Predictive Model for Inventory Management

Sales Analysis and Forecasting in Department Stores in Turkey

01 The data from three .csv files were loaded into Microsoft Fabric.

02 The files are: 'stores.csv', 'product.csv' e 'sales.csv'

03 An initial Exploratory Data Analysis (EDA) was performed on the data to understand its quality.

Data Sources

Bronze

Raw data was transformed into a managed, transactional format (Delta Lake) within the Bronze Lakehouse.

Silver

Goal --> standardized and clean data

Gold

EDA: Initial Insights

EDA: Proof of Concept

EDA: Proof of Concept

Data ELT

Medallion Architecture

Projects Goals

Linear Regression

PROOF OF CONCEPT

Stores "Stor01", "Store1", "Stor01", "Store1"

Categories Hbc, Hbi, Hlcp and Hcs

"avg_stock",	12 em 16
"avg_price"	4 em 16
"lag_sales_1w",	8 em 16
"lag_sales_2w",	3 em 16
"lag_sales_3w",	7 em 16
"week"	3 em 16

Train R^2: 0.11915454802471326
Train MAE: 0.4351829771075341

R^2 on test set: 0.3820
MAE: 0.3241

Features Table

Time Series Models

Dashboard

Thank you All!!!

Grupo_01

Angel Teixeira
Patrícia Pereira
Rebeque Duque
Yves Mercelles

Thrash

Sales and Inventory Analysis

The project aims for a detailed analysis of sales and inventory in department stores in Turkey. This analysis is essential for understanding consumption patterns and inventory dynamics.

Predictive Model Development

Based on this analysis, the project aims to develop an effective predictive model that allows for the forecasting of weekly sales, thereby contributing to more efficient inventory management.

Projects Goals

Sales and Inventory Analysis

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Medallion Architecture

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03 An initial Exploratory Data Analysis (EDA) was performed on the data to understand its quality.

Data Sources

CITIES.CSV

STORE_ID
- Store Unique Identifier Code
- 63 distinct stores
- No duplicates
- No missing values

STORETYPE_ID
- Store Type Code
- No missing values

STORE_SIZE
- Store Size Value
- No missing values

CITY_ID_OLD
- City Unique Identifier Code
- No missing values

COUNTRY_ID
- Country Name (where stores and cities are located)
- Only "TURKEY"
- No missing values

PRODUCT.CSV

PRODUCT_ID
- Product Unique Identifier Code
- 699 distinct products
- No missing values

PRODUCT_LENGTH
- Product Length Value (cm)
- 18 records with missing values (2.57%)

PRODUCT_DEPTH
- Product Depth Value (cm)
- 16 records with missing values (2.28%)

PRODUCT_WIDTH
- Product Width Value (cm)
- 16 records with missing values (2.28%)

CLUSTER_ID
- Product Cluster Code
- 50 records with missing values (7.15%)

HIERARCHY_ID (1 À 5)
- Product Hierarchy Code
- Ranges from the broadest hierarchy (hierarchy1_id) to the most specific (hierarchy5_id)
- No missing values

SALES.CSV

_CO
- Column with repeated indexes from the dataset
- No missing values

STORE_ID
- Store Unique Identifier Code
- No missing values

PRODUCT_ID
- Product Unique Identifier Code
- No missing values

DATE
- Sale Date (for product X at store Y)
- No missing values

SALES
- Quantity of Product X Sold at Store Y on Date Z
- 302,296 fields with missing values (3.40%)

REVENUE
- Revenue (€) of Product X Sold at Store Y on Date Z
- 302,296 fields with missing values (3.40%)

STOCK
- Stock Quantity of Product X at Store Y on Date Z
- 302,296 fields with missing values (3.40%)

PRICE
- Unit Price of Product (€)
- 91,381 fields with missing values (1.03%)

SALES.CSV

PROMO_TYPE_1
- Promotion Type 1 Identifier Code
- No missing values

PROMO_BIN_1
- Column with Unique Values 'verylow', 'moderate', 'low', 'high', and 'veryhigh'
- 7,653,515 fields with missing values (86.13%)

PROMO_TYPE_2
- Promotion Type 2 Identifier Code
- No missing values

PROMO_BIN_2
- Column with Unique Values 'verylow', 'high', and 'veryhigh'
- 8,873,337 fields with missing values (99.85%)

PROMO_DISCOUNT_2
- Column with Values that Appear to Be Discount Percentages
- 8,873,337 fields with missing values (99.85%)

PROMO_DISCOUNT_TYPE_2
- Discount Code for Promotion Type 2
- 8,873,337 fields with missing values (99.85%)

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PRODUCT.CSV

PRODUCT_ID

Product Unique Identifier Code

699 distinct products

No missing values

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PRODUCT_DEPTH

Product Depth Value (cm)

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Column with repeated indexes from the dataset

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PRODUCT_ID

Product Unique Identifier Code

No missing values

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Silver

Goal --> standardized and clean data

cities_bronze -> cities_silver

- City Name Correction: Removed the "?" character from city names. Ex: ?zmir --> Izmir
- Column Removal - city_old_id: This column was removed as it appeared to be an old city ID. Since the granularity of this table is based on store_id, this old city ID was not relevant, as the city name depends on the store_id.
- Column Removal - country_id: This column was removed as all data pertains to the same country (Turkey).

product_bronze -> product_silver

- Null Handling - Product Dimensions: Null values in product_length, product_depth, and product_width were filled with 0.0.
- Null Handling - cluster_id: Null values in cluster_id were filled with the string "unknown_cluster".

sales_bronze -> sales_silver

- Column Removal - _c0: The _c0 column (repeated indexes) was removed.
- Numerical Column Processing:
  - sales, revenue, stock, and promo_discount_2 columns were converted to float (double) data types. Null values in these columns were imputed with 0.0.
  - For the price column, the median was used for null imputation, as a product price of 0.0 would not make sense.
- Categorical Column Processing:
  - trim was applied to categorical columns.
  - Null values in categorical columns were replaced with the string "NA".

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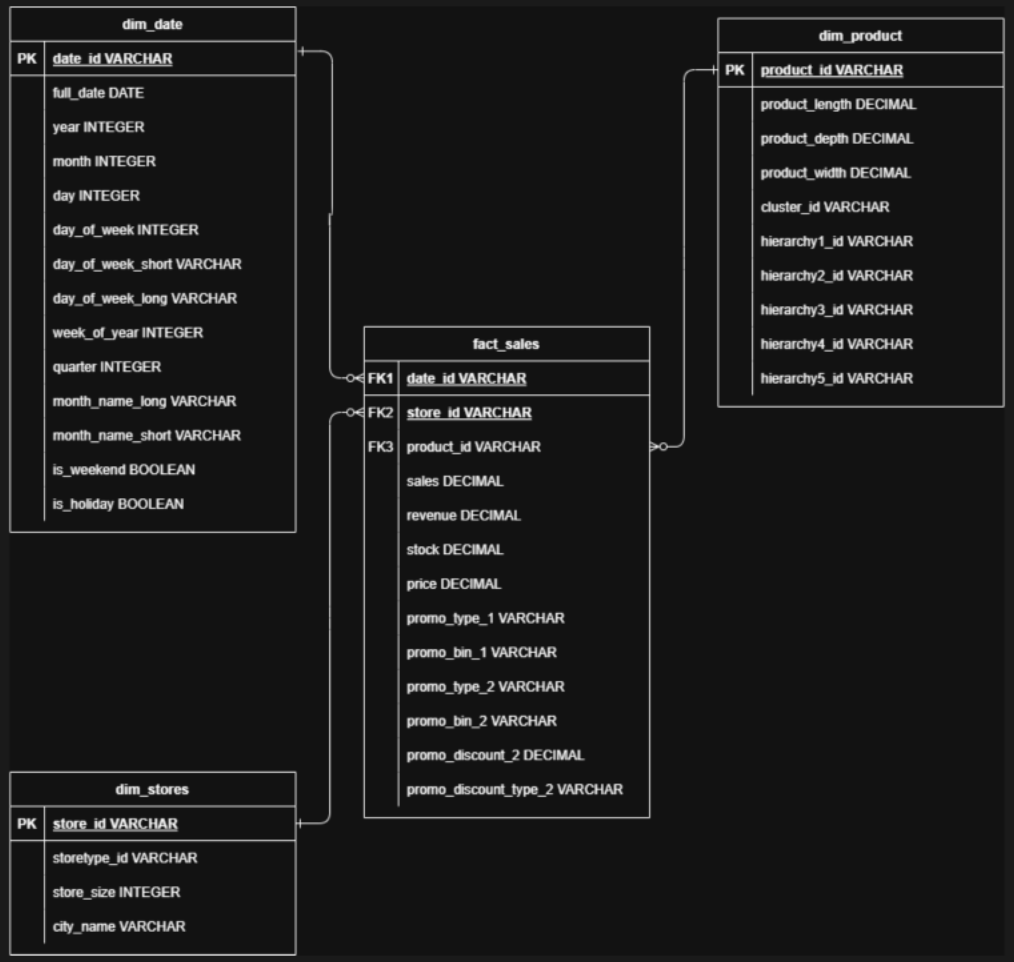
Gold


1
GOLD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PK date_id VARCHAR
full_date DATE
year INTEGER
month INTEGER
day INTEGER
day_of_week INTEGER
day_of_week_short VARCHAR
day_of_week_long VARCHAR
week_of_year INTEGER
quarter INTEGER
month_name_long VARCHAR
month_name_short VARCHAR
is_weekend BOOLEAN
is_holiday BOOLEAN
dim_product
PK product_id VARCHAR
product_length DECIMAL
product_depth DECIMAL
product_width DECIMAL
cluster_id VARCHAR
hierarchy1_id VARCHAR
hierarchy2_id VARCHAR
hierarchy3_id VARCHAR
hierarchy4_id VARCHAR
hierarchy5_id VARCHAR
fact_sales
FK1 date_id VARCHAR
FK2 store_id VARCHAR
FK3 product_id VARCHAR
sales DECIMAL
revenue DECIMAL
stock DECIMAL
price DECIMAL
promo_type_1 VARCHAR
promo_bin_1 VARCHAR
promo_type_2 VARCHAR
promo_bin_2 VARCHAR
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promo_discount_type_2 VARCHAR
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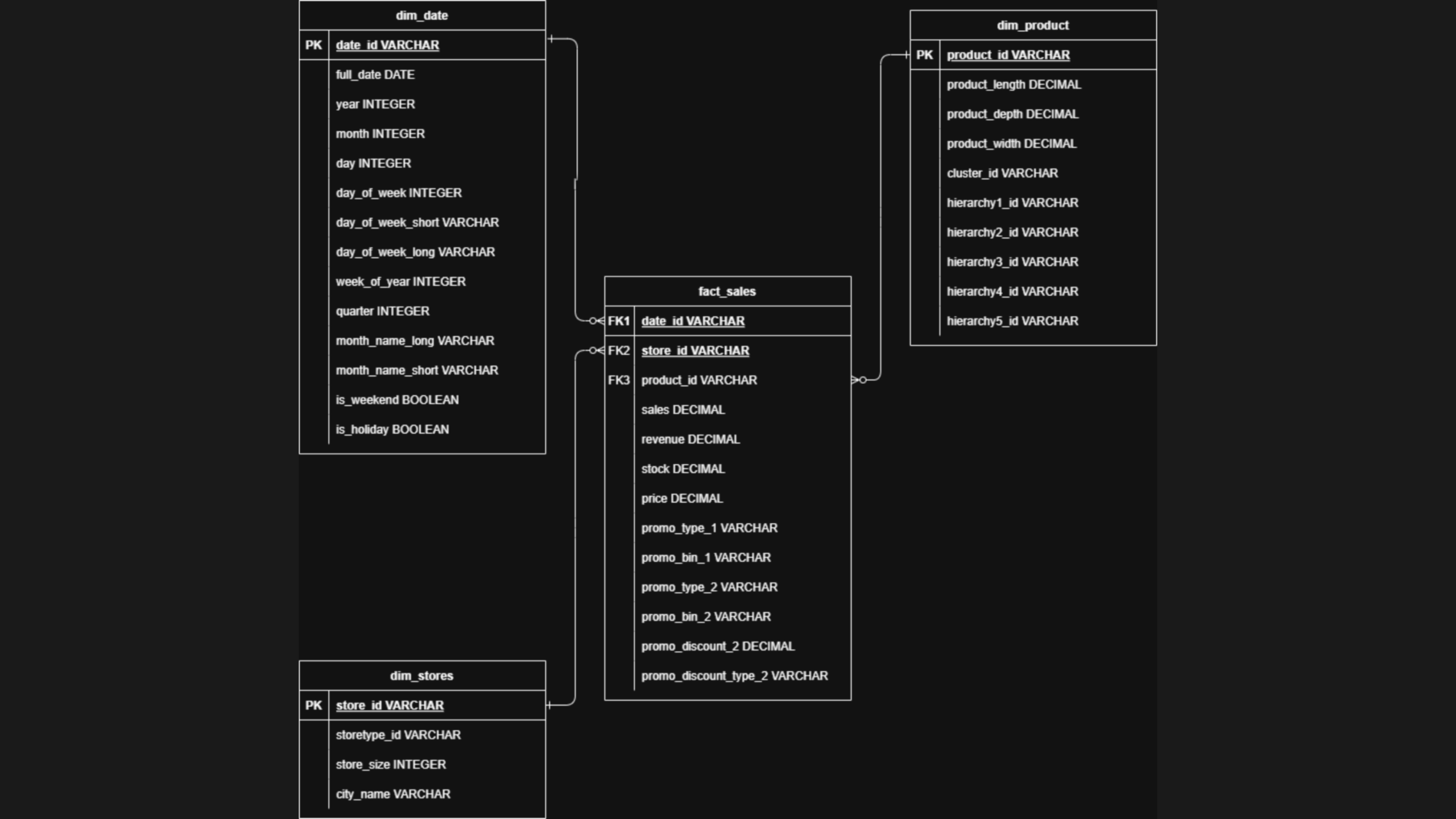
store_size INTEGER
city_name VARCHAR


dim_date
PK
date_id VARCHAR
full_date DATE
year INTEGER
month INTEGER
day INTEGER
day_of_week INTEGER
day_of_week_short VARCHAR
day_of_week_long VARCHAR
week_of_year INTEGER
quarter INTEGER
month_name_long VARCHAR
month_name_short VARCHAR
is_weekend BOOLEAN
is_holiday BOOLEAN
dim_product
PK
product_id VARCHAR
product_length DECIMAL
product_depth DECIMAL
product_width DECIMAL
cluster_id VARCHAR
hierarchy1_id VARCHAR
hierarchy2_id VARCHAR
hierarchy3_id VARCHAR
hierarchy4_id VARCHAR
hierarchy5_id VARCHAR
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FK1
date_id VARCHAR
FK2
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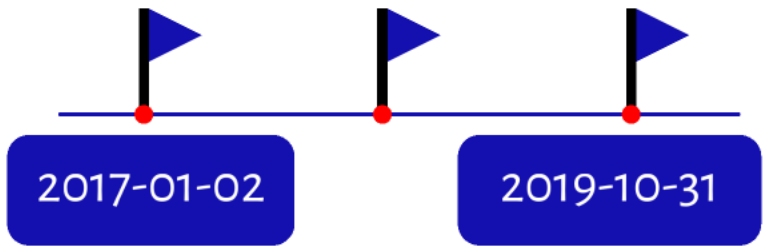
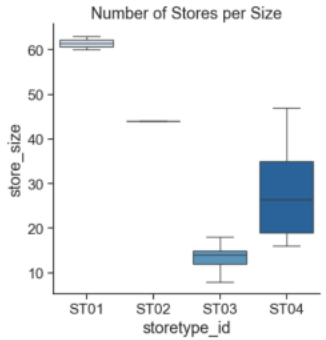
product_id VARCHAR
sales DECIMAL
revenue DECIMAL
stock DECIMAL
price DECIMAL
promo_type_1 VARCHAR
promo_bin_1 VARCHAR
promo_type_2 VARCHAR
promo_bin_2 VARCHAR
promo_discount_2 DECIMAL
promo_discount_type_2 VARCHAR
dim_stores
PK
store_id VARCHAR
storetype_id VARCHAR
store_size INTEGER
city_name VARCHAR

EDA: INITIAL INSIGHTS

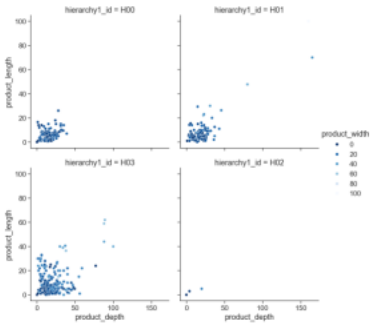
Timeline



- 4 store types.
- ST01 and ST02: 2 and 1 stores, respectively, but larger store sizes.
- ST03 and ST04: 20 and 40 stores, respectively, but smaller in size.

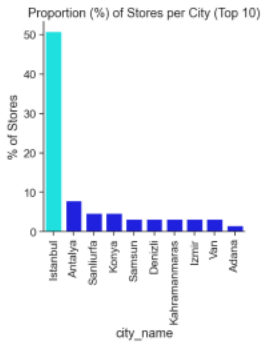


- Small products in general.
- No clear difference between categories in Hierarchy 1.
- Values of zero are due to imputation regarding missing values (NA) or when one of the feature is zero (fabric peace).



- 5 products hierarchy.
- Hierarchy 1 has 4 categories.
- H02 represents only 1.6% of total products.

- 19 cities.
- Around 51% of the stores are in Istanbul.



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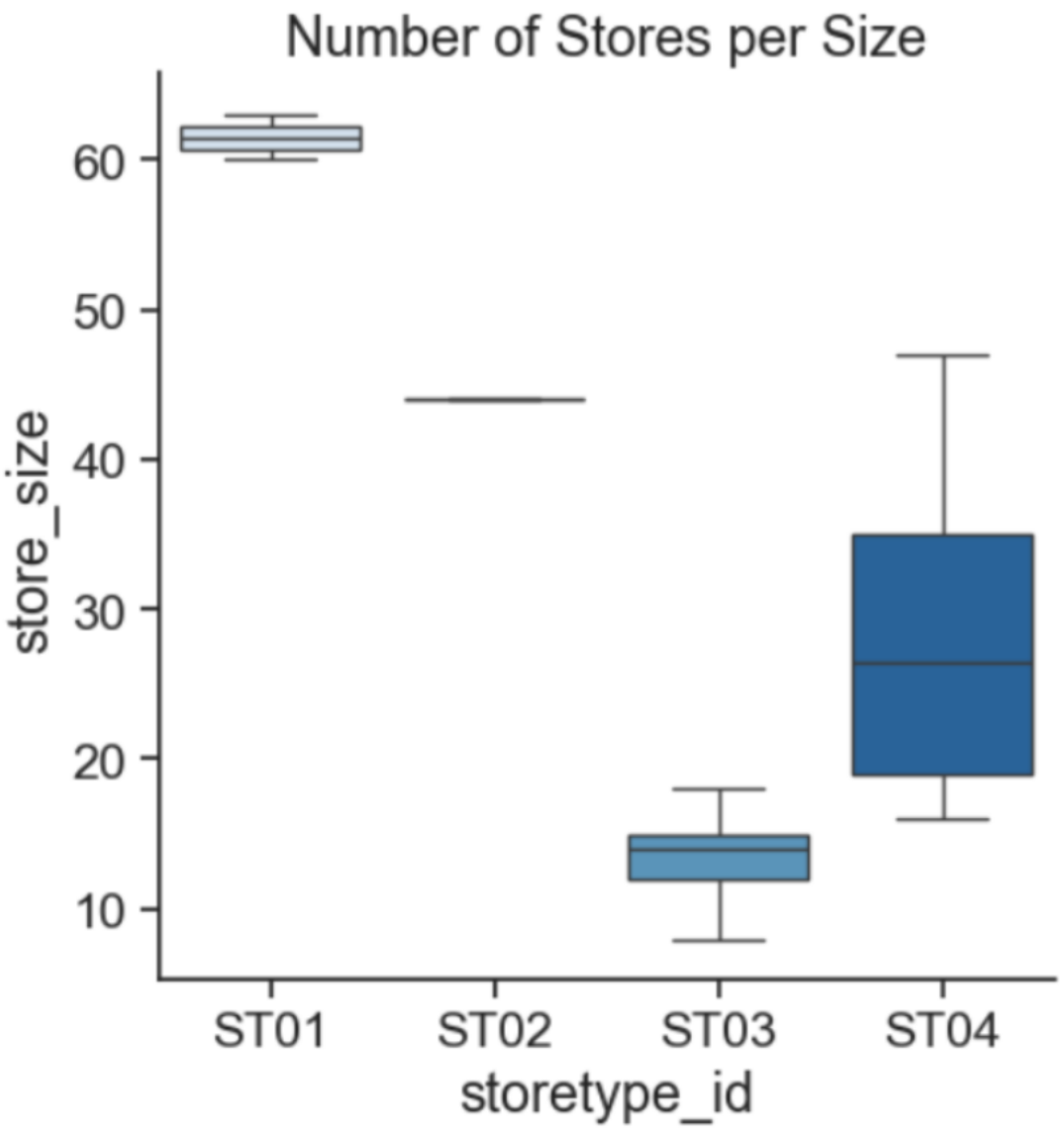

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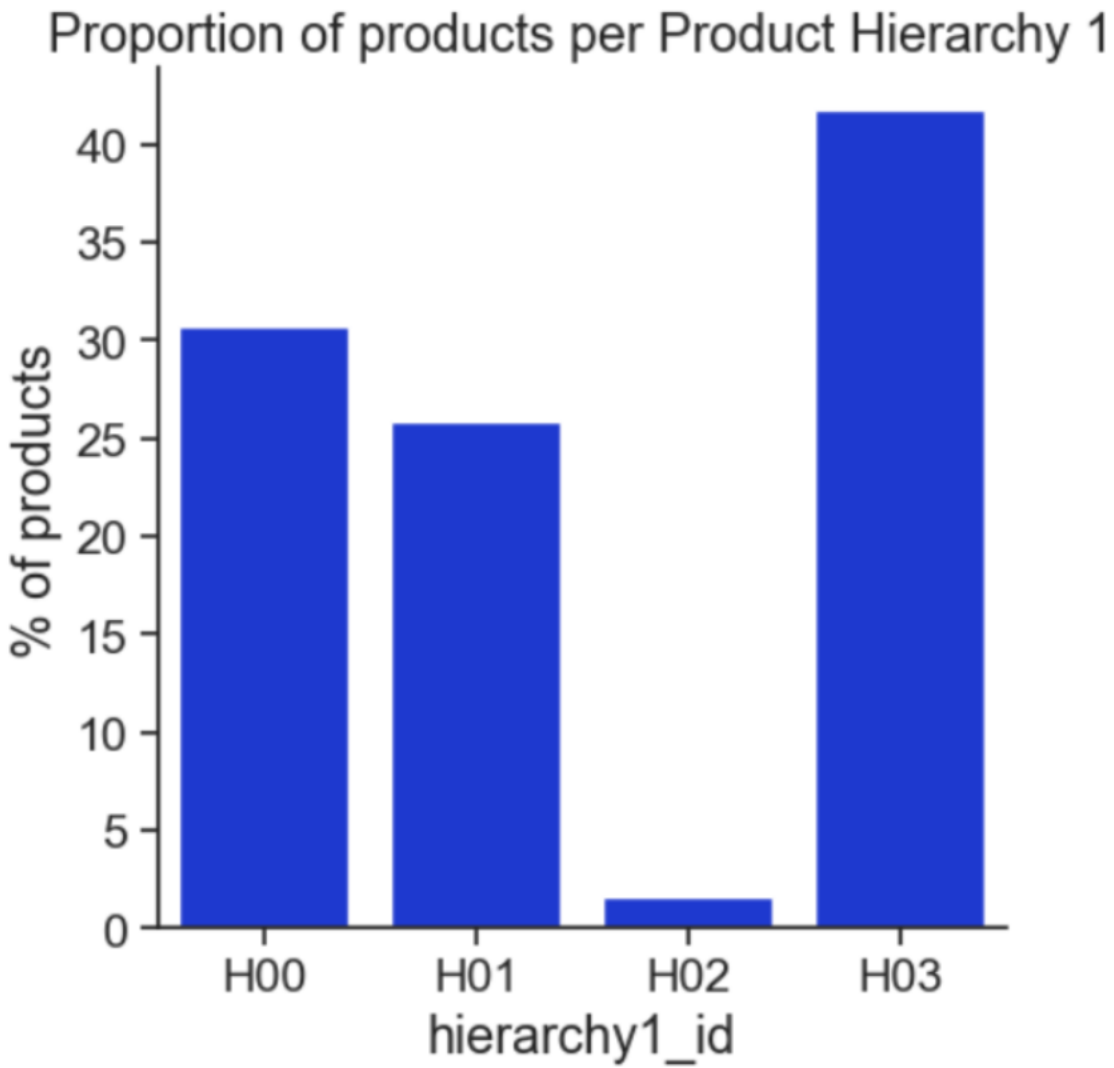

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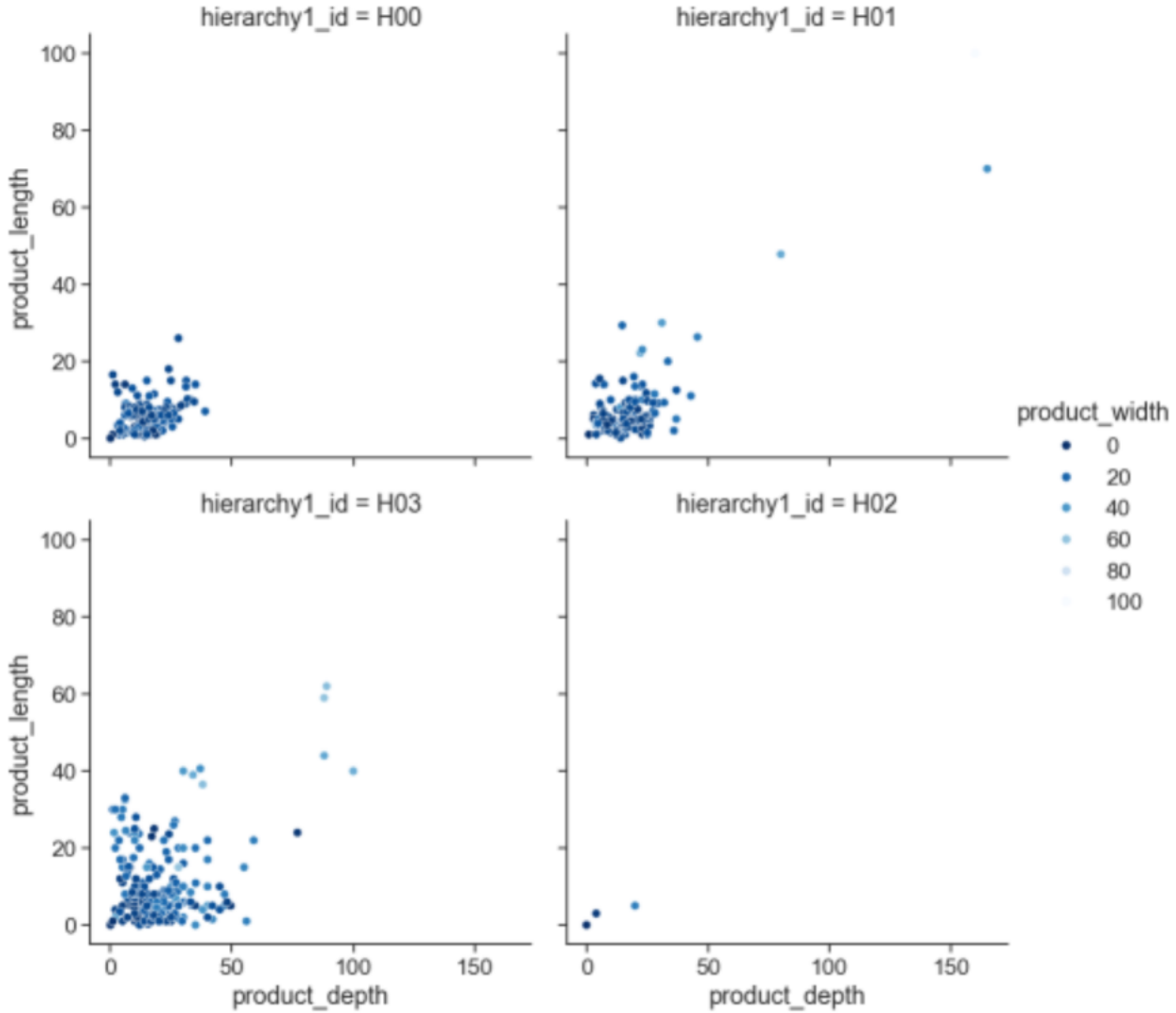

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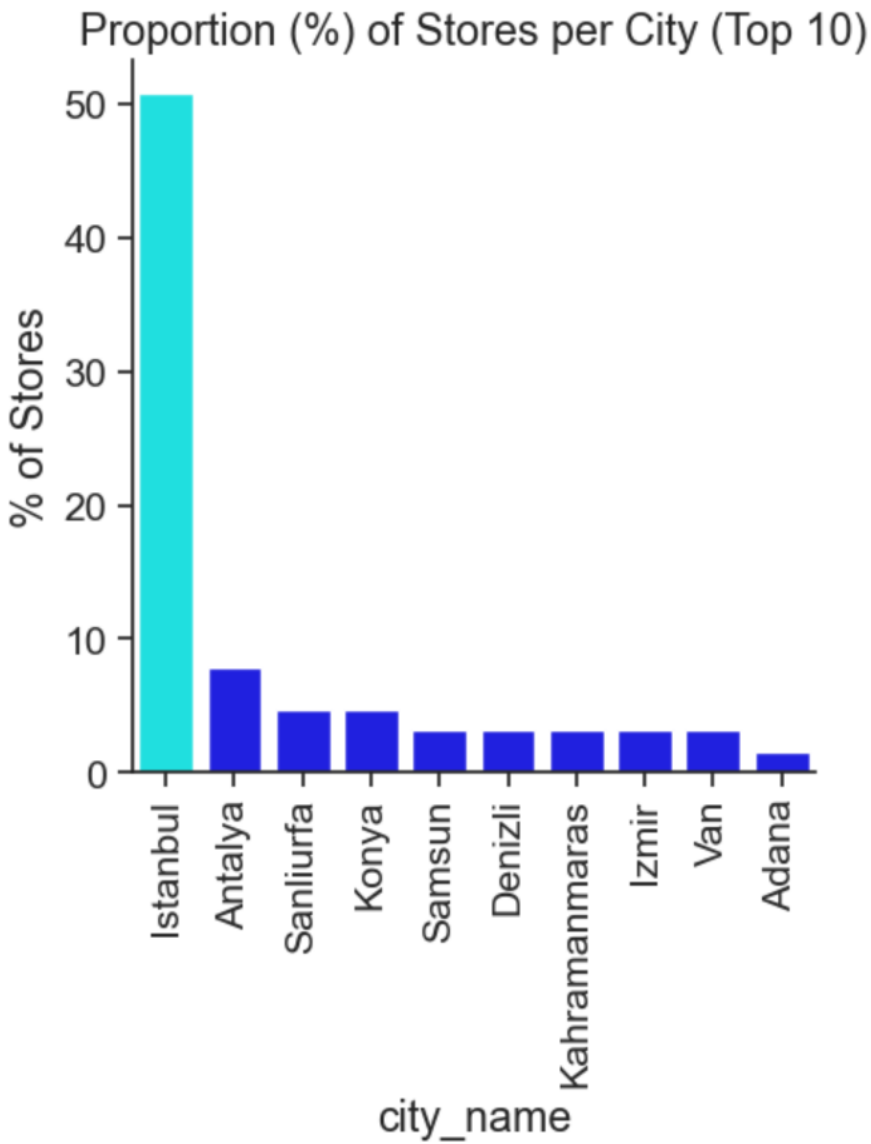
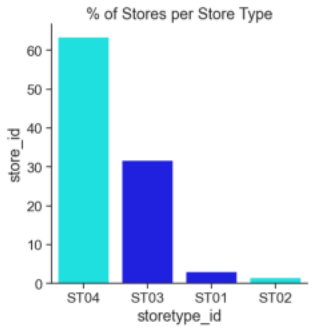
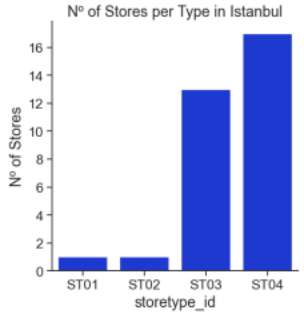


EDA: PROOF OF CONCEPT

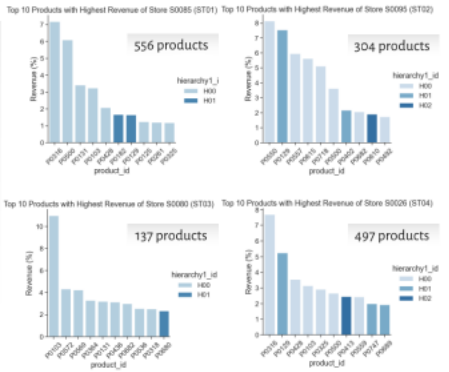
- ST04 has the highest number of stores
- ST02 (and ST01) have a signifant low number of stores.



- Bursa has the highest revenue and sales mean.
- However, Bursa has only 1 store.
- Istanbul has the second highest revenue and sales mean.
- Istanbul has all type of stores.

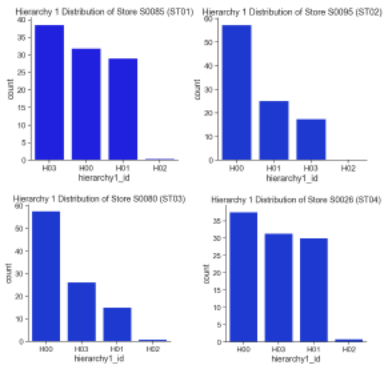


- The Top 10 products in each store represents between 29% and 44% of total Revenue.
- Majority of products are H00, a few H01 and H02, and no H03 products.

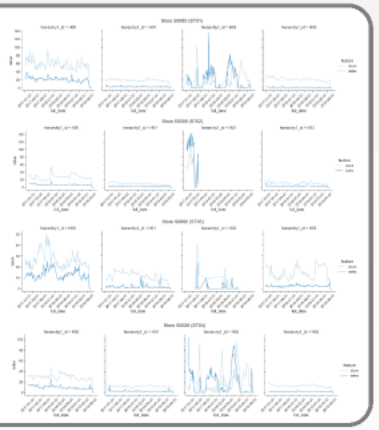


- ST02 (and ST01) stores represent the highest revenue mean per store.

- PoC Scope:
  - 1 store per type in Istanbul.
  - Select the stores with the highest revenue and sales.
  - Hierarchy 1 division.



- Clear higher amount of stock than sales in the end of each week, except for H02.
- Min-max inventory analysis.



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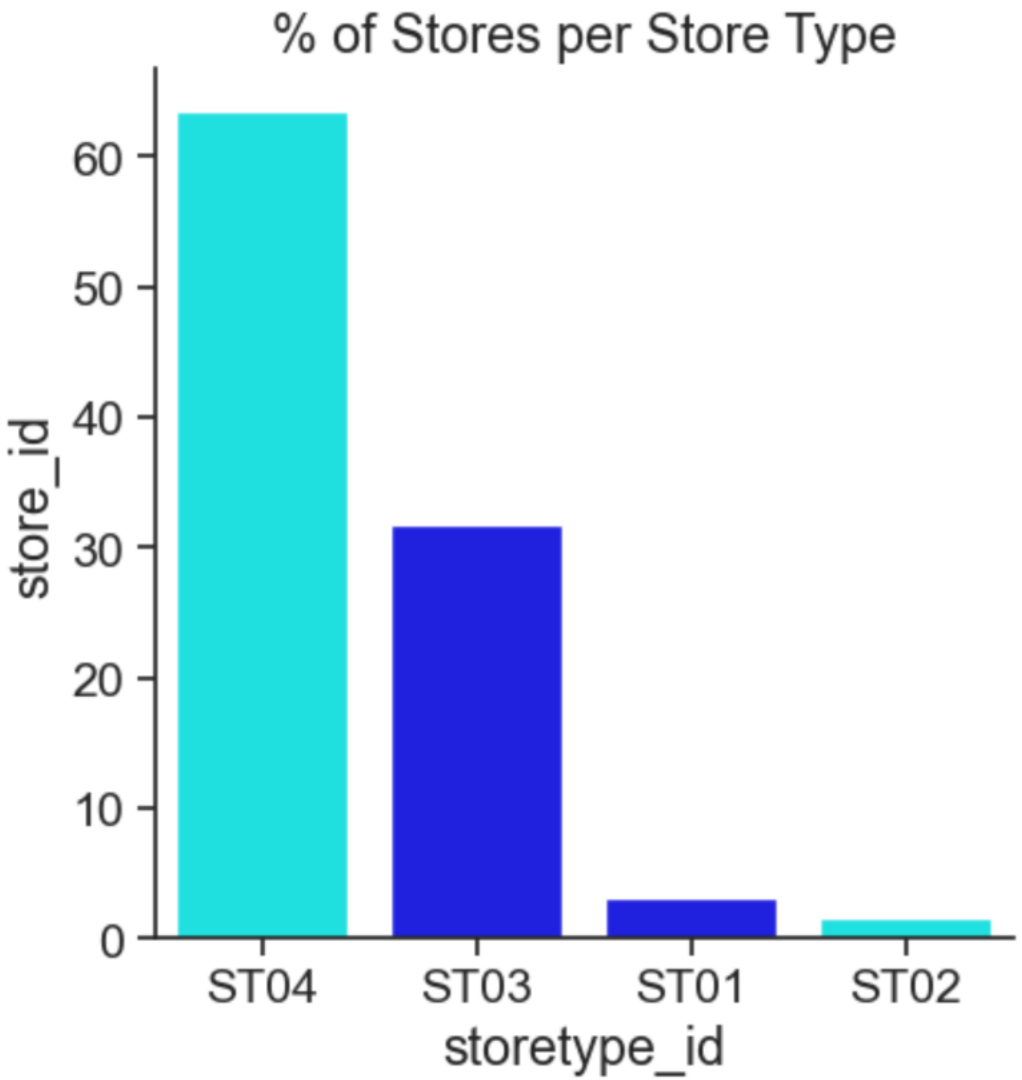

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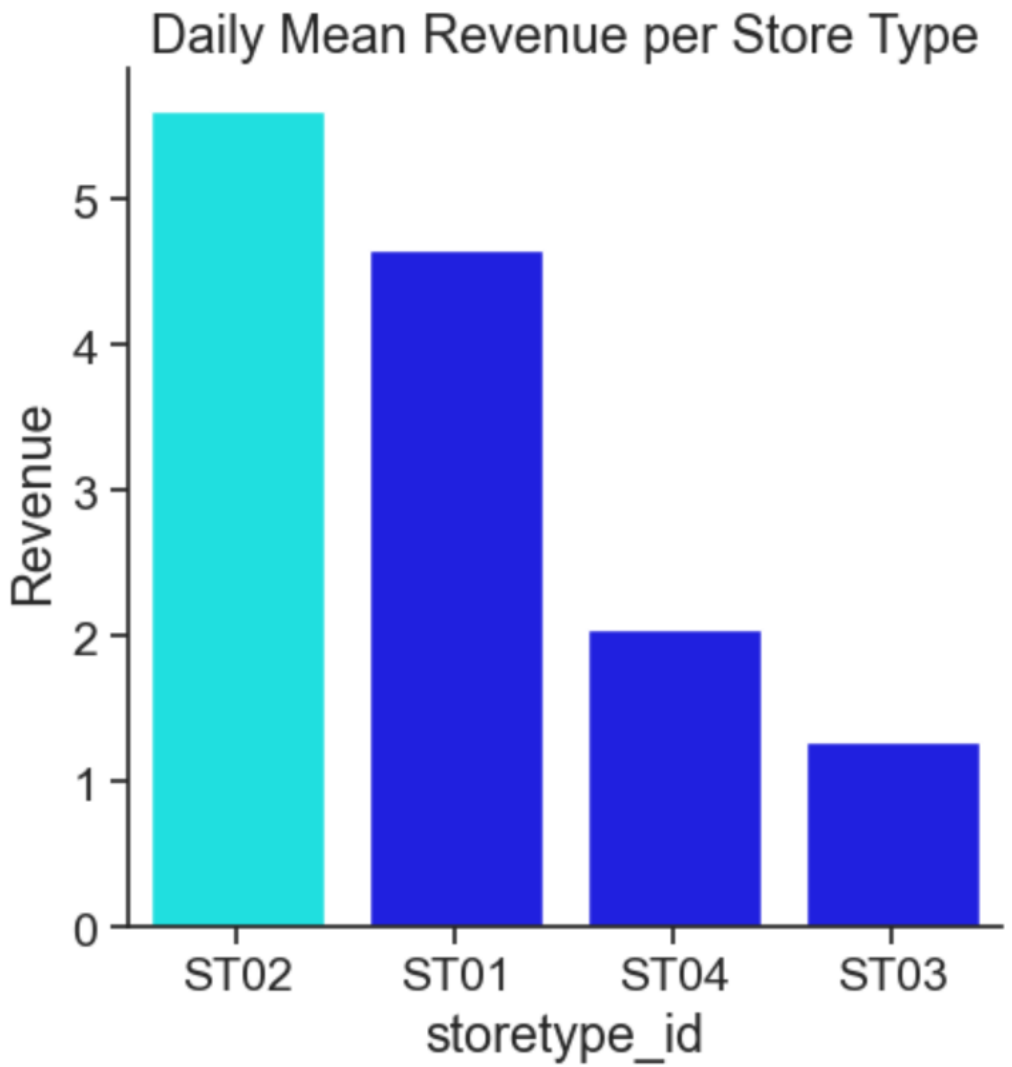

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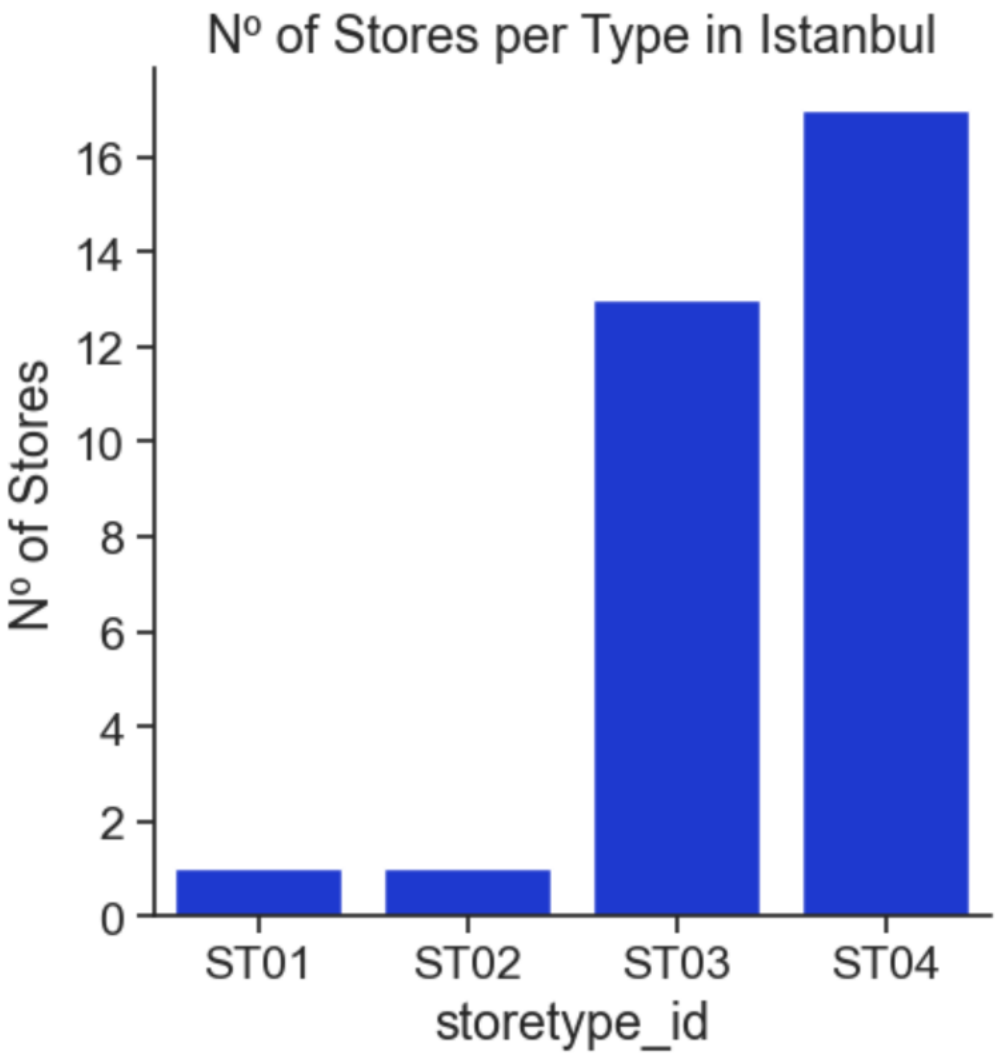

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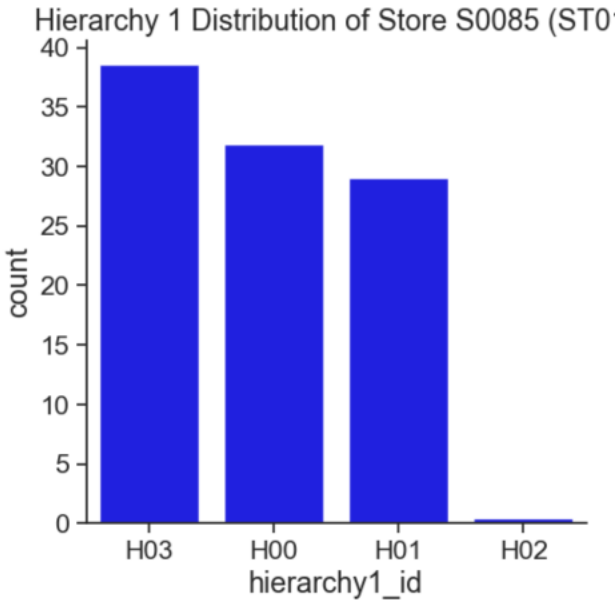

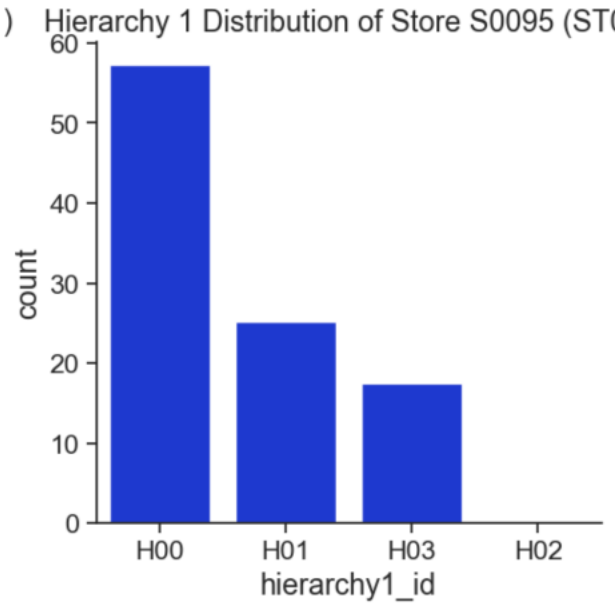

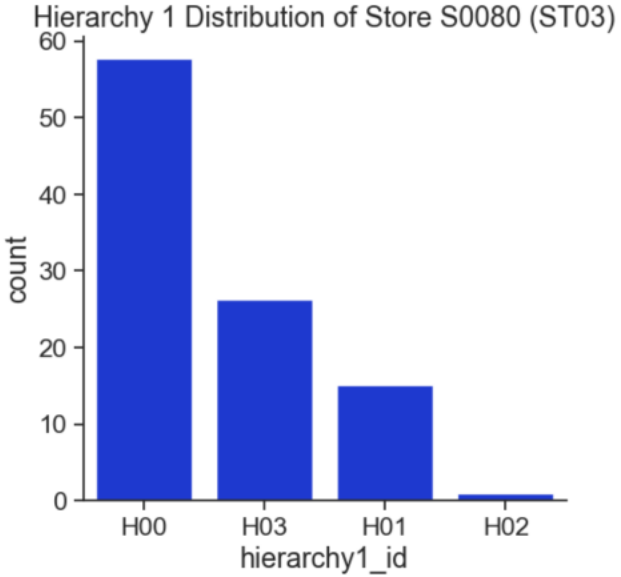

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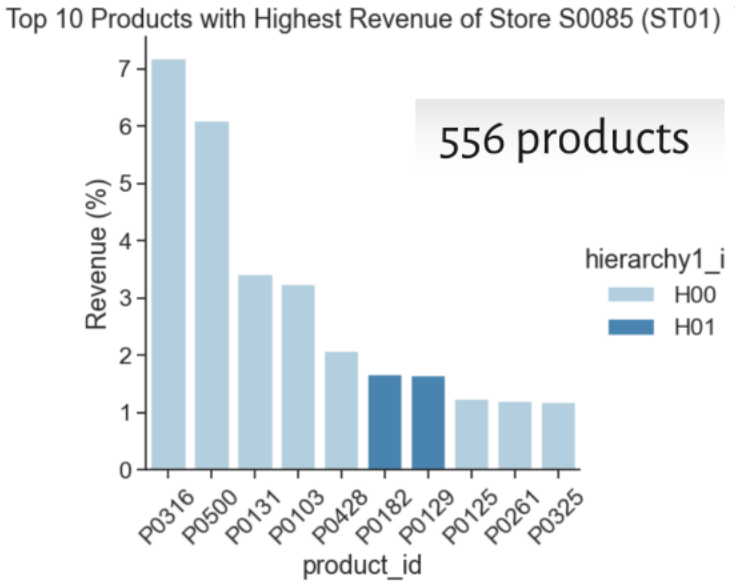

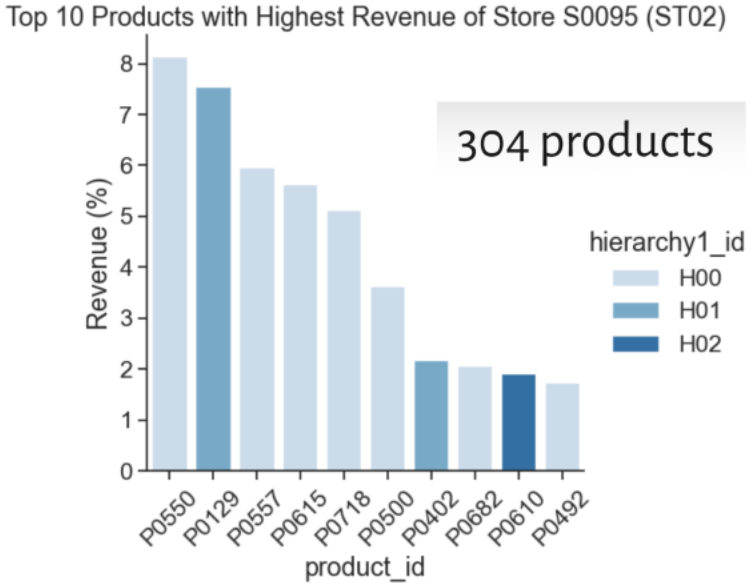

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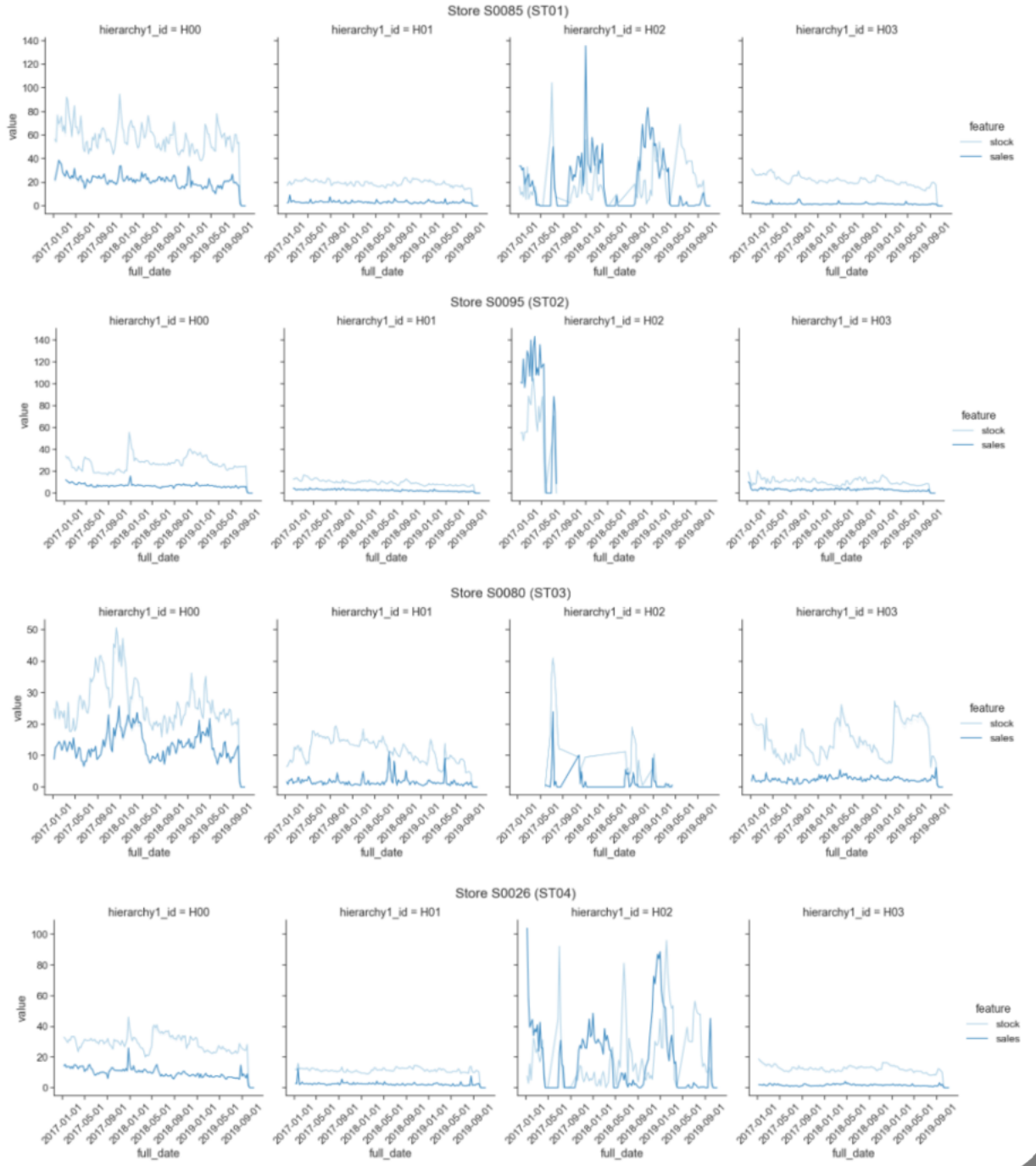
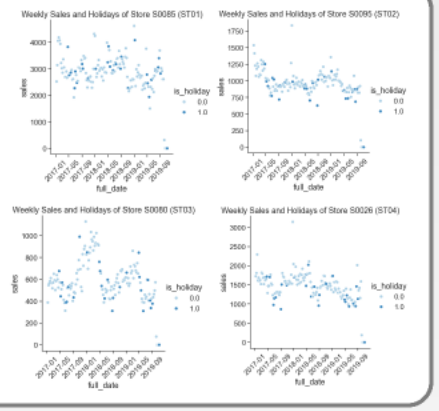


EDA: PROOF OF CONCEPT

- It looks like there is no difference on sales between weeks with and without holidays.



- There are 17 types of promo 1.
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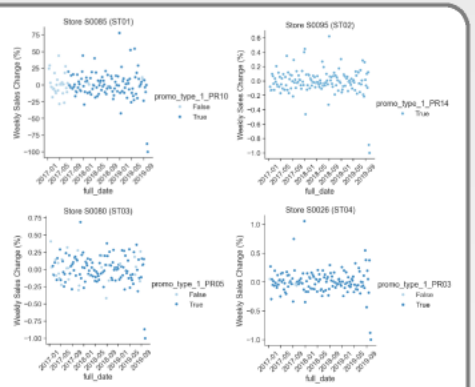

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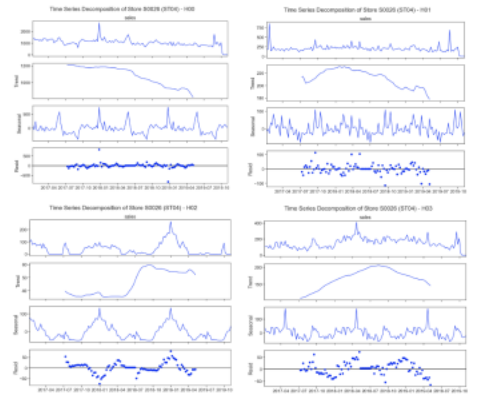

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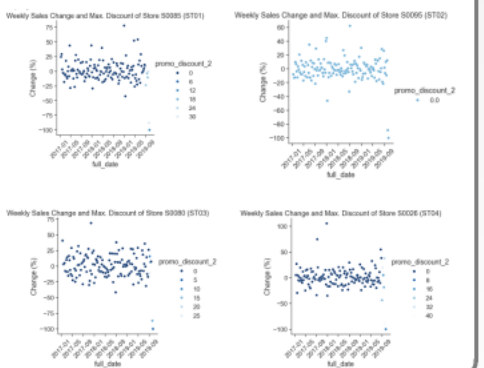
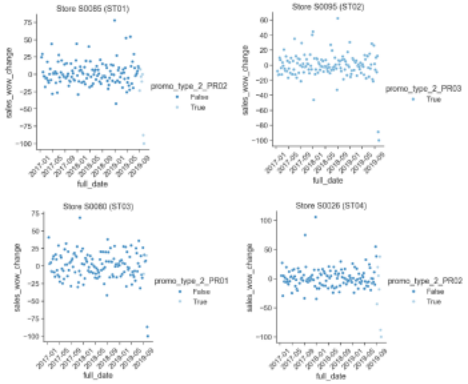
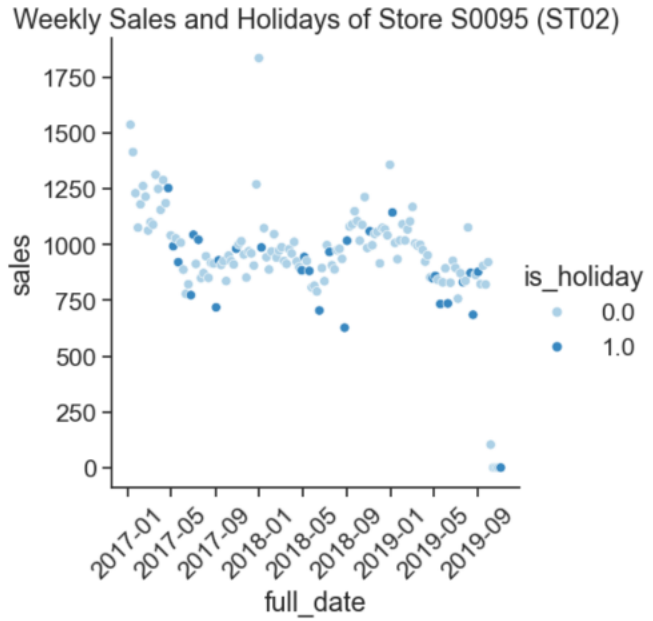
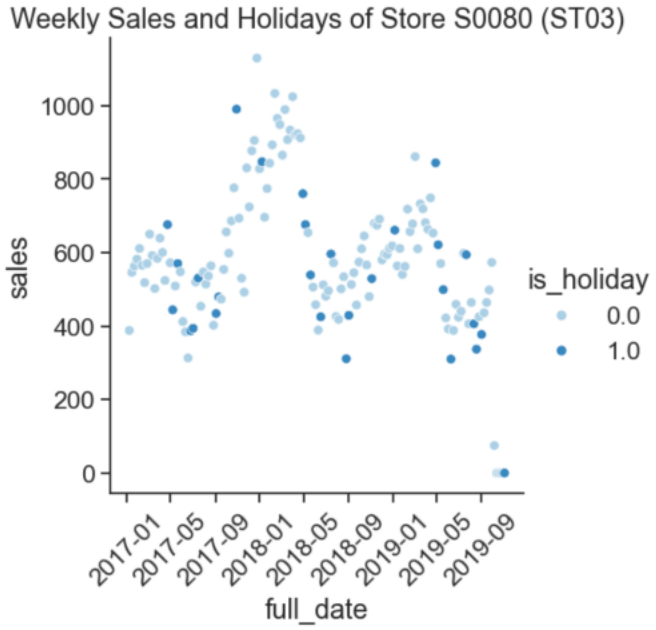


- There are 4 types of promo 2.
- It looks like there is no significant impact of promotions of type 2 in the weekly sales change.



- It looks like there is no difference on sales between weeks with and without holidays.





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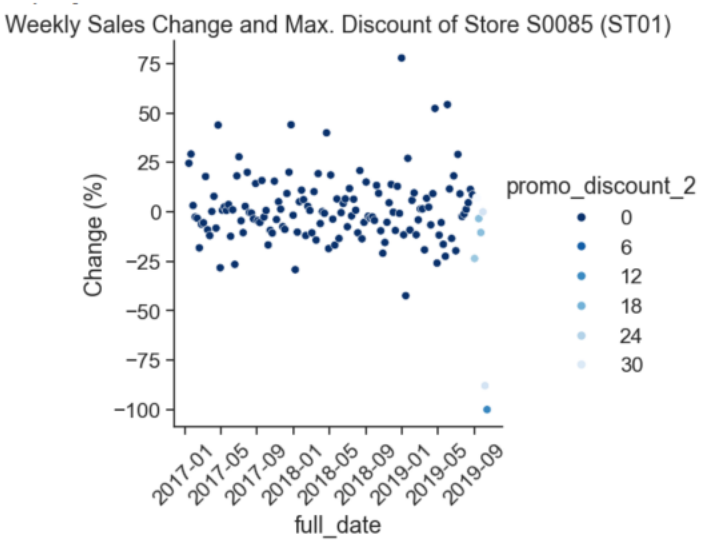

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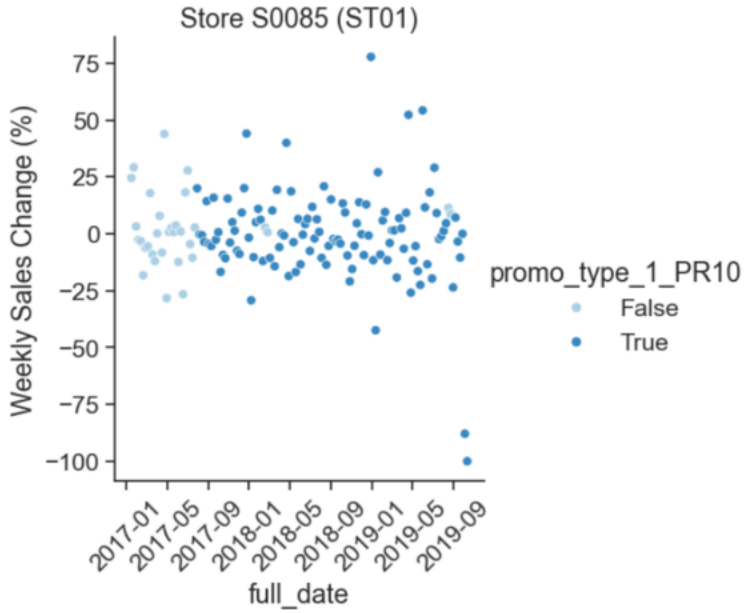

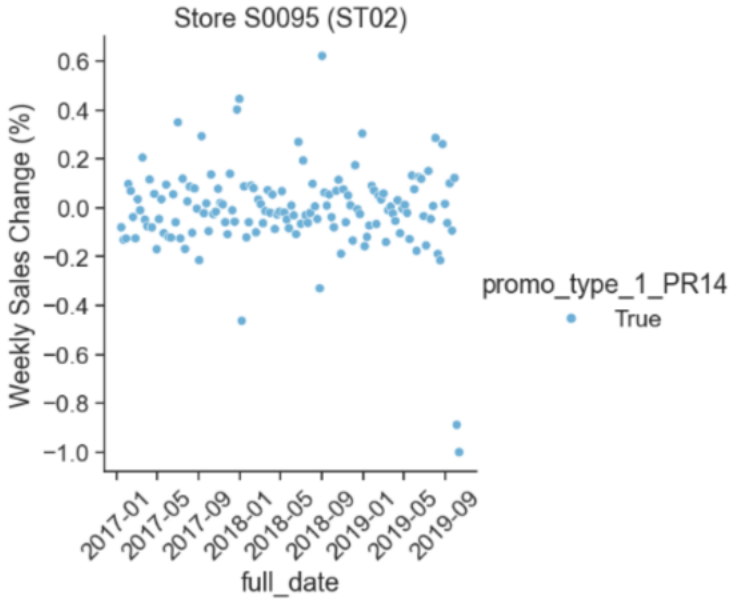

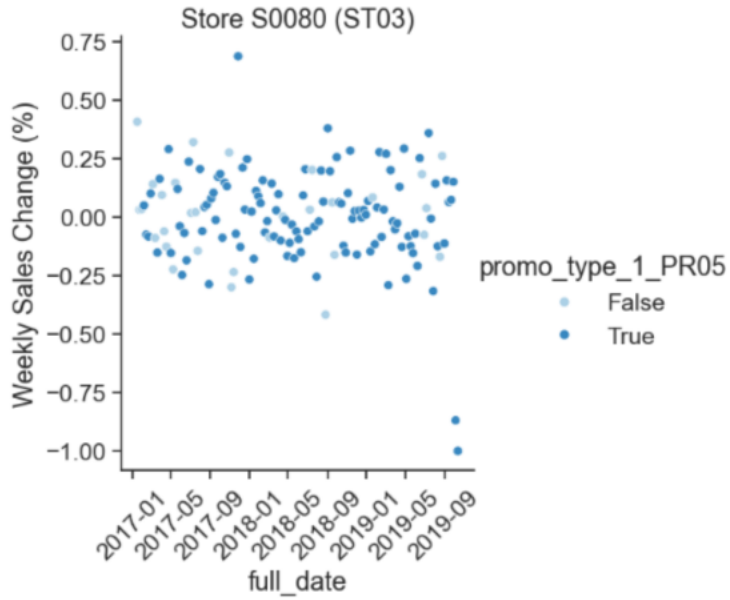

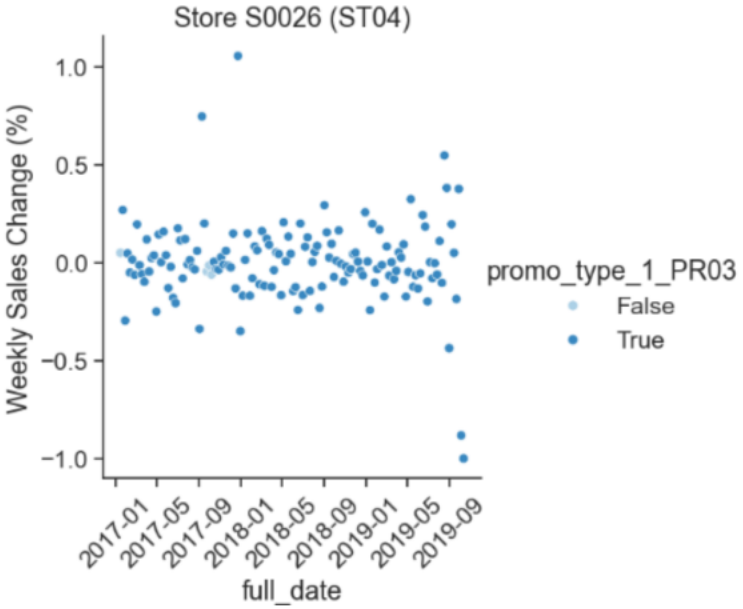

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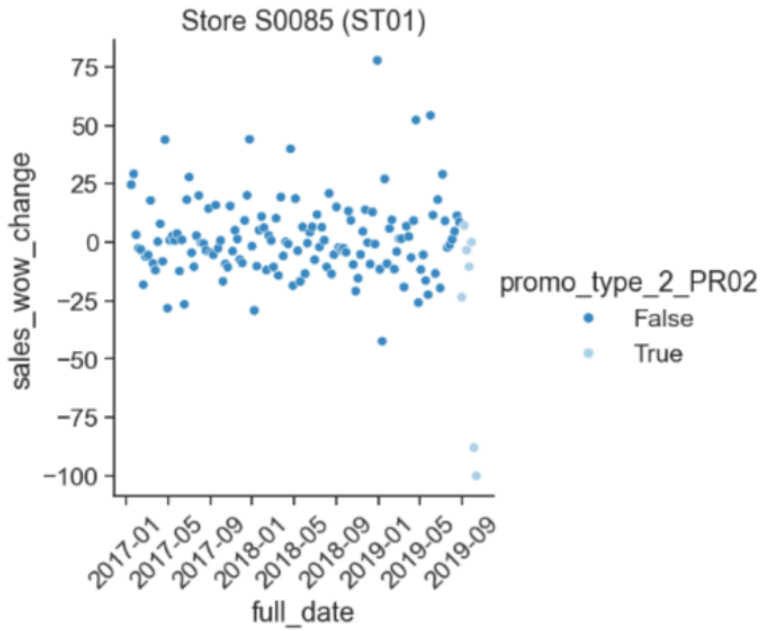

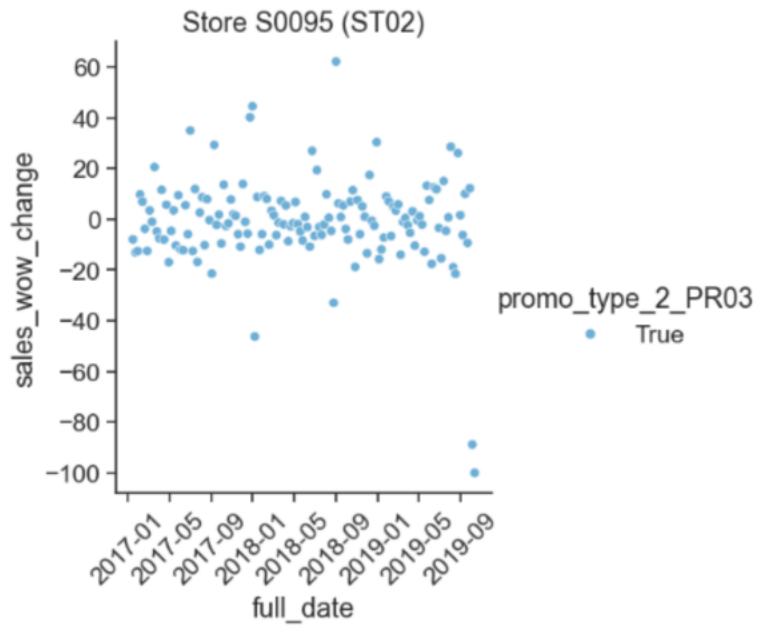

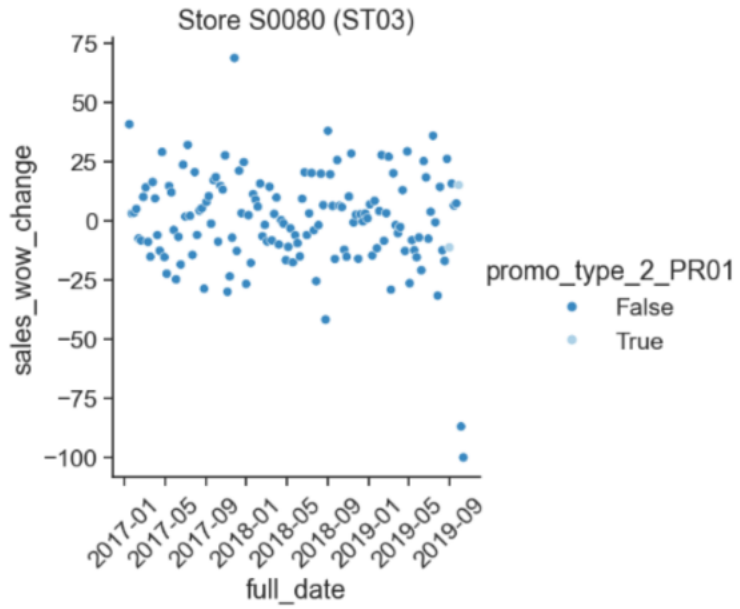

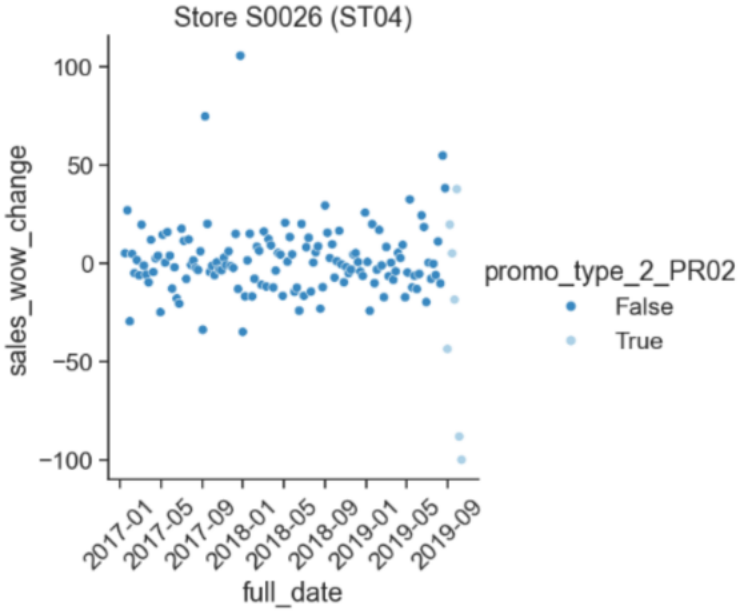

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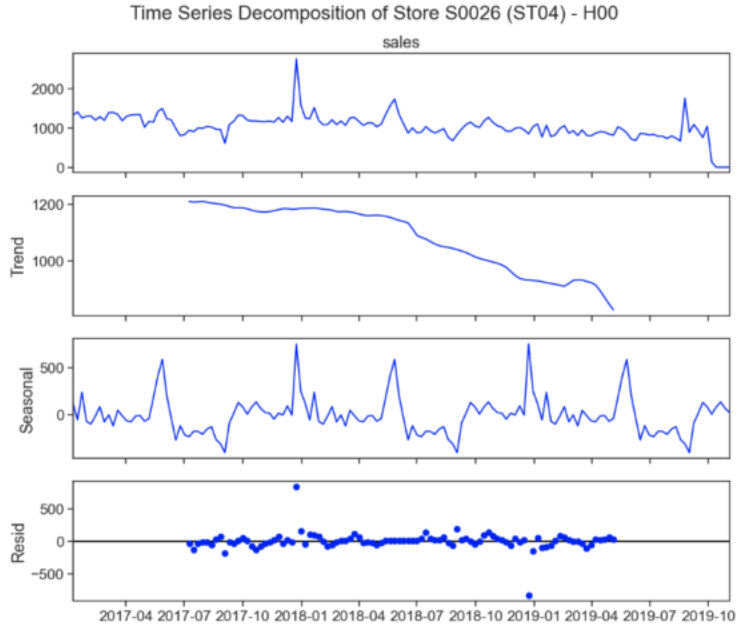
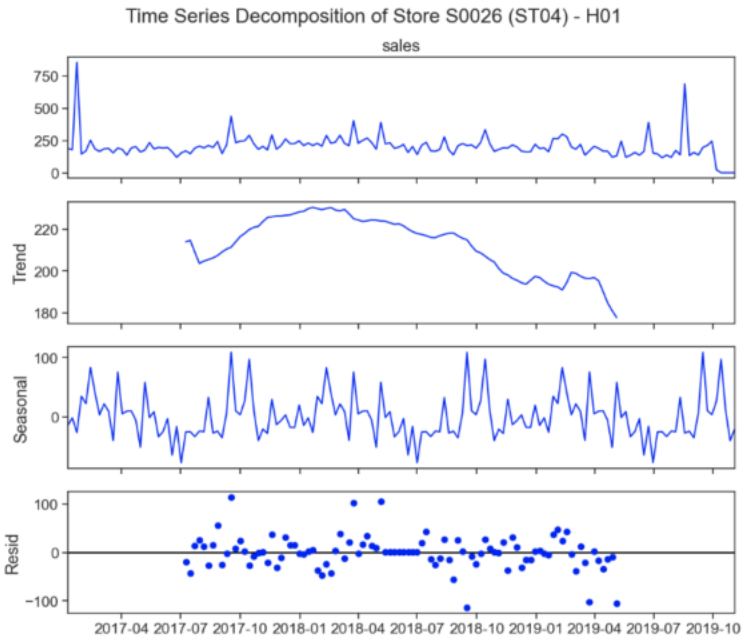
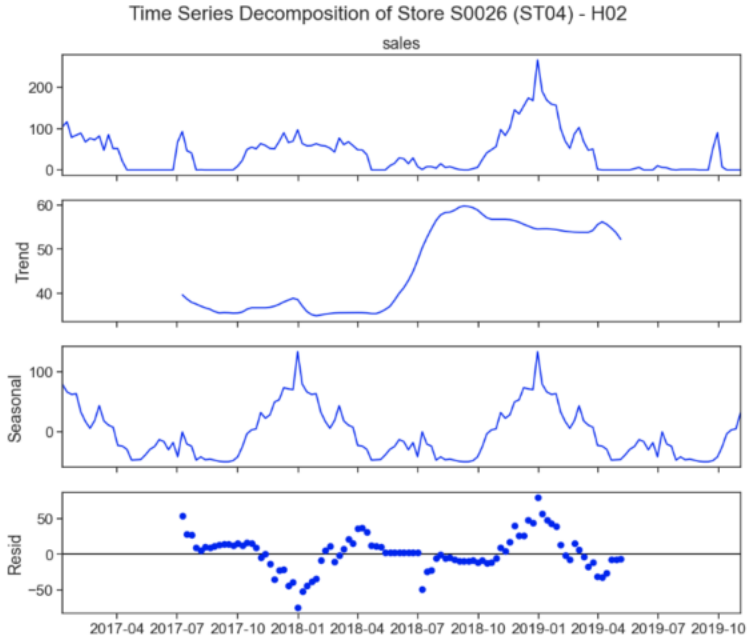
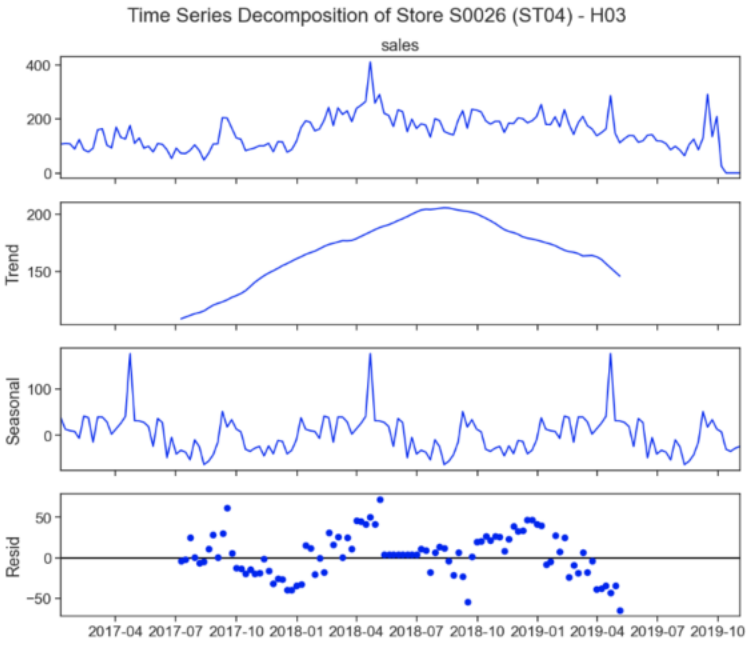






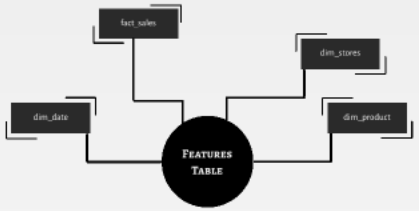


Features Table

Features Creation

Features Table

- weekly_sales(target)
- avg_stock
- avg_price
- num_obs
- is_holiday
- is_weekend
- lag_sales_1w
- lag_sales_2w
- lag_sales_3w
- week_start



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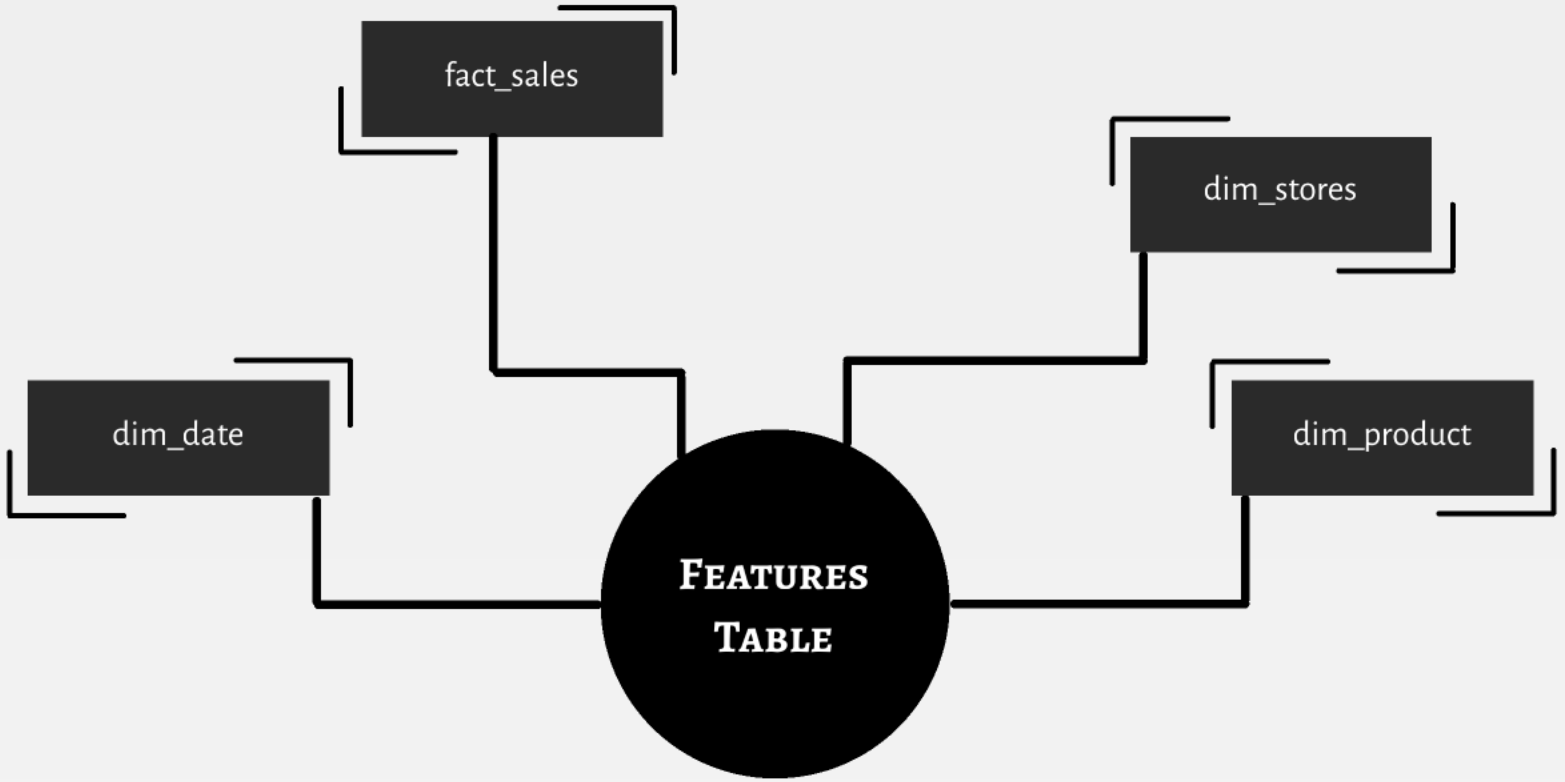

Linear Regression

PROOF OF CONCEPT

PROOF OF CONCEPT

Stores "S0085", "S0095", "S0080", "S0026"

Categories H00, H01, H02 and H03

Proof of Concept Process

1- Filter the Store and Product Category
2- Do train-test split according to dates
3- Regression with target "weekly sales" and features "other variables"
4- Check model metrics (R2 and MAE)

We didn't think it was enough

We used Lasso to identify the most important variables in the model.

S0085	H00	"avg_stock", "lag_sales_1w", "lag_sales_3w",
S0085	H01	"avg_stock"
S0085	H02	"week", "avg_stock", "lag_sales_1w", "lag_sales_3w"
S0085	H03	"avg_stock", "avg_price"
S0095	H00	"avg_stock", "avg_price", "lag_sales_1w"
S0095	H01	"avg_stock"
S0095	H02	"avg_stock"
S0095	H03	"avg_price" "lag_sales_1w", "lag_sales_3w",
S0080	H00	"avg_stock", "lag_sales_1w", "lag_sales_3w",
S0080	H02	"Week"
S0080	H03	"avg_stock", "avg_price", "product_width"
S0026	H00	"avg_stock", "lag_sales_1w", "lag_sales_2w", "lag_sales_3w"
S0026	H01	"avg_stock"
S0026	H02	"week", "avg_stock","lag_sales_1w", "lag_sales_2w", "lag_sales_3w"
S0026	H03	"lag_sales_1w", "lag_sales_2w", "lag_sales_3w"

"avg_stock",	12 em 16
"avg_price"	4 em 16
"lag_sales_1w",	8 em 16
"lag_sales_2w",	3 em 16
"lag_sales_3w",	7 em 16
"week"	3 em 16

S0085	H00	0.9935	R^2: 0.7956	1.0035	R^2 on test set: 0.7956
S0085	H01	0.3704	R^2: 0.1475	0.3293	R^2 on test set: 0.1475
S0085	H02	2.2462	R^2: -1.8740	1.8308	R^2 on test set: -1.8740
S0085	H03	0.1644	R^2: 0.7182	0.1894	R^2 on test set: 0.7182
S0095	H00	0.4019	R^2: 0.7956	0.231	R^2 on test set: 0.7956
S0095	H01	0.2804	R^2: 0.2822	0.1772	R^2 on test set: 0.2822
S0095	H02	8.6106	R^2: -5.5166	8.2994	R^2 on test set: -5.5166
S0095	H03	0.2278	R^2: 0.8196	0.231	R^2 on test set: 0.8196
S0080	H00	0.7543	R^2: 0.6879	0.7817	R^2 on test set: 0.6879
S0080	H01	0.2433	R^2: -0.4934	0.2659	R^2 on test set: -0.4934
S0080	H02	0.2926	R^2: -0.0829	0.4684	R^2 on test set: -0.0829
S0080	H03	0.3553	R^2: 0.6812	0.4193	R^2 on test set: 0.6812
S0026	H00	0.5114	R^2: 0.1743	0.5154	R^2 on test set: 0.1743
S0026	H01	0.3358	R^2: 0.1110	0.2914	R^2 on test set: 0.1110
S0026	H02	2.3408	R^2: -0.2775	1.7344	R^2 on test set: -0.2775
S0026	H03	0.183	0.8436	0.1896	R^2 on test set: 0.8436

R^2: 0.7956	1.0035	R^2 on test set: 0.7956
R^2: 0.1475	0.3293	R^2 on test set: 0.1475
R^2: -1.8740	1.8308	R^2 on test set: -1.8740
R^2: 0.7182	0.1894	R^2 on test set: 0.7182
R^2: 0.7956	0.231	R^2 on test set: 0.7956
R^2: 0.2822	0.1772	R^2 on test set: 0.2822
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R^2: 0.8196	0.231	R^2 on test set: 0.8196
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R^2: -0.4934	0.2659	R^2 on test set: -0.4934
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R^2: 0.6812	0.4193	R^2 on test set: 0.6812
R^2: 0.1743	0.5154	R^2 on test set: 0.1743
R^2: 0.1110	0.2914	R^2 on test set: 0.1110
R^2: -0.2775	1.7344	R^2 on test set: -0.2775
0.8436	0.1896	R^2 on test set: 0.8436

Train R^2: 0.11915454802471326
Train MAE: 0.4351829771075341

Regressão Linear (3 Features) - Coeficientes:

beta1: 0.0147
beta2: -0.0017
beta3: 0.2449
beta4: 0.0099
beta5: 0.1876

beta0 (intercepto): 0.0727

📊 Avaliação do Modelo:
MAE: 0.3022
R^2: 0.3820

R^2 on test set: 0.3820
MAE: 0.3241

Predictive Model for Inventory Management

Sales Analysis and Forecasting in Department Stores in Turkey

01 The data from three .csv files were loaded into Microsoft Fabric.

02 The files are: 'stores.csv', 'product.csv' e 'sales.csv'

03 An initial Exploratory Data Analysis (EDA) was performed on the data to understand its quality.

Data Sources

Bronze

Raw data was transformed into a managed, transactional format (Delta Lake) within the Bronze Lakehouse.

Silver

Goal --> standardized and clean data

Gold

EDA: Initial Insights

EDA: Proof of Concept

EDA: Proof of Concept

Data ELT

Medallion Architecture

Projects Goals

Linear Regression

PROOF OF CONCEPT

Stores "Stor01", "Store1", "Stor01", "Store1"

Categories Hbc, Hbi, Hlcp and Hcs

"avg_stock",	12 em 16
"avg_price"	4 em 16
"lag_sales_1w",	8 em 16
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"lag_sales_3w",	7 em 16
"week"	3 em 16

Train R^2: 0.11915454802471326
Train MAE: 0.4351829771075341

R^2 on test set: 0.3820
MAE: 0.3241

Features Table

Time Series Models

Dashboard

Thank you All!!!

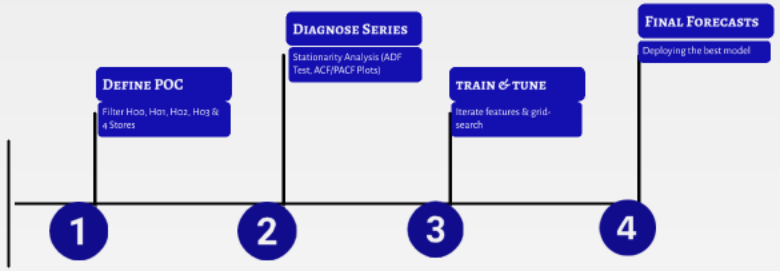
Grupo_01

Angel Teixeira
Patrícia Pereira
Rebeque Duque
Yves Mercelles

Thrash

Time Series Models

4-Step Modelling Pipeline



Baseline Results
ARIMA vs ARIMAX

Model	Exogs Used	MAE
ARIMA	None	2846.303435
ARIMAX	Stock	3026.366468
ARIMAX	Stock + Price	3026.366468
ARIMAX	Top 5 Features	3026.366468
ARIMAX	All Features	2846.303435
LinearReg	Stock + Price	619.562897

- We start our model baseline tests with Arima/Arimax and Lin.Regression to validate their predictive results
- Main objetive was to obtain some overall results about each P.O.C hierarchy
- Major insight - ARIMAX was not capturing the signals from the different exog. features

P.O.C Results - SARIMA/ SARIMAX

MAE Values

Hierarchy	Store	SARIMA Train	SARIMA Test	SARIMAX Train	SARIMAX Test
H00	S0095	14.47	62.3	14.9	12.14
	S0085	53.47	123.76	44.16	34.73
	S0026	20.79	41.01	20.88	9.82
	S0080	12.63	81.46	12.95	70.26
H01	S0095	3.73	6.65	3.65	3.51
	S0085	11.51	32.12	10.52	16.74
	S0026	7.63	29.72	7.83	7.72
	S0080	1.49	1.86	1.54	0.29
H02	S0095	3.79	5.21	3.79	5.21
	S0085	2.91	1.6	2.78	1.12
	S0026	4.55	16.27	68.82	18.27
	S0080	0.55	0.87	0.55	0.87
H03	S0095	4.12	9.97	3.52	5.02
	S0085	9.1	18.11	9.04	3.81
	S0026	7.15	12.72	7.67	8
	S0080	2.57	11.72	2.59	11.29

Not Overfitted | Light Overfitting | Overfitting

- SARIMAX wins 15 of 16 cases (94%)
- SARIMA over-fits on high-volume series
- SARIMA showed a better performance on stores with lower volume of observations

Model Selection - Final Winners

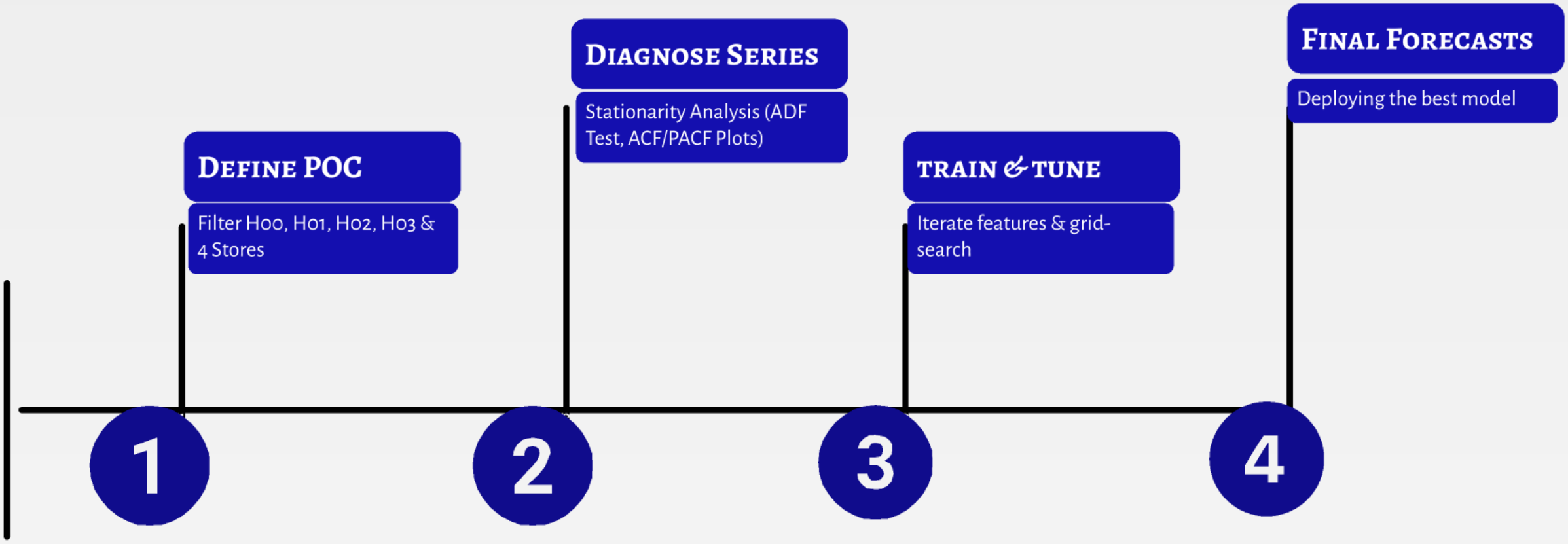
Hierarchy	Store	SARIMA Test	SARIMAX Test	LASSO Train	LASSO Test	LASSO R^2 Test	Best Model
H00	S0095	62.3	12.14	0.40	0.23	0.80	LASSO
	S0085	123.76	34.73	0.99	1.00	0.80	LASSO
	S0026	41.01	9.82	0.51	0.52	0.17	SARIMAX
	S0080	81.46	70.26	0.75	0.78	0.69	LASSO
H01	S0095	6.65	3.51	0.28	0.16	0.28	SARIMAX
	S0085	32.12	16.74	0.37	0.35	0.15	SARIMAX
	S0026	29.72	7.72	0.34	0.29	0.11	SARIMAX
	S0080	1.86	0.29	0.24	0.27	-0.49	SARIMAX
H02	S0095	5.21	5.21	8.61	8.30	-5.52	SARIMAX
	S0085	1.6	1.12	2.25	1.83	-1.87	SARIMAX
	S0026	16.27	18.27	2.34	1.73	-0.28	SARIMA
	S0080	0.87	0.87	0.29	0.42	-0.08	SARIMAX
H03	S0095	9.97	5.02	0.23	0.23	0.82	LASSO
	S0085	18.11	3.81	0.16	0.19	0.72	LASSO
	S0026	12.72	8	0.18	0.19	0.84	LASSO
	S0080	11.72	11.29	0.36	0.42	0.66	SARIMAX

- R2-Score: Good | Poor | Negative
- MAE Values: Good | Bad

- Criteria → Positive R^2 + No over-fit + Lowest MAE.
- Best Model: SARIMAX = 9

Best model

4-Step Modelling Pipeline



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	S0085	53.47	123.76	44.16	34.73
	S0026	20.79	41.01	20.88	9.82
	S0080	12.63	81.46	12.95	70.26
H01	S0095	3.73	6.65	3.65	3.51
	S0085	11.51	32.12	10.52	16.74
	S0026	7.63	29.72	7.83	7.72
	S0080	1.49	1.86	1.54	0.29
H02	S0095	3.79	5.21	3.79	5.21
	S0085	2.91	1.6	2.78	1.12
	S0026	4.55	16.27	68.82	18.27
	S0080	0.55	0.87	0.55	0.87
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	S0085	9.1	18.11	9.04	3.81
	S0026	7.15	12.72	7.67	8
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Model Selection - Final Winners

Hierarchy	Store	SARIMA Test	SARIMAX Test	LASSO Train	LASSO Test	LASSO R² Test	Best Model
H00	S0095	62.3	12.14	0.40	0.23	0.80	LASSO
	S0085	123.76	34.73	0.99	1.00	0.80	LASSO
	S0026	41.01	9.82	0.51	0.52	0.17	SARIMAX
	S0080	81.46	70.26	0.75	0.78	0.69	LASSO
H01	S0095	6.65	3.51	0.28	0.18	0.28	SARIMAX
	S0085	32.12	16.74	0.37	0.33	0.15	SARIMAX
	S0026	29.72	7.72	0.34	0.29	0.11	SARIMAX
	S0080	1.86	0.29	0.24	0.27	-0.49	SARIMAX
H02	S0095	5.21	5.21	8.61	8.30	-5.52	SARIMAX
	S0085	1.6	1.12	2.25	1.83	-1.87	SARIMAX
	S0026	16.27	18.27	2.34	1.73	-0.28	SARIMA
	S0080	0.87	0.87	0.29	0.42	-0.08	SARIMAX
H03	S0095	9.97	5.02	0.23	0.23	0.82	LASSO
	S0085	18.11	3.81	0.16	0.19	0.72	LASSO
	S0026	12.72	8	0.18	0.19	0.84	LASSO
	S0080	11.72	11.29	0.36	0.42	0.68	SARIMAX

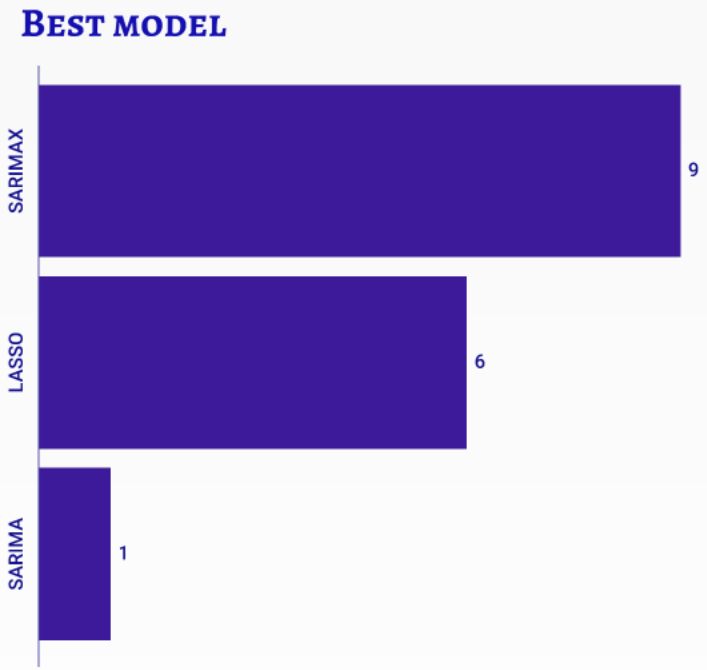
- R2-Score

Good Poor Negative

- Mae Values

Good Bad

- Criteria → Positive R^2 + No over-fit + Lowest MAE.
- Best Model: SARIMAX = 9

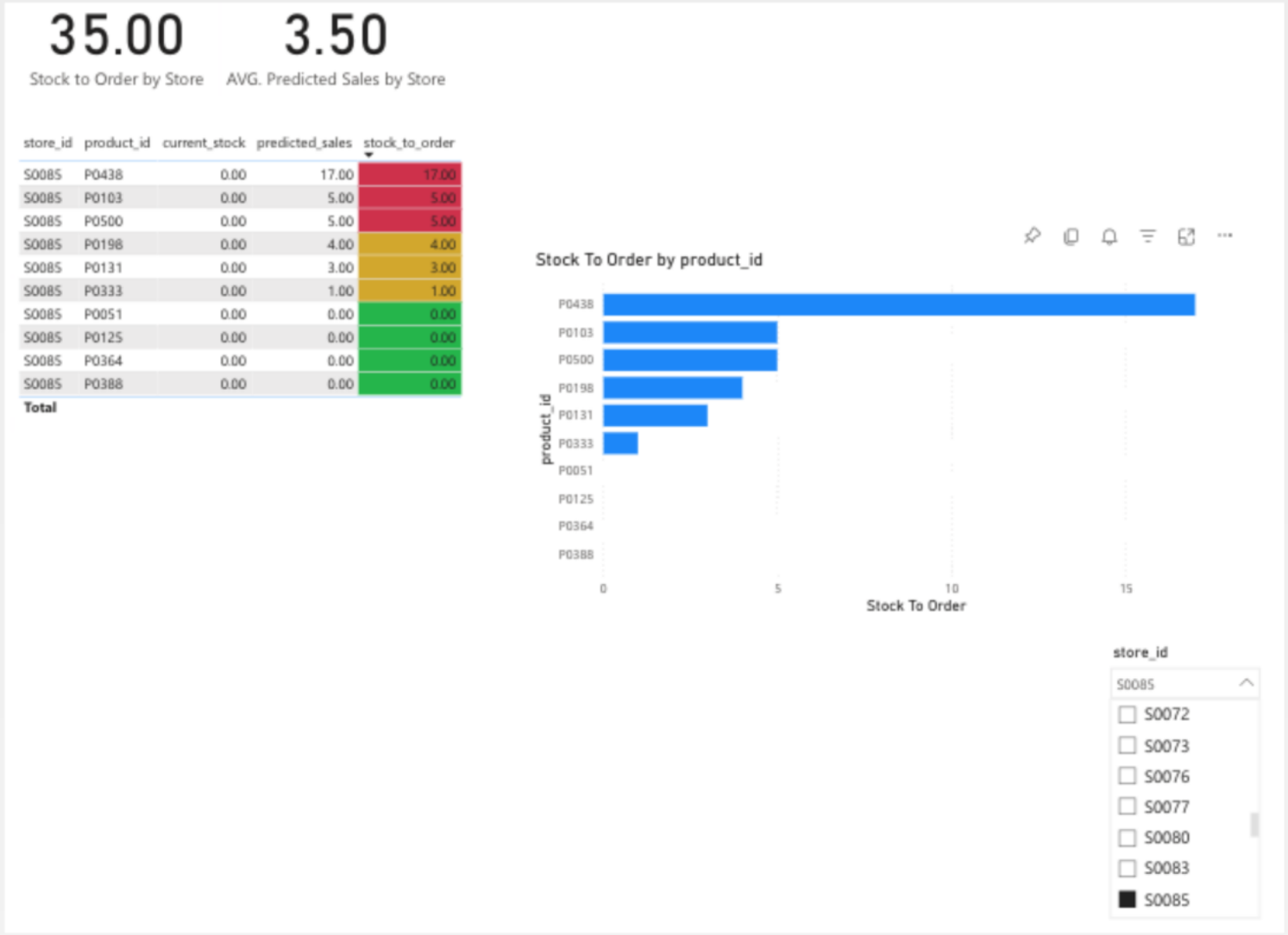


Dashboard

Live Replenishment Dashboard

- Auto-Refreshed fom ML Pipeline
- Stockholders see exact product units to order per store

Live Replenishment Dashboard



- Auto-Refreshed fom ML Pipeline
- Stockholders see exact product units to order per store

Thank you All!!!

Grupo_III

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5th of July 2025