System Analysis & Design

Manufacturing Downtime Analysis

3.1 System Architecture

The project follows a standard Business Intelligence architecture:

1. **Data Source:** Excel Flat Files (Line Productivity, Line Downtime, Products, Operators).
2. **ETL Layer (Power Query):** Data extraction, cleaning (type conversion, unpivoting), and transformation.
3. **Semantic Layer (Data Model):** Star Schema implementation with DAX measures.
4. **Presentation Layer (Power BI):** Interactive dashboards and reports.

Data Modeling

Data Model

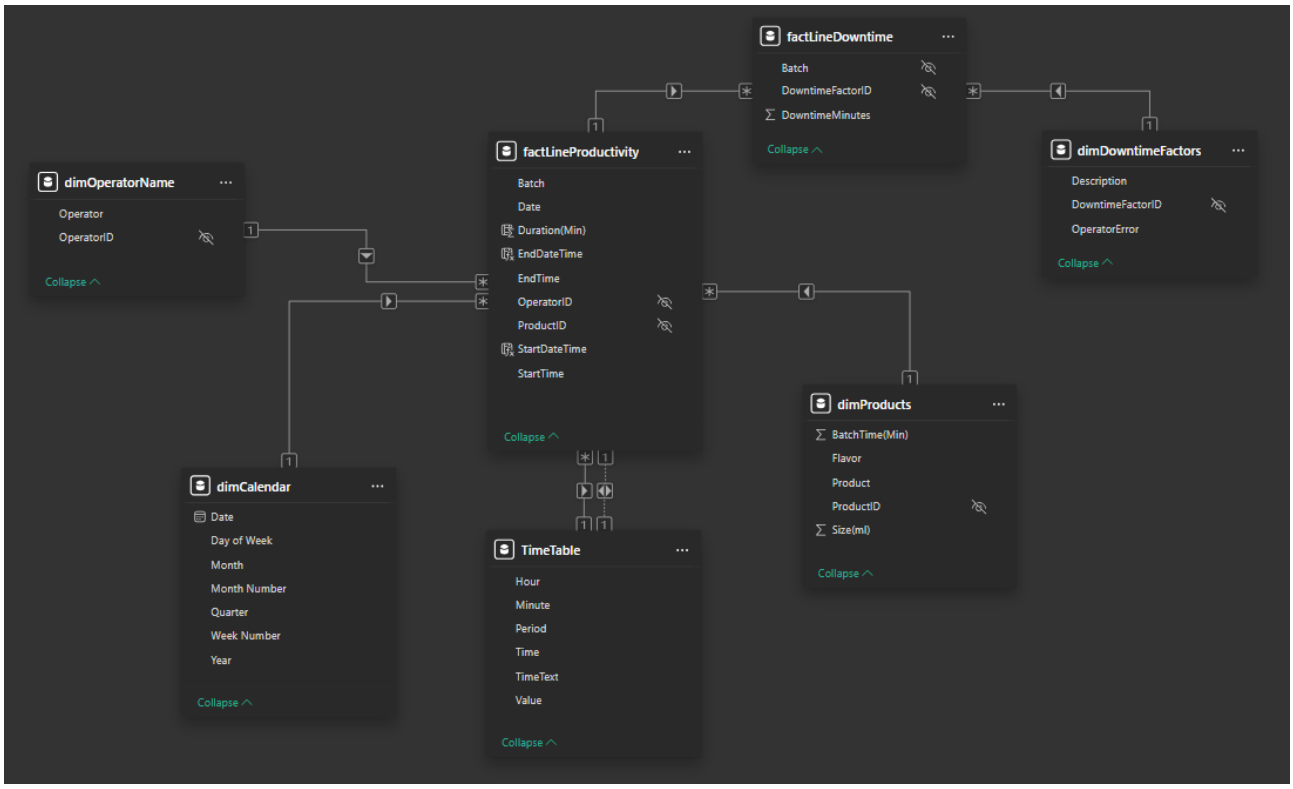

Figure 1: Data model

Data Model Description

Model Overview

The Power BI data model integrates production and downtime information to evaluate overall manufacturing performance. It follows a **star schema**, centered around two main fact tables — **factLineProductivity** and **factLineDowntime** — that connect to several descriptive dimension tables. This design allows for flexible analysis by product, operator, date, and time, supporting KPIs like *Average Production Time*, *Average Downtime*, and *Operator Efficiency*.

Meta data

1. Table: factLineProductivity

Description: Stores production event data including duration, batch, operator, and product. It acts as the primary fact table for measuring efficiency.

Column Name	Data Type	Description
Date	Date	The date of the production run[2].
ProductID	Whole Number (Int64)	Foreign key linking to dimProducts. Used to identify the product being manufactured[3].
Batch	Text	Unique identifier for the production batch. Converted to text to align with other tables[4].
OperatorID	Text	Foreign key linking to dimOperatorName. Identifies the operator responsible for the batch[5].
StartTime	Time	The specific time production started[6].
EndTime	Time	The specific time production ended[7].
StartDateTime	DateTime (Calculated)	Combines Date and StartTime into a single timestamp for accurate duration calculations[8].
EndDateTime	DateTime (Calculated)	Determines the actual end date/time, accounting for operations that cross over midnight (End Time < Start Time)[9].
Duration (Min)	Whole Number (Calculated)	Calculates the total duration of the operation in minutes (Difference between StartDateTime and EndDateTime)[10].

2. Table: factLineDowntime

Description: Captures machine downtime incidents, including the specific factor (reason) and the duration of the stoppage.

Column Name	Data Type	Description
Batch	Text	Foreign key linking to factLineProductivity. Associates the downtime with a specific production batch[12].
DowntimeFactorID	Text	Foreign key linking to dimDowntimeFactors. Represents the category or reason for the downtime[13].
DowntimeMinutes	Whole Number (Int64)	The duration of the downtime event in minutes[14].

3. Table: dimProducts

Description: Contains product master data such as flavor, size, and target batch times. Used for analyzing performance by product type.

Column Name	Data Type	Description
ProductID	Whole Number (Int64)	Unique identifier for the product. Generated via Index in Power Query[16].
Product	Text	The name or code of the product (e.g., CO-600)[17].
Flavor	Text	The flavor variant of the product[18].
Size(ml)	Whole Number (Int64)	The volume size of the product in milliliters (cleaned from text like "2 L" to 2000)[19].
BatchTime (Min)	Whole Number (Int64)	The **Target** minimum time required to produce a batch of this product. Used to calculate if a batch met its target[20].

4. Table: dimOperatorName

Description: A dimension table containing information about machine operators, ensuring standardized names and IDs.

Column Name	Data Type	Description
OperatorID	Text	Unique identifier for the operator[22].
Operator	Text	The full name of the machine operator[23].

5. Table: dimDowntimeFactors

Description: Describes the reasons for downtime (e.g., "Machine Failure") and categorizes whether the issue is related to operator error.

Column Name	Data Type	Description
DowntimeFactorID	Text	Unique identifier for the downtime cause[25].
Description	Text	Descriptive name of the downtime reason (e.g., "Machine adjustment", "Inventory shortage")[26].
OperatorError	Text	A flag ("Yes"/"No") indicating if the downtime factor is attributed to human/operator error[27].

6. Table: dimDate (dimCalendar)

Description: A generated calendar table for time-based analysis (Year, Month, Day). It supports trending metrics over time.

Column Name	Data Type	Description
Date	Date	The specific calendar date[29].
Year	Whole Number	The 4-digit year (e.g., 2025)[30].
Quarter	Text	The quarter of the year (e.g., "Q1")[31].
Week Number	Whole Number	The week number of the year (1-52)[32].
Month Number	Whole Number	The month number (1-12)[33].
Month	Text	The full name of the month (e.g., "January")[34].
Day of Week	Text	The full name of the day (e.g., "Monday")[35].

7. Table: TimeTable

Description: A DAX-generated table with one row per minute (0-1439). It is used to analyze performance by hour and shift.

Column Name	Data Type	Description
Value	Whole Number	Sequential index representing minutes since midnight (0 to 1439)[37].
Time	Time	The actual time value (e.g., 08:30:00)[38].
Hour	Whole Number	The hour component (0-23). Useful for hourly trend analysis[39].
Minute	Whole Number	The minute component (0-59)[40].
Period	Text	Indicator for "AM" or "PM"[41].
TimeText	Text	Readable string format (e.g., "08:30 AM") for slicers[42].
Shift Time	Text (Calculated)	Classifies the time into "Day Shift" (AM) or "Night Shift" (PM)[43].

Relationships Summary

From Table (Foreign Key)	To Table (Primary Key)	Relationship Type
factLineProductivity [OperatorID]	dimOperatorName [OperatorID]	Many-to-One (Single)
factLineProductivity [ProductID]	dimProducts [ProductID]	Many-to-One (Single)
factLineProductivity [Date]	dimDate [Date]	Many-to-One (Single)
factLineProductivity [StartTime]	TimeTable [Time]	Many-to-One (Single)
factLineDowntime [DowntimeFactorID]	dimDowntimeFactors [DowntimeFactorID]	Many-to-One (Single)
factLineDowntime [Batch]	factLineProductivity [Batch]	Many-to-One (Single)

Model Characteristics

- **Schema Type:** Star Schema
- **Primary Relationships:** Based on surrogate keys (IDs and Dates)
- **Cross-Filtering:** Primarily single-direction for performance; bidirectional between downtime and productivity where batch alignment is required
- **Purpose:** To enable combined performance insights, such as total production vs. downtime, per product, operator, and time frame.

Visualization and answering business questions

Wire framing

UI Wireframing and Dashboard Design

Purpose

The wireframe was designed in **Figma** to visualize the structure, layout, and interaction flow of the **Manufacturing Downtime Analysis Dashboard** before implementation in Power BI. This step ensured that all required insights — such as productivity trends, downtime factors, and operator performance — were clearly represented with a user-friendly interface.

Overview

The wireframe defines:

- **Dashboard layout:** Placement of KPI cards, charts, and filters
- **Navigation flow:** Logical grouping of downtime analysis, production metrics, and operator performance
- **Color scheme and hierarchy:** Consistent with professional manufacturing analytics dashboards
- **Data storytelling flow:** From high-level performance (KPIs) down to root cause analysis and downtime trends

Design Tool

- **Tool Used:** Figma
- **Purpose:** Create a visual mockup to align stakeholders on report structure and user experience prior to Power BI development.

Integration with Power BI

The wireframe guided the following design aspects in Power BI:

1. **Page Layout:** Balanced visual hierarchy between KPIs, charts, and filters.
2. **Color Usage:** Consistent use of blue, orange, and gray tones to emphasize status and categories.
3. **Navigation:** Logical flow from overall production efficiency to detailed downtime causes.
4. **User Experience:** Optimized for intuitive interpretation by managers and operators.

Outcome

The Figma wireframe acted as the **visual blueprint** for building the Power BI dashboard, ensuring:

- Faster report development
- Alignment between data engineers and stakeholders
- A consistent and professional visual identity