End-to-End Loan Data Processing and Analytics Pipeline Using Azure Data Factory and Databricks

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Project Statement

Create an Azure Data Factory pipeline that triggers the execution of Azure Databricks notebooks.

Use Azure DevOps for version control and continuous deployment of the notebooks.

Project Overview

Customer loan management and credit risk analysis are critical for financial institutions. Loan datasets contain continuous updates on customer demographics, income, expenditure, and repayment history. The project showcases:

- Ingestion Layer (Azure Data Lake Storage – Bronze): Capturing raw loan records in CSV format from multiple sources.
- Processing Layer (Azure Databricks – Silver): Cleaning, standardizing, and transforming the raw data for consistency and quality.
- Storage Layer (Delta Lake – Gold): Aggregating and summarizing key metrics such as total loan amounts, average income/expenditure, overdue counts, and repayment behavior.
- Analytics (Power BI): Visualizing loan distributions, repayment performance, and customer insights through interactive dashboards.

Prerequisites

1. Python Knowledge: Familiarity with Python and PySpark for data processing.

2. Databricks Cluster: A running Azure Databricks cluster with Delta Lake enabled for batch processing.
3. Azure Subscription: Active Azure subscription to manage resources.
4. Azure Databricks Workspace: Set up a workspace to create and manage notebooks.
5. Databricks Cluster Setup: Configure a cluster to execute Spark jobs.
6. Libraries and Dependencies: Install required Python libraries (e.g., pyspark, databricks-cli) in Databricks.
7. Monitoring and Logging: Enable monitoring and logging within Databricks to track job execution.
8. Azure Data Lake Storage (ADLS Gen2): Storage account with bronze, silver, and gold folders mounted in Databricks.
9. Azure Data Factory (ADF): For orchestrating ETL pipelines from Bronze → Silver → Gold.
10. Azure DevOps: Repository for storing notebooks and pipeline YAML files, with a CI/CD pipeline configured to deploy notebooks to Databricks.
11. Power BI: Installed and configured for connecting to Delta tables for analytics.

Azure Resources Used for this Project:

- Azure Data Lake Storage Gen2 (ADLS)
- Azure Databricks Workspace
- Azure Databricks Cluster

- Azure Key Vault
- Azure Data Factory (ADF)
- Azure DevOps
- Azure Storage Account

Project Objectives:

- Ingest raw loan data from Azure Storage into a structured data pipeline.
- Implement a Bronze-Silver-Gold architecture using Delta Lake for data refinement.
- Clean, standardize, and transform loan data for downstream analytics.
- Aggregate key metrics such as total loan amounts, overdue trends, and customer statistics.
- Enable seamless integration with Power BI for reporting and visualization.
- Orchestrate the pipeline using Azure Data Factory for automated execution.
- Maintain version control and CI/CD for notebooks and pipelines via Azure DevOps.
- Ensure scalability, fault tolerance, and monitoring across the data pipeline.

Tools Used:

- **Azure Data Factory (Orchestrator):**
    - Orchestrates the end-to-end ETL/ELT pipeline for loan data.
    - Copy Activity: Transfers raw CSV files from the Bronze folder in Azure Storage to a staging location.

    - Databricks Notebook Activity: Triggers Databricks notebooks to transform raw data into Silver and Gold Delta tables.
- **Azure Databricks (Transformation Engine):**
    - Executes PySpark and Python notebooks for data cleaning, transformation, and aggregation.
    - Handles schema enforcement, type casting, and computation of aggregate metrics like total loan amounts, average income, and overdue trends.
- **Azure Storage (Blob / Data Lake Gen2):**
    - Stores raw (Bronze), cleaned (Silver), and aggregated (Gold) datasets.
    - Supports Delta Lake format for ACID-compliant transactions.
- **Azure DevOps (CI/CD & Version Control):**
    - Maintains version control for notebooks and pipeline definitions.
    - Enables automated deployment of notebooks and pipeline updates to Databricks via pipelines.
- **Power BI (Analytics & Reporting):**
    - Connects to Gold Delta tables to generate dashboards and visualize key loan metrics.

Execution Overview:

1. **Data Storage:**
    - Raw loan CSV files are stored in Azure Blob Storage or Azure Data Lake Storage Gen2 (Bronze layer).
    - Transformed Silver and Gold Delta tables, and Parquet outputs, are stored in the same storage accounts with Delta Lake format for ACID compliance.

2. **Orchestration with Azure Data Factory (ADF):**
    - Pipeline Creation: An ADF pipeline is defined with multiple stages for end-to-end ETL.
    - Copy Activity: Copies raw CSV files from the source container (Bronze) to a temporary staging location in Azure Storage.
    - Databricks Notebook Activity: Triggers Databricks notebooks to perform transformations and generate Silver/Gold datasets.
3. **Data Transformation in Azure Databricks:**
    - Notebook Execution: PySpark notebooks process the data to:
        - Clean and enforce schema.
        - Convert CSV files into optimized Parquet format.
        - Compute aggregates like total loan amount, average income, and overdue metrics.
        - Partition and compress the data for better query performance.
        - Write results to Silver and Gold Delta tables in ADLS.
4. **Scheduling and Monitoring:**
    - Pipeline Scheduling: ADF triggers the pipeline at regular intervals for automated ingestion and transformation.
    - Performance Monitoring: ADF and Databricks monitoring tools track pipeline execution, cluster utilization, and job performance.
    - Analysis and Optimization: Execution logs and metrics are analyzed to detect bottlenecks, improve throughput, and optimize storage access.

Implementation – Tasks Performed

1. **Create Azure Storage Account and Containers**
    - Provision a Storage Account for raw and processed data.
    - Create containers: source folder for CSV files and destination folder for converted Delta files.
    - Upload raw CSV files into the source container.
2. **Define Data Sources and Locations**
    - Identify the location of raw loan CSV files in Azure Blob Storage or Azure Data Lake Storage Gen2 (Bronze layer).
    - Choose the destination for transformed Silver and Gold Delta tables in ADLS.
3. **Mount Azure Storage in Databricks**
    - Mount ADLS Gen2 or Blob Storage containers to Databricks for easy access.

4. **Develop Databricks Notebooks**

    - Bronze Layer – Raw Ingestion: Read CSV files using Spark DataFrames, write raw data to Delta.
    - Silver Layer – Cleaned Data: Apply transformations like schema enforcement, missing value handling, trimming, and data type casting.
    - Gold Layer – Aggregations: Compute metrics such as total loan amount, average income, overdue counts, and other KPIs.
    - Write results: Save to ADLS in appropriate Bronze, Silver, and Gold folders.

5. **Set Up Azure Data Factory (ADF)**

    - Create an ADF pipeline with two main activities:
        - Copy Activity: Copies CSV files from the source container to a temporary staging location in Azure Storage.
        - Databricks Notebook Activity: Triggers a Databricks notebook that handles data transformation, cleaning, and conversion to Delta format.

6. **ADF Implementation Steps**

    - Linked Services:

        - Azure Data Lake Storage Gen2 (for input/output folders)
        - Azure Databricks (for notebook execution)
    - Pipeline Activities:
        - Databricks Notebook Activity – Bronze: Load raw loan data → Delta Bronze
        - Databricks Notebook Activity – Silver: Transform, clean, and write → Delta Silver
        - Databricks Notebook Activity – Gold: Aggregate metrics → Delta Gold
    - Dependencies/Chaining: Use success dependency so each notebook runs after the previous finishes successfully.
    - Triggers: Schedule trigger (nightly batch) or event-based trigger (when new files arrive in ADLS).

7. **Source Control & Versioning (Azure DevOps)**
    - Git Repository: Store all Databricks notebooks, ADF pipeline JSON definitions, and configuration files.
    - Branching Strategy: main for production-ready code, dev for development/testing.

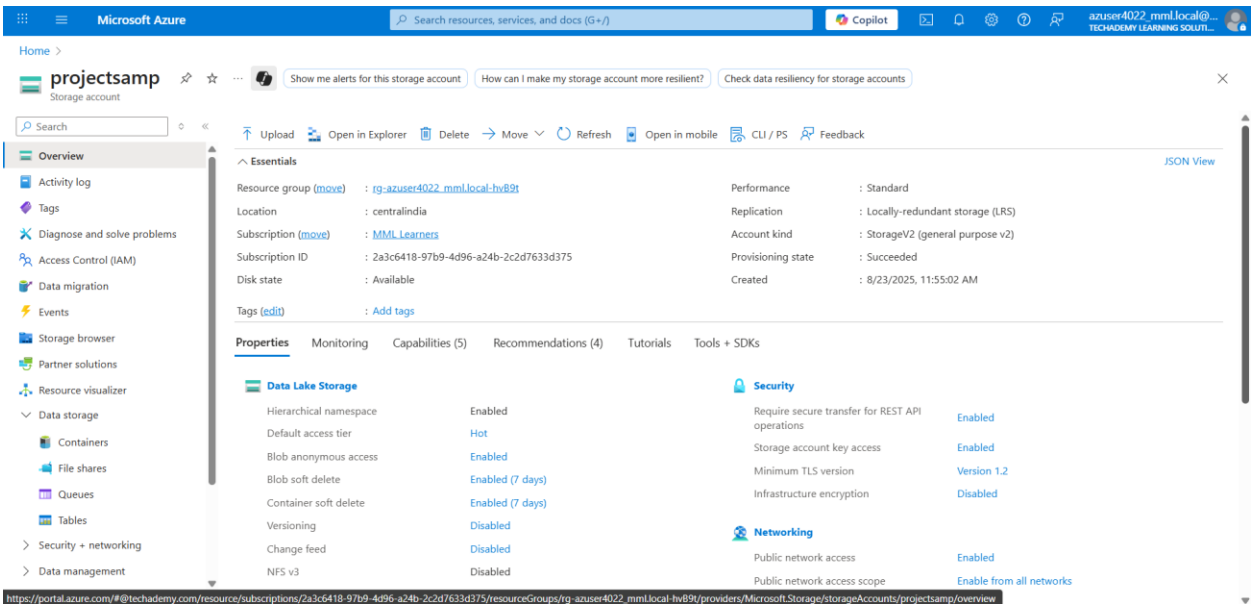
8. **Visualization with Power BI**

- Connect Power BI to Gold Delta tables in ADLS via Azure Synapse Analytics or Databricks SQL endpoint.
- Create dashboards for metrics such as: total loans per category, average income/expenditure, overdue trends, returned cheque counts.
- Schedule refreshes to show near real-time analytics from Gold tables.

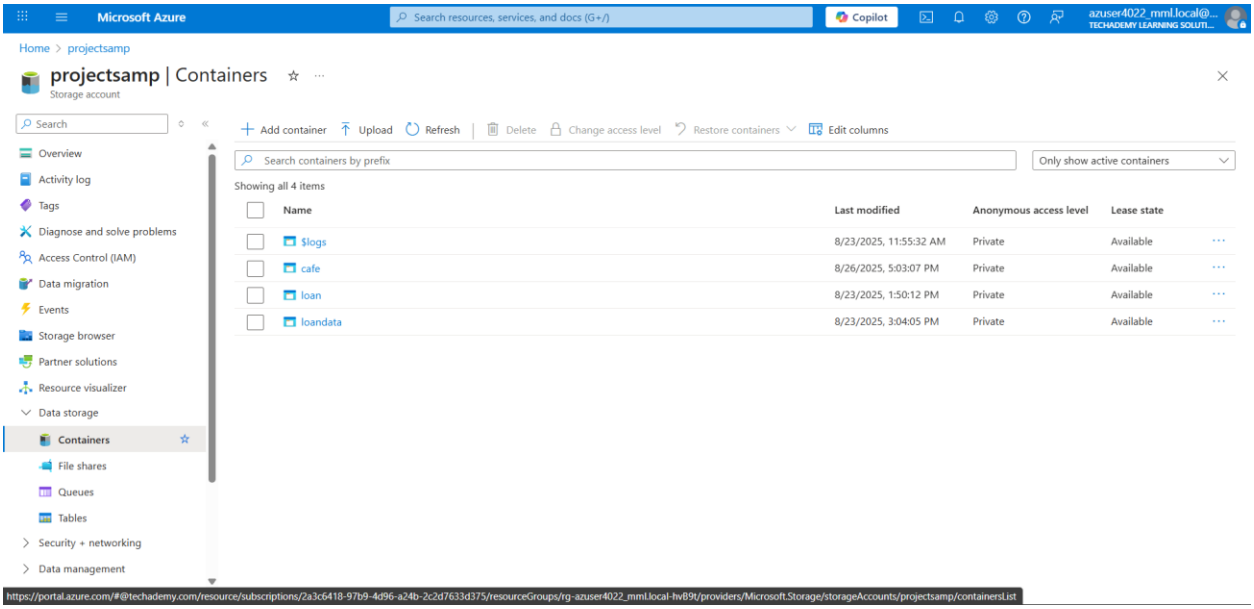
Practical Implementation on Azure Portal

Step 1: Create Azure Storage Account

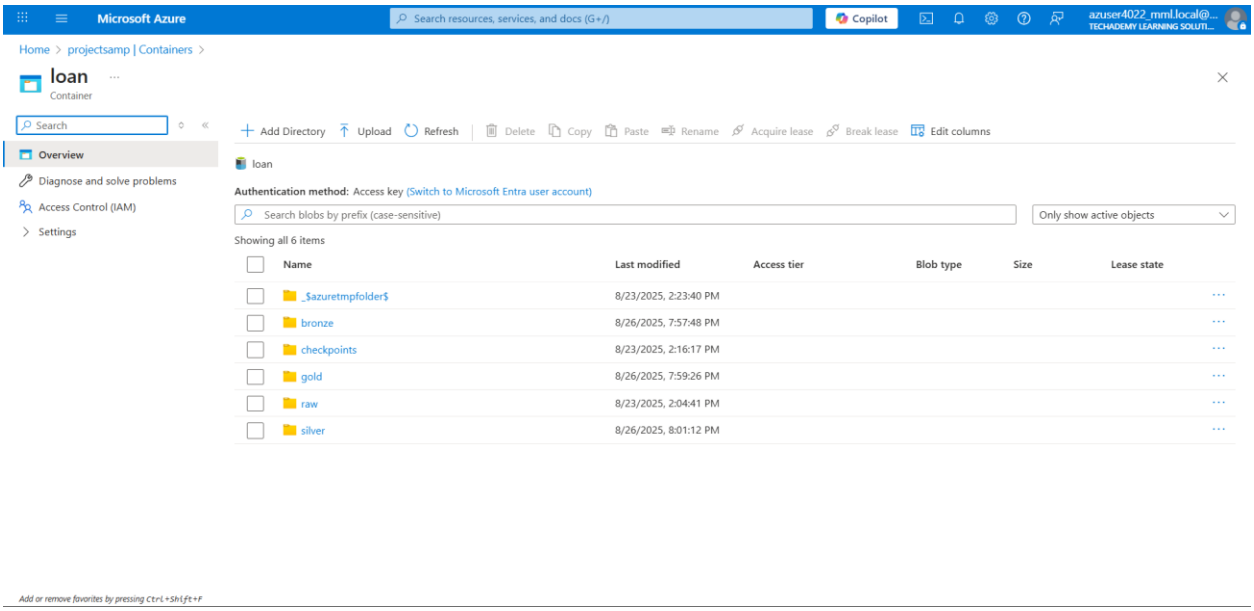
- Provision a Storage Account for raw and processed data.



- Create two containers: sourcecontainer for CSV files, destinationparquetcontainer for converted Delta files.

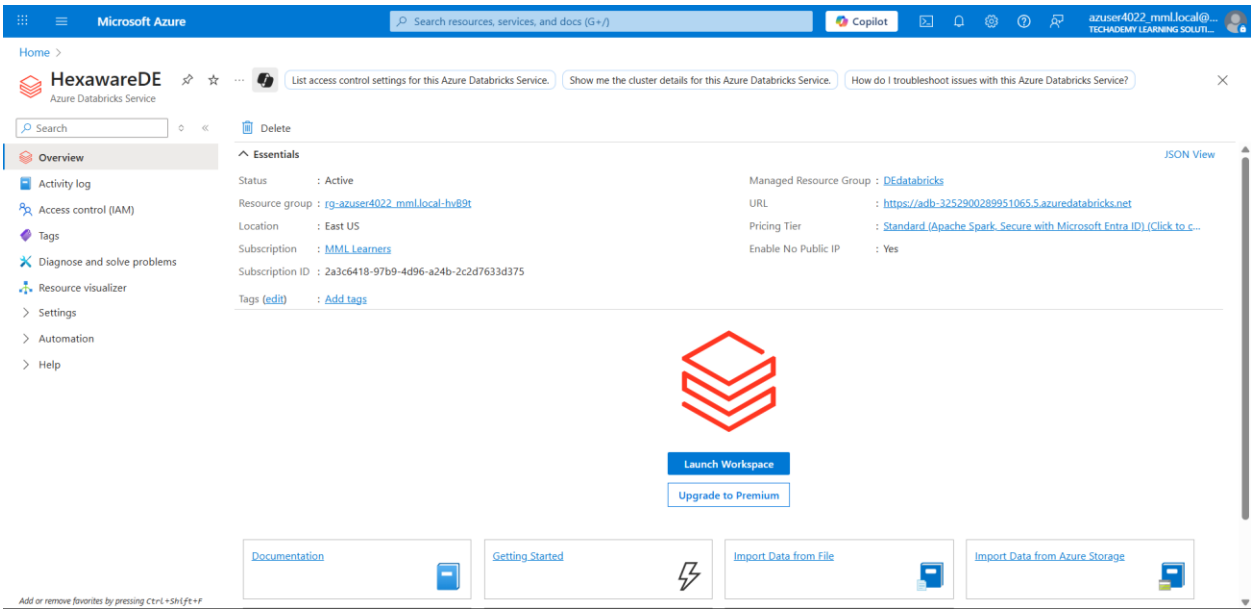


- Upload CSV files into the source container.

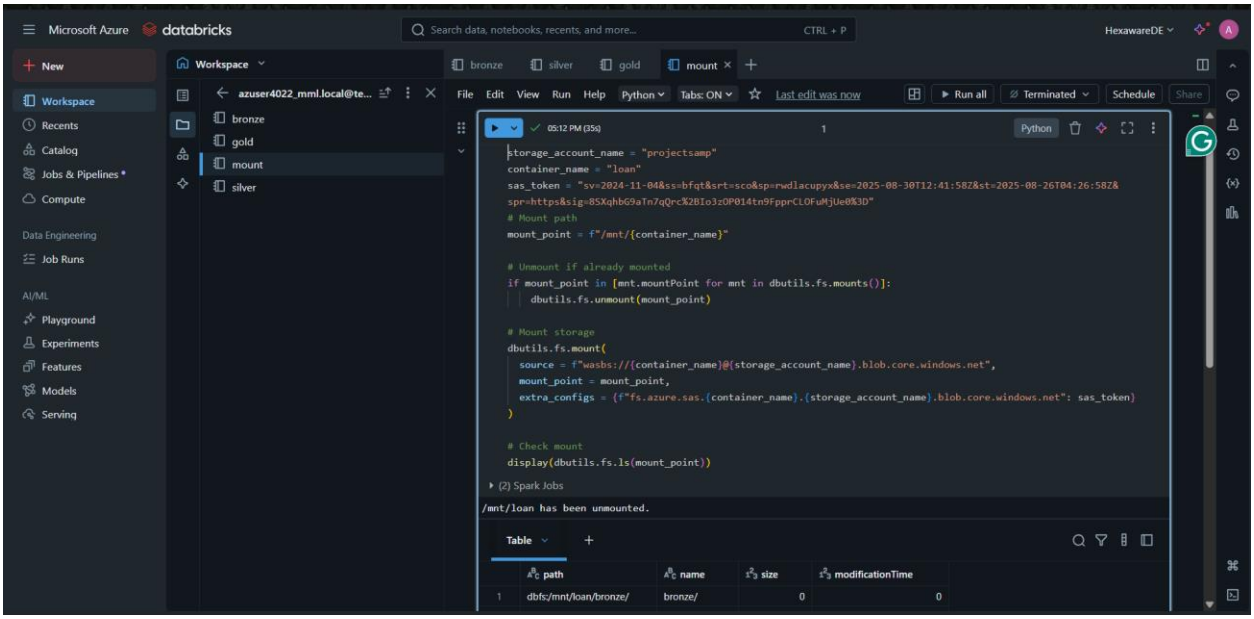


Step 2: Set Up Azure Databricks

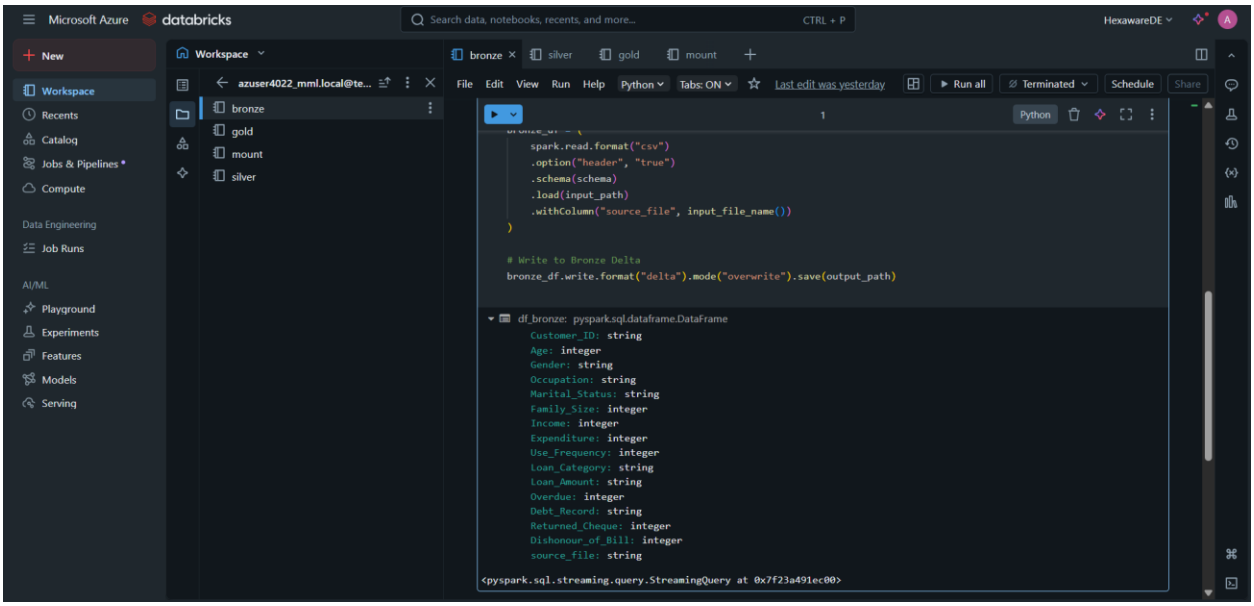
- Create a Databricks workspace and cluster in the Azure Portal.



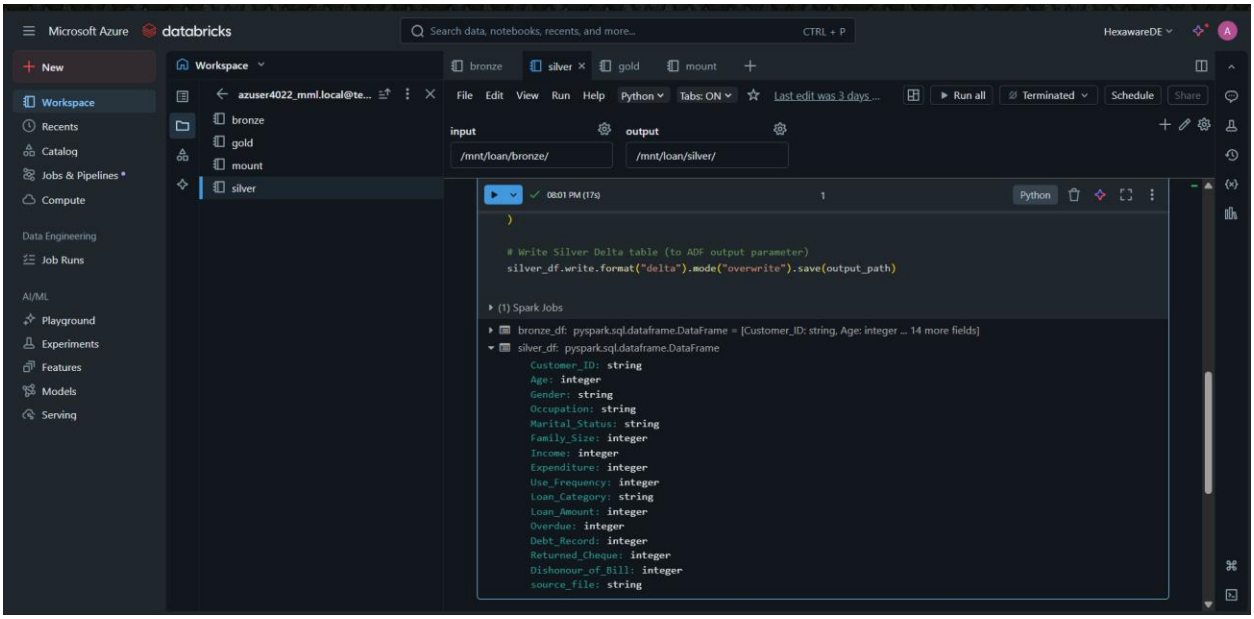
- Create a new Notebook to mount storage accounts and process files.



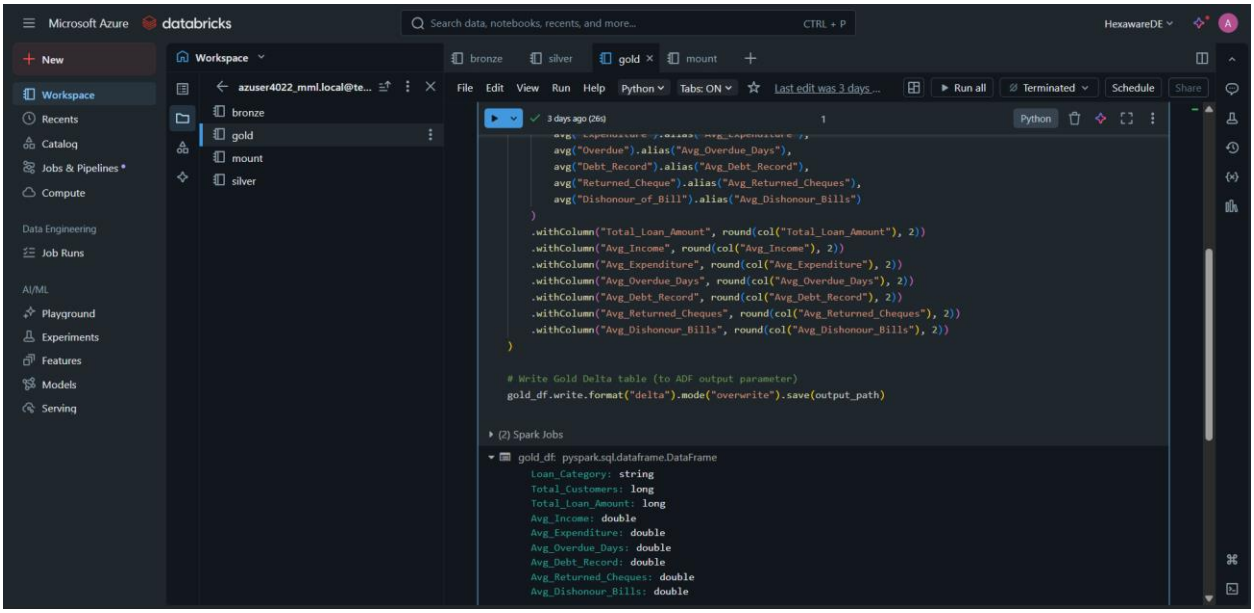
Create Bronze Notebook to copy the raw data



Create silver notebook to clean the data

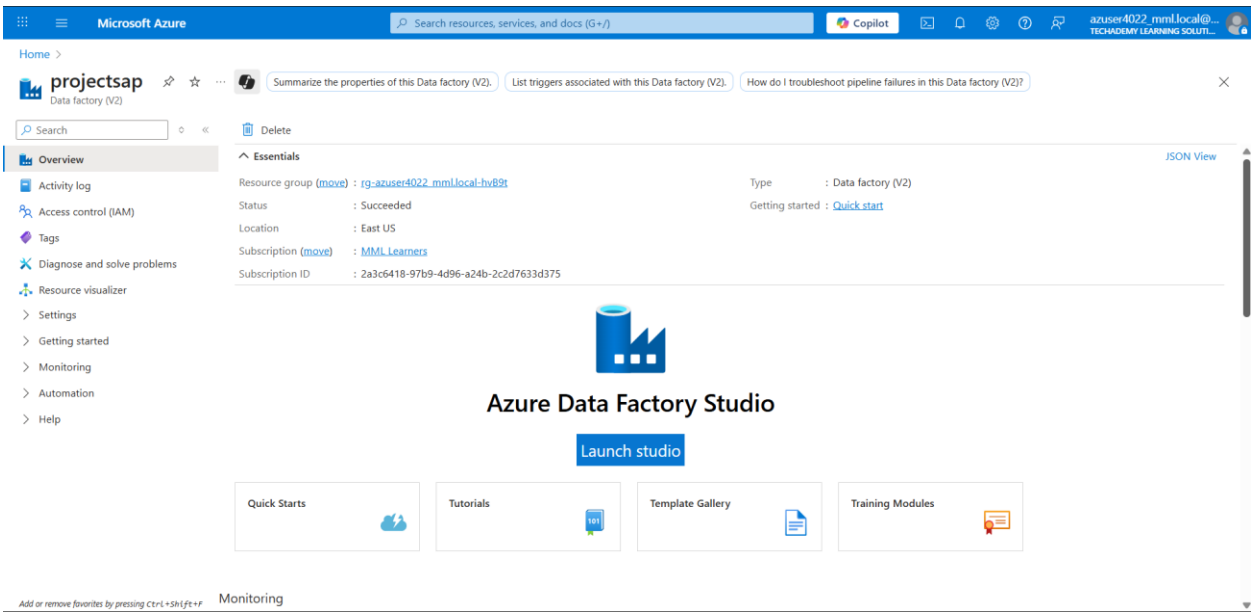


Create gold notebook for aggregation function



Step 3: Create a Data Factory

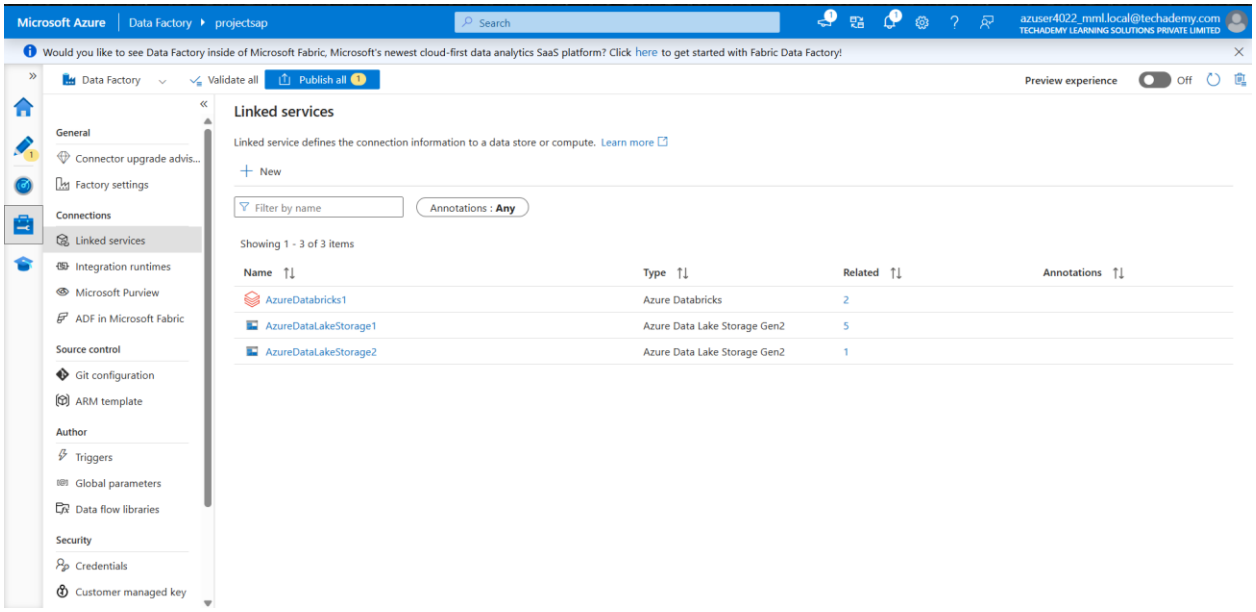
- Launch Azure Data Factory Studio.



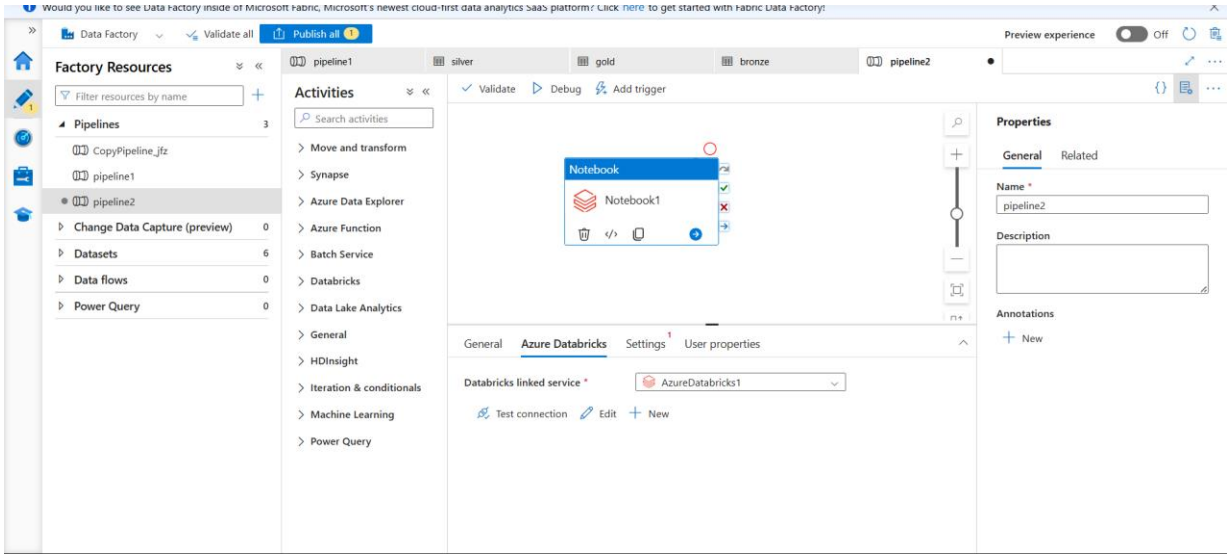
- Create an ADF pipeline with Databricks Notebook Activities.

Step 4: Configure ADF Pipeline Activities

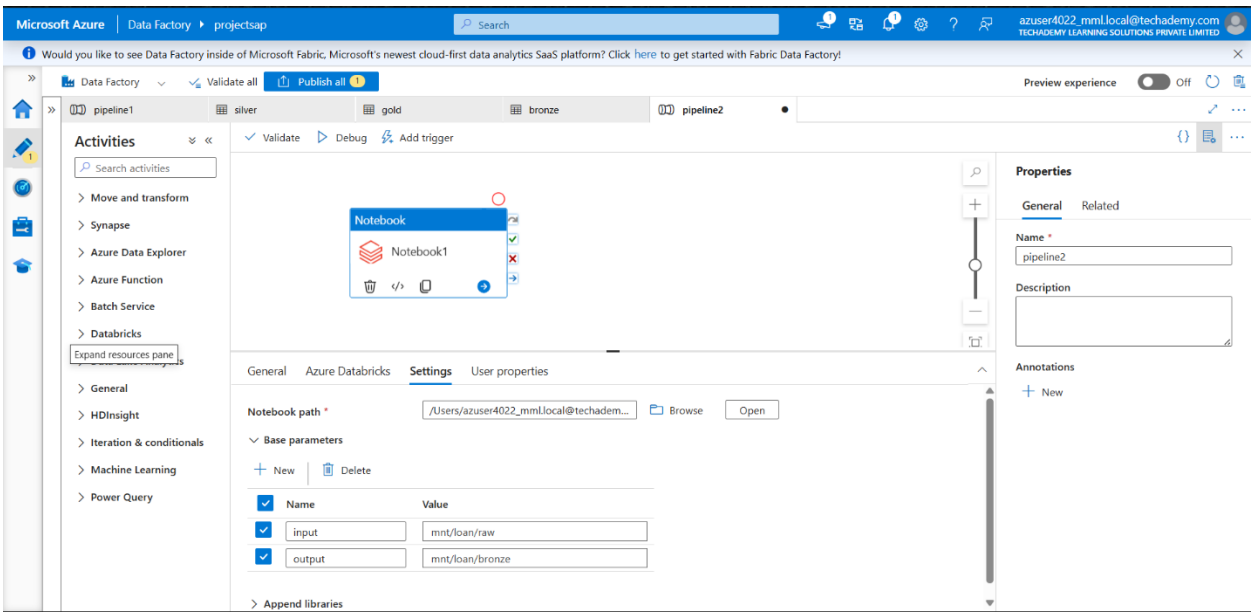
- Define linked services for Azure Storage and Databricks.



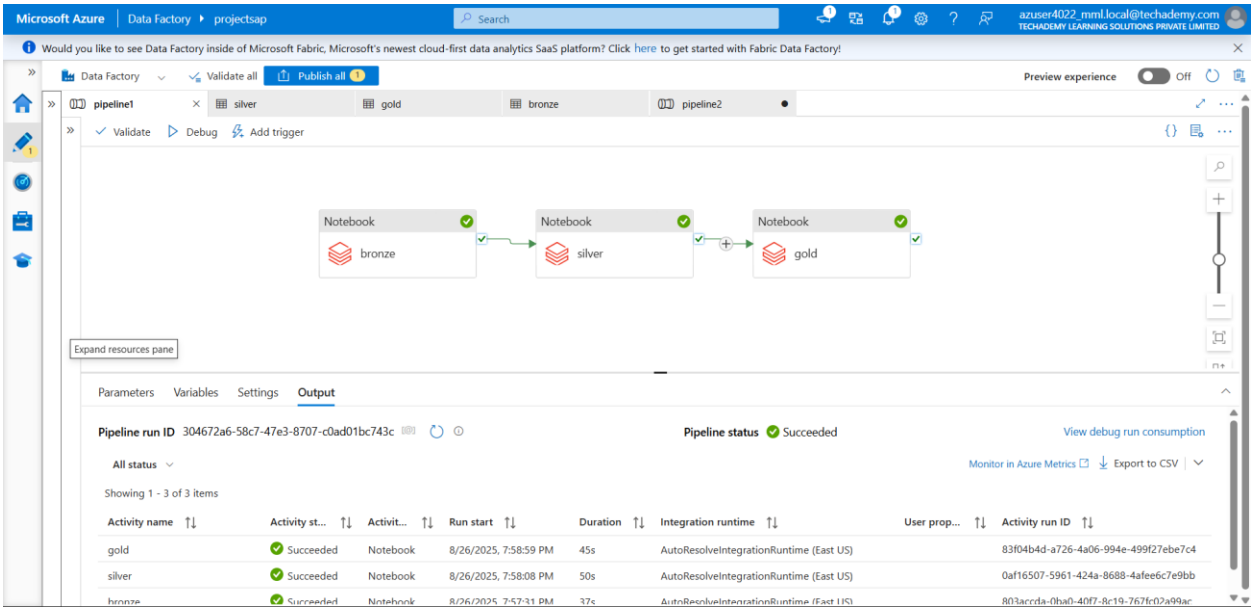
- Select the Databricks Notebook paths for Bronze, Silver, and Gold processing.



- Configure parameters for input/output paths.



- Validate and debug pipeline to ensure success.



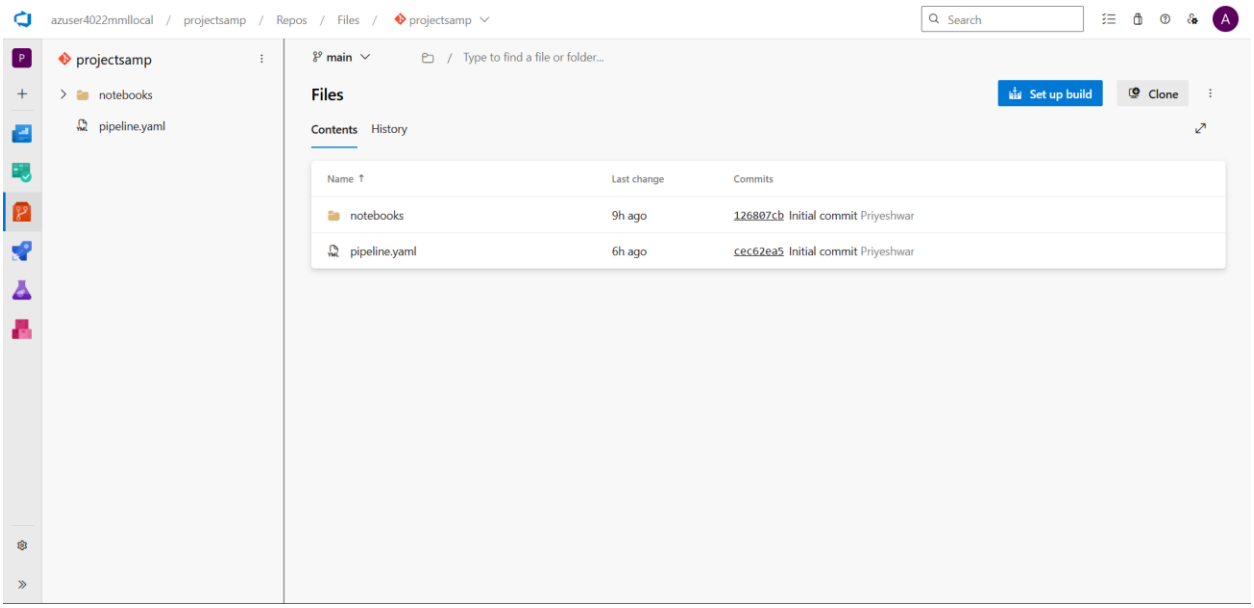
- Run the pipeline to copy CSV files and trigger Databricks notebooks.

- Check Delta folders in ADLS for Bronze, Silver, and Gold outputs.

Step 5 : Set up Azure Devops

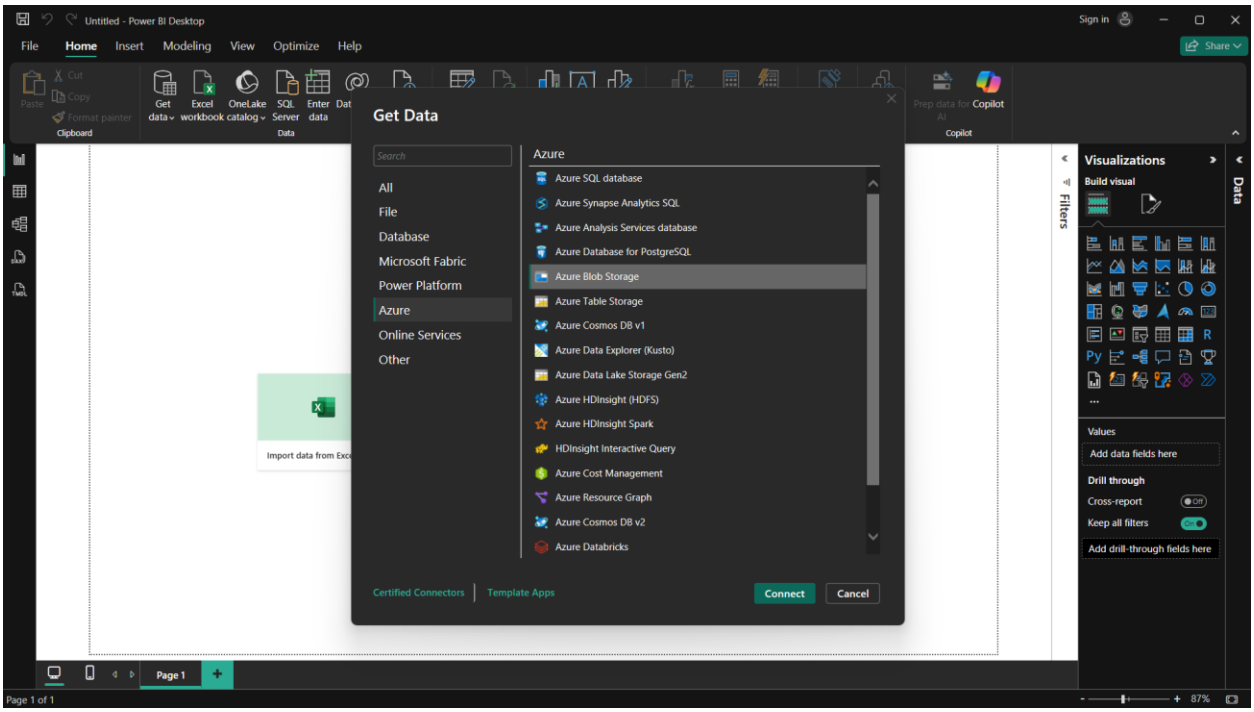
- In the Git Repository, Store all Databricks notebooks, ADF pipeline JSON definitions, and configuration files.

- Add yaml file in the repository and set up the pipeline

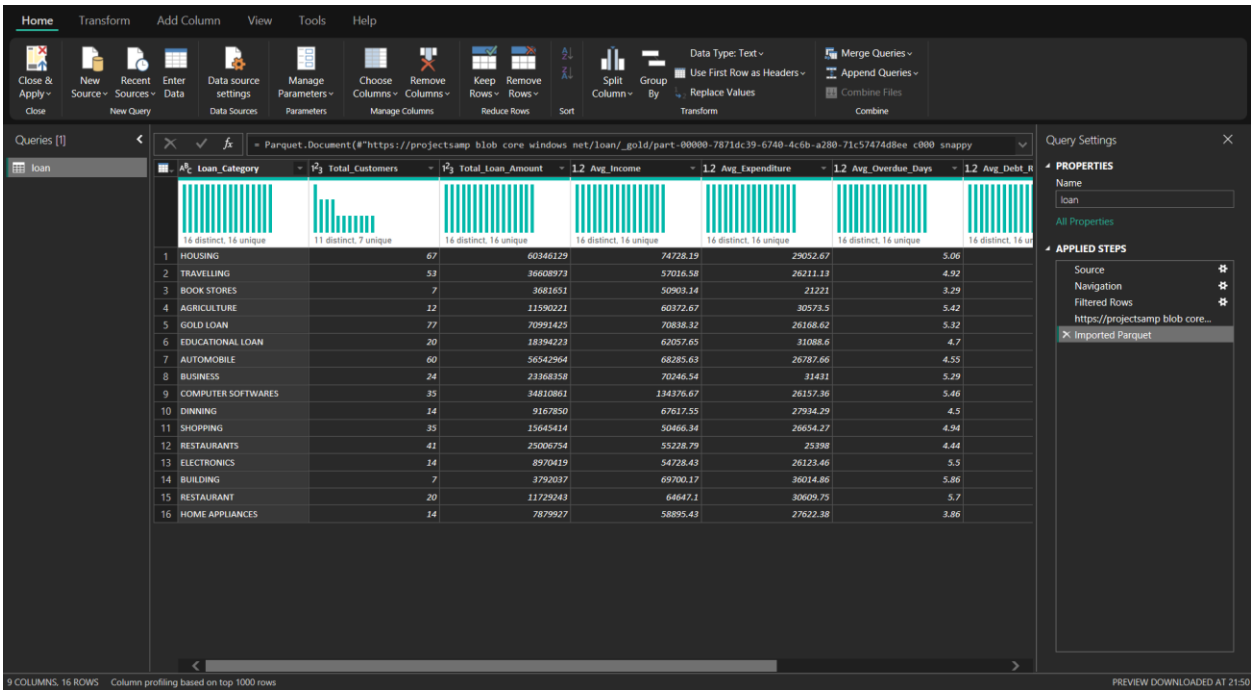


Step 6: Verify Data & Visualize

- Open Power BI→get data source→Azure→Azure blob Storage



- Connect Power BI to Gold Delta tables for dashboards and analytics.



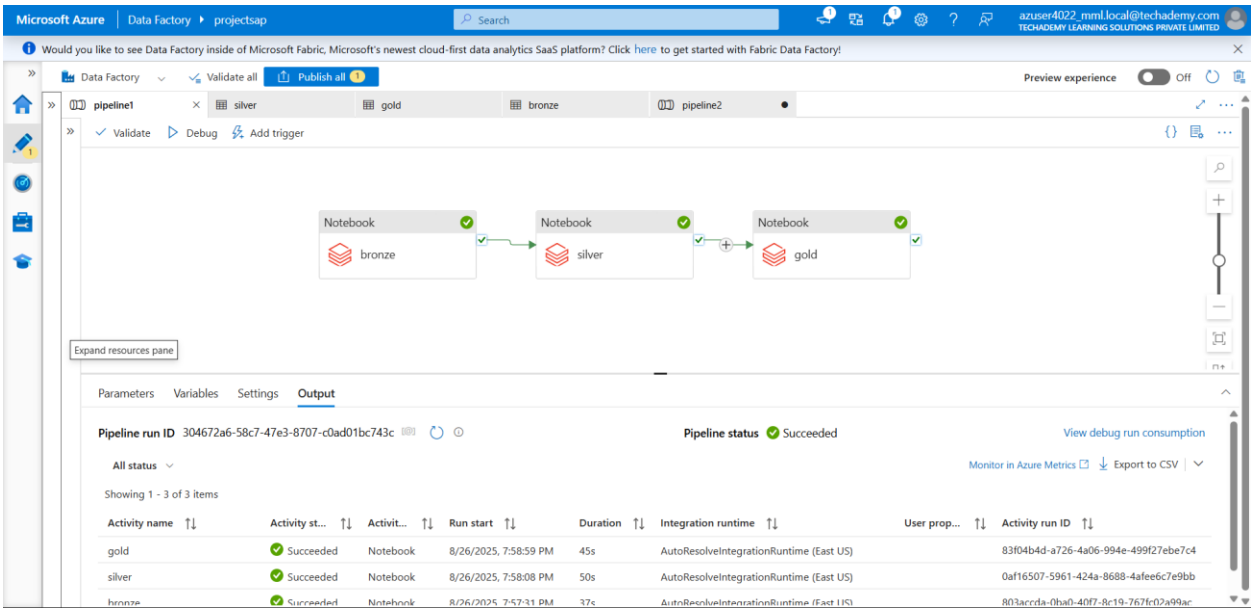
	Loan_Category	Total_Customers	Total_Loan_Amount	Avg_Income	Avg_Expenditure	Avg_Overdue_Days
1	HOUSING	67	60346129	74728.19	29052.67	5.06
2	TRAVELLING	53	36608973	57016.58	26211.13	4.92
3	BOOK STORES	7	3681651	50903.14	21221	3.29
4	AGRICULTURE	12	11590221	60372.67	30573.5	5.42
5	GOLD LOAN	77	70991425	70838.32	26168.62	5.32
6	EDUCATIONAL LOAN	20	18394223	62057.65	31088.6	4.7
7	AUTOMOBILE	60	56542964	68285.63	26787.66	4.55
8	BUSINESS	24	23368358	70246.54	31431	5.29
9	COMPUTER SOFTWARES	35	34810861	134376.67	26157.36	5.46
10	DINNING	14	9167850	67617.55	27934.29	4.5
11	SHOPPING	35	15645414	50466.34	26654.27	4.94
12	RESTAURANTS	41	25006754	55228.79	25398	4.44
13	ELECTRONICS	14	8970419	54728.43	26123.46	5.5
14	BUILDING	7	3792037	69700.17	36014.86	5.86
15	RESTAURANT	20	11729243	64647.1	30609.75	5.7
16	HOME APPLIANCES	14	7879927	58895.43	27622.38	3.86

- Perform some analysis and create a report

Successful Output Generated

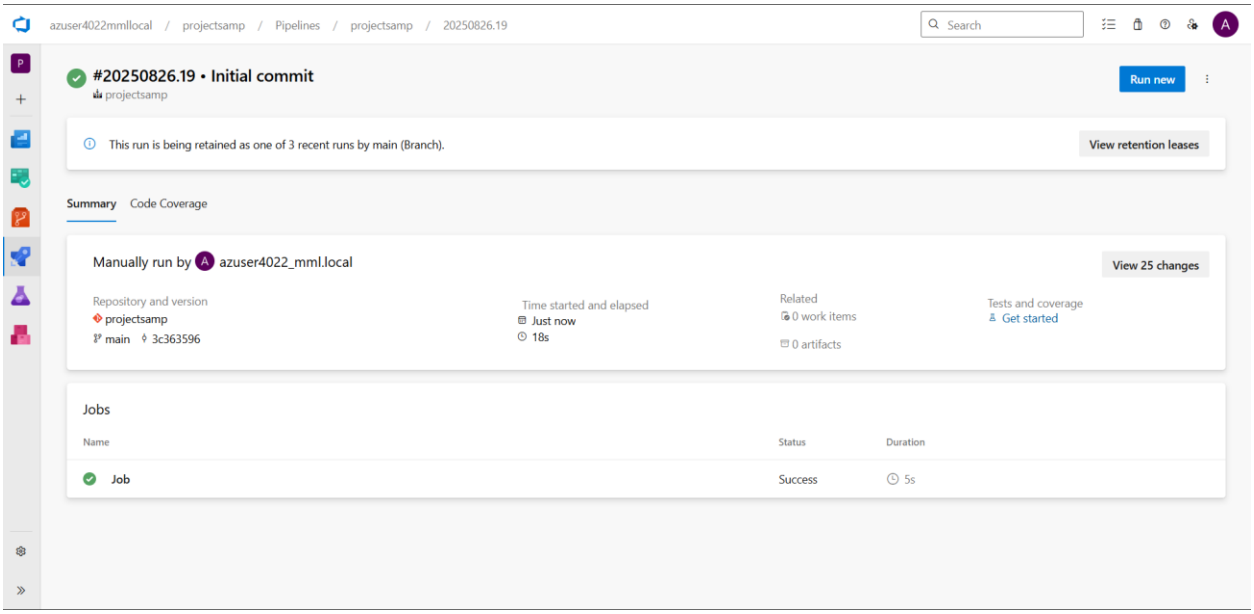
1. Azure Data Factory (ADF) Pipeline Execution

- After creating and configuring the pipeline with Databricks Notebook Activities, the pipeline was validated and debugged successfully.
- The pipeline execution status showed “Succeeded”, confirming that:
    - Raw CSV files from the source container were ingested into the Bronze Delta layer.
    - Transformations were applied, and data was written into Silver Delta tables.
    - Aggregated insights were generated in the Gold Delta tables.
- The ADF Monitoring dashboard displayed execution times, resource utilization, and confirmed that dependencies were executed in the correct order.



2. Azure DevOps Pipeline Job

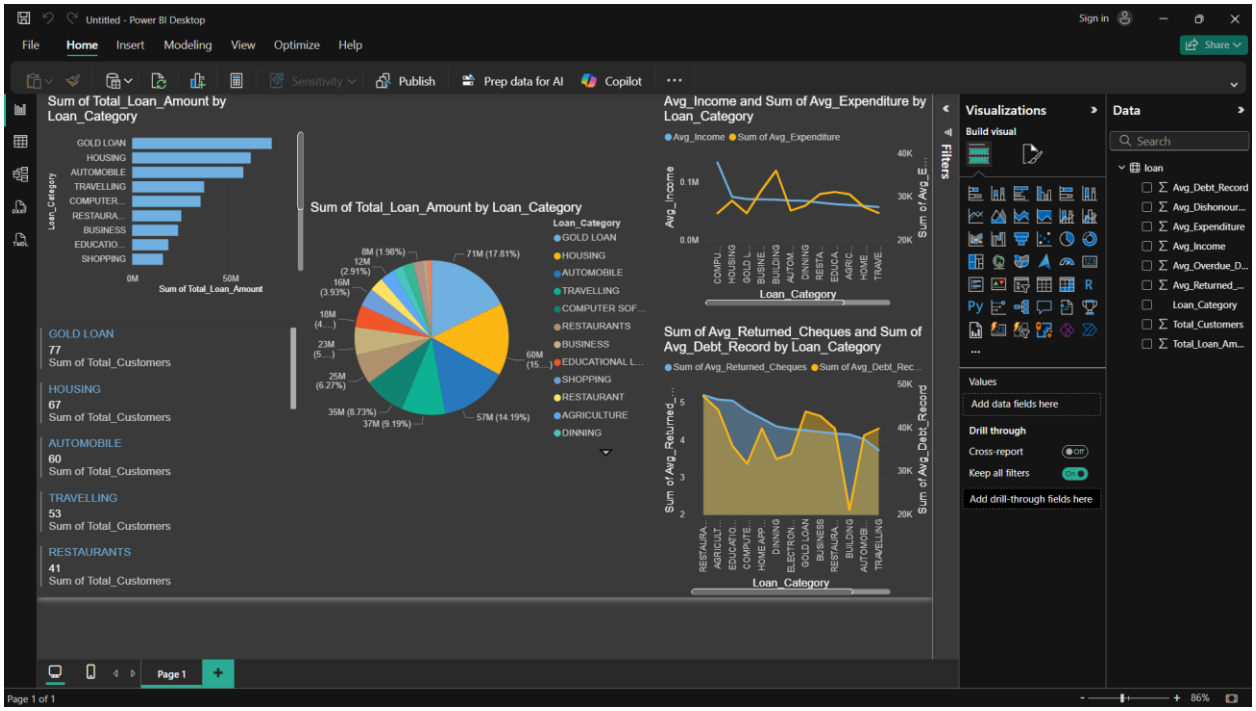
- A CI/CD pipeline was created in Azure DevOps to automate deployment of:
    - Databricks notebooks (bronze.py, silver.py, gold.py)
    - Configuration files (parameters, mount scripts)



- The job status showed “Succeeded”, confirming that changes were deployed seamlessly without manual intervention.

3. Power BI Visualization

- Power BI was connected to the Gold Delta tables using Azure Synapse Analytics / Databricks SQL Endpoint.
- The dashboards showed clean, optimized data coming from the Delta Gold layer, validating that the end-to-end pipeline was functioning correctly.



Strategies for Optimizing Process

1. **Data Cleaning and Transformation**
    - Handle missing or inconsistent values in the CSV/Delta tables.
    - Standardize column names and data types across Bronze, Silver, and Gold layers.
    - Apply trimming, type casting, and formatting only once to avoid redundant computations.
2. **Algorithmic Optimization**
    - Choose efficient Spark transformations and actions.
    - Avoid unnecessary joins or shuffles when aggregating Gold metrics.
3. **Data Structures Optimization**
    - Use Delta tables and partitioning to optimize read/write operations.
    - Store numeric fields in appropriate types (Integer, Double) to save memory.

4. **Parallelization**
    - Leverage Spark's distributed processing to run transformations on multiple nodes.
    - Use parallel read/write operations where applicable.
5. **Caching**
    - Cache intermediate Silver datasets when multiple transformations are applied.
    - Reduce repeated disk reads for the same data.
6. **Code Profiling and Analysis**
    - Use Spark UI or Databricks Ganglia metrics to identify slow stages.
    - Optimize the longest-running transformations first.
7. **Vectorization**
    - Use PySpark built-in functions (col, withColumn, agg) for vectorized operations instead of Python loops.
8. **Memory Optimization**
    - Repartition data appropriately to avoid data skew.
    - Avoid keeping large intermediate datasets in memory unnecessarily.
9. **I/O Optimization**
    - Write Delta tables with partitioning and compression (e.g., snappy).
    - Minimize reading/writing CSV; use Delta format for faster performance.
10. **Concurrency and Multithreading**
    - Run multiple Databricks notebooks in parallel for different datasets.
11. **Batch Processing**
    - For historical loan data, process in batches to reduce cluster memory pressure.

- Stream new files incrementally into Bronze and process in micro-batches.

12. **Distributed Computing**
    - Use the Databricks cluster's full computing capacity for large loan datasets.
13. **Dynamic Resource Allocation**
    - Enable auto-scaling on the cluster to handle variable workloads efficiently.
14. **Checkpointing**
    - Use checkpoints for streaming or incremental processing to resume efficiently after failures.

Conclusion

This project successfully implemented a robust and scalable loan data processing pipeline using Azure Data Factory (ADF) and Azure Databricks, converting raw CSV files into optimized Delta tables stored in Azure Data Lake Storage (ADLS).

Successful Implementation of the Data Pipeline

- Azure Data Factory provided seamless orchestration of multiple stages, from ingesting raw CSV files to executing Databricks notebooks for data transformation.

- The pipeline ensured reliable scheduling and execution, supporting both batch and incremental data loads.

Efficient Data Transformation and Storage

- Raw loan CSV data was ingested into the Bronze Delta layer, maintaining original data for traceability.
- Data cleaning and schema enforcement were applied in the Silver layer, resulting in structured and validated datasets.
- Aggregations and business metrics were computed in the Gold layer, supporting downstream analytics.

Exploration, Optimization, and Analytics Using Databricks

- Databricks notebooks enabled interactive data exploration, validation, and transformation of the loan datasets.
- Optimization techniques such as partitioning, caching, vectorized operations, and checkpointing were applied to improve performance and reduce processing time.
- The pipeline supports near real-time analytics, enabling insights such as total loan amounts, average income, overdue trends, and returned cheque counts.

Integration and Reporting

- The processed Gold-level data was made accessible to Power BI, allowing creation of dashboards for business insights and decision-making.

- Azure DevOps pipelines were used for CI/CD, ensuring version-controlled notebooks and reproducible deployments across environments.

Overall, this project demonstrates a scalable, end-to-end solution for processing and analyzing loan data, leveraging the synergy between ADF, Databricks, ADLS, DevOps, and Power BI for effective data engineering and business intelligence.