

# Smart Inventory Pallets - Requirements Specification Document

**Version:** 1.0

**Project:** Smart Inventory Pallets for Beverage Distribution Warehouses

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**Course:** Embedded Systems Project

## 1. Introduction

### 1.1 Purpose

This document specifies the functional and non-functional requirements for the Smart Inventory Pallets system. The system aims to automate inventory tracking in beverage distribution warehouses using embedded IoT devices integrated with existing SaaS platforms.

### 1.2 Scope

The Smart Inventory Pallets system covers:

- Automated weight measurement using load cells
- Real-time inventory calculation based on weight changes
- ESP32-based embedded device for local processing
- WiFi connectivity for cloud data transmission
- Integration with existing SaaS platform for beverage distribution
- Real-time dashboard updates and reporting

### 1.3 Document Conventions

- **SHALL/MUST:** Mandatory requirement
- **SHOULD:** Highly recommended requirement
- **MAY/COULD:** Optional requirement
- **FR:** Functional Requirement
- **NFR:** Non-Functional Requirement

### 1.4 Intended Audience

- Project supervisor and academic reviewers
- Development team (student)
- Future maintainers and developers
- End users (warehouse staff)

## 2. Overall Description

### 2.1 Product Perspective

The Smart Inventory Pallets system is an embedded IoT solution that extends the existing SaaS platform for beverage distribution. It operates as a complementary system that automates manual inventory tracking processes currently performed by warehouse clerks.

### 2.2 Product Functions

- **Automated Weight Monitoring:** Continuous monitoring of pallet weight using load cells
- **Inventory Calculation:** Real-time calculation of bottle/product quantities based on weight
- **Data Transmission:** Wireless transmission of inventory data to cloud platform
- **Local Display:** Real-time status display on embedded device
- **Cloud Integration:** Seamless integration with existing SaaS dashboard

### 2.3 User Classes and Characteristics

- **Warehouse Staff:** Primary users who load/unload vehicles and monitor inventory
- **Warehouse Managers:** Users who review reports and monitor overall inventory status
- **System Administrators:** Technical users responsible for system maintenance
- **Delivery Drivers:** Indirect users whose activities trigger inventory changes

### 2.4 Operating Environment

- **Physical Environment:** Industrial warehouse setting with temperature variations
- **Network Environment:** WiFi network with internet connectivity
- **Power Environment:** Mains power with optional battery backup
- **Mechanical Environment:** Subject to loading/unloading vibrations and weight changes

## 3. Functional Requirements

### 3.1 Weight Measurement System (FR-WM)

#### FR-WM-001: Load Cell Integration

- The system SHALL integrate with 20kg capacity load cells to measure pallet weight
- The system SHALL use HX711 amplifier for accurate weight signal conditioning
- The system SHALL support calibration procedures for accurate weight measurement

#### FR-WM-002: Real-time Weight Monitoring

- The system SHALL continuously monitor pallet weight at configurable intervals
- The system SHALL detect weight changes greater than a configurable threshold
- The system SHALL filter out vibrations and temporary weight fluctuations

### **FR-WM-003: Weight Data Processing**

- The system SHALL calculate net product weight by subtracting pallet tare weight
- The system SHALL convert weight measurements to product quantities using configurable unit weights
- The system SHALL maintain weight measurement history for analysis

## **3.2 Display and User Interface (FR-UI)**

### **FR-UI-001: Local Display**

- The system SHALL display current weight measurements on an integrated screen
- The system SHALL show calculated product quantities in real-time
- The system SHALL display system status and connectivity information

### **FR-UI-002: Status Indicators**

- The system SHALL provide visual indicators for system operational status
- The system SHALL display error conditions and alerts
- The system SHALL show network connectivity status

## **3.3 Data Communication (FR-DC)**

### **FR-DC-001: WiFi Connectivity**

- The system SHALL connect to wireless networks using WPA2/WPA3 security protocols
- The system SHALL automatically reconnect to known networks after connectivity loss
- The system SHALL support network configuration through user interface

### **FR-DC-002: Cloud Data Transmission**

- The system SHALL transmit weight and inventory data to cloud platform via HTTP/HTTPS
- The system SHALL send data in JSON format with standardized data structures
- The system SHALL include timestamp and device identification in all transmissions

### **FR-DC-003: Offline Operation**

- The system SHALL continue local operation when network connectivity is unavailable
- The system SHALL store unsent data locally during network outages
- The system SHALL automatically sync stored data when connectivity is restored

## **3.4 SaaS Platform Integration (FR-SI)**

### **FR-SI-001: API Integration**

- The system SHALL integrate with existing SaaS platform through RESTful APIs
- The system SHALL authenticate with cloud services using secure protocols
- The system SHALL handle API responses and error conditions appropriately

### **FR-SI-002: Real-time Updates**

- The system SHALL enable real-time inventory updates on SaaS dashboard
- The system SHALL support configurable update intervals based on weight changes
- The system SHALL provide inventory change notifications to the SaaS platform

#### **FR-SI-003: Data Synchronization**

- The system SHALL maintain data consistency between local device and cloud platform
- The system SHALL resolve data conflicts using timestamp-based resolution
- The system SHALL support bulk data synchronization for initial setup

### **3.5 Configuration and Calibration (FR-CC)**

#### **FR-CC-001: System Configuration**

- The system SHALL support configuration of product-specific weight parameters
- The system SHALL allow configuration of network settings and cloud endpoints
- The system SHALL provide factory reset functionality

#### **FR-CC-002: Load Cell Calibration**

- The system SHALL support guided calibration procedures using known weights
- The system SHALL store calibration parameters in non-volatile memory
- The system SHALL detect and alert for calibration drift or errors

## **4. Non-Functional Requirements**

### **4.1 Performance Requirements (NFR-P)**

#### **NFR-P-001: Weight Measurement Accuracy**

- The system SHALL achieve weight measurement accuracy within  $\pm 50$  grams
- The system SHALL maintain accuracy across operating temperature range
- The system SHALL provide consistent measurements under normal warehouse conditions

#### **NFR-P-002: Response Time**

- The system SHALL display weight changes within 500 milliseconds of detection
- The system SHALL transmit critical data to cloud within 2 seconds
- The system SHALL respond to user interface interactions within 200 milliseconds

#### **NFR-P-003: Data Processing Speed**

- The system SHALL process weight data and calculate inventory quantities within 100 milliseconds
- The system SHALL handle multiple simultaneous weight measurements efficiently
- The system SHALL maintain real-time performance under normal load conditions

## **4.2 Reliability Requirements (NFR-R)**

### **NFR-R-001: System Availability**

- The system SHALL maintain 99% uptime during normal operating hours
- The system SHALL recover automatically from temporary power interruptions
- The system SHALL continue operation during brief network connectivity issues

### **NFR-R-002: Data Integrity**

- The system SHALL ensure 100% accuracy in data transmission to cloud platform
- The system SHALL implement error detection and correction for critical data
- The system SHALL maintain audit trails for all inventory transactions

### **NFR-R-003: Fault Tolerance**

- The system SHALL detect and report sensor failures automatically
- The system SHALL continue operation with degraded functionality during component failures
- The system SHALL provide graceful degradation rather than complete system failure

## **4.3 Usability Requirements (NFR-U)**

### **NFR-U-001: Ease of Use**

- The system SHALL require minimal training for warehouse staff operation
- The system SHALL provide intuitive user interface with clear visual indicators
- The system SHALL support operation by users with basic technical knowledge

### **NFR-U-002: Installation and Setup**

- The system SHALL support installation by technical staff within 2 hours
- The system SHALL provide automated setup procedures where possible
- The system SHALL include comprehensive setup documentation

## **4.4 Security Requirements (NFR-S)**

### **NFR-S-001: Data Security**

- The system SHALL encrypt all data transmissions to cloud platform
- The system SHALL implement secure authentication for cloud services
- The system SHALL protect against unauthorized access to configuration settings

### **NFR-S-002: Network Security**

- The system SHALL support secure WiFi protocols (WPA2/WPA3)
- The system SHALL validate server certificates for cloud connections
- The system SHALL implement secure firmware update mechanisms

## 4.5 Compatibility Requirements (NFR-C)

### NFR-C-001: Hardware Compatibility

- The system SHALL be compatible with standard warehouse pallet sizes
- The system SHALL operate with common 20kg load cell specifications
- The system SHALL support standard power supply voltages (5V/12V)

### NFR-C-002: Software Compatibility

- The system SHALL integrate with existing SaaS platform APIs without modifications
- The system SHALL support common WiFi router configurations
- The system SHALL maintain compatibility with standard JSON data formats

## 4.6 Environmental Requirements (NFR-E)

### NFR-E-001: Operating Conditions

- The system SHALL operate in temperature range of 0°C to 50°C
- The system SHALL function in humidity levels up to 85% non-condensing
- The system SHALL withstand typical warehouse dust and vibration levels

### NFR-E-002: Power Requirements

- The system SHALL operate on 5V DC power supply with  $\pm 5\%$  tolerance
- The system SHALL consume less than 2 watts during normal operation
- The system SHALL support optional battery backup for 8+ hours operation

## 5. System Constraints

### 5.1 Hardware Constraints

- **Microcontroller:** ESP32-based development board with WiFi capability
- **Load Cells:** Maximum 20kg capacity with appropriate load distribution
- **Display:** OLED or LCD display suitable for industrial environment
- **Power:** Standard 5V/12V power supply with optional battery backup

### 5.2 Software Constraints

- **Development Platform:** Arduino IDE or ESP-IDF for firmware development
- **Programming Language:** C/C++ for embedded firmware
- **Communication Protocol:** HTTP/HTTPS for cloud communication
- **Data Format:** JSON for data exchange with SaaS platform

### 5.3 Regulatory Constraints

- **Safety Standards:** Compliance with industrial equipment safety standards
- **Electromagnetic Compatibility:** FCC/CE compliance for wireless operation
- **Data Protection:** Compliance with applicable data privacy regulations

## 6. Assumptions and Dependencies

### 6.1 Assumptions

- Existing SaaS platform provides stable APIs for integration
- Warehouse WiFi network provides reliable internet connectivity
- Standard warehouse pallets support load cell integration
- Warehouse staff will receive basic training on system operation
- Product weights are consistent and known for accurate inventory calculation

### 6.2 Dependencies

- **Hardware Procurement:** Timely delivery of electronic components
- **SaaS Platform:** Availability of existing platform for integration testing
- **Network Infrastructure:** Functional WiFi network in warehouse environment
- **Power Supply:** Reliable electrical power or battery backup system
- **Technical Support:** Access to technical documentation and support resources

## 7. Acceptance Criteria

### 7.1 Functional Acceptance

- All functional requirements (FR-WM, FR-UI, FR-DC, FR-SI, FR-CC) are implemented and tested
- System successfully integrates with existing SaaS platform
- Real-time inventory updates are accurately reflected in dashboard
- Local display shows correct weight and inventory information

### 7.2 Performance Acceptance

- Weight measurement accuracy meets  $\pm 50\text{g}$  specification
- System response times meet specified performance targets
- Network connectivity and data transmission function reliably
- System maintains 99% uptime during testing period

### 7.3 Integration Acceptance

- Seamless integration with existing SaaS platform without disruption

- API calls function correctly with proper authentication
- Data synchronization maintains consistency between device and cloud
- Error handling and recovery procedures function as specified

## 8. Validation and Verification

### 8.1 Testing Strategy

- **Unit Testing:** Individual component functionality verification
- **Integration Testing:** System-level operation and API integration
- **Performance Testing:** Load testing and response time validation
- **User Acceptance Testing:** End-user workflow validation

### 8.2 Test Environment

- **Development Environment:** Breadboard prototype with test weights
- **Integration Environment:** Test SaaS platform instance
- **Production-like Environment:** Warehouse simulation with actual pallets
- **Field Testing:** Limited deployment in actual warehouse environment

## 9. Future Considerations

### 9.1 Scalability

- Support for multiple smart pallets in single warehouse
- Central management system for multiple devices
- Enhanced analytics and reporting capabilities
- Integration with additional warehouse management systems

### 9.2 Enhancement Opportunities

- Advanced sensor integration for improved accuracy
- Machine learning for predictive inventory management
- Mobile application for warehouse staff
- Enhanced security and authentication mechanisms



## 10. Glossary

| Term               | Definition   |
|--------------------|--|
| <b>Load Cell</b>   | Sensor that converts mechanical force/weight into electrical signal    |
| <b>HX711</b>       | 24-bit analog-to-digital converter designed for load cell applications |
| <b>ESP32</b>       | Microcontroller with integrated WiFi and Bluetooth capabilities        |
| <b>SaaS</b>        | Software as a Service - cloud-based software delivery model            |
| <b>Tare Weight</b> | Weight of empty pallet without products                                |
| <b>JSON</b>        | JavaScript Object Notation - data interchange format                   |
| <b>API</b>         | Application Programming Interface                                      |
| <b>MQTT</b>        | Message Queuing Telemetry Transport protocol                           |
| <b>IoT</b>         | Internet of Things   |

### Document Control:

- **File Location:** [docs/requirements-specification-v1.pdf](#)
- **Version History:** Initial version
- **Related Documents:** Project Proposal, System Architecture Design
- **Next Version:** v2.0