the dataronauts

MANUFACTURING DOWNTIME

Manufacturing Downtime Analysis Report

1. Team Name: The Dataronauts

3. Team Leader: Abdallah Mousa Abdelhakeem Mousa

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1. Project Definition and Goal

- **Definition:** The project analyzes manufacturing downtime data to identify its causes, patterns, and impact on production efficiency and cost. The goal is to provide actionable insights that help reduce downtime, improve productivity, and optimize resource allocation.

2. Work Background

- **Industry Context:** Manufacturing downtime is a critical problem across many industries. It represents lost production capacity, increased costs (labor, maintenance, and scrapped materials), and potential delays in fulfilling orders.
- **Why It Matters:**
    - **Increased Efficiency:** Reducing downtime directly translates to higher production output.
    - **Cost Reduction:** Fewer breakdowns mean lower maintenance expenses and less wasted materials.
    - **Improved Planning:** Understanding downtime patterns helps improve schedule maintenance and resource allocation.
    - **Competitive Advantage:** More efficient manufacturing processes lead to a stronger competitive position.

Workflow (Data Analytics Project Steps)

Data Preparation

Excel Power Query:

- Unpivoted downtime factors table
- Standardized data formats

Data Exploration:

- **Descriptive Statistics:** Calculate summary statistics (mean, median, etc.) for downtime duration, frequency, etc.

    - **Data Visualization:**
        - Create histograms to visualize the distribution of downtime duration.
        - Use bar charts to compare downtime frequency across different machines or cause codes.
        - Generate line charts to show downtime trends over time.
        - Create scatter plots to explore relationships between variables (e.g., downtime duration vs. machine age).
    - **SQL for Data Aggregation:** Use SQL queries to aggregate data, calculate averages, sums, counts, etc

3. Data Types

- **Numerical:**
    - Downtime duration (in minutes, hours, etc.)
    - Product size
    - Min batch time
- **Text:**
    - Downtime Factors
    - Product ID
    - Batch ID
    - Operator name
    - Flavor
    - Factor ID
- **Date/Time:**
    - Downtime start time
    - Downtime end time
    - Batch date
- Boolean
    - Operator error

Dashboards

1. Strategic Dashboard

Audience: Senior Management (e.g., Plant Manager, Directors)

Purpose: Provide a high-level overview of production performance and long-term trends.

Business Questions:

1. What is the overall efficiency of the production line?
2. What are the major causes of downtime, and how do they impact productivity?
3. Are there any long-term trends in productivity or downtime?

KPI	Metric	Formula
Overall Efficiency Ratio	Percentage	`(Total Planned Production Time/Total Production Time) * 100`
Total Downtime	Minutes	`SUM(Downtime across all batches)`
Downtime by Major Factor	Minutes	`SUM(Downtime for each major factor)`
Average Production Time	Minutes	`AVERAGE(End Time - Start Time)`
Trend in Productivity	Percentage change over time	`(Current Efficiency - Previous Efficiency) / Previous Efficiency * 100`

KPIs and Metrics:Visualizations:

- Big Number Cards: Overall Efficiency Ratio, Total Downtime, Average Production Time.
- Treemap: Downtime by Major Factor (e.g., Operator Error, Machine Failure).
- Line Chart: Trend in Productivity over time (e.g., weekly or monthly).
- Bar Chart: Efficiency Ratio by Product.

Strategic Dashboard Layout

Sections:

1. Header Section:
    - Title: "Strategic Dashboard - Production Overview"
    - Date Range Selector: Users can filter data by week, month, or quarter.
2. Key Metrics Section:
    - Big Number Cards:
        - Overall Efficiency Ratio
        - Total Downtime
        - Average Production Time
    - Layout: 3 cards in a single row.
3. Trends Section:
    - Line Chart: Trend in Productivity over time (e.g., weekly or monthly).
    - Bar Chart: Efficiency Ratio by Product.
    - Layout: Two charts side by side.
4. Downtime Analysis Section:
    - Treemap: Downtime by Major Factor (e.g., Operator Error, Machine Failure).
    - Layout: One chart centered below the Trends Section.

2. Analytical Dashboard

Audience: Data Analysts, Business Analysts

Purpose: Enable deep dives into data to identify root causes and correlations.

Business Questions:

1. Why does a specific product have higher downtime?
2. Are there correlations between operator experience and downtime?
3. What are the root causes of inefficiencies in the production line?

KPIs and Metrics:

KPI	Metric	Formula
Downtime by Specific Factor	Minutes	`SUM(Downtime for each factor)`
Operator Error Downtime	Minutes	`SUM(Downtime where Operator Error = "Yes")`
Correlation: Operator Experience vs. Downtime	Correlation coefficient	Statistical analysis (e.g., Pearson correlation).
Root Cause Analysis	Percentage of downtime by cause	`(Downtime for a specific cause / Total Downtime) * 100`
Batches with Excessive Downtime	Number of batches	`COUNT(Batches where Downtime > Threshold)`

Visualizations:

- Drill-Down Bar Chart: Downtime by Specific Factor (e.g., machine failure, operator error).
- Scatter Plot: Operator Experience vs. Downtime.
- Heatmap: Downtime by Operator and Product.
- Pivot Table: Detailed breakdown of downtime by batch, operator, and factor.
- Tree Map: Root causes of downtime (e.g., machine failure, operator error, etc.).

Analytical Dashboard Layout

Sections:

1. Header Section:
    - Title: "Analytical Dashboard - Root Cause Analysis"
    - Filters: Allow users to filter by Product, Operator, Date Range, and Downtime Factor.
2. Downtime Breakdown Section:
    - Drill-Down Bar Chart: Downtime by Specific Factor (e.g., machine failure, operator error).
    - Heatmap: Downtime by Operator and Product.
    - Layout: Two charts side by side.
3. Correlation Analysis Section:
    - Scatter Plot: Operator Experience vs. Downtime.
    - Layout: One chart centered below the Downtime Breakdown Section.
4. Root Cause Analysis Section:
    - Tree Map: Root causes of downtime (e.g., machine failure, operator error, etc.).
    - Pivot Table: Detailed breakdown of downtime by batch, operator, and factor.
    - Layout: Two visualizations side by side.

3. Operational Dashboard

Audience: Supervisors, Team Leads, Operators

Purpose: Provide real-time metrics and alerts for day-to-day operations.

Business Questions:

1. How is the production line performing today?
2. Which batches are experiencing the most downtime, and why?
3. Are there any immediate issues that need to be addressed?

KPIs and Metrics:

KPI	Metric	Formula
Daily Production Time	Minutes	`SUM(End Time - Start Time for the day)`
Daily Downtime	Minutes	`SUM(Downtime for the day)`
Downtime by Batch	Minutes	`SUM(Downtime for each batch)`
Operator Performance Today	Percentage	`(Production Time / Time Worked) * 100`
Batches Completed Today	Number of batches	`COUNT(Batches completed today)`

Visualizations:

- Big Number Cards: Daily Production Time, Daily Downtime, Batches Completed Today.
- Bar Chart: Downtime by Batch (top 10 batches with the most downtime).
- Table: Operator Performance Today (real-time or daily summary).
- Line Chart: Hourly Downtime (trend throughout the day).

Alert System: Highlight batches with excessive downtime or operator errors.

3. Operational Dashboard LayoutP

Header Section:

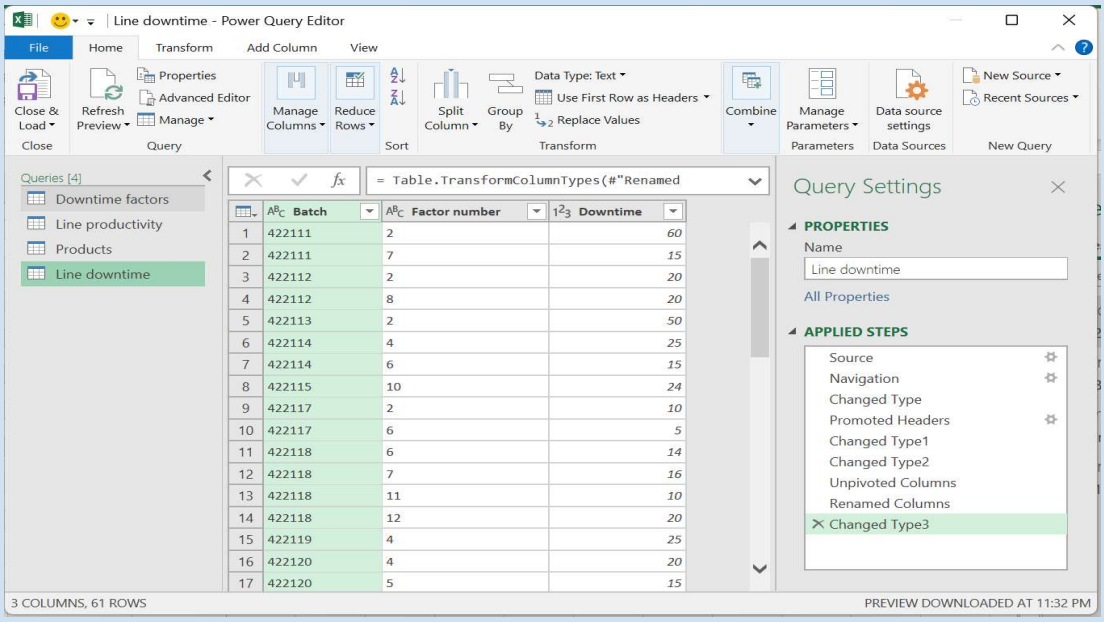
- Title: "Operational Dashboard - Real-Time Monitoring"
- Date/Time Selector: Allow users to view data for the current day or shift.

2. Key Metrics Section:
   - Big Number Cards:
     - Daily Production Time
     - Daily Downtime
     - Batches Completed Today
   - Layout: 3 cards in a single row.
3. Downtime Alerts Section:
   - Bar Chart: Downtime by Batch (top 10 batches with the most downtime).
   - Alert System: Highlight batches with excessive downtime or operator errors (e.g., red/yellow/green indicators).
   - Layout: One chart and alert system side by side.
4. Operator Performance Section:
   - Table: Operator Performance Today (real-time or daily summary).
   - Line Chart: Hourly Downtime (trend throughout the day).
   - Layout: Two visualizations side by side.

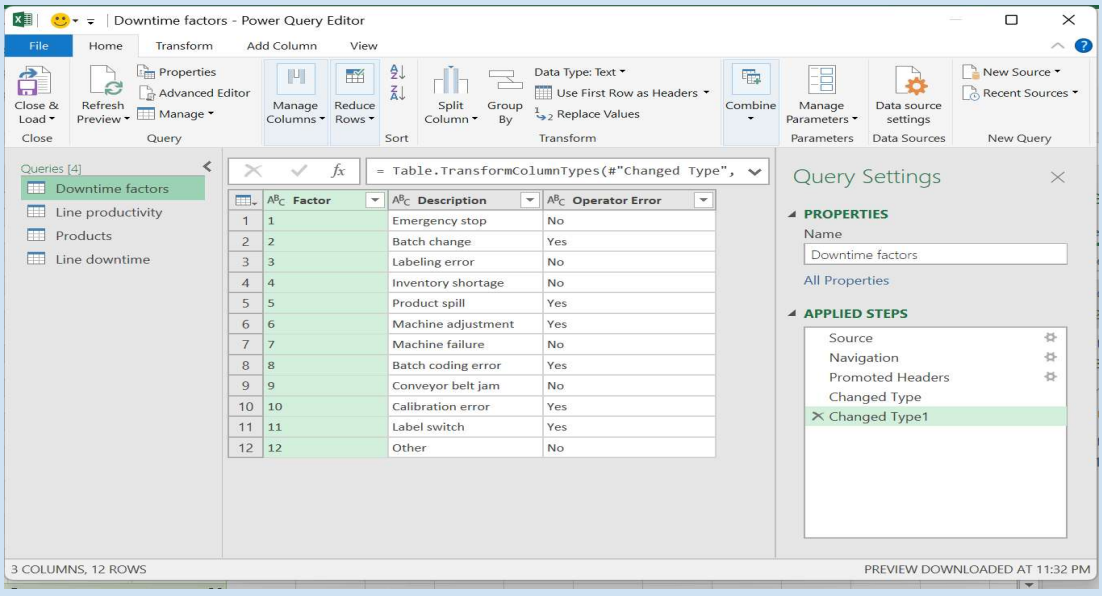
1 - Data cleaning :

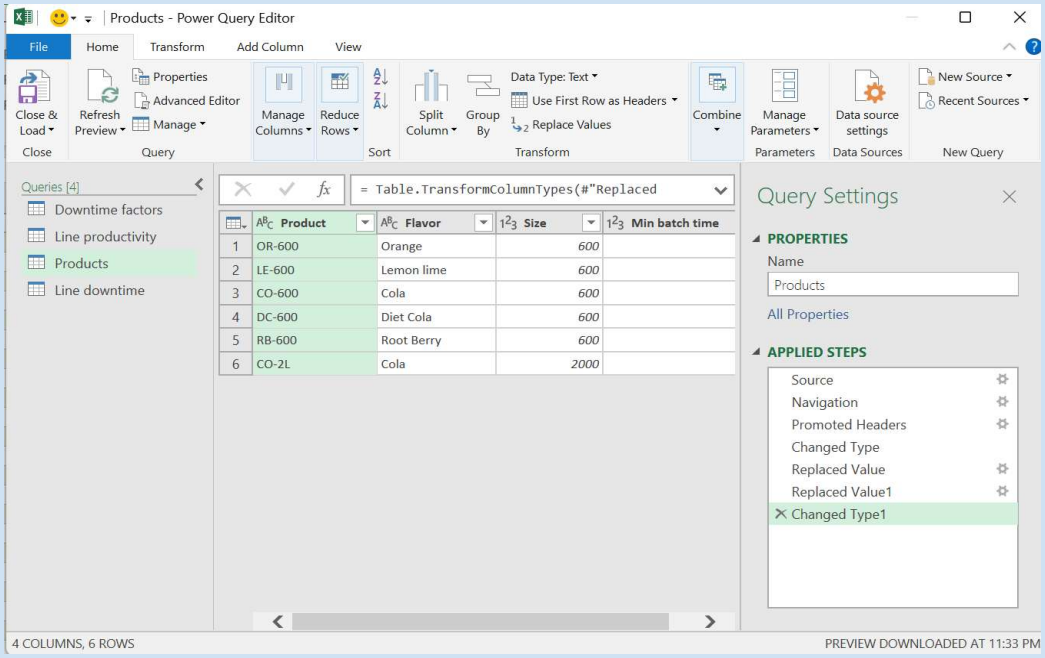
Excel was used for initial data exploration and cleaning.

- Unpivoting the **Line downtime** sheet using Power Query (as explained earlier).



- Standardize data formats

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Home
Transform
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View
Close & Load
Refresh Preview
Properties
Advanced Editor
Manage
Manage Columns
Reduce Rows
Split Column
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Data Type: Text
Use First Row as Headers
Replace Values
Combine
Manage Parameters
Data source settings
New Source
Recent Sources
Close
Query
Sort
Transform
Parameters
Data Sources
New Query
Queries [4]
Downtime factors
Line productivity
Products
Line downtime
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Flavor
Size
Min batch time
1 OR-600 Orange 600
2 LE-600 Lemon lime 600
3 CO-600 Cola 600
4 DC-600 Diet Cola 600
5 RB-600 Root Berry 600
6 CO-2L Cola 2000
Query Settings
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Products
All Properties
APPLIED STEPS
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Replaced Value1
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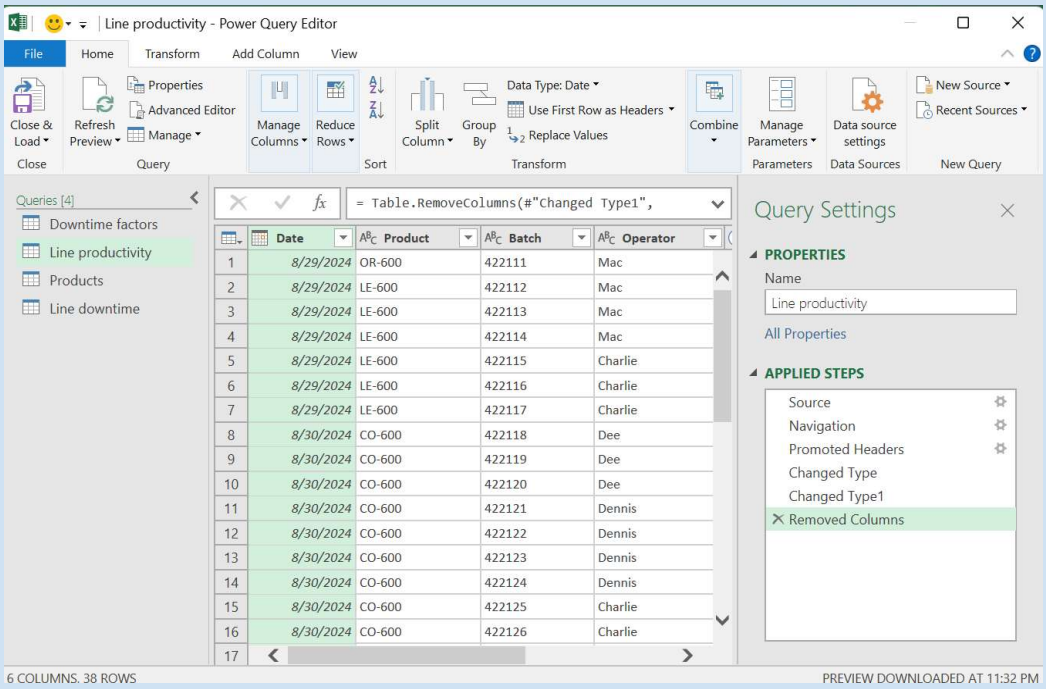
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File
Home
Transform
Add Column
View
Close & Load
Refresh Preview
Properties
Advanced Editor
Manage
Manage Columns
Reduce Rows
Split Column
Group By
Data Type: Date
Use First Row as Headers
Replace Values
Combine
Manage Parameters
Data source settings
New Source
Recent Sources
Close
Query
Sort
Transform
Parameters
Data Sources
New Query
Queries [4]
Downtime factors
Line productivity
Products
Line downtime
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Date
Product
Batch
Operator
1 8/29/2024 OR-600 422111 Mac
2 8/29/2024 LE-600 422112 Mac
3 8/29/2024 LE-600 422113 Mac
4 8/29/2024 LE-600 422114 Mac
5 8/29/2024 LE-600 422115 Charlie
6 8/29/2024 LE-600 422116 Charlie
7 8/29/2024 LE-600 422117 Charlie
8 8/30/2024 CO-600 422118 Dee
9 8/30/2024 CO-600 422119 Dee
10 8/30/2024 CO-600 422120 Dee
11 8/30/2024 CO-600 422121 Dennis
12 8/30/2024 CO-600 422122 Dennis
13 8/30/2024 CO-600 422123 Dennis
14 8/30/2024 CO-600 422124 Dennis
15 8/30/2024 CO-600 422125 Charlie
16 8/30/2024 CO-600 422126 Charlie
17
Query Settings
PROPERTIES
Name
Line productivity
All Properties
APPLIED STEPS
Source
Navigation
Promoted Headers
Changed Type
Changed Type1
Removed Columns
6 COLUMNS, 38 ROWS
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2 - Data exploration and analysis :

By using **SQL** for data exploration and starting to analyse it

- Creating table→ productivity, downtime, factors and products.
- Creating view →line_downtim

```
CREATE VIEW line_downtime  AS
SELECT p.date, p.product, p.batch, p.operator, p.start_time,
p.end_time, p.duration,
      r.flavor ,r.size, r.min_batch_time, f.factor, f.description,
f.operator_error, d.downtime
FROM productivity AS p
JOIN products AS r ON r.product = p.product
JOIN downtime AS d ON d.batch = p.batch
JOIN factors AS f ON f.factor = d.factor_number;
```

1. Strategic dashboard business questions

Q.1 - What is the overall efficiency of the production line?

```
select Round(((sum(duration)-sum (downtime))/(sum(duration)))*100) as
efficiency
from line_downtime
```

Q.2 - What are the major causes of downtime, and how do they impact productivity?

```
SELECT d.factor_number, SUM(d.downtime) as total_downtime,
f.description
FROM downtime d
JOIN factors f ON f.factor = d.factor_number
GROUP BY d.factor_number, f.description
order by total_downtime desc
limit 5
```

#	factor_number	total_downtime	description
1	6	332	Machine adjustment
2	7	254	Machine failure
3	4	225	Inventory shortage
4	2	160	Batch change
5	8	145	Batch coding error

```sql
SELECT
 factor_number,
  COUNT(*) AS count_of_values,
  round((COUNT(*) * 100.0 / (SELECT COUNT(*) FROM  downtime)),2) AS
percentage
FROM downtime
GROUP BY 1
ORDER BY percentage DESC;
```

Q.3 - Are there any long-term trends in productivity or downtime?

```sql
SELECT
    DATE(Date) AS Production_Date,
    AVG(downtime) AS Avg_downtime
FROM
    line_downtime
GROUP BY
    DATE(Date)
ORDER BY
    Production_Date;
```

#	production_date	avg_downtime
1	2024-08-29	40.6666666666666667
2	2024-08-30	37.0000000000000000
3	2024-08-31	33.0000000000000000
4	2024-09-02	45.7272727272727273
5	2024-09-03	32.0000000000000000

```sql
SELECT
    DATE(Date) AS Production_Date,
    AVG(duration) AS Avg_duration
FROM
    line_downtime
GROUP BY
    DATE(Date)
ORDER BY
    Production_Date;
```

#	production_date	avg_duration
1	2024-08-29	94.8571428571428571
2	2024-08-30	97.0000000000000000
3	2024-08-31	83.5714285714285714
4	2024-09-02	119.5454545454545455
5	2024-09-03	130.0000000000000000

2. Analytical dashboard business questions

Q .1 - Why does a specific product have higher downtime?

```
select product, sum(downtime) as downtime
from line_downtime
group by product
order by downtime desc
limit 1
```

The product with higher downtime is → CO-600 (494 min)

```
SELECT
    Factors,
    SUM(Downtime) AS Total_Downtime
FROM
    line_downtime
WHERE
    Product = 'CO-600'
GROUP BY
    Factors
ORDER BY
    Total_Downtime DESC;
```

Inventory shortage (43 mins), Machine failure (30 mins)	73
Label switch (10 mins), Other (20 mins), Machine adjustment (14 mins), Machine failure (16 mins)	60

Q .2 - What is the average downtime caused by each operator?

```
SELECT pv.Operator,avg(dt.Downtime) AS Operator_Dependent_Downtime
FROM downtime dt
JOIN productivity as pv
ON dt.Batch = pv.Batch
JOIN factors f
ON dt.Factor_number = f.Factor
WHERE f.Operator_Error = 'Yes'
GROUP BY pv.Operator
ORDER BY Operator_Dependent_Downtime DESC;
```

#	operator	operator_dependent_downtime
1	Mac	27.4285714285714286
2	Dennis	27.3333333333333333
3	Charlie	25.3333333333333333
4	Dee	19.2000000000000000

Q .3 -What are the root causes of inefficiencies in the production line?

```
SELECT f.factor, SUM(d.downtime) AS down, round((SUM(d.downtime) * 100.0 /
(SELECT SUM(downtime) FROM downtime)),2) AS total_downtime_percentage
FROM productivity AS pv
JOIN downtime AS d ON pv.batch = d.batch
JOIN factors AS f ON f.factor = d.factor_number
GROUP BY f.factor
ORDER BY down DESC
```

#	factor	down	total_downtime_percentage
1	6	332	23.92
2	7	254	18.30
3	4	225	16.21
4	2	160	11.53
5	8	145	10.45
6	12	74	5.33
7	5	57	4.11
8	10	49	3.53

KPI

1. Downtime by Specific Factor

```
select f.factor,sum(d.downtime) as down,f.description
from productivity as pv
join downtime as d
on pv.batch = d.batch
join factors as f
on f.factor = d.factor_number
group by f.factor,f.description
order by down desc
```

#	factor	down	description
1	6	332	Machine adjustment
2	7	254	Machine failure
3	4	225	Inventory shortage
4	2	160	Batch change
5	8	145	Batch coding error
6	12	74	Other
7	5	57	Product spill
8	10	49	Calibration error

2- Operator Error Downtime

```
SELECT pv.Operator, sum(dt.Downtime) AS Operator_Dependent_Downtime
FROM downtime dt
JOIN productivity as pv
ON dt.Batch = pv.Batch
JOIN factors f
ON dt.Factor_number = f.Factor
WHERE f.Operator_Error = 'Yes'
GROUP BY pv.Operator
ORDER BY Operator_Dependent_Downtime DESC;
```

#	operator	operator_dependent_downtime
1	Charlie	228
2	Dee	192
3	Mac	192
4	Dennis	164

3- Batches with Excessive Downtime

```
SELECT batch
FROM line_downtime
WHERE downtime > (duration * 0.5)
```

#	batch
1	422111
2	422123
3	422140
4	422147

3. Operational dashboard business questions

Q. .1- How is the production line performing today?

```
select date, sum(duration) as total_production_time
from line_downtime
group by date
order by 1
```

#	date	total_production_time
1	2024-08-29	664.00
2	2024-08-30	1164.00
3	2024-08-31	585.00
4	2024-09-02	1315.00
5	2024-09-03	130.00

Q .2- Which batches are experiencing the most downtime, and why?

```
select batch, sum(downtime) as total_downtime
from line_downtime
group by 1
having sum(downtime) is not null
order by 2 desc
```

#	batch	total_downtime
1	422147	107
2	422111	75
3	422123	73

```
SELECT batch, SUM(downtime) AS total_downtime, factors
FROM line_downtime
GROUP BY batch, factors
HAVING SUM(downtime) IS NOT NULL
ORDER BY total_downtime DESC
```

#	batch	total_downtime	factors
1	422147	107	Machine failure (30 mins), Machine adjustment (60 mins), Inventory shortage (17 mins)
2	422111	75	Machine failure (15 mins), Batch change (60 mins)
3	422123	73	Machine failure (30 mins), Inventory shortage (43 mins)
4	422140	63	Machine adjustment (50 mins), Label switch (13 mins)
5	422146	62	Machine failure (25 mins), Machine adjustment (30 mins), Other (7 mins)

Q.3- Are there any immediate issues that need to be addressed?

```
SELECT
 factor_number,
  COUNT(*) AS count_of_values,
  round((COUNT(*) * 100.0 / (SELECT COUNT(*) FROM  downtime)),2) AS
percentage
FROM downtime
GROUP BY 1
ORDER BY percentage DESC;
```

#	factor_number	count_of_values	percentage
1	6	12	19.67
2	7	11	18.03
3	4	9	14.75
4	8	6	9.84
5	12	6	9.84
6	2	5	8.20
7	5	3	4.92
8	10	3	4.92

Answer → The machines want to be changed or customized, and the operators need some training

Kpi

```
1- Daily Downtime:
select date, sum(downtime) as total_downtime
from line_downtime
group by date
order by 1
```

#	date	total_production_time
1	2024-08-29	244
2	2024-08-30	444
3	2024-08-31	165
4	2024-09-02	503
5	2024-09-03	32

2- Operator Performance Today:

```
select pv.operator ,round(avg(p.min_batch_time/pv.duration)*100) as
performance
from products as p
join productivity as pv
on p.product = pv.product
group by 1
```

#	operator	performance
1	Dennis	66
2	Dee	67
3	Charlie	71
4	Mac	63

3- Batches Completed Today:

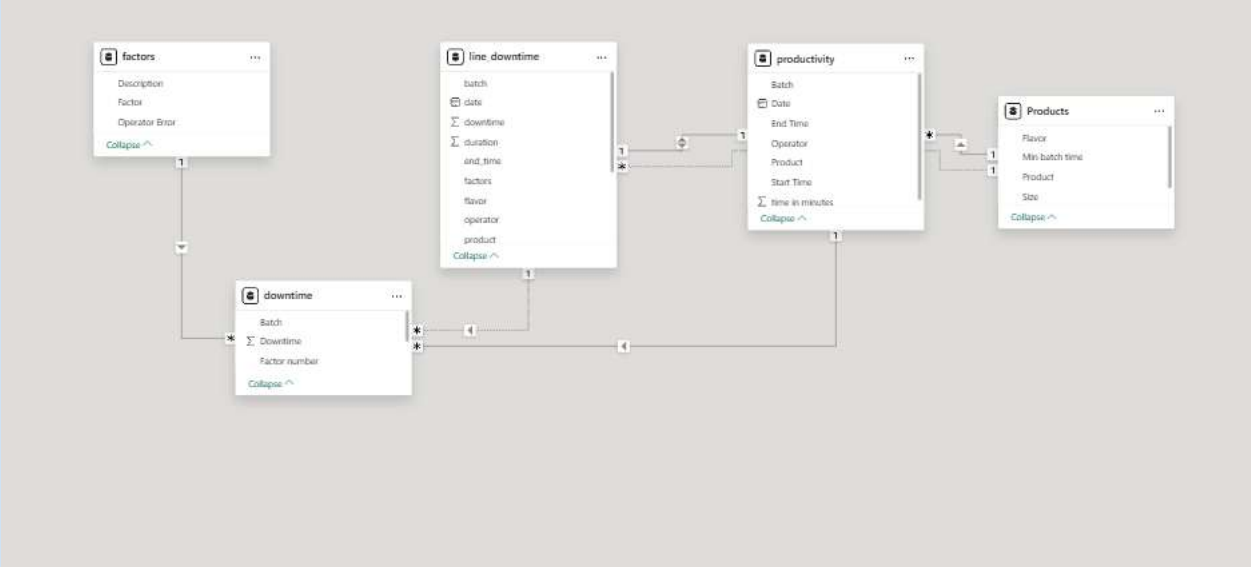
```sql
SELECT batch
FROM line_downtime
GROUP BY batch
HAVING SUM(downtime) IS NULL
```

#	batch
1	422132
2	422116
3	422136

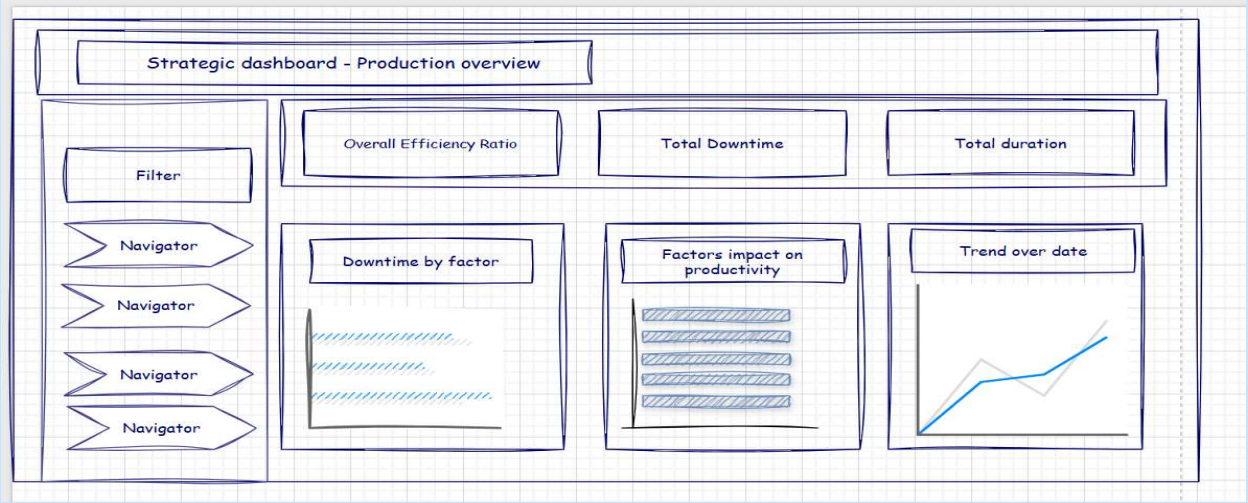
3 - Data visualization :

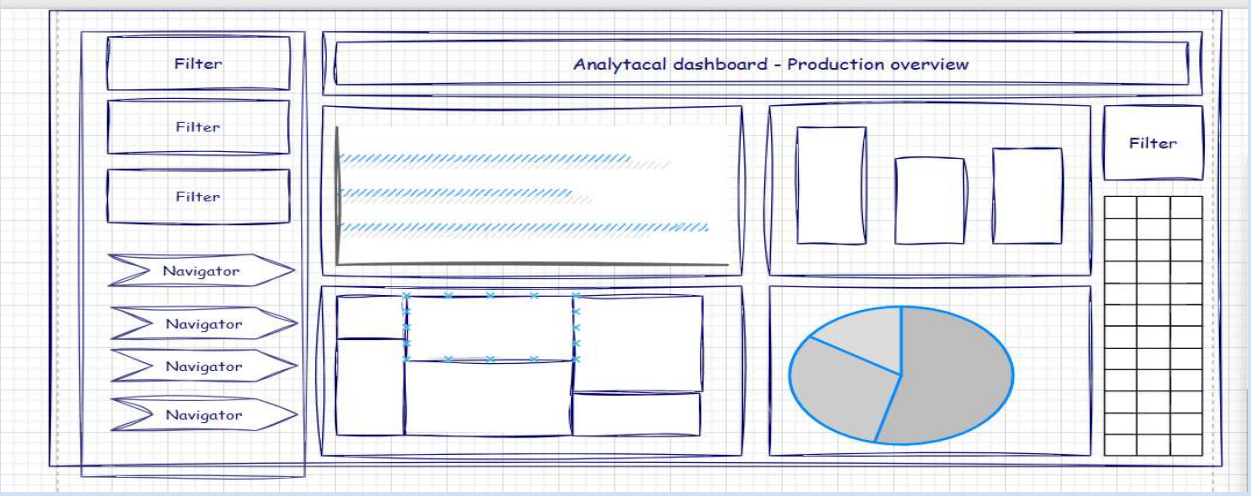
By using **Power BI** to visualize the data :

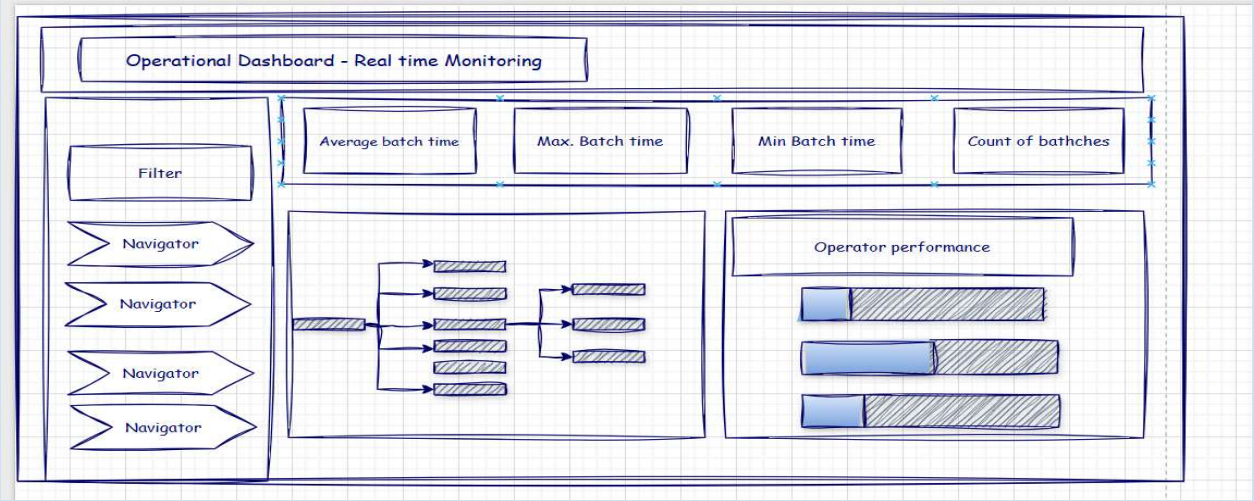
- Start making the dashboards
- Customize the data
- Making relations between the tables
- Making the dashboards



Dashboard mockups

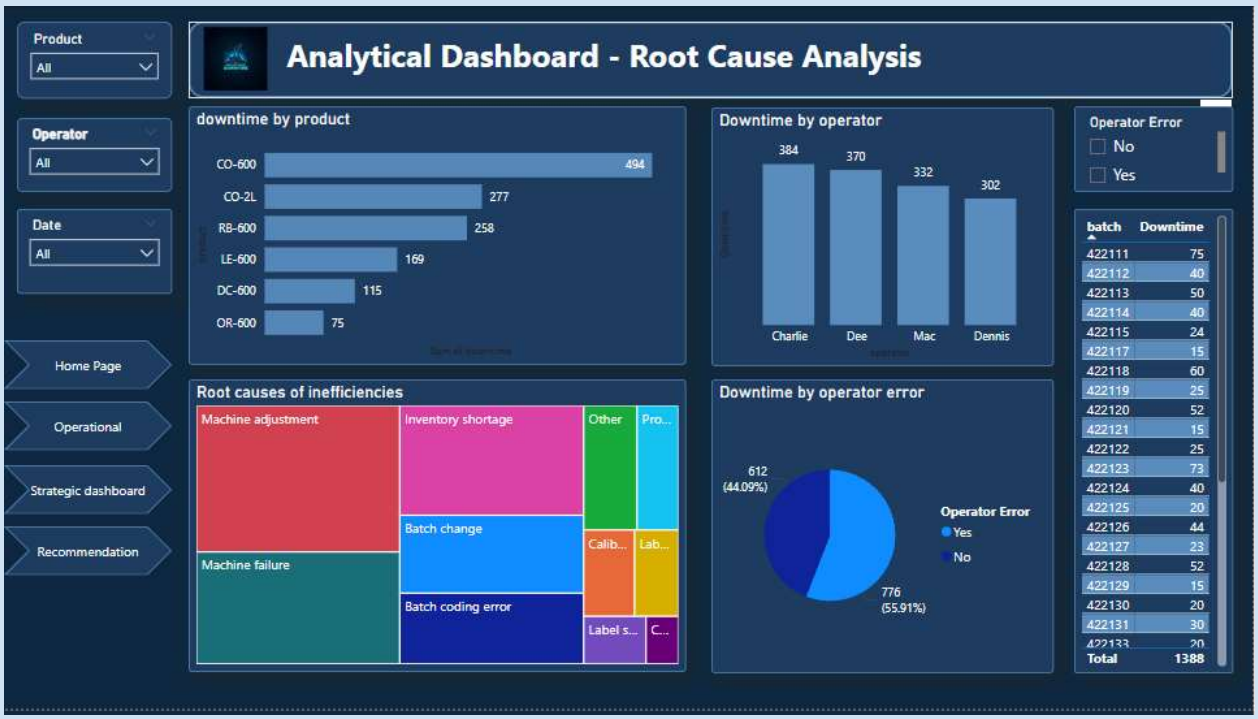




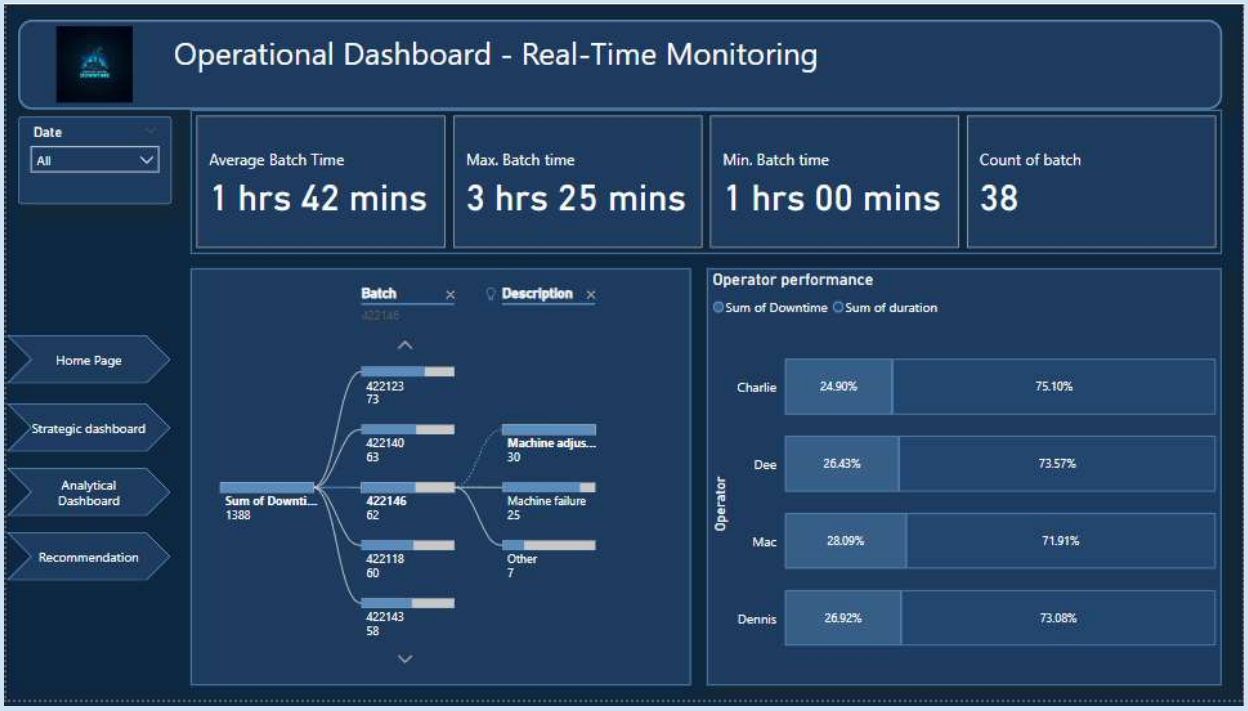
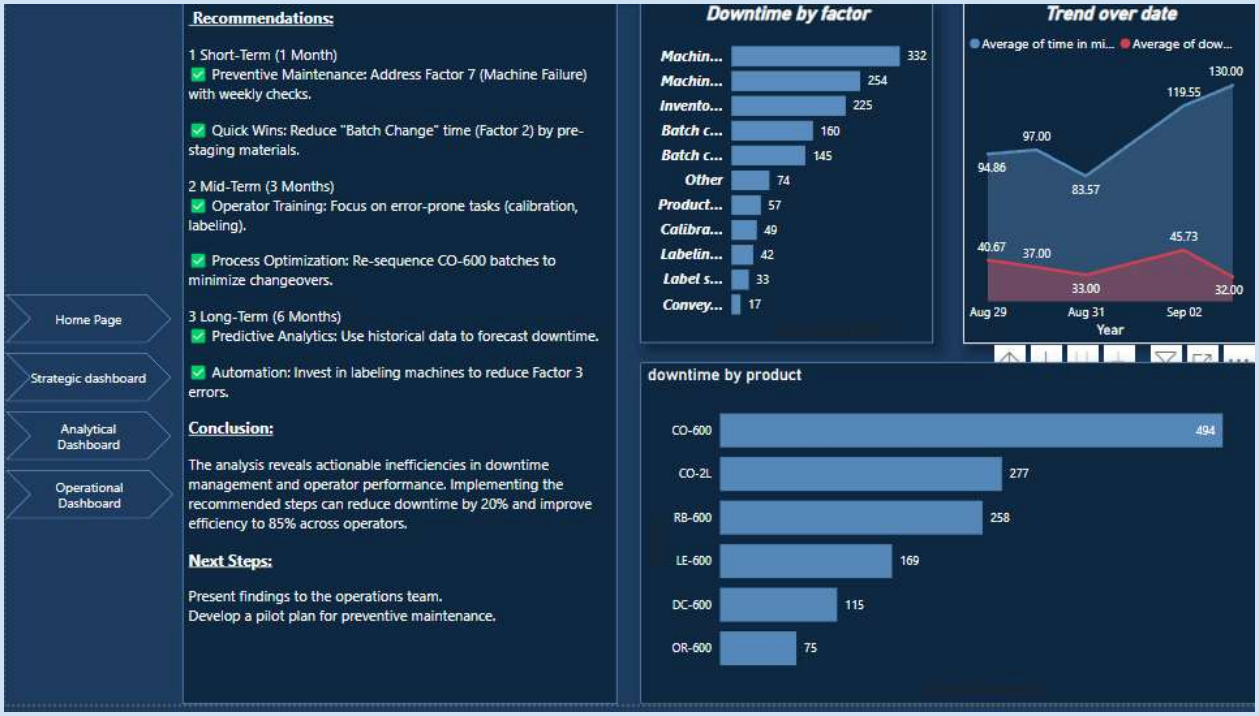


1- Strategic Dashboard

2-Analytical Dashboard



3- Operational Dashboard



*Recommendation