Invoice-Based Dimensional Modelling Assignment

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Overview

This assignment involves designing an end-to-end dimensional model for a mid-sized retail company based on a sample invoice dataset. Without explicit business requirements, we reverse-engineer the model from the data, focusing on dimensions like Customer, Product, Time, and Store. The solution supports analytical reporting, drill-down capabilities, historical tracking, and scalability, aligning with inferred objectives of analyzing sales trends, customer behavior, and store performance.

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1. Data Profiling & Inference

Identifying Dimensions

Analyzing the sample invoice dataset reveals key business entities that can be modeled as dimensions:

- **Customer Dimension**: Includes `Customer_ID` (e.g., C001) and `Customer_Name` (e.g., "John Smith"). This captures who is purchasing, enabling customer-centric analysis.
- **Product Dimension**: Comprises `Product_ID` (e.g., P1001), `Product_Name` (e.g., "Wireless Mouse"), and `Unit_Price` (e.g., 25.00). This describes what is sold, critical for product performance insights.
- **Time Dimension**: Derived from `Invoice_Date` (e.g., "2025-03-15 09:15:00"), with attributes like `Year`, `Month`, `Day`, and `Hour`. This supports temporal analysis of sales trends.
- **Store Dimension**: Based on `Store_ID` (e.g., S01), representing sales locations for store-level reporting.
- **Invoice Dimension**: `Invoice_ID` (e.g., INV001) acts as a degenerate dimension, a transactional identifier without additional attributes.

These dimensions are inferred from the dataset's structure, reflecting the retail context of sales transactions.

Determining Fact Table Granularity

The fact table granularity is set at the **invoice line-item level**, where each row represents a single product sold in a transaction (e.g., INV001 has two rows: one for "Wireless Mouse," another for "Mechanical Keyboard").

Justification:

1. **Detailed Analysis**: Enables queries like "How many Wireless Mice did John Smith buy at S01?" supporting fine-grained insights.
2. **Aggregation**: Allows summing `Line_Total` or `Quantity` across dimensions (e.g., total sales by store or product).
3. **Drill-Down**: Facilitates multi-level analysis, from yearly totals to hourly breakdowns, meeting the drill-down objective.

This granularity ensures flexibility for both operational and strategic reporting.

2. Dimensional Modeling Strategy

Star Schema Design

A star schema integrates the fact table with conformed dimensions for simplicity and query efficiency.

Fact Table: `Sales_Fact`

Attribute	Description
`Sales_Key` (PK)	Surrogate key for uniqueness
`Customer_Key` (FK)	Links to `Customer_Dim`
`Product_Key` (FK)	Links to `Product_Dim`
`Store_Key` (FK)	Links to `Store_Dim`
`Time_Key` (FK)	Links to `Time_Dim`
`Invoice_ID` (Degenerate)	Transaction identifier (e.g., INV001)
`Quantity`	Units sold (e.g., 2)
`Line_Total`	Revenue per line item (e.g., 50.00)

Dimension Tables:

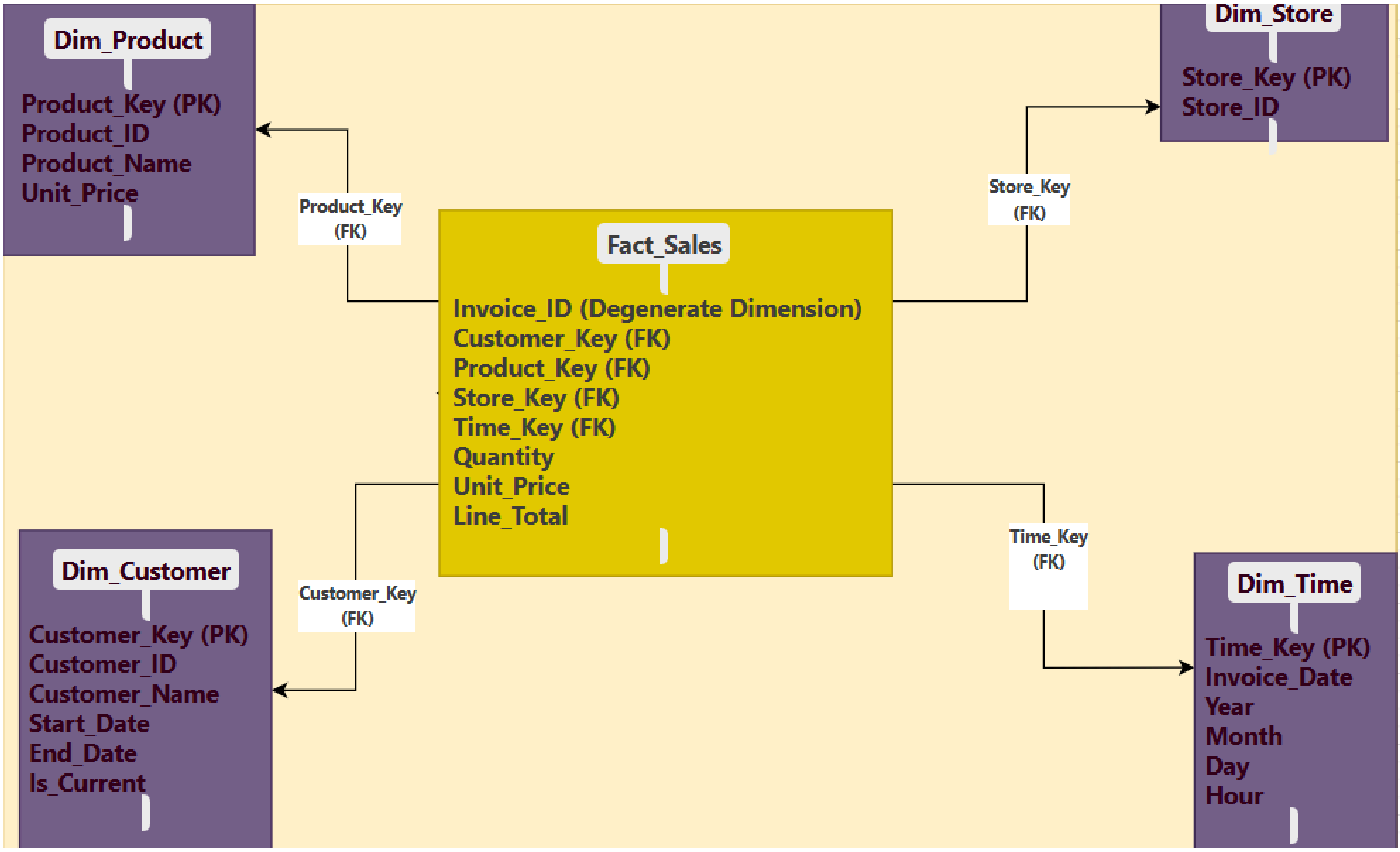
1. **Customer_Dim**
    - `Customer_Key` (PK)
    - `Customer_ID` (e.g., C001)
    - `Customer_Name` (e.g., "John Smith")
    - `Start_Date`, `End_Date` (for SCD)
2. **Product_Dim**
    - `Product_Key` (PK)
    - `Product_ID` (e.g., P1001)
    - `Product_Name` (e.g., "Wireless Mouse")
    - `Unit_Price` (e.g., 25.00)
    - `Effective_Start_Date`, `Effective_End_Date` (for SCD)
3. **Store_Dim**
    - `Store_Key` (PK)
    - `Store_ID` (e.g., S01)
    - `Store_Name` (assumed, e.g., "Downtown")
4. **Time_Dim**

- Time_Key (PK, e.g., 202503150915)
- Date (e.g., "2025-03-15")
- Year, Month, Day, Hour (e.g., 2025, "March", 15, 09)

Handling Degenerate Dimensions

Invoice_ID is a degenerate dimension, stored directly in Sales_Fact rather than a separate table. This simplifies the schema while allowing grouping by invoice (e.g., total revenue for INV001), aligning with reporting needs without adding complexity.

Dimensional Model Diagram



3. Slowly Changing Dimensions (SCD)

SCD Implementation

Attributes like Unit_Price (in Product_Dim) and Customer_Name (in Customer_Dim) may change over time, requiring an SCD strategy.

- **Product_Dim**: Use **SCD Type 2** for Unit_Price. Add Effective_Start_Date, Effective_End_Date, and a new row for each price change (e.g., "Wireless Mouse" from 25.00 to 30.00 on 2025-04-01).
- **Customer_Dim**: Apply **SCD Type 2** for Customer_Name changes (e.g., "John Smith" to "John A. Smith"), tracking historical purchases.
- **Store_Dim**: Use **SCD Type 1** for Store_Name, overwriting updates as location history is less critical.

Trade-Offs:

- **Type 2**: Preserves history (benefit) but increases storage and complexity (cost).
- **Type 1**: Simplifies maintenance (benefit) but loses historical data (cost).
- **Type 3**: Tracks one prior value but is impractical for frequent changes.

SCD Type 2 is chosen for `Product_Dim` and `Customer_Dim` to support historical tracking, aligning with forecasting needs.

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4. ETL/ELT Strategy

Data Integration

- **Batch Processing**: Extract daily invoice data (e.g., from a POS system CSV) and-
    - Extract daily invoice data (e.g., from a POS system CSV) nightly, transform, and load into the data warehouse.
- **Incremental Updates**: Process only new/changed records based on `Invoice_Date` (e.g., > last load date), reducing overhead.

Data Quality & Consistency

1. **Surrogate Keys**: Generate `Customer_Key`, `Product_Key`, etc., for performance and SCD support.
2. **Cleansing**: Standardize `Customer_Name` (e.g., "John Smith" vs. "john smith") and validate `Line_Total`.
3. **Integrity**: Ensure foreign keys match dimension tables.
4. **Deduplication**: Remove duplicate `Invoice_ID` + line item entries.

ETL Process Flow

```
[Invoice CSV] --> [Extract: Load Rows] --> [Stage: Validate Line_Total, Dedupe]
    |
    v
[Transform: Parse Invoice_Date, SCD Type 2, Assign Keys] --> [Load: Dimensions → Sales_Fact]
```

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5. Advanced Analysis & Scalability

Hierarchical Relationships

- **Time**: `Year → Month → Day → Hour` (e.g., 2025 → March → 15 → 09).
- **Product**: Future `Category → Product_Name` (e.g., "Electronics → Wireless Mouse").
- **Store**: Potential `Region → Store_ID` (e.g., "East → S01").

Performance Optimization

1. **Partitioning**: Split `Sales_Fact` by `Time_Key` (e.g., monthly) for faster queries.
2. **Indexing**: Index foreign keys (`Customer_Key`, etc.) and composite keys (e.g., `Store_ID` + `Time_Key`).
3. **Surrogate Keys**: Enhance join performance and SCD management.

Assumptions & Trade-Offs

- **Assumptions**: No returns/refunds, `Store_Name` exists in a master list.
- **Trade-Offs**: SCD Type 2 increases storage but ensures history; line-item granularity adds detail but requires more space.

Conclusion

This model delivers:

- **Analytical Reporting**: Sales trends via `Line_Total` aggregations.
- **Drill-Down**: Hierarchies enable multi-level analysis.
- **Historical Tracking**: SCD Type 2 preserves past data.
- **Scalability**: Partitioning and indexing ensure performance.

It meets all business objectives with a robust, scalable design.
