# MIDLANDS STATE UNIVERSITY


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| **Assignment** | Data Science Model(DSI-341) |
| **Level** | 3.2 |
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| **Department** | Information and Marketing Sciences |
| **Institution** | Midlands State University |
| **Company Name** | Chinhoyi Provincial Hospital |

# Pharmaceutical Inventory Tracking system

## 1. Brief description of the model

Efficient pharmaceutical inventory management is critical for healthcare institutions to ensure the availability of essential medicines, minimize wastage, and maintain optimal operational performance. Poor inventory management, often caused by stock discrepancies, leads to significant losses, stock outs, or overstocking, ultimately compromising patient care and the hospital's ability to deliver quality services. Inventory discrepancies occur when there is a mismatch between the physical stock count and the recorded inventory in the system, resulting in financial losses and operational inefficiencies.

This project develops a Pharmaceutical Inventory Tracking System for Chinhoyi Provincial Hospital to detect, analyse, and mitigate inventory discrepancies. The system leverages the Isolation Forest (IF) machine learning model to identify anomalies and potential irregularities in pharmaceutical stock data. Isolation Forest is an unsupervised anomaly detection algorithm that excels at identifying outliers in datasets, making it ideal for detecting unusual patterns in inventory records. The algorithm operates on the principle of isolating anomalies by randomly partitioning the data using binary decision trees, known as Isolation Trees (iTrees).

The system trains on key inventory variables, including previous stock levels, stock received from suppliers, medicines dispensed to patients, stock issued to hospital wards and clinics, expired or damaged stock, current stock levels, and returns from wards or clinics. Using these variables, the system estimates the expected stock levels for a given period and compares them with the recorded stock levels. The Isolation Forest algorithm analyses variances between expected and actual stock levels, flagging any significant discrepancies that may indicate potential issues such as theft, misplacement, or data entry errors. The algorithm uses a hyper-parameter called contamination (typically set to a low value, e.g., 0.01%) to determine the sensitivity of outlier detection.

The system provides actionable insights to hospital administrators, pharmacists, and auditors by identifying outliers, generating alerts, and providing recommendations. It detects unusual patterns in stock data that may indicate inventory shrinkage or mismanagement and notifies

stakeholders of significant discrepancies for further investigation. Additionally, it suggests corrective actions to minimize inventory losses and improve stock management practices.

By implementing this system, Chinhoyi Provincial Hospital reduces pharmaceutical stock losses and wastage, ensures the availability of essential medicines for patients, improves inventory accuracy and operational efficiency, and enhances transparency and accountability in pharmaceutical management. The Pharmaceutical Inventory Tracking System serves as a critical tool for optimizing inventory management, reducing costs, and ultimately improving healthcare delivery in Chinhoyi Province.

## 2. Problems identified

Inventory discrepancies are a significant problem faced by Chinhoyi Provincial Hospital, resulting in financial losses, stock outs, and inefficiencies in healthcare delivery. These discrepancies arise due to various factors, including theft, misplacement, administrative errors, expired or damaged stock, and inaccuracies in recording stock movements. Such issues not only lead to financial losses but also compromise the hospital's ability to provide essential medicines to patients, ultimately affecting the quality of healthcare services. Traditional methods of inventory management in the hospital rely heavily on manual processes, which are prone to human error, bias, and inefficiency. These methods often fail to detect irregularities such as stock theft, misplacement, or data entry errors in a timely manner. Additionally, the lack of a robust system for tracking and analysing inventory data makes it difficult to identify the root causes of discrepancies and implement corrective measures.

## 3. Requirements Engineering

### Data Requirements

- ✓ Transaction Data
- ✓ Inventory Data
- ✓ Operational Data
- ✓ Additional Data

### Technical Requirements

- ✓ Database for storage and management
- ✓ Data processing and analysis tools (python programming language, machine learning algorithms, data visualization libraries, performance metrics)
- ✓ User interface tools (python-flask framework)
- ✓ Deployment tools (On-premise Deployment)

## 4. Aim

The main aim of the system is to streamline the tracking, management and optimal of medical supplies, equipment and pharmaceuticals in the hospital. This ensures that the hospital has the right resources available at the right time, reduce wastage and improve overall operational efficiency

## 4.1. Objectives

- To accurately record medical and pharmaceutical tools inventory levels, ensuring real-time updates and data integrity.
- To continuously monitor inventory levels of medicines and medical tools, automating alerts for stakeouts and low-stock situations.
- To systematically track expiration dates of pharmaceuticals to issue timely notifications for products nearing expiration.
- To analyse pharmaceutical trends in reordering and usage over time, providing insights on medical consumption rates.
- To generate detailed reports on inventory usage, trends and forecasts to support informed decision-making and resource allocation

## 4.2. Benefits of the model

**Improved Inventory Accuracy**

- Reduces discrepancies between physical stock and recorded inventory.
- Ensures accurate tracking of medicine quantities, batch numbers, and expiration dates.

**Minimized Stock Losses**

- Detects and prevents theft, misplacement, and administrative errors.
- Reduces financial losses due to inventory shrinkage.

**Enhanced Operational Efficiency**

- Automates manual inventory management processes, saving time and effort.
- Provides real-time updates on stock levels and movements.

**Better Decision-Making**

- Offers actionable insights through data analysis and visualizations.
- Enables evidence-based decisions for inventory replenishment and management.

**Cost Savings**

- Reduces wastage of expired or damaged medicines.
- Optimizes stock levels to avoid overstocking or stock outs.

**Improved Patient Care**

- ✓ Ensures the availability of essential medicines for patients.

- Prevents stock outs that could delay treatment or compromise care.

## 5. Tools and technologies used to develop the model

**Frontend Development tools and technologies**

- ✓ Python-flask framework
- ✓ HTML
- ✓ CSS

**Backend Development tools and technologies**

- ✓ Python-Machine Learning Algorithms

**Data pre-processing tools and technologies**

- ✓ Pandas
- ✓ Sklearn
- ✓ Isolation Forest (Model training tools and technologies)
- ✓ Plotly (graphical analysis)

**Deployment tools and technologies**

- ✓ On-premises deployments

## 6. Justification of the research project

Business Impact

- ✓ Inventory discrepancies and stock losses have a significant financial impact on healthcare institutions, reducing their ability to allocate resources effectively. The Pharmaceutical Inventory Tracking System helps mitigate these losses by identifying and addressing the root causes of discrepancies, such as theft, misplacement, and administrative errors. By minimizing stock losses, the hospital can improve its financial performance and allocate saved resources to other critical areas of healthcare delivery.

Compliance and Risk Management

- ✓ Healthcare institutions are required to maintain accurate inventory records and comply with regulations related to medicine storage, distribution, and reporting. The system ensures compliance by providing accurate, real-time tracking of pharmaceutical stock and generating audit trails for all transactions. It reduces the risk of fraud, theft, and mismanagement by flagging irregularities and enabling timely corrective actions.

Patient Care and Satisfaction

- ✓ Patients rely on the availability of essential medicines for effective treatment. Stockouts or delays in accessing medicines can compromise patient care and satisfaction. The system improves medicine availability by optimizing inventory levels, reducing stockouts, and ensuring timely replenishment. By enhancing the reliability of pharmaceutical services, the system contributes to better healthcare outcomes and increased patient trust in the hospital

## Justification for the ML-based Algorithm

Pattern Recognition

- ✓ Machine learning algorithms, such as Isolation Forest, are highly effective at identifying patterns and anomalies in pharmaceutical stock data. The system can be trained on historical inventory data to detect unusual patterns, such as sudden drops in stock levels, discrepancies between issued and dispensed medicines, or irregularities in returns and expirations. By analysing these patterns, the system identifies potential causes of inventory discrepancies, such as theft, misplacement, or administrative errors, enabling timely interventions.

Accuracy and Reliability

- ✓ Unlike manual or judgment-based analysis, machine learning algorithms provide highly accurate and reliable results when trained on sufficient and high-quality data. The system ensures that inventory discrepancies are detected with precision, minimizing false positives and false negatives. By generating meaningful insights and alerts, the system empowers hospital staff to take proactive measures, improving overall inventory management and reducing losses.

Customization

- ✓ Machine learning algorithms can be customized to meet the specific needs of Chinhoyi Provincial Hospital, considering factors such as the types of medicines, storage conditions, and operational workflows. The system can be tailored to account for unique challenges, such as tracking high-value medicines, managing perishable stock, or integrating with existing hospital management systems. Customization ensures that the system aligns with the hospital's inventory management practices, enhancing its effectiveness and usability.

## 7. Deployment platforms and its evaluation

The choice of deployment platform for the Pharmaceutical Inventory Tracking System is critical, as it directly impacts the system's performance, security, and accessibility. The evaluation of deployment options focuses on two primary approaches: on premise deployment and cloud-based platforms. Each option is assessed based on key factors such as cost, scalability, security, and accessibility

**On-premises deployment**

This involves deploying the system within the Chinhoyi Provincial Hospital environment and systems. It offers complete control over the infrastructure, data and security measures, allowing for customization to specific sections and seamless integration with existing systems infrastructure. However, this approach demands a significant upfront investment for hardware, software and maintenance, along with the operational overhead of managing infrastructure, updates and security. There is need for a careful modular planning for seamless integration of this system as a component to the company's existing systems.

**Cloud-based deployment**

This is a modern approach for deploying machine learning projects which uses cloud computing services like AWS, Azure or Google Cloud Platform to host and manage systems. This offers cost-effectiveness through a pay-as-you-go pricing model, reducing upfront investment and operational costs. Accessibility is enhanced, allowing the system to be accessed from anywhere with an internet connection, promoting collaboration and remote management. However, data security and privacy depend on the cloud provider's security measures and switching providers can be challenging and potentially costly. Customization options may also be restricted compared to on-premises deployments.

**Hybrid Deployment**

Hybrid deployment combines elements of both on-premises and cloud-based deployments, incorporating the strengths of each. This offers flexibility in choosing the best deployment model for specific components of the system, balancing upfront investments with cloud-based scalability and cost efficiency. Enhanced security can be achieved by combining on-premises control with cloud-based security features. However, managing a hybrid environment requires expertise in both on-premises and cloud technologies, potentially increasing operational costs and complexity.

Considering this Pharmaceutical Inventory Tracking system, on-premises deployment is the best option since it is readily available and does not require exceptional cost to install and integrate. Customization is easy as the system can be modularised to existing Pharmaceutical Inventory Tracking system

**8. Evaluation criteria for on premise infrastructure**

Implementing the Pharmaceutical Inventory Tracking System on premise offers Chinhoyi Provincial Hospital significant benefits, including strong data security and privacy, as the hospital retains full control over sensitive patient and inventory data, ensuring compliance with stringent healthcare regulations. The proximity of data sources and computing resources enhances system performance, reduces latency, and ensures reliability even during internet outages. On-premise deployment is cost-effective in the long term, maximizing the use of existing hardware and software resources while avoiding recurring cloud service fees. It also provides unparalleled customization and flexibility, allowing seamless integration with existing hospital systems and tailored configurations to meet specific data science needs. Additionally, it safeguards intellectual property by keeping proprietary algorithms within the hospital's infrastructure. However, this approach requires technical expertise for planning and maintenance, along with significant upfront investment in hardware and software. Despite these challenges, on premise deployment is the best option for the hospital, balancing control, performance, compliance, and cost efficiency to support effective pharmaceutical inventory management

## 9. Achievement of objectives

| Objective | Achievement status | Explanation |
|---|---|---|
| To accurately record medical and pharmaceutical tools inventory levels, ensuring real-time updates and data integrity. | ✓ | ll transactions (e.g., dispensing medicines to patients, transferring tools to departments) are logged in real-time, ensuring the inventory database is always up-to-date. |
| To continuously monitor inventory levels of medicines and medical tools, automating alerts for stakeouts and low-stock situations | ✓ | The system continuously tracks stock levels for every item in the inventory. For instance, if the stock of a specific antibiotic drops below the predefined threshold (e.g., 20 units), the system automatically sends an alert to the procurement team |
| To systematically track expiration dates of pharmaceuticals to issue timely notifications for products nearing expiration | ✓ | When a new batch of medicines is added to the inventory, the system records the expiration date for each item. For example, if a batch of painkillers expires in six months, the system logs this information. |
| To analyse pharmaceutical trends in reordering and usage over time, providing insights on medical consumption rates | ✓ | The system collects and analyses data on how often specific medicines are used and reordered. For example, it might identify that a particular antibiotic is used more frequently during flu season |

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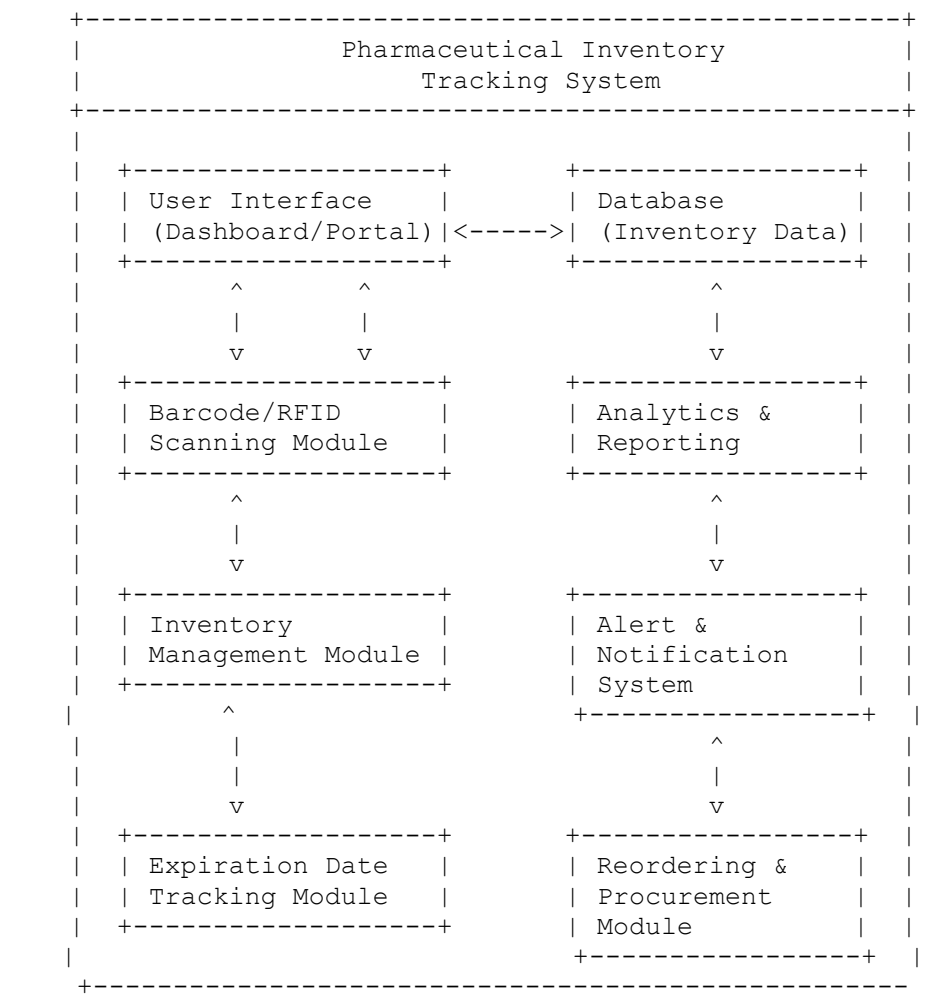
| To generate detailed reports on inventory usage, trends and forecasts to support informed decision-making and resource allocation | ✓ | The system compiles data on inventory usage, stock levels, and expiration trends into comprehensive reports. For example, it can generate a monthly report showing which medicines were used the most and which ones are nearing expiration. |

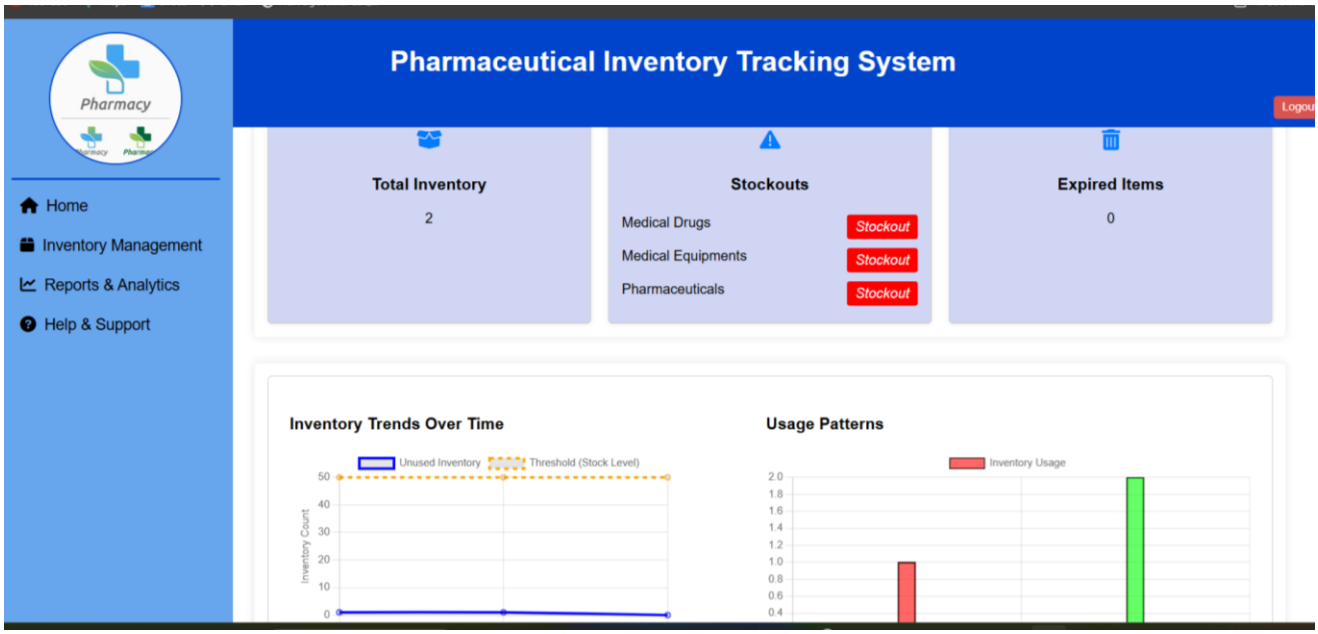
## 9.1. Model Functionality

**The Diagram below illustrate feature interactions of pharmaceutical inventory management system**



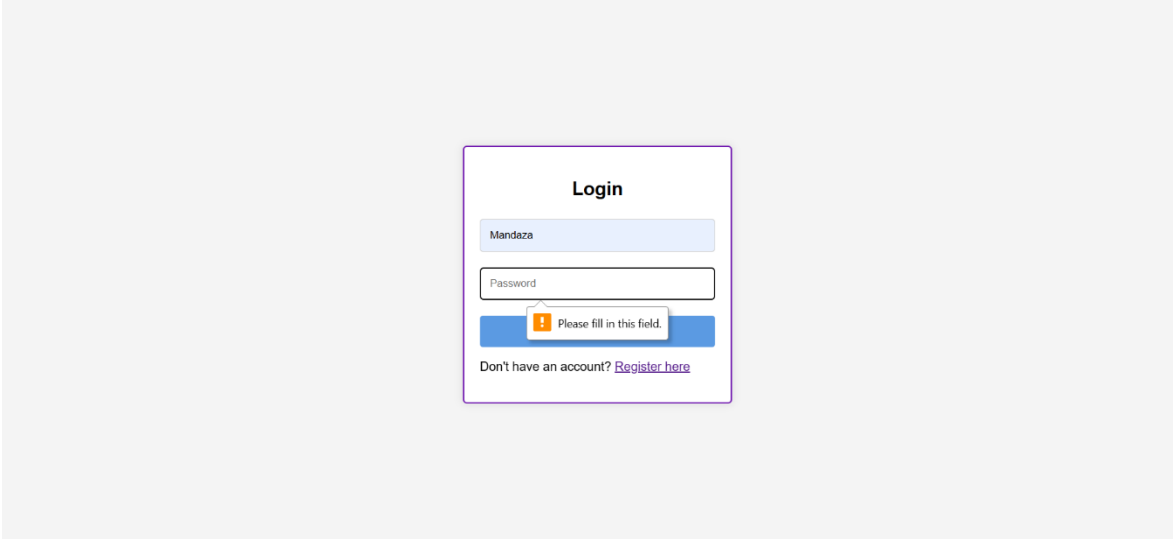
# 10. User Manual Scenarios

## 10.1 Home Page

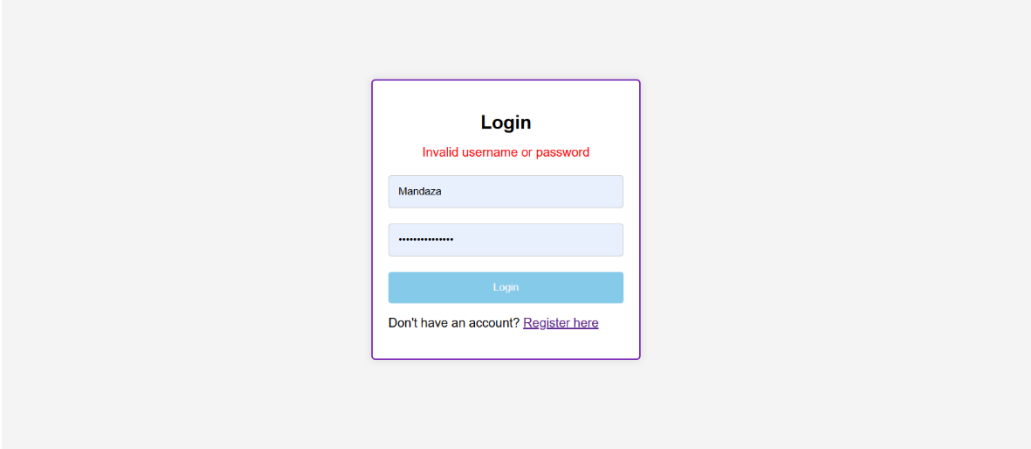


## Validating User Credentials

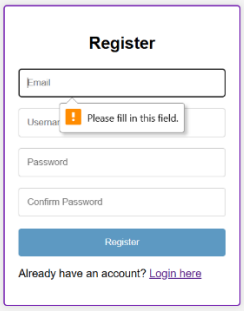
## 10.2 Accessing the menu without login



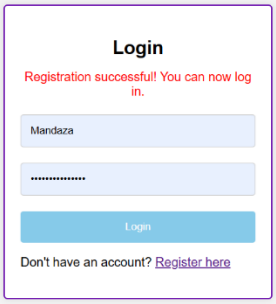

## 10.3 Attempting to login without registering



## 10.4 Registering and login with no details entered

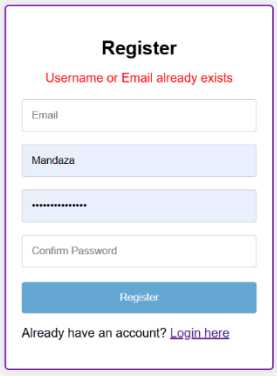



## 10.5 Validating users in the Database



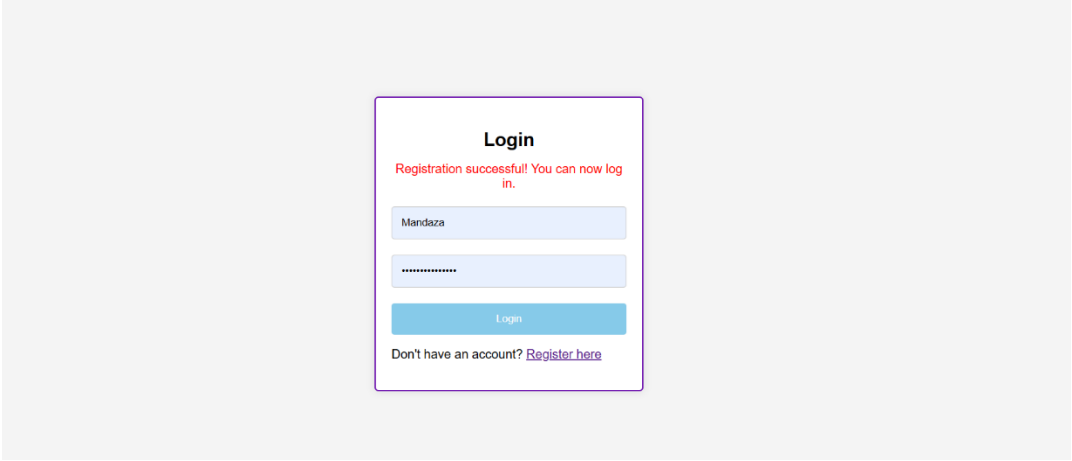

## 10.6 Registering with the same user name

Users should register with different and unique registration usernames

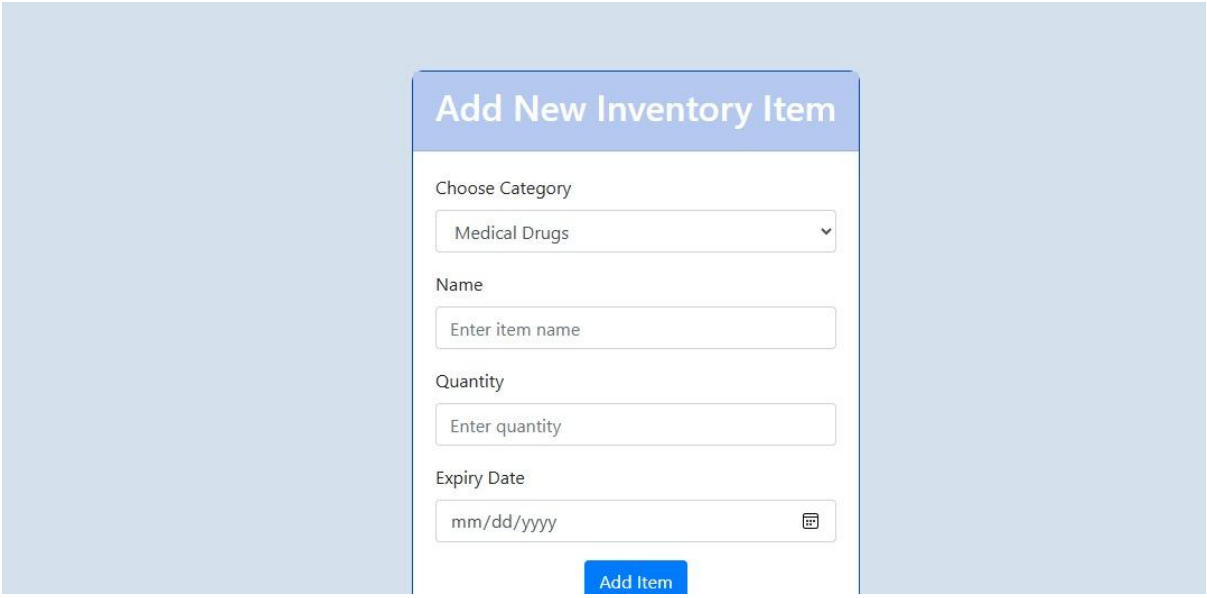


### 10.7. Login with correct details

The system redirects to the main menu

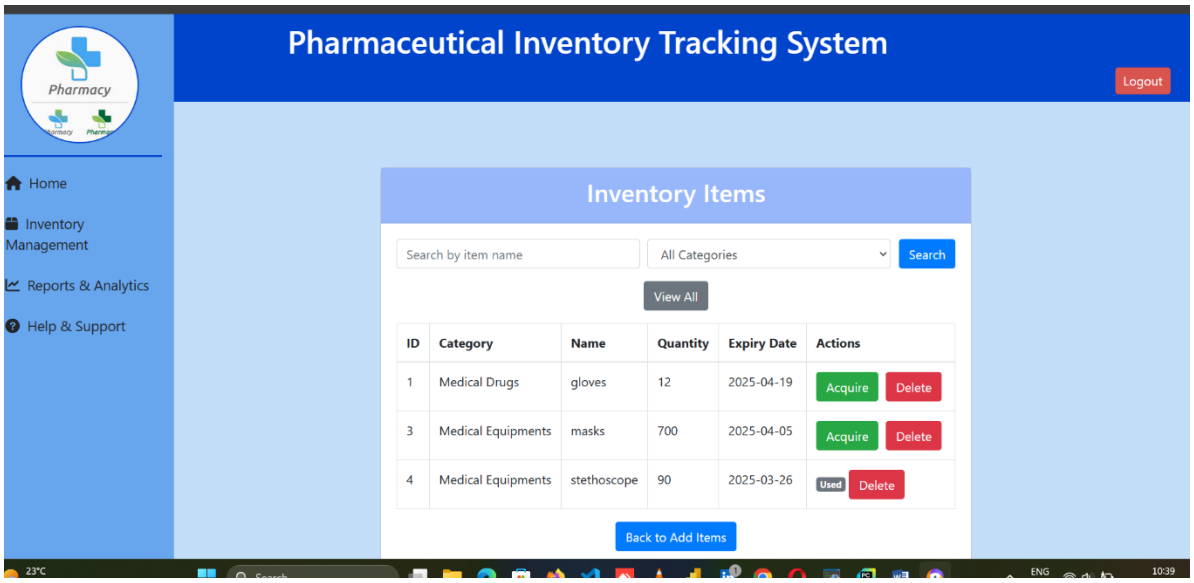



### 10.8 Adding New Inventory



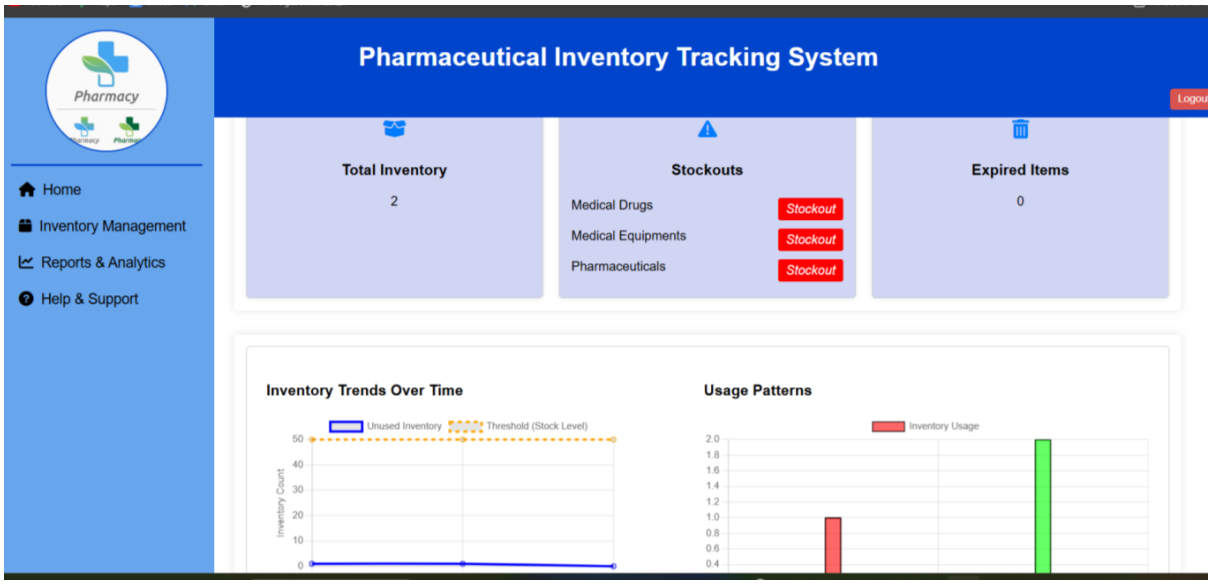
## 10.9 Selecting Variables

## Selecting Variables



## Visualizing Variance Reports

In visualising the reports, the system provides an option for the user to download the report




## Additional Analysis