
```

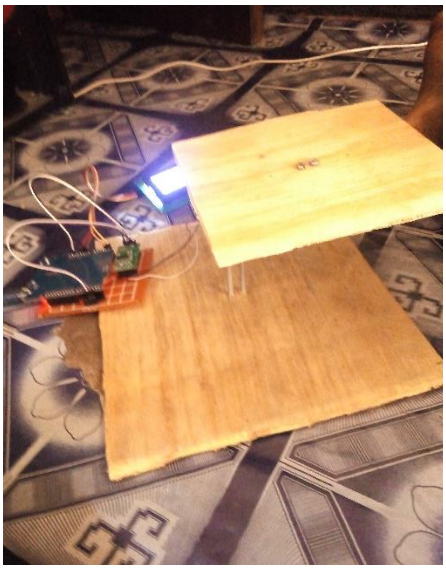
```
lcd.setCursor(-4, 3);
if (occupiedSeats == TOTAL_SEATS) {
lcd.print("ALL SEATS OCCUPIED");
} else {
lcd.print(" "); //Clear line
}

lcd.setCursor(-4, 3);
if (occupiedSeats == 0) {
lcd.print("ALL SEATS EMPTY");
} else {
lcd.print(" ");
}

lcd.setCursor(6, 2);
lcd.print(weight, 1);
lcd.print("kg");
}

void setup() {
Serial.begin(9600);

pinMode(BUZZER, OUTPUT);
digitalWrite(BUZZER, LOW);
pinMode(BUTTON_PIN, INPUT_PULLUP);

scale.begin(DOUT, CLK);
scale.set_scale(calibration_factor);
scale.tare(); //Zero with no load

lcd.init();
lcd.backlight();

lcd.setCursor(0, 0);
lcd.print("Seat Monitor");
lcd.setCursor(0, 1);
lcd.print("System Ready");
delay(2000);
lcd.clear();

updateLCD(0.0);
Serial.println("Seat Occupancy System Ready");
}

void loop() {
float weight = getFilteredWeight(7);

//Button press mutes the buzzer
if (digitalRead(BUTTON_PIN) == LOW) {
buzzerMuted = true;
}

//Occupancy logic with hysteresis
```

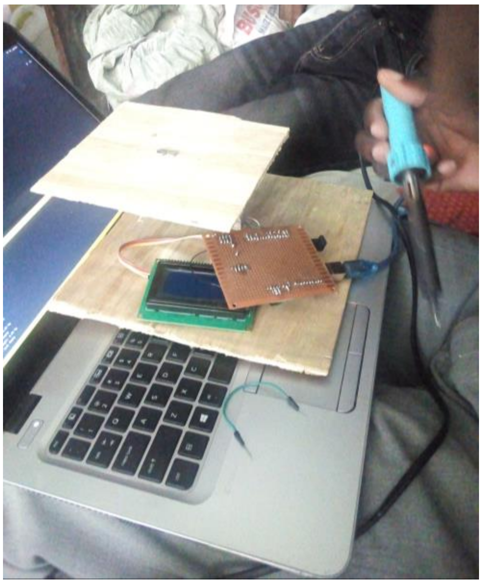
```
static int occupancyCounter = 0;
if (weight > OCCUPIED_THRESHOLD) {
occupancyCounter++;
if (occupancyCounter >= 2) {
occupiedSeats = 1;
emptySeats = 0;
}
} else {
occupancyCounter = 0;
occupiedSeats = 0;
emptySeats = 1;
buzzerMuted = false; //unmute when seat becomes empty
}

updateLCD(weight);

Serial.print("Weight: ");
Serial.print(weight);
Serial.print(" kg | Occupied: ");
Serial.print(occupiedSeats);
Serial.print(" Empty: ");
Serial.println(emptySeats);

if (!buzzerMuted) {
if (weight > OVERLOAD_THRESHOLD) {
tone(BUZZER, 1000); //continuous beep
fullOccupancyAlertDone = false; //reset
}
//5beep alert for full occupancy (weight btn 1.0 and 1.5 kg)
else if (occupiedSeats == TOTAL_SEATS) {
if (!fullOccupancyAlertDone) {
for (int i = 0; i < 5; i++) {
tone(BUZZER, 1000);
delay(200);
noTone(BUZZER);
delay(200);
}
fullOccupancyAlertDone = true;
} else {
noTone(BUZZER); //buzzer quiet when alert already done
}
}
else {
//no alert condition
noTone(BUZZER);
fullOccupancyAlertDone = false;
}
} else {
noTone(BUZZER);
fullOccupancyAlertDone = false;
}

delay(300);
}
```

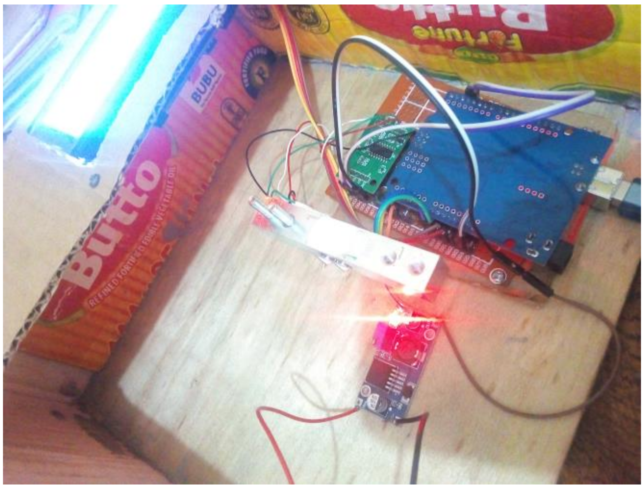
Appendix 2:prototype photos



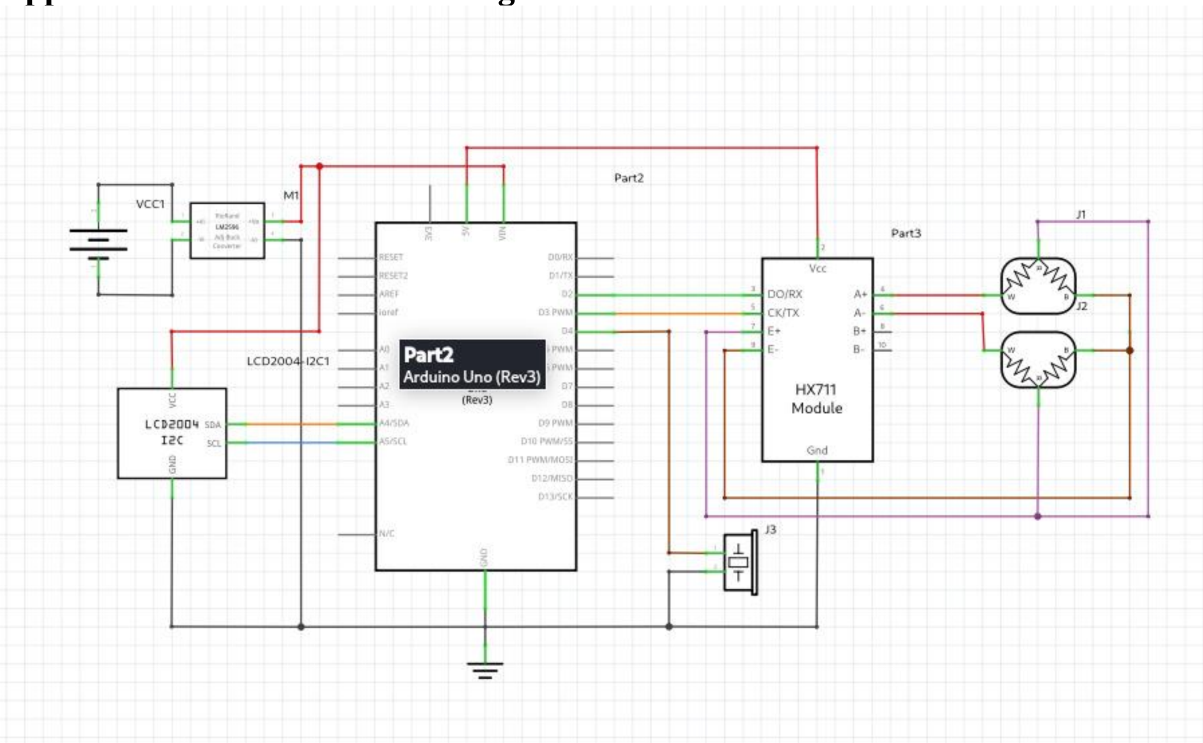








Appendix 3:Circuit schematic diagram



Appendix 4: Project work-plan

Activity	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Proposal writing & approval	■	■						
Component procurement		■	■					
Prototype construction			■	■				
Firmware development & calibration				■	■			
Testing and validation					■	■		
Data analysis						■	■	
Report writing & submission							■	■