PROJECT SENTINEL

Retail Analytics & Optimization Platform Challenge

Project Sentinel

THE SCENARIO

Many retail companies are facing an existential crisis in today's competitive market. They are losing an estimated significant amount annually due to a combination of inventory shrinkage, operational inefficiencies, and customer abandonment. Their recent investment in self-checkout technology, intended to reduce costs, has instead introduced new complications, including an increase in theft incidents, customer frustration, and challenges in staffing allocation.

The four critical challenges facing the modern retail industry are:

1. Inventory shrinkage
2. Self-checkout security and efficiency issues
3. Resource allocation inefficiencies
4. Poor customer experience

1. Inventory shrinkage

Inventory shrinkage refers to the loss of products between purchases from suppliers and points of sale. This represents a significant financial challenge for retailers.

Theft: Products stolen by shoplifters or employees, resulting in direct financial losses. This includes both opportunistic theft and organized retail crime.

Misplacement: Products that are moved from their designated locations and cannot be found when needed, creating artificial stockouts even when items are physically present in the store.

Record Inaccuracies:
Discrepancies between inventory management systems and actual physical inventory, often caused by scanning errors, receiving mistakes, or software issues.

2. Self-checkout security and efficiency issues

While self-checkout systems offer convenience, they introduce unique challenges that can impact both store profitability and customer satisfaction.

Scan Avoidance: Customers deliberately fail to scan items before placing them in the bagging areas—either by moving the products through the scanning area without scanning them, whether due to intentional theft or accidental oversight

Barcode Switching: The fraudulent practice of replacing expensive product barcodes with those from cheaper items, resulting in underpayment.

Weight Discrepancies: The weight detected in the scanning area does not match the expected weight of the scanned items. This discrepancy may occur due to a system error or intentional theft, such as when additional goods are added to scanned items.

Unexpected System Crashes and Scanning Errors: Technical malfunctions that interrupt the checkout process, frustrating customers and requiring employee assistance to resolve.

3. Resource allocation inefficiencies

Inefficient distribution of store resources leads to increased operational costs and reduced customer satisfaction.

Staff Allocations: Challenges in scheduling appropriate numbers of employees for different store areas at the right times, often resulting in overstaffing during slow periods and understaffing during peak times.

Checkout Lanes Allocation: Difficulty in predicting and responding to customer flow, leading to inefficient use of available checkout lanes and increased wait times.

4. Poor customer experience

Negative shopping experiences drive customers to competitors, representing a critical business challenge.

Long Wait Times: Extended periods spent waiting in checkout lines or for assistance, which significantly impact on customer satisfaction and the likelihood of return visits.

Difficult Self-Checkout Processes: Confusing interfaces, frequent intervention requirements, and complicated procedures that frustrate customers and slow down the checkout process.

To address the challenges mentioned above, modern supermarkets have implemented new technological solutions. The following diagram illustrates how these advancements are utilized in contemporary self-checkout counters.

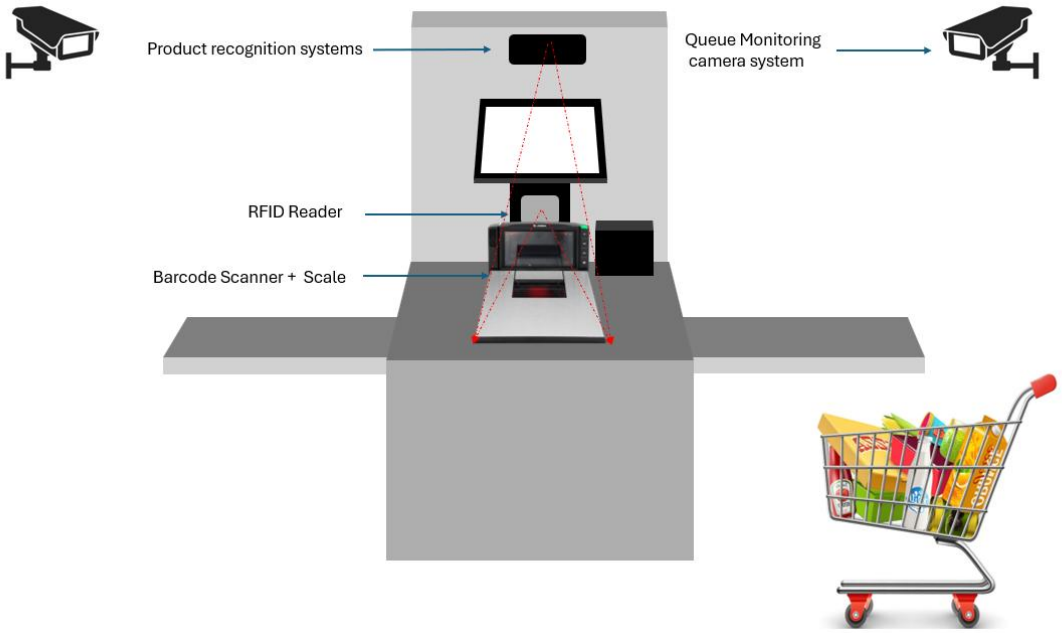

Figure 1: Self-checkout Counter

Barcode Scanner

Rapidly captures and processes product barcodes in the scanning area, enabling efficient product identification and pricing during the self-checkout process.

Scale

Precisely measures the weight of products placed in the designated scanning area, ensuring accurate pricing for items sold by weight and providing security verification against theft.

RFID Reader

Detects and reads RFID-enabled products in the scanning area, allowing contactless identification of items and enhancing checkout efficiency.

Product Recognition System

Identifies products in the scanning area using advanced machine vision technology and improving the checkout experience for items without barcodes.

Queue Monitoring System

Monitors checkout queues to analyze customer wait times and behaviors, providing valuable data for optimizing staffing levels and improving overall store efficiency.

THE CHALLENGE

Explore the layout of a modern supermarket:

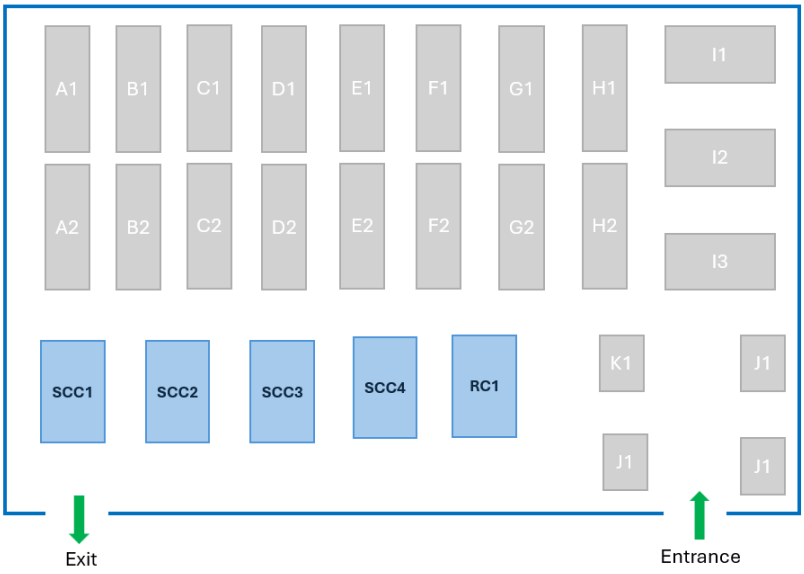

Figure 2: Supermarket layout

There are **Four self-checkout** counters and **one regular counter**. Customers are encouraged to use the self-checkout counters rather than the regular counter; however, the regular counter remains open for those who prefer not to use self-checkout. At the start of the day, one self-checkout counter and one regular counter are opened. As more customers arrive, additional self-checkout counters are activated to accommodate the increased demand.

In this **4-hour** challenge, your team of 4 must design and build a prototype for an integrated **Retail Intelligence System**.

This system must:

- Process and analyze data streams from various in-store devices/sensors
- Detects and identify the above four challenges situations
- Deliver actionable insights through an intuitive dashboard

DATA SOURCES

Your system must integrate these heterogeneous data streams:

1. **RFID Data** -
   - Format: JSONL with tag IDs, location and timestamps
   -

```
{"timestamp": "TIME STAMP",
 "station_id": "SCCX"| RC1,
 "status": "Active" | “Read Error”,
 "data”:{
        "epc": "EPC",
        "sku": "SKU”,
         "location": "IN_SCAN_AREA" | OUT_SCAN_AREA,
         }
}
```

   - Update frequency: Continuous, 5-second intervals

2. **Queue Monitoring System Data**-
   - Format: JSONL with customer counts, dwell times
   -

```
{"timestamp": " TIME STAMP ",
 "station_id": " SCCX| RC1",
"status": ""Active" | “Read Error”,
 "data": {
        "customer_count": CUTOMER COUNT,
         "average_dwell_time": DWELL TIME
        }
}
```

   - Update frequency: Continuous, 5-second intervals

3. **Point-of-Sale Transactions** -
   - Format: JSONL with records with transaction details
   -

```
{"timestamp": "TIME STAMP",
 "station_id": " SCCX| RC1",
 "status": " Active" | “Read Error | System Crash ",
 "data": {
        "customer_id": "CUSTOMER ID",
         "sku": "SKU",
         "product name": "PRODUCT NAME",
         "barcode": "BARCODE",
```

"price": PRICE,
"weight_g": WEIGHT
}
}

– Update frequency: Real-time as transactions occur

4. **Products Recognition Analytics** –
   – Format: JSONL with Predicted product details
   –

{"timestamp": "TIME STAMP",
"station_id": " SCCX| RC1",
"status": " Active" | "Read Error | System Crash",
"data": {
"predicted_product": "SKU",
"accuracy": ACCURACY}
}

   – Update frequency: Real-time as transactions occur

5. **Current Inventory Data**
   - Format: JSONL with current inventory data

{"timestamp": "TIME STAMP",
"data": {
["SKU": QUANTITY, ……]}
}

   – Update frequency: 10-minutes Interval

6. **Product Data**- List of products in the supermarket
   – Format: CSV
   – **[SKU, product_name, quantity, EPC_range, barcode, weight, price]**

7. **Customer Data**- List of registered customers in the supermarket
   – Format: CSV
   – **[Customer_ID, Name, Age, Address, TP]**

TECHNICAL REQUIREMENTS

1. Data Processing

Use the given data streaming service or develop a data integration module that

- Synchronizes timestamped data across different sources
- Correlates self-checkout activities with POS transactions, RFID and camera data
- Handles missing, corrupt, or delayed data

3. Self-Checkout Optimization System

Develop algorithms to identify the following scenarios:

1. Scan avoidance incidents
2. Barcode switching incidents
3. Unexpected system crashes and scanning errors
4. Weight discrepancies potentially indicating theft attempts
5. Situations involving long queue lengths
6. Inventory discrepancies between expected and actual stock levels
7. Identifying and resolving periods of extended customer wait times

Leverage these algorithms to generate actionable operational insights, including:

1. Forecasting optimal checkout staffing requirements based on historical and real-time traffic patterns
2. Dynamically adjusting the number of open self-checkout stations according to store traffic (e.g., maintaining a target ratio of approximately six customers per active kiosk to support smooth throughput)
3. Surfacing additional relevant insights that improve efficiency, loss prevention, customer experience, and overall self-checkout performance

4. Visualization Dashboard

Design and implement an intuitive interface that:

- Provides real-time store status overview
- Highlights anomalies and alerts with appropriate priority levels
- Visualizes customer flow, inventory status, and resource allocation

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