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# Intelligent Electronic Weighing System with Dual Verification and Tamper Detection for Fair Price Shops

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**ABSTRACT :**

India has a Public Distribution System (PDS) for wheat and rice supplies for subsidised prices for eligible families via Fair Price Shops. Yet despite these initiatives, everyday activities within these shops are vulnerable to inaccurate weighing, errors in log books, unauthorised manipulation of equipment, and irregularities that are only discovered late on. This paper describes the design and construction of an affordable IoT-based ration distribution demonstrator which employs role-based RFID authentication, weight measurement, entitlement validation, digital stock records, and enclosure tamper detection. An ESP32 microcontroller acts as the primary controller, communicating with an RC522 RFID reader, a load cell with a HX711 amplifier, a 16×2 I2C LCD, a tamper switch, and a SIM800 GSM module. Separate RFID cards are used to authenticate government employees, shop keepers and customers. Stocking of goods requires both a government employee and the shop keeper to authenticate, whereas selling of grain requires both the shop keeper and the customer to authenticate. Prior to completing a transaction, the weighed amount is cross-checked with the customer's remaining entitlement. A web-based GUI hosted by the ESP32 shows the live weight, current step of the process, stock levels and recent transactions, while Google Apps Script and Google Sheets track users, entitlements, stocks, and transactions. If an enclosure is opened, a warning is displayed on the LCD and GUI, and an SMS message with the shop name and location is sent to a designated government office number. This is a non-commercial education demonstrator and not a replacement for an official PDS authentication and monitoring solution. Calibration, network state, authentication strength, and SMS reliability all impact performance.

**Keywords: Smart Ration Distribution, Public Distribution System, ESP32, RFID Authentication, Load Cell, HX711, Internet of Things, Google Sheets, Inventory Management, Tamper Detection, Gsm SMS Alert.**

## INTRODUCTION

The Public Distribution System (PDS) is the main element of India's food security system. It offers subsidised wheat and rice to eligible households through a vast network of Fair Price Shops (FPS), also known as ration shops. Technological advancement in recent years, such as Electronic Point of Sale (ePoS) machines and One Nation One Ration Card (ONORC) have helped with beneficiary verification and enable portability of benefits.

However, there are still some problems at shop level. There is sometimes a weighing error of grains, handwritten stock entries may contain errors, there may be a difference between stock and real stock, and no one notices that the equipment is being blocked. These issues need to be solved by combining the weighing, authentication, records, and alarm system instead of isolating them.

The prototype described here combines an ESP32, an RC522 RFID reader, a load cell and HX711 amplifier, an LCD, a web dashboard, Google Sheets storage, and a GSM module (SIM800) all in one device. The ESP32 authenticates the role of each cardholder, reads the weight of the wheat or rice, compares it to the customer's remaining quota, and records the transaction. It also includes a tamper switch that detects the box being opened and sends an SMS message. This device is purely for demo and testing – it does not detect false transactions on its own and does not replace PDS infrastructure. Its performance in the field will depend on location, network quality, calibration, and card reader authentication method.

## RELATED WORK AND RESEARCH GAPS

PDS has been computerised in India througha combination of digitising ration cards, automated fair price shops and use of ePoS machines to identify beneficiaries and record transactions. The ONORC scheme allows all eligible beneficiaries to buy grain from shops in other locations. Studies on its implementation focus on access and public information, and a variety of digital infrastructure issues, with portability among migrant households identified as a specific concern.

Many smart ration systems were reported. Katpatal et al. proposed an RFID smart ration system using ATmega16 microcontroller with LCD display showing the name of the beneficiary and amount of quota monthly with GSM message sent to the beneficiary and the authorities; their aim was to prevent forgery and leakage. Lokhande and Shinde studied using RFID tags and microcontroller for replacing the identification by ration card. These studies conclude that RFID identification and GSM messaging are a feasible element of a smart ration distribution scheme.

Exhibit: Low-cost, integrated prototype system for: (a) role-based RFID authentication of government agents, shop-owners, and shop-keepers; (b) load-cell weighing with an entitlement verification stage before confirmation; (c) centralised record-keeping of entitlements, stock, and transactions; (d) visual representation through a web page; (e) physical tamper alarm to an SMS messaging system. Thus, note that: (1) checking a card and an SMS message does not verify the quantity of grain actually sold, update the shop's stock, or register that the equipment has been physically tampered with; (2) what this work attempts to provide is a low-cost, integrated system that combines (a), (b), (c), (d), and (e) above. No particular claim is made as to the novelty of an individual function, or to the fact that the system should be useful in lowering the instances of fraud, both of which can only be shown through controlled field trials.

## 2. Mathematical Formulation

The relations below describe the weighing, entitlement, stock, and evaluation calculations carried out by the system. Their numerical accuracy rests on proper calibration of the weighing platform and on correctly configured entitlement and stock values.

### A. Weight Measurement

The HX711 converts the load-cell signal to a digital value. Once the empty platform has been tared, the weight is obtained from the raw reading as

$$W = (R - R_0) / C \quad (1)$$

where W is the measured weight, R is the present sensor reading, $R_0$ is the zero (tare) reading, and C is the calibration scale factor. The value of C depends on the load cell, the wiring, and the mechanical arrangement, and it is tuned using known reference weights.

### B. Remaining Entitlement

The amount of a commodity that a customer can still collect is

$$E_R = E_T - Q_D \quad (2)$$

where $E_R$ is the remaining entitlement, $E_T$ is the total allocated entitlement, and $Q_D$ is the quantity already issued. For instance, a customer entitled to 5 kg of wheat who has already received 2 kg has $E_R = 5 - 2 = 3$ kg.

### C. Transaction Validation

A distribution is accepted only if the stable measured quantity $Q_m$ satisfies

$$0 < Q_m \leq min(E_R, S_B, Q_{max}) \quad (3)$$

where $S_B$ is the available stock of the chosen commodity and $Q_{max}$ is the configured maximum batch quantity, set to 10 kg in this prototype. The customer must also be marked active in the database.

### D. Stock Balance

The balance of each commodity is calculated as

$$S_B = S_O + S_R - S_D \quad (4)$$

where $S_O$ is the opening stock, $S_R$ is the total stock received, and $S_D$ is the total stock distributed. As an example, $S_O = 50$ kg, $S_R = 100$ kg, and $S_D = 35$ kg give $S_B = 115$ kg. This digital balance still has to be reconciled against the physical stock.

### E. Evaluation Metrics

For a reference weight $W_r$ and a measured weight $W_m$, the absolute and percentage weighing errors are

$$E_a = |W_r - W_m| \quad (5)$$

$$E_p = (|W_r - W_m| / W_r) \times 100 \quad (6)$$

$E_p$ has meaning only when the reference weight is non-zero. The other reliability metrics are defined from repeated trials:

$$S_a = (N_s / N_v) \times 100 \quad (7)$$

$$S_c = (N_{ok} / N_{tot}) \times 100 \quad (8)$$

$$D_t = (N_{det} / N_{act}) \times 100 \quad (9)$$

$$S_{SMS} = (N_{dlv} / N_{att}) \times 100 \quad (10)$$

Here $S_a$ is the authentication success rate ($N_s$ correct authentications out of $N_v$ valid attempts), $S_c$ is the cloud request success rate, $D_t$ is the tamper detection rate ($N_{det}$ events detected out of $N_{act}$ actual test events), and $S_{SMS}$ is the SMS delivery success rate ($N_{dlv}$ delivered out of $N_{att}$ attempted). A GSM modem merely accepting an SMS command is not treated as delivery; delivery is counted only when a delivery report or confirmation from the recipient exists.

## 3. PROPOSED SYSTEM ARCHITECTURE

The proposed Smart Ration Distribution System is an integrated IoT system that seamlessly integrates identification, weighing, processing, cloud storing and security monitoring. It has been categorised into five functional blocks- identification and authentication, weighing, central processing, online monitoring and data storing, and tapper detection and alert by GSM. The major blocks are highlighted in Table I.

**Table I. Main blocks of the proposed SYSTEM**

| Block | Function | Implementation |
|---|---|---|
| Processing unit | Runs the firmware, manages the workflow, hosts the dashboard, and talks to the backend | ESP32 DevKit V1 |
| Authentication | Reads the card UID for employee, owner, and customer roles | RC522 reader, RFID cards |
| Weighing unit | Measures the quantity of wheat or rice | Load cell, HX711 |
| Display interface | Shows local status messages and the live dashboard | 16×2 I²C LCD, web page |
| Cloud storage | Holds users, entitlements, stock, and transactions | Apps Script, Google Sheets |
| Security alert | Detects enclosure opening and sends an SMS | Tamper switch, SIM800 |
| Power supply | Portable rechargeable power | 3.7 V, 3 Ah Li-ion, charger |

### A. ESP32 Processing Unit

The ESP32 acts as the master controller. It sleeps on a cycle that reads the RFID reader and HX711, checks the flow state, manages the LCD, reads the tamper switch input, and communicates to the backend over Wi-Fi [7]. As it has built-in Wi-Fi, not only does it provide the local dashboard, it also issues all HTTP requests to Google Apps Script; therefore, all functionalities that depend on backend service are also impacted when Wi-Fi is down.

### B. RFID Authentication Unit

The RC522 reader communicates with the ESP32 on SPI and supplies the UID of the card being presented [8]. Each UID is associated with a role (government employee, shop owner, or customer) in the backend. This separation of roles is necessary because there are different rules for authorisation to be applied to stock receipt and to ration distribution. On their own, UID values are not very convincing proof of identity, since they are cloneable; in production systems, some form of more robust authentication would be required.

### C. Weighing Unit

The load cell transforms the force into a very small electrical signal that the HX711 then amplifies and digitises [9]. The ESP32 then scales the reading in kg using the tare offset and calibration factor in Eq. (1). A number is only accepted when the reading stabilises and is within limits set.

### D. Display and Web Dashboard

The LCD displays authentication results, the weight measured, the chosen commodity, receipt/distribution confirmations, and tamper alerts. The dashboard, developed using HTML, CSS, and JavaScript, displays the current weight, status of workflow, the commodity that has been selected, the tare control, stock balances, and past transactions. It updates itself with interval queries; meaning there is no need to refresh the page.

### E. Cloud Backend and Database

Google Apps Script acts as a bridge between the ESP32 and Google Sheets [11] and four sheets are used. The Users sheet stores each UID along with role, name and active status. The Customers sheet stores wheat and rice entitlements, the amount handed out, and active status. The Stock sheet stores the opening, received, distributed, and remaining quantities, as well as the last time it was updated. The Transactions sheet stores the transaction id, date/time, type, commodity, quantity, authorising UID, customer id, and remarks.

### F. Tamper Detection & GSM Alerting

A normally closed tamper switch is attached to the inside of the enclosure and connected to an ESP32 input. When the enclosure is opened or the circuit is broken (being tampered with), the input switches. The ESP then displays a warning on the LCD and dashboard and sends an SMS via the SIM800 module [10] to the designated government office.

### G. Power Supply

The prototype operates from a 3.7 V, 3 Ah lithium-ion battery and matching charging module with no DC-DC booster. This configuration requires that you check the power supply to ensure the ESP32 and all peripherals are supplied with their rated voltages. The SIM800 especially needs a power source that can handle the peak transmission current demand and should not be connected directly to an unchecked power supply.

### H. Advantages of the Proposed Architecture

The design offers weighing, authentication, record-keeping and alerting in a single, low-cost unit. Dual-role verification offers some measure of operational control, while digital transaction records can be used to track movement, and the modular design means the display, database, or sensors can be swapped out without a whole redesign. How practical it will turn out to be depends on calibration, connectivity and validation test results.

## 4. Implementation of Core Functions

### A. Hardware Interfacing

Each module connects to the ESP32 through its native interface: SPI for the RC522, I²C for the LCD, UART for the SIM800, and plain digital pins for the HX711 and the tamper switch. All modules share a common ground. The GPIO assignments are listed in Table II.

**Table II. ESP32 GPIO allocation**

| Component | Signal | ESP32 pin |
|---|---|---|
| HX711 | DOUT / SCK | GPIO 32 / 33 |
| RC522 | SDA (SS) | GPIO 5 |
| RC522 | SCK / MISO / MOSI | GPIO 18 / 19 / 23 |
| RC522 | RST | GPIO 4 |
| I²C LCD | SDA / SCL | GPIO 21 / 22 |
| SIM800 | ESP32 RX / ESP32 TX | GPIO 26 / 17 |
| Tamper switch | Digital input | GPIO 27 |

### B. Role-Based RFID Authentication

When a card is presented, the ESP32 reads its UID and sends a lookup request to the Apps Script backend. The backend confirms that the UID is registered and active, then returns the holder's role together with any customer details. That role determines which workflow the person may take part in. Stock receipt needs both a government employee and the shop owner, while customer distribution needs both the customer and the shop owner.

### C. Incoming Stock Receipt

The operator starts the stock receipt workflow from the dashboard. The government employee scans a card first, followed by the shop owner. Once both are verified, the commodity (wheat or rice) is chosen and the grain is placed on the load cell. When the weight has stabilised and lies within the permitted range, the operator confirms receipt on the dashboard. The ESP32 sends the transaction to the backend, which adds the quantity to stock according to Eq. (4) and records the transaction.

### D. Customer Ration Distribution

For distribution, the operator selects the workflow and the customer scans a card; the backend replies with the customer's details and remaining entitlement from Eq. (2). The shop owner then scans a card to authorise the distribution. The grain is weighed and the result appears on the LCD and the dashboard. The transaction can be confirmed only if the condition in Eq. (3) is met, after which the backend updates the distributed quantity, the customer's remaining entitlement, and the stock balance.

### E. Tamper Alert Generation

The ESP32 monitors the tamper input continuously. When the state changes, it shows a warning and composes an SMS of the form "MACHINE TAMPERING ALERT — Shop Name, Location, Status: machine enclosure opened or tamper circuit interrupted. Action: please inspect the machine." The alert only reports that the monitored circuit changed state. It cannot tell whether the cause was malicious, accidental, or authorised maintenance.

## 5. Research Methodology

This segment lists the process of developing, constructing, and evaluating the system. The biggest goal was to measure the rations with precise weighing, role-dependent approval, digital logs, and alert mechanism for tampering. Hardware selection preceded the development: the ESP32, the RC522 reader,

the load cell with its HX711 amplifier, the I2C LCD, the SIM800 module, the tamper switch, and the rechargeable battery with its charging circuit. Modules were wired separately and tested individually first, then the complete circuit was arranged for a printed circuit board using EasyEDA [13].

Software development. The ESP32 firmware is written using the Arduino IDE [12] and divided into functions for RFID read, user lookup, weight read, stock received, ration dispensed, entitlement changed, dashboard response, and security, using the WiFi, Web Server, HTTPClient, MFRC522, HX711, LiquidCrystal_I2C, and Arduino Json libraries. The dashboard is written in HTML, CSS, and JS, and data storage is handled by a Google Apps Script backend connected to Google Sheets.

The load cell was calibrated. With no item on the platform a tare was taken then a reference mass was placed on the platform and the calibration factor adjusted until the display showed the same mass as the reference. This was done with a number of reference masses, then the masses were removed and replaced in order to determine the repeatability. Averaging and stability detection can reduce the amount of fluctuation but too much averaging makes each transaction very slow.

Table III system tests the functions in question. Authentication tests with registered and unregistered cards. Distribution tests require the number of the subtotal not in the remaining entitlement and in stock, and the number in stock that exceed both. Stock tests compare the dashboard's and the spreadsheet's number at reception and distribution. Tamper tests open the enclosure and break the switch circuit. SMS tests require the recipient number to have a SIM-card, be in coverage and has been set up correctly. Record trials, conditions of tests and the number of failed trials to ensure a repeatable assessment.

**TABLE III. EVALUATION PLAN OF THE PROTOTYPE**

| Parameter | Test method | Metric |
|---|---|---|
| RFID authorisation | Valid and invalid cards for each role | $S_a$, Eq. (7) |
| Weighing accuracy | Known reference weights, repeated | $E_a$, $E_p$, Eqs. (5), (6) |
| Entitlement check | Quantities within and above $E_R$ | Accept / reject |
| Inventory | Receipt and distribution cycles | $S_B$, Eq. (4) |
| Cloud link | Dashboard and backend requests | $S_c$, Eq. (8) |
| Tamper detection | Enclosure and circuit events | $D_t$, Eq. (9) |
| SMS alert | Alerts to the office number | $S_{SMS}$, Eq. (10) |

In this way, the methodology offers a structured route for developing and evaluating the system, and it shows how embedded hardware, cloud-based records, and GSM communication can be combined in a ration shop prototype.

## Conclusion

This paper has presented an Intelligent Electronic Weighing System with Dual Verification and Tamper Detection for Fair Price Shops that combines an ESP32, role-based RFID authentication, load-cell weighing, entitlement checking, Google Sheets inventory records, a web dashboard, and a tamper switch with SIM800 SMS alerting. Requiring a government employee and the shop owner for stock receipt, and the customer and the shop owner for distribution, provides a basic level of control, while checking the weight against the remaining entitlement and keeping digital transaction records supports accuracy and traceability.

The system remains a prototype for demonstration and evaluation. Its reliability hinges on calibration, Wi-Fi and GSM coverage, power design, and the strength of authentication, and its performance should be established through the repeated tests defined here rather than taken for granted.

## 6. Limitations and Future Scope

Because transactions go through the cloud, a lost connection may prevent immediate confirmation; an offline queue with safe synchronisation would address this. Comparing RFID UIDs alone leaves the system open to card cloning. Weighing accuracy is governed by load-cell capacity, mounting, calibration, vibration, and electrical noise. SMS delivery depends on the SIM card, network coverage, and power, and detecting a tamper event does not guarantee that the message gets through. A single tamper switch covers only the condition it is placed and wired for. Google Sheets, though convenient for a prototype, lacks the consistency, access control, and audit features of a robust database.

Future work includes cryptographically secure credentials with server-side permission checks; a mechanically stable weighing platform with overload detection and periodic calibration; daily and monthly reports that flag unusual stock variations; additional tamper sensors with local event logs and alert retries; an improved PCB with better grounding and power paths; and measurement of real power consumption to optimise battery capacity and regulation. Before any pilot at a Fair Price Shop, compliance with government PDS procedures, secure handling of customer data, and backup of transaction records would need to be confirmed.

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