IT5006 Milestone 1 - Exploratory Data Analysis (EDA)

This notebook is structured to align with the IT5006 project brief for Milestone 1.

It covers:

- Data preparation and cleaning methodology
- Temporal pattern analysis
- Spatial distribution study
- Crime correlation analysis
- Key findings used to support dashboard design and model preparation

Scope and split strategy used in this notebook:

- Analysis window: 2015 to 2025
- Modeling split: 2015-2024 for training, 2025 for test/validation

In [202…
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

Data Loading and Scope

We load the raw Chicago crime dataset and restrict the analysis window to 2015-2025 to match the project scope (recent decade for model development and 2025 for testing/validation).

In [203…
```
# Load raw data and constrain to the project analysis window (2015–2025).
df = pd.read_csv('Crimes_-_2001_to_Present_20260202.csv')
df = df[(df['Year'] >= 2015) & (df['Year'] <= 2025)].copy()
```

Initial Inspection

We inspect the schema, sample rows, and summary statistics to understand data types, ranges, and potential quality issues before cleaning.

In [204…
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 2755508 entries, 12281 to 2767788
Data columns (total 22 columns):
 #   Column                Dtype  
---  ------                -----  
 0   ID                    int64  
 1   Case Number           object 
 2   Date                  object 
 3   Block                 object 
 4   IUCR                  object 
 5   Primary Type          object 
 6   Description           object 
 7   Location Description  object 
 8   Arrest                bool   
 9   Domestic              bool   
 10  Beat                  int64  
 11  District              float64
 12  Ward                  float64
 13  Community Area        float64
 14  FBI Code              object 
 15  X Coordinate          float64
 16  Y Coordinate          float64
 17  Year                  int64  
 18  Updated On            object 
 19  Latitude              float64
 20  Longitude             float64
 21  Location              object 
dtypes: bool(2), float64(7), int64(3), object(10)
memory usage: 446.7+ MB
```

In [205…
```
df.head()
```

Out[205]:

	ID	Case Number	Date	Block	IUCR	Primary Type	Description	Location Description	Arrest	Domestic	...	Ward	Commu A
12281	14075483	JK105557	12/31/2025 11:58:00 PM	050XX S PAULINA ST	0560	ASSAULT	SIMPLE	RESIDENCE	False	False	...	20.0	6
12282	14070833	JK100050	12/31/2025 11:55:00 PM	053XX W WASHINGTON BLVD	0930	MOTOR VEHICLE THEFT	THEFT / RECOVERY - AUTOMOBILE	APARTMENT	False	True	...	37.0	2
12283	14070845	JK100006	12/31/2025 11:54:00 PM	013XX W LAKE ST	0454	BATTERY	AGGRAVATED P.O. - HANDS, FISTS, FEET, NO / MIN...	RESTAURANT	True	False	...	27.0	2
12284	14070745	JK100011	12/31/2025 11:54:00 PM	100XX W OHARE ST	2890	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	...	41.0	7
12285	14070799	JK100014	12/31/2025 11:54:00 PM	100XX W OHARE ST	2890	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	...	41.0	7

5 rows × 22 columns

In [206…

```
df.describe()
```

Out[206]:

	ID	Beat	District	Ward	Community Area	X Coordinate	Y Coordinate	Year	Latitud
count	2.755508e+06	2.755508e+06	2.755507e+06	2.755452e+06	2.755329e+06	2.713255e+06	2.713255e+06	2.755508e+06	2.713255e+0
mean	1.199882e+07	1.147835e+03	1.124928e+01	2.316696e+01	3.669468e+01	1.165042e+06	1.886548e+06	2.019885e+03	4.184427e+0
std	1.323831e+06	7.004106e+02	6.998368e+00	1.396870e+01	2.150027e+01	1.634312e+04	3.155335e+04	3.201904e+00	8.677656e-0
min	2.171400e+04	1.110000e+02	1.000000e+00	1.000000e+00	1.000000e+00	0.000000e+00	0.000000e+00	2.015000e+03	3.661945e+0
25%	1.103952e+07	6.110000e+02	6.000000e+00	1.000000e+01	2.300000e+01	1.153425e+06	1.859275e+06	2.017000e+03	4.176913e+0
50%	1.200848e+07	1.031000e+03	1.000000e+01	2.400000e+01	3.200000e+01	1.166873e+06	1.893218e+06	2.020000e+03	4.186282e+0
75%	1.305087e+07	1.723000e+03	1.700000e+01	3.400000e+01	5.400000e+01	1.176607e+06	1.909355e+06	2.023000e+03	4.190694e+0
max	1.409747e+07	2.535000e+03	3.100000e+01	5.000000e+01	7.700000e+01	1.205119e+06	1.951535e+06	2.025000e+03	4.202267e+0

Data Cleaning and Preprocessing

Key cleaning steps include datetime parsing, removing unused columns, handling missing values, and ensuring geographic fields are valid for spatial analysis.

In [207…
```
# Standardize timestamp columns for reliable time-based feature extraction.
df['Date'] = pd.to_datetime(df['Date'], errors='coerce')
df['Updated On'] = pd.to_datetime(df['Updated On'], format='%m/%d/%Y %I:%M:%S %p', errors='coerce')
```

In [209…
```
# Checking conversion results
print("Date conversion check:")
print(df[['Date', 'Updated On']].head())
```

```
Date conversion check:
            Date          Updated On
12281  2025-12-31 2026-01-09 15:40:47
12282  2025-12-31 2026-01-08 15:46:48
12283  2025-12-31 2026-01-08 15:46:48
12284  2025-12-31 2026-01-08 15:46:48
12285  2025-12-31 2026-01-08 15:46:48
```

In [208…
```
df['Time'] = df['Date'].dt.time
df['Date'] = df['Date'].dt.date
```

In [149…
```
df['Updated_Date'] = df['Updated On'].dt.date
df['Updated_Time'] = df['Updated On'].dt.time
```

In [150…
```
col_index = df.columns.get_loc('Updated On')
df.drop(columns=['Updated On'], inplace=True)
```

In [151…
```
cols = df.columns.tolist()
cols.insert(col_index, 'Updated_Time')
cols.insert(col_index, 'Updated_Date')

df = df[cols]
```

In [152…
```
df.head(10)
```

Out[152]:

	ID	Case Number	Date	Time	Block	IUCR	Primary Type	Description	Location Description	Arrest	...	X Coordinate	Coordi
12281	14075483	JK105557	2025-12-31	23:58:00	050XX S PAULINA ST	0560	ASSAULT	SIMPLE	RESIDENCE	False	...	1165860.0	18713
12282	14070833	JK100050	2025-12-31	23:55:00	053XX W WASHINGTON BLVD	0930	MOTOR VEHICLE THEFT	THEFT / RECOVERY - AUTOMOBILE	APARTMENT	False	...	1140809.0	19002
12283	14070845	JK100006	2025-12-31	23:54:00	013XX W LAKE ST	0454	BATTERY	AGGRAVATED P.O. - HANDS, FISTS, FEET, NO / MIN...	RESTAURANT	True	...	1167120.0	19015
12284	14070745	JK100011	2025-12-31	23:54:00	100XX W OHARE ST	2890	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	...	1100658.0	19342
12285	14070799	JK100014	2025-12-31	23:54:00	100XX W OHARE ST	2890	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	...	1100658.0	19342
12286	14071367	JK100694	2025-12-31	23:50:00	005XX S MICHIGAN AVE	0460	BATTERY	SIMPLE	HOTEL / MOTEL	False	...	1177364.0	18979
12287	14070841	JK100162	2025-12-31	23:50:00	068XX S PERRY AVE	0486	BATTERY	DOMESTIC BATTERY SIMPLE	APARTMENT	False	...	1176577.0	18596
12288	14070783	JK100009	2025-12-31	23:49:00	0000X E WACKER DR	143A	WEAPONS VIOLATION	UNLAWFUL POSSESSION - HANDGUN	SIDEWALK	True	...	1177013.0	19026
12289	14070846	JK100015	2025-12-31	23:47:00	004XX W SURF ST	0486	BATTERY	DOMESTIC BATTERY SIMPLE	STREET	False	...	1172790.0	19194
12290	14071594	JK100608	2025-12-31	23:45:00	006XX E GRAND AVE	1150	DECEPTIVE PRACTICE	CREDIT CARD FRAUD	OTHER (SPECIFY)	False	...	1180796.0	19040

10 rows × 26 columns

In [153…
```
df.dtypes
```

Out[153]:
```
ID                        int64
Case Number              object
Date                     object
Time                     object
Block                    object
IUCR                     object
Primary Type             object
Description              object
Location Description     object
Arrest                     bool
Domestic                   bool
Beat                      int64
District                float64
Ward                    float64
Community Area          float64
FBI Code                 object
X Coordinate            float64
Y Coordinate            float64
Year                      int64
Updated_Date             object
Updated_Time             object
Latitude                float64
Longitude               float64
Location                 object
Updated_Date             object
Updated_Time             object
dtype: object
```

In [154…
```
df.shape
```

Out[154]:
```
(2755508, 26)
```

In [155…
```
max_year = df['Date'].max()
min_year = df['Date'].min()
print(f"Latest Year: {max_year}")
print(f"Earliest Year: {min_year}")
```

```
Latest Year: 2025-12-31
Earliest Year: 2015-01-01
```

In [159…
```
df.shape
```

Out[159]: (2755508, 26)

Data Quality Audit and Cleaning Pipeline

This section applies a transparent cleaning pipeline:

- quantify missing values
- remove non-essential columns
- handle missing categorical/numeric fields with explicit rules
- remove records that cannot support spatial analysis (missing latitude/longitude)

These steps are documented to satisfy reproducibility and report requirements.

In [160…
```
x = df.isnull().sum()
x = x[x > 0]
print("Missing Values in Dataset:\n", x)
```

```
Missing Values in Dataset:
 Location Description    13632
District                     1
Ward                        56
Community Area             179
X Coordinate             42253
Y Coordinate             42253
Latitude                 42253
Longitude                42253
Location                 42253
dtype: int64
```

In [161…
```
# Drop identifiers and high-cardinality fields that are not needed for this EDA scope.
drop_col = ['ID', 'Case Number', 'IUCR', 'Updated_Date', 'Updated_Time',
```

```
                'X Coordinate', 'Y Coordinate', 'Location']
df.drop(columns=drop_col, inplace=True)
```

In [162…

```
df.head(10)
```

Out[162]:

	Date	Time	Block	Primary Type	Description	Location Description	Arrest	Domestic	Beat	District	Ward	Community Area	FBI Code
12281	2025-12-31	23:58:00	050XX S PAULINA ST	ASSAULT	SIMPLE	RESIDENCE	False	False	931	9.0	20.0	61.0	08A
12282	2025-12-31	23:55:00	053XX W WASHINGTON BLVD	MOTOR VEHICLE THEFT	THEFT / RECOVERY - AUTOMOBILE	APARTMENT	False	True	1522	15.0	37.0	25.0	07
12283	2025-12-31	23:54:00	013XX W LAKE ST	BATTERY	AGGRAVATED P.O. - HANDS, FISTS, FEET, NO / MIN...	RESTAURANT	True	False	1215	12.0	27.0	28.0	08B
12284	2025-12-31	23:54:00	100XX W OHARE ST	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	1651	16.0	41.0	76.0	24
12285	2025-12-31	23:54:00	100XX W OHARE ST	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	1651	16.0	41.0	76.0	24
12286	2025-12-31	23:50:00	005XX S MICHIGAN AVE	BATTERY	SIMPLE	HOTEL / MOTEL	False	False	123	1.0	4.0	32.0	08B
12287	2025-12-31	23:50:00	068XX S PERRY AVE	BATTERY	DOMESTIC BATTERY SIMPLE	APARTMENT	False	True	722	7.0	6.0	69.0	08B
12288	2025-12-31	23:49:00	0000X E WACKER DR	WEAPONS VIOLATION	UNLAWFUL POSSESSION - HANDGUN	SIDEWALK	True	False	111	1.0	42.0	32.0	15
12289	2025-12-31	23:47:00	004XX W SURF ST	BATTERY	DOMESTIC BATTERY SIMPLE	STREET	False	True	1934	19.0	44.0	6.0	08B
12290	2025-12-31	23:45:00	006XX E GRAND AVE	DECEPTIVE PRACTICE	CREDIT CARD FRAUD	OTHER (SPECIFY)	False	False	1834	18.0	42.0	8.0	11

In [163…

```
x = df.isnull().sum()
x = x[x > 0]
```

```
print("Missing Values in Dataset:\n", x)
```

```
Missing Values in Dataset:
 Location Description    13632
District                     1
Ward                        56
Community Area             179
Latitude                 42253
Longitude                42253
dtype: int64
```

In [164…
```
df['Location Description'].fillna('UNKNOWN', inplace=True)
```

In [165…
```
df = df.dropna(subset=['District'])
```

In [166…
```
df.drop(columns=['Ward'], inplace=True)
```

In [167…
```
df['Community Area'].fillna(-1, inplace=True)
```

In [168…
```
df = df.dropna(subset=['Latitude', 'Longitude'])
```

In [169…
```
print("Missing Values After Cleaning:\n", df.isnull().sum())
```

```
Missing Values After Cleaning:
 Date                    0
Time                     0
Block                    0
Primary Type             0
Description              0
Location Description     0
Arrest                   0
Domestic                 0
Beat                     0
District                 0
Community Area           0
FBI Code                 0
Year                     0
Latitude                 0
Longitude                0
dtype: int64
```

In [170…
```
df.shape
```

Out[170]: (2713254, 15)

In [171…
```
df.head(10)
```

Out[171]:

	Date	Time	Block	Primary Type	Description	Location Description	Arrest	Domestic	Beat	District	Community Area	FBI Code	Year
12281	2025-12-31	23:58:00	050XX S PAULINA ST	ASSAULT	SIMPLE	RESIDENCE	False	False	931	9.0	61.0	08A	2025
12282	2025-12-31	23:55:00	053XX W WASHINGTON BLVD	MOTOR VEHICLE THEFT	THEFT / RECOVERY - AUTOMOBILE	APARTMENT	False	True	1522	15.0	25.0	07	2025
12283	2025-12-31	23:54:00	013XX W LAKE ST	BATTERY	AGGRAVATED P.O. - HANDS, FISTS, FEET, NO / MIN...	RESTAURANT	True	False	1215	12.0	28.0	08B	2025
12284	2025-12-31	23:54:00	100XX W OHARE ST	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	1651	16.0	76.0	24	2025
12285	2025-12-31	23:54:00	100XX W OHARE ST	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	1651	16.0	76.0	24	2025
12286	2025-12-31	23:50:00	005XX S MICHIGAN AVE	BATTERY	SIMPLE	HOTEL / MOTEL	False	False	123	1.0	32.0	08B	2025
12287	2025-12-31	23:50:00	068XX S PERRY AVE	BATTERY	DOMESTIC BATTERY SIMPLE	APARTMENT	False	True	722	7.0	69.0	08B	2025
12288	2025-12-31	23:49:00	0000X E WACKER DR	WEAPONS VIOLATION	UNLAWFUL POSSESSION - HANDGUN	SIDEWALK	True	False	111	1.0	32.0	15	2025
12289	2025-12-31	23:47:00	004XX W SURF ST	BATTERY	DOMESTIC BATTERY SIMPLE	STREET	False	True	1934	19.0	6.0	08B	2025
12290	2025-12-31	23:45:00	006XX E GRAND AVE	DECEPTIVE PRACTICE	CREDIT CARD FRAUD	OTHER (SPECIFY)	False	False	1834	18.0	8.0	11	2025

In [172…

```
df.dtypes
```

Out[172]:
```
Date                   object
Time                   object
Block                  object
Primary Type           object
Description            object
Location Description   object
Arrest                   bool
Domestic                 bool
Beat                    int64
District              float64
Community Area        float64
FBI Code               object
Year                    int64
Latitude              float64
Longitude             float64
dtype: object
```

Data Type Optimization

Convert categorical fields to `category` and downcast integer-like fields to reduce memory footprint for large-scale analysis.

In [173…
```
# Optimize dtypes to reduce memory usage and improve plotting/groupby performance.
cat_cols = ['Primary Type', 'Description', 'Location Description', 'FBI Code']
for col in cat_cols:
    df[col] = df[col].astype('category')

int_cols = ['District', 'Community Area']
for col in int_cols:
    df[col] = pd.to_numeric(df[col], downcast='integer', errors='coerce')

print(df.dtypes)
```

```
Date                    object
Time                    object
Block                   object
Primary Type          category
Description           category
Location Description  category
Arrest                    bool
Domestic                  bool
Beat                     int64
District                  int8
Community Area            int8
FBI Code              category
Year                     int64
Latitude               float64
Longitude              float64
dtype: object
```

Feature Engineering

Create time-based features (Month, DayOfWeek, Hour) from the incident timestamp to support temporal pattern analysis.

In [174…
```
df['Date'] = pd.to_datetime(df['Date'], errors='coerce')
df['Month'] = df['Date'].dt.month
df['DayOfWeek'] = df['Date'].dt.day_name()
df['Hour'] = pd.to_datetime(df['Time'], format='%H:%M:%S', errors='coerce').dt.hour
```

In [175…
```
df.head(10)
```

Out[175]:

	Date	Time	Block	Primary Type	Description	Location Description	Arrest	Domestic	Beat	District	Community Area	FBI Code	Year
12281	2025-12-31	23:58:00	050XX S PAULINA ST	ASSAULT	SIMPLE	RESIDENCE	False	False	931	9	61	08A	2025
12282	2025-12-31	23:55:00	053XX W WASHINGTON BLVD	MOTOR VEHICLE THEFT	THEFT / RECOVERY - AUTOMOBILE	APARTMENT	False	True	1522	15	25	07	2025
12283	2025-12-31	23:54:00	013XX W LAKE ST	BATTERY	AGGRAVATED P.O. - HANDS, FISTS, FEET, NO / MIN...	RESTAURANT	True	False	1215	12	28	08B	2025
12284	2025-12-31	23:54:00	100XX W OHARE ST	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	1651	16	76	24	2025
12285	2025-12-31	23:54:00	100XX W OHARE ST	PUBLIC PEACE VIOLATION	OTHER VIOLATION	AIRCRAFT	False	False	1651	16	76	24	2025
12286	2025-12-31	23:50:00	005XX S MICHIGAN AVE	BATTERY	SIMPLE	HOTEL / MOTEL	False	False	123	1	32	08B	2025
12287	2025-12-31	23:50:00	068XX S PERRY AVE	BATTERY	DOMESTIC BATTERY SIMPLE	APARTMENT	False	True	722	7	69	08B	2025
12288	2025-12-31	23:49:00	0000X E WACKER DR	WEAPONS VIOLATION	UNLAWFUL POSSESSION - HANDGUN	SIDEWALK	True	False	111	1	32	15	2025
12289	2025-12-31	23:47:00	004XX W SURF ST	BATTERY	DOMESTIC BATTERY SIMPLE	STREET	False	True	1934	19	6	08B	2025
12290	2025-12-31	23:45:00	006XX E GRAND AVE	DECEPTIVE PRACTICE	CREDIT CARD FRAUD	OTHER (SPECIFY)	False	False	1834	18	8	11	2025

In [176…

```
crimes_per_year = df['Year'].value_counts().sort_index()
crimes_per_year
```

Out[176]:
```
2015    257908
2016    267223
2017    264935
2018    263523
2019    259170
2020    207970
2021    202871
2022    234884
2023    261243
2024    257554
2025    235973
Name: Year, dtype: int64
```

Train/Test Split (Per Project Guideline)

Use 2015-2024 for model development and 2025 for testing/validation. This mirrors the recommended usage in the project description.

In [ ]:
```
# Build a temporal holdout: train on historical years, validate on the most recent year.
df['Date'] = pd.to_datetime(df['Date'], errors='coerce')
df['Year'] = df['Date'].dt.year

train_df = df[(df['Year'] >= 2015) & (df['Year'] <= 2024)].copy()
test_val_df = df[df['Year'] == 2025].copy()

print("Train set shape:", train_df.shape)
print("Test/Val set shape:", test_val_df.shape)
```

```
Train set shape: (2519453, 26)
Test/Val set shape: (236055, 26)
```

In [302…
```
# Export cleaned split files for model development and dashboard consumption.
train_df.to_csv("crime_train_2015_2024.csv", index=False)
test_val_df.to_csv("crime_test_val_2025.csv", index=False)

print("   - crime_train_2015_2024.csv")
print("   - crime_test_val_2025.csv")
```

```
   - crime_train_2015_2024.csv
   - crime_test_val_2025.csv
```

Temporal Pattern Analysis

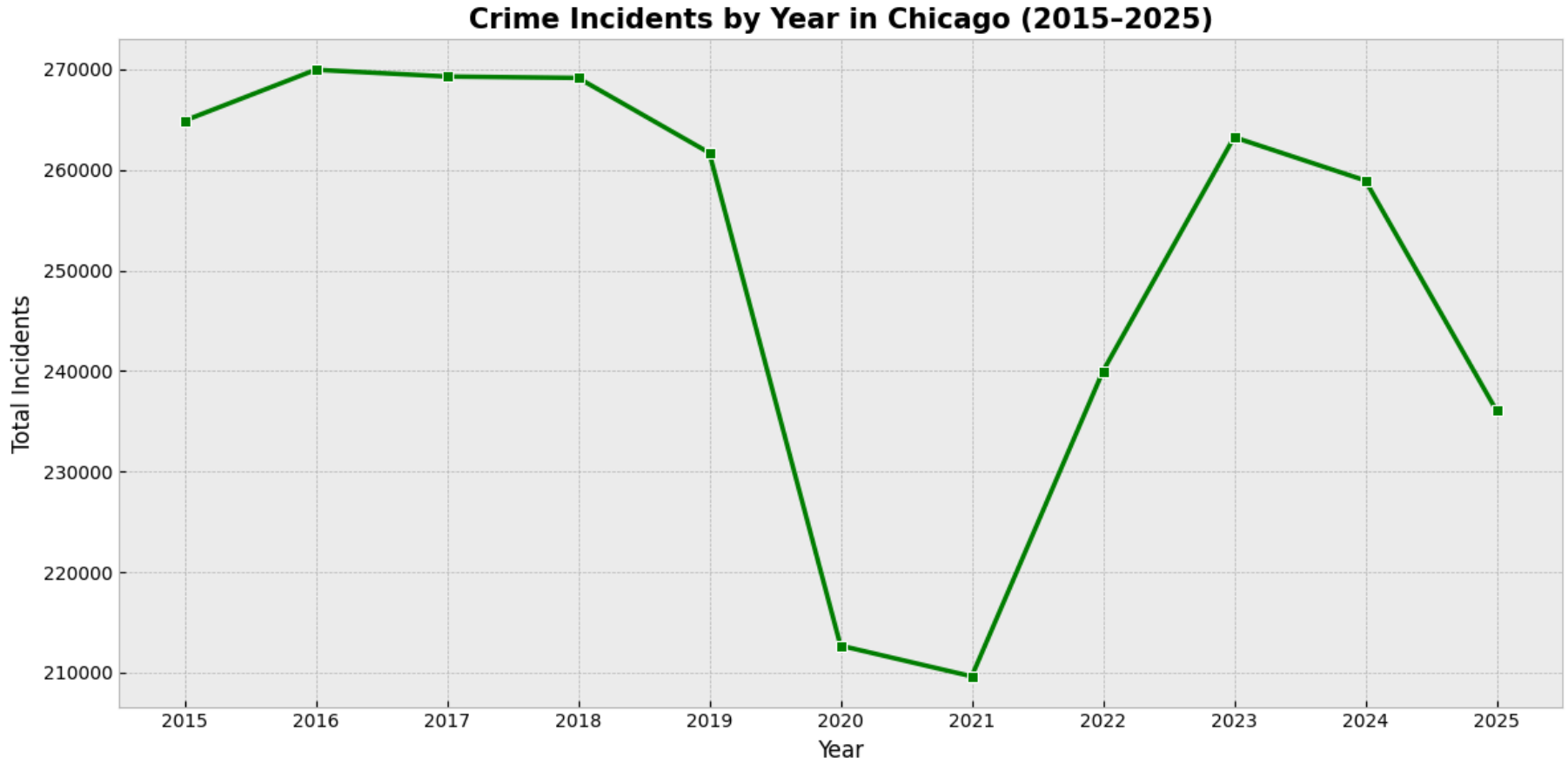
This section examines long-term, seasonal, weekly, and hourly crime trends. It addresses the temporal analysis requirement in the project brief.

Objectives

- Identify long-term trends across years
- Examine seasonal and weekly patterns
- Analyze intra-day (hourly) crime intensity
- Summarize temporal hotspots for later modeling and dashboard design

In [269…

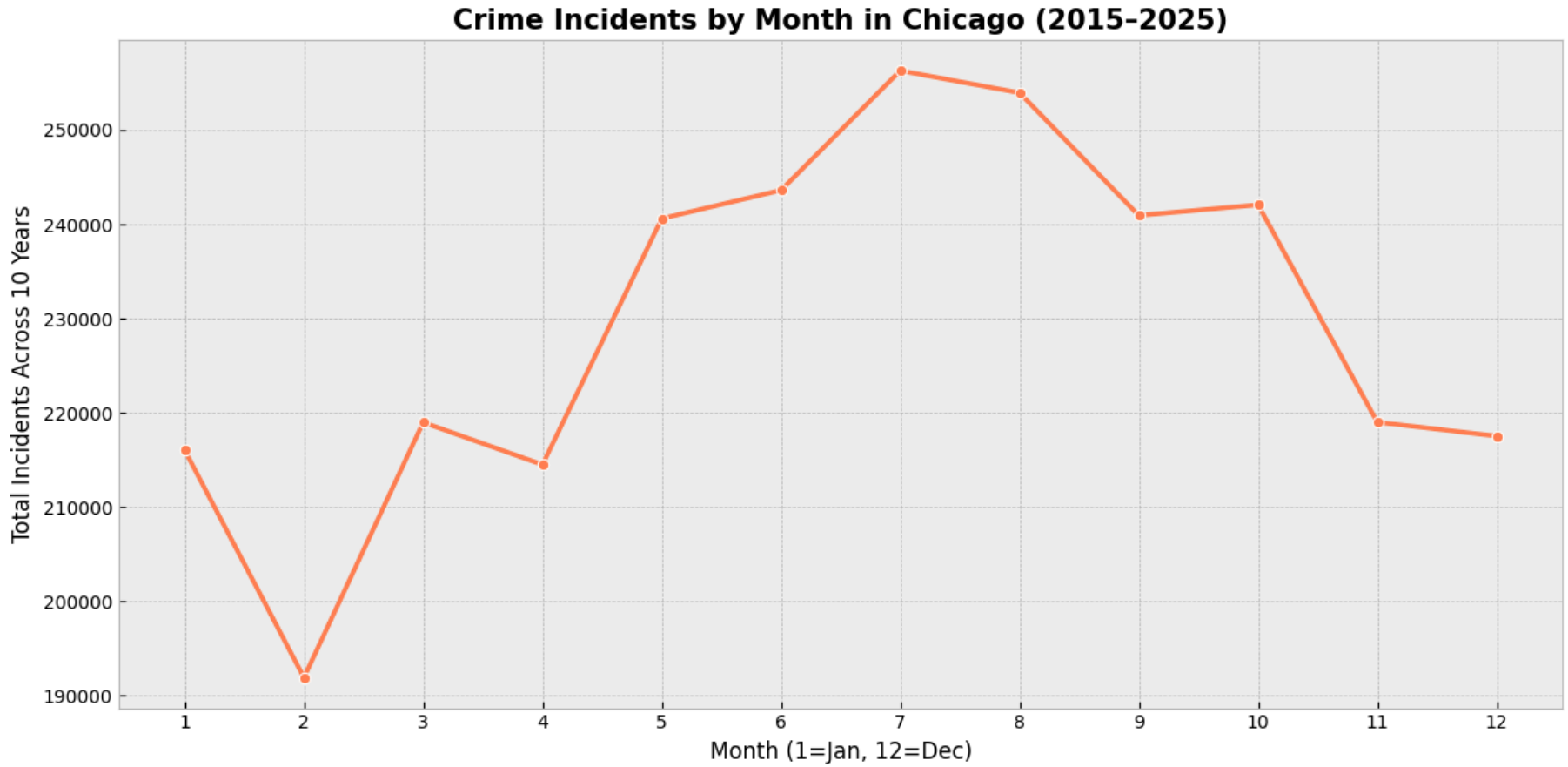
```
# 1. Long-term crime trend.
plt.figure(figsize=(12, 6))

yearly_counts = df.groupby('Year').size()

sns.lineplot(x=yearly_counts.index, y=yearly_counts.values, marker='s', linewidth=2.5, color='green')
plt.title("Crime Incidents by Year in Chicago (2015–2025)", fontsize=15,fontweight='bold')
plt.xlabel("Year", fontsize=12)
plt.ylabel("Total Incidents", fontsize=12)
plt.xticks(yearly_counts.index)

plt.tight_layout()
```



In [268…

```
# 2. Seasonal crime pattern
df['Date'] = pd.to_datetime(df['Date'], errors='coerce')
df['Month'] = df['Date'].dt.month

monthly_counts = df.groupby('Month').size().reindex(range(1,13), fill_value=0)

plt.figure(figsize=(12, 6))
sns.lineplot(
    x=monthly_counts.index,
    y=monthly_counts.values,
    marker='o',
    linewidth=2.5,
    color='coral'
```

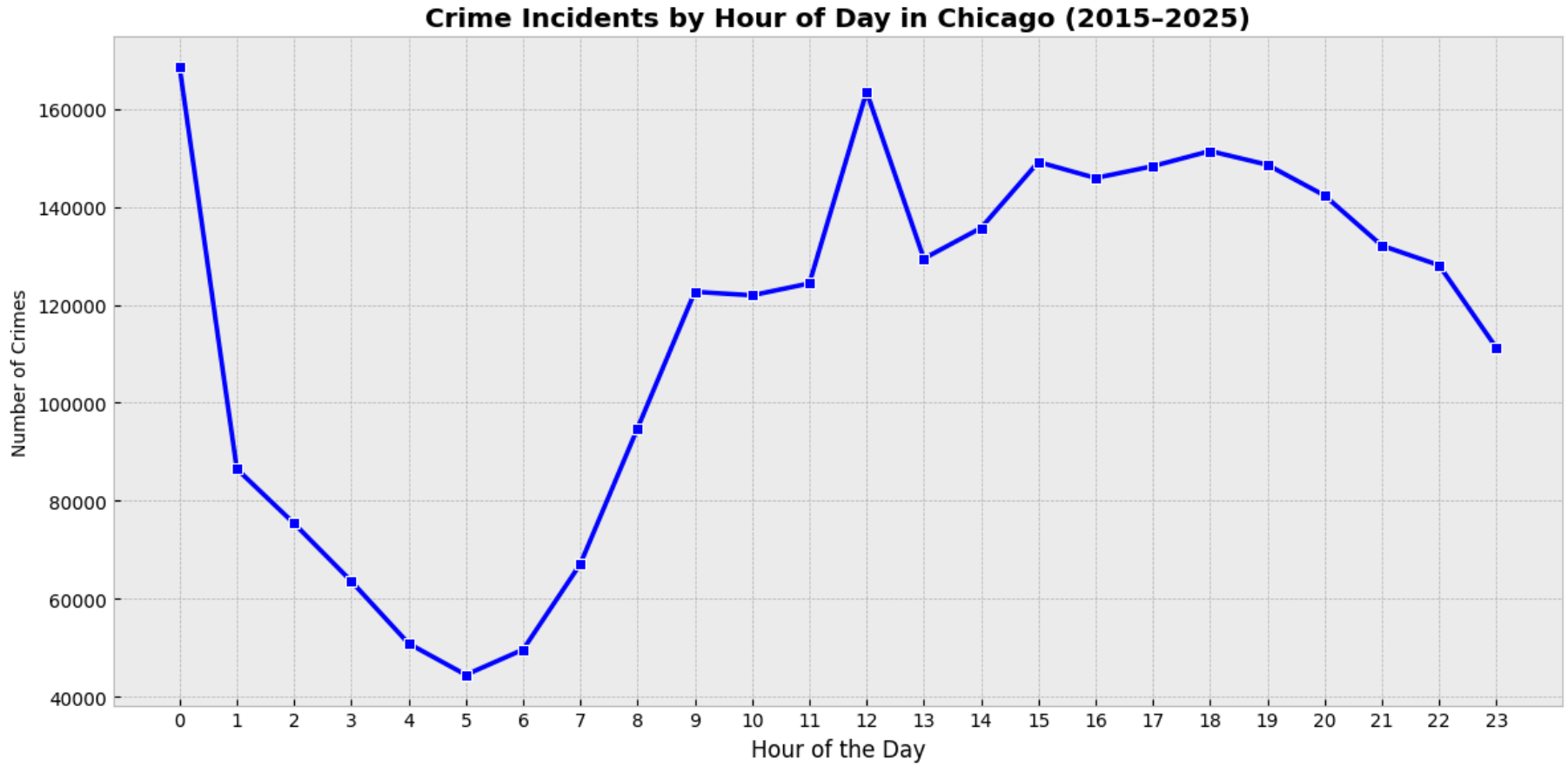
```
)
plt.title("Crime Incidents by Month in Chicago (2015–2025)", fontsize=15,fontweight='bold')
plt.xlabel("Month (1=Jan, 12=Dec)", fontsize=12)
plt.ylabel("Total Incidents Across 10 Years", fontsize=12)
plt.xticks(range(1, 13))
plt.grid(True, linestyle='--')


plt.tight_layout()
```



In [267…

```
# 3. Daily crime pattern
df['Hour'] = pd.to_datetime(df['Time'], format='%H:%M:%S', errors='coerce').dt.hour
```

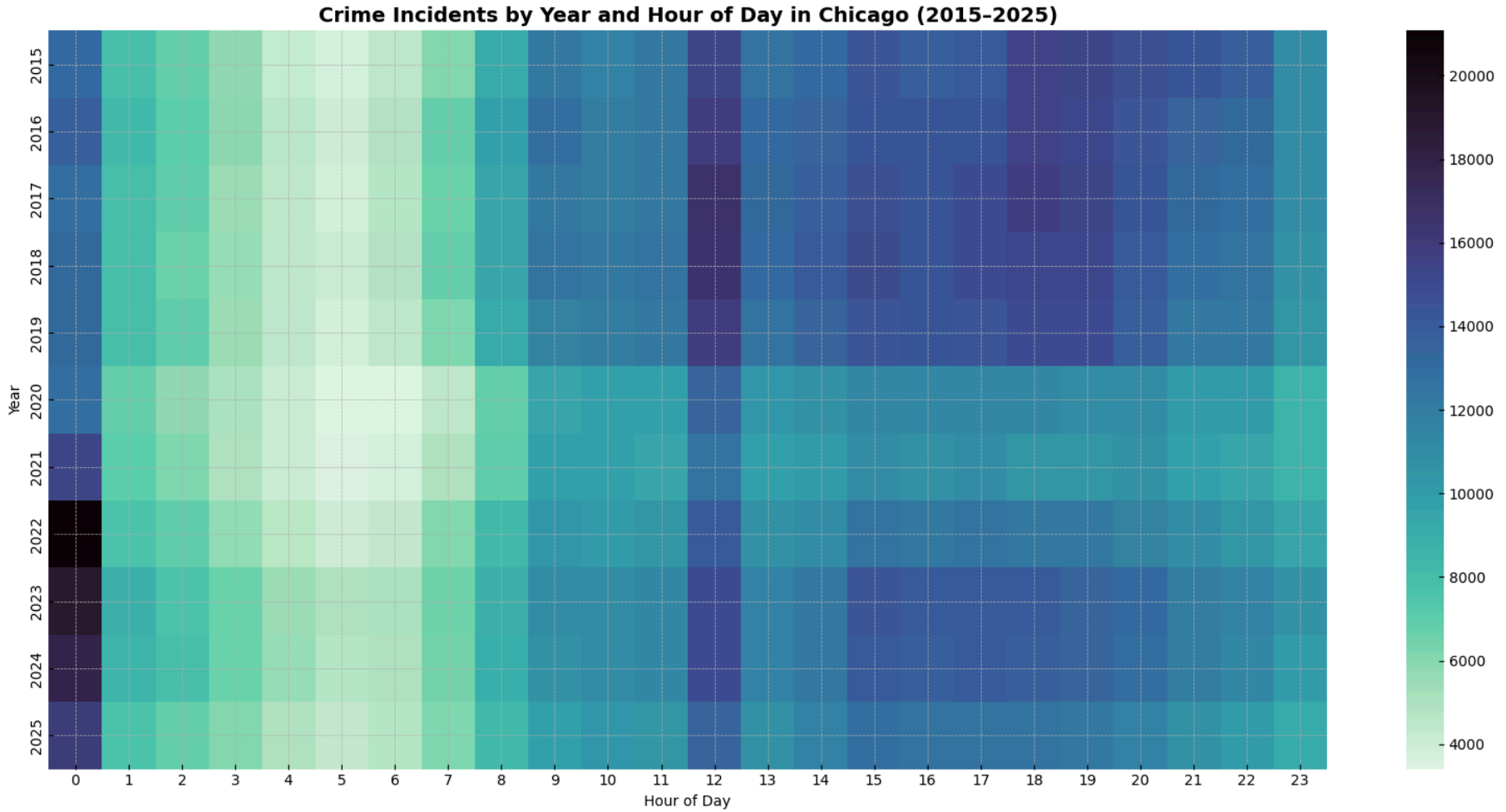
```
crime_by_hour = df['Hour'].value_counts().sort_index()

plt.figure(figsize=(12, 6))
sns.lineplot(x=crime_by_hour.index, y=crime_by_hour.values, marker='s', linewidth=2.5, color="b")
plt.xticks(ticks=range(24), labels=range(24))
plt.xlabel("Hour of the Day",fontsize=12)
plt.ylabel("Number of Crimes")
plt.title("Crime Incidents by Hour of Day in Chicago (2015–2025)",fontweight='bold')
plt.tight_layout()
```



In [250…

```
# 4. Hourly pattern across years.
df['Year'] = pd.to_datetime(df['Date']).dt.year
df['Hour'] = pd.to_datetime(df['Time'], format='%H:%M:%S', errors='coerce').dt.hour
```

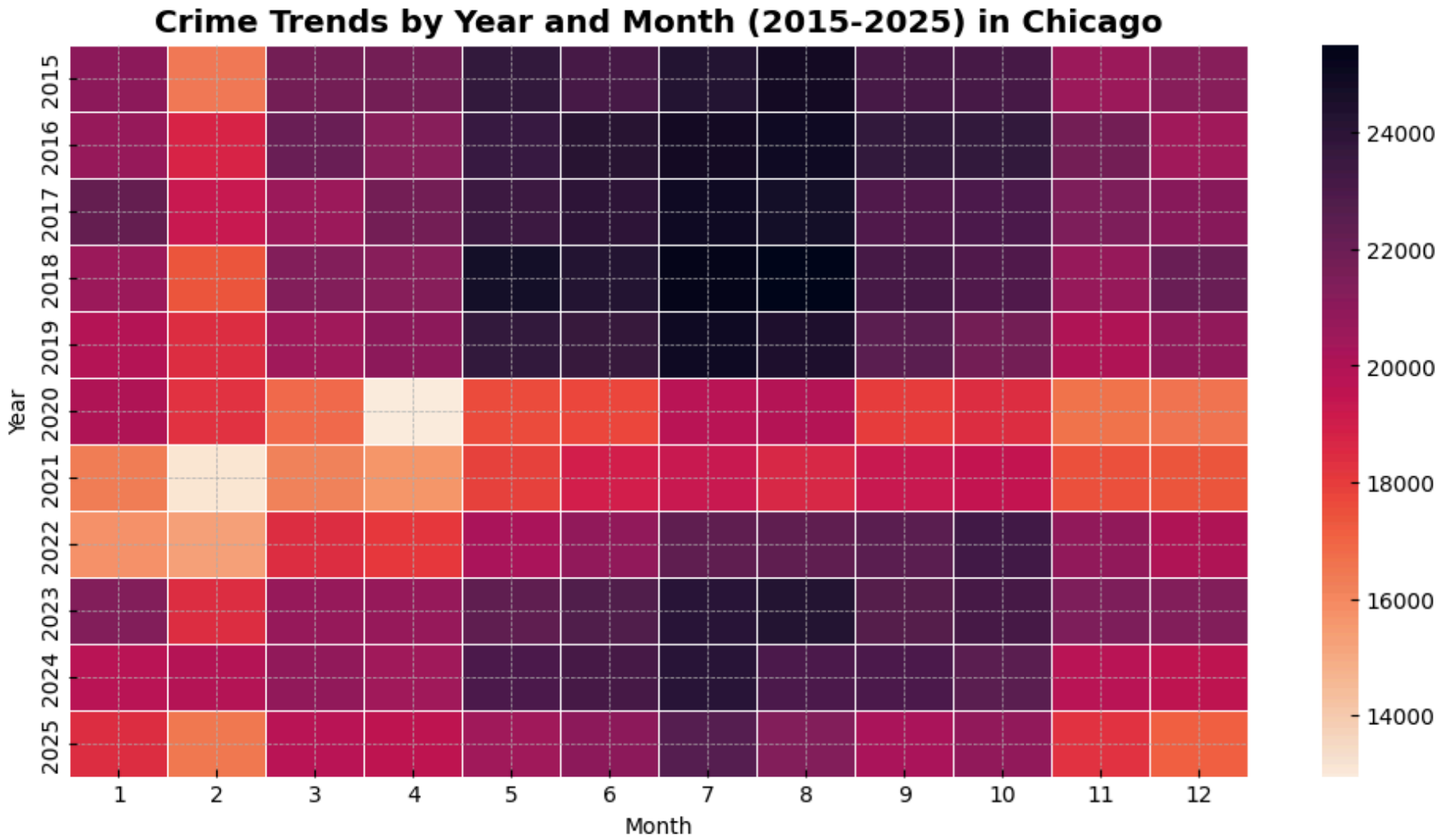
```
pivot = df.pivot_table(
    index='Year',
    columns='Hour',
    aggfunc='size',
    fill_value=0
).reindex(columns=range(24), fill_value=0)

plt.figure(figsize=(16, 8))
sns.heatmap(pivot, cmap='mako_r')

plt.title('Crime Incidents by Year and Hour of Day in Chicago (2015–2025)', fontsize=14, fontweight='bold')
plt.xlabel('Hour of Day')
plt.ylabel('Year')
plt.tight_layout()
plt.show()
```



In [266…

```
# 5. Monthly pattern across years
df['Month'] = pd.to_datetime(df['Date'], errors='coerce').dt.month

crimes_per_month = df.groupby(['Year', 'Month']).size().unstack()

plt.figure(figsize=(12, 6))
sns.heatmap(crimes_per_month, cmap="rocket_r", linewidths=0.5, cbar=True)
plt.xlabel("Month")
plt.ylabel("Year")
```

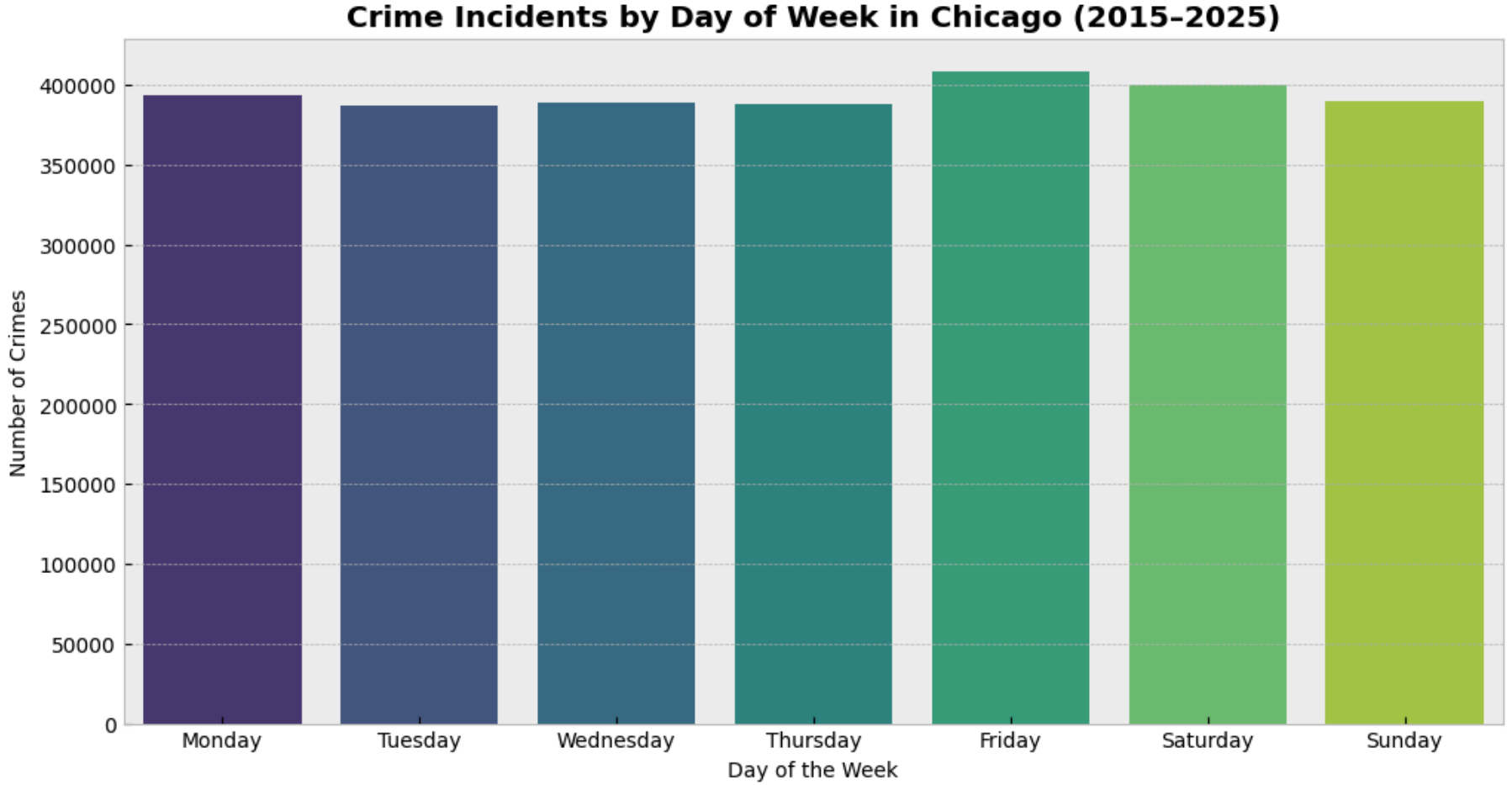
```
plt.title("Crime Trends by Year and Month (2015-2025) in Chicago",fontweight='bold')
plt.show()
```



In [265…

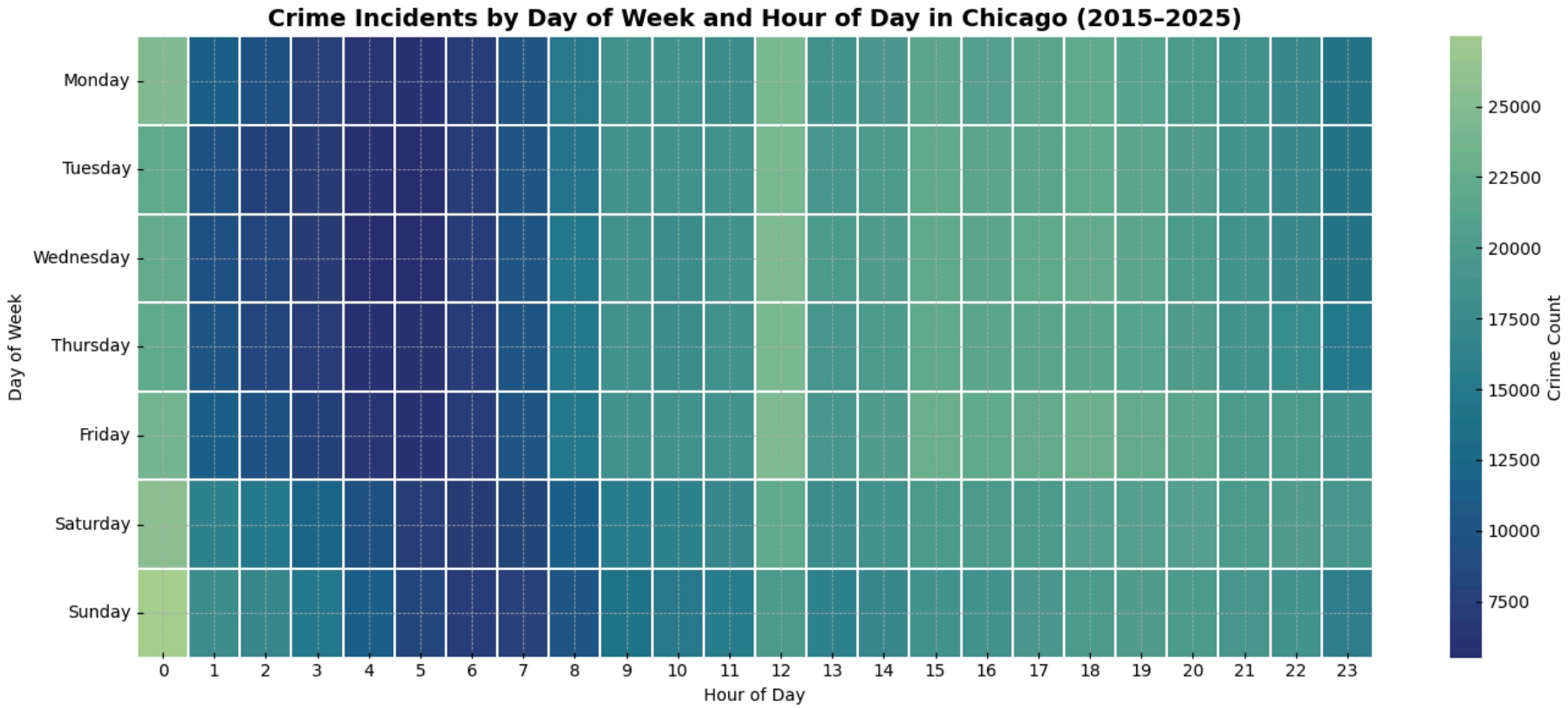
```
# 6. Weekly crime pattern
df['DayOfWeek'] = pd.to_datetime(df['Date'], errors='coerce').dt.day_name()

crime_by_day = df['DayOfWeek'].value_counts()[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday',
```

```
plt.figure(figsize=(12, 6))
sns.barplot(x=crime_by_day.index, y=crime_by_day.values, palette="viridis")
plt.xlabel("Day of the Week")
plt.ylabel("Number of Crimes")
plt.title("Crime Incidents by Day of Week in Chicago (2015–2025)",fontweight='bold')
plt.show()
```



In [ ]:
```
# 7. Weekly-hourly crime pattern
df['Date'] = pd.to_datetime(df['Date'], errors='coerce')
df['Hour'] = pd.to_datetime(df['Time'], format='%H:%M:%S', errors='coerce').dt.hour
df['DayOfWeek'] = df['Date'].dt.day_name()
```

```
heatmap_data = (
    df.groupby(['DayOfWeek', 'Hour'])
      .size()
      .unstack(fill_value=0)
      .reindex(columns=range(24), fill_value=0)
)

days_order = ['Monday','Tuesday','Wednesday','Thursday','Friday','Saturday','Sunday']
heatmap_data = heatmap_data.reindex(days_order)

plt.figure(figsize=(14,6))
sns.heatmap(
    heatmap_data,
    cmap='crest_r',
    linewidths=0.3,
    cbar_kws={'label': 'Crime Count'}
)

plt.title('Crime Incidents by Day of Week and Hour of Day in Chicago (2015–2025)', fontsize=14, fontweight='bold')
plt.xlabel('Hour of Day')
plt.ylabel('Day of Week')
plt.tight_layout()
```



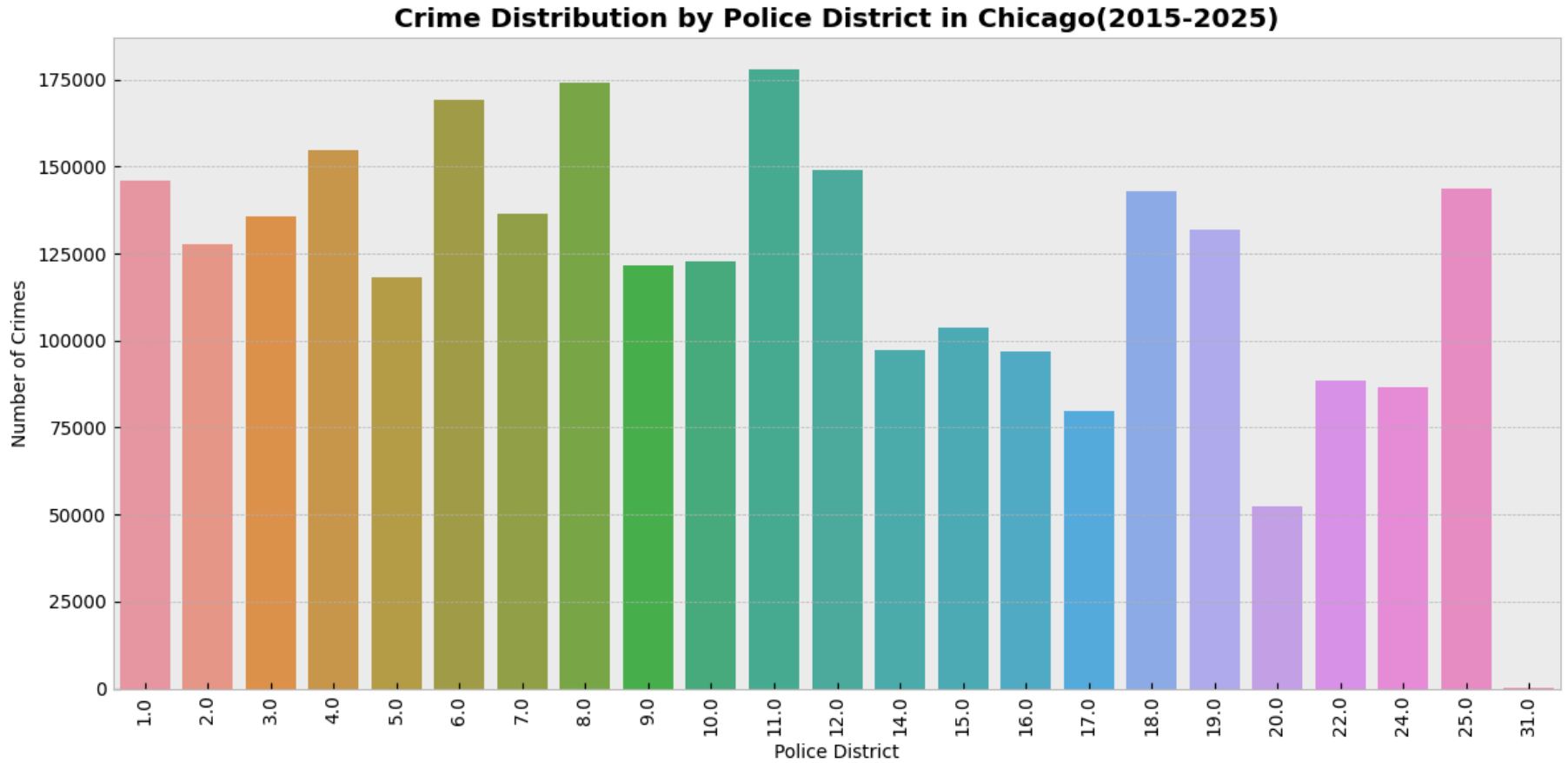
Spatial Distribution Study

This section analyzes where crimes are concentrated across districts, community areas, and map coordinates. It addresses the spatial analysis requirement in the project brief.

Objectives

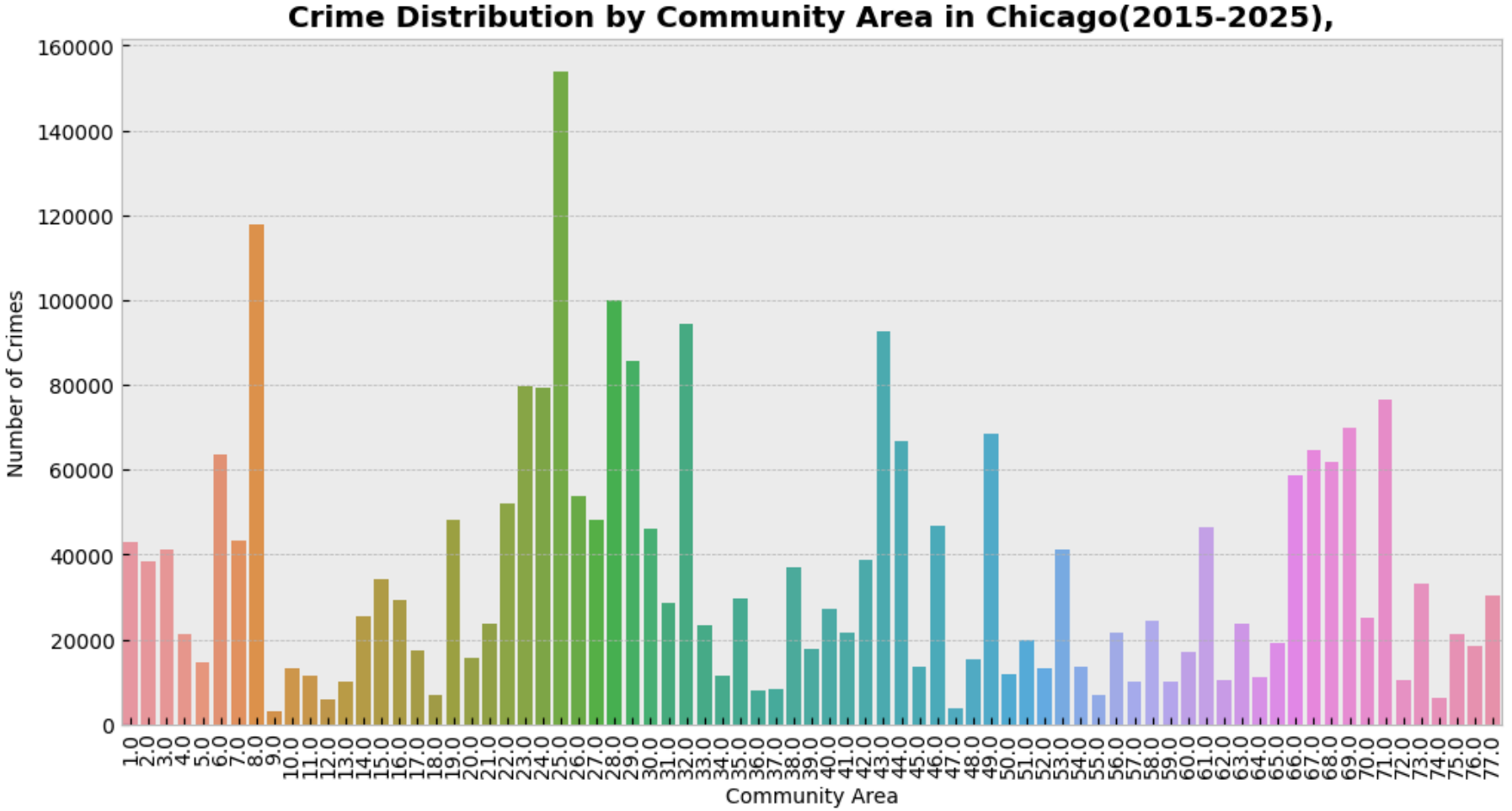
- Compare crime intensity across districts and community areas
- Identify geographic hotspots and common locations
- Provide spatial evidence to support resource allocation discussions

In [270…
```
district_crime_counts = df['District'].value_counts().sort_index()

plt.figure(figsize=(12, 6))
sns.barplot(x=district_crime_counts.index, y=district_crime_counts.values)
plt.xlabel("Police District")
plt.ylabel("Number of Crimes")
plt.title("Crime Distribution by Police District in Chicago(2015-2025)",fontweight='bold')
plt.xticks(rotation=90)
plt.tight_layout()
```



In [271…
```
community_crime_counts = df['Community Area'].value_counts().sort_index()

plt.figure(figsize=(12, 6))
```

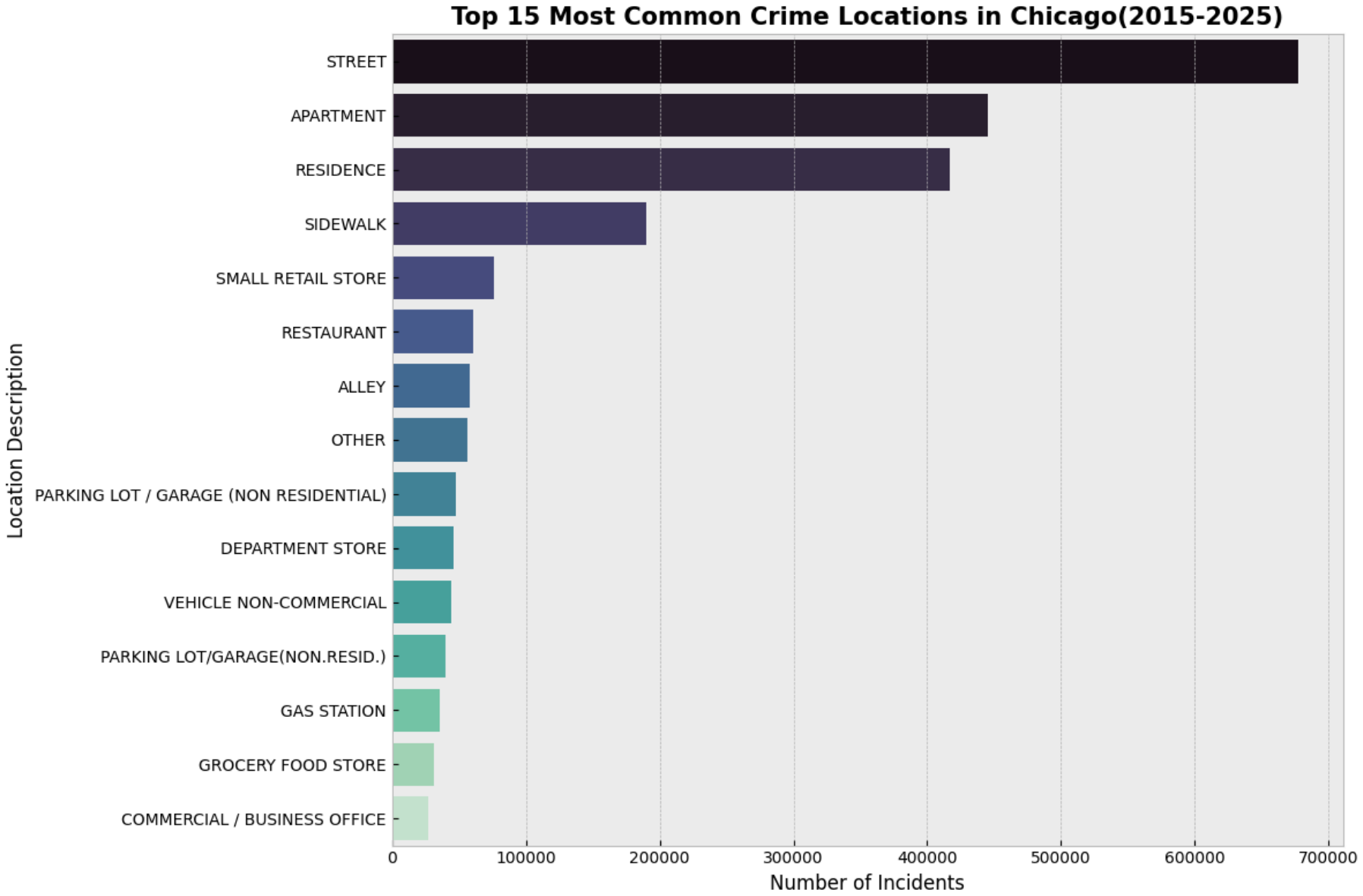
```
sns.barplot(x=community_crime_counts.index, y=community_crime_counts.values)
plt.xlabel("Community Area")
plt.ylabel("Number of Crimes")
plt.title("Crime Distribution by Community Area in Chicago(2015-2025),",fontweight='bold')
plt.xticks(rotation=90)
plt.show()
```



In [272…

```
plt.figure(figsize=(12, 8))

top_locations = df['Location Description'].value_counts().head(15)
```

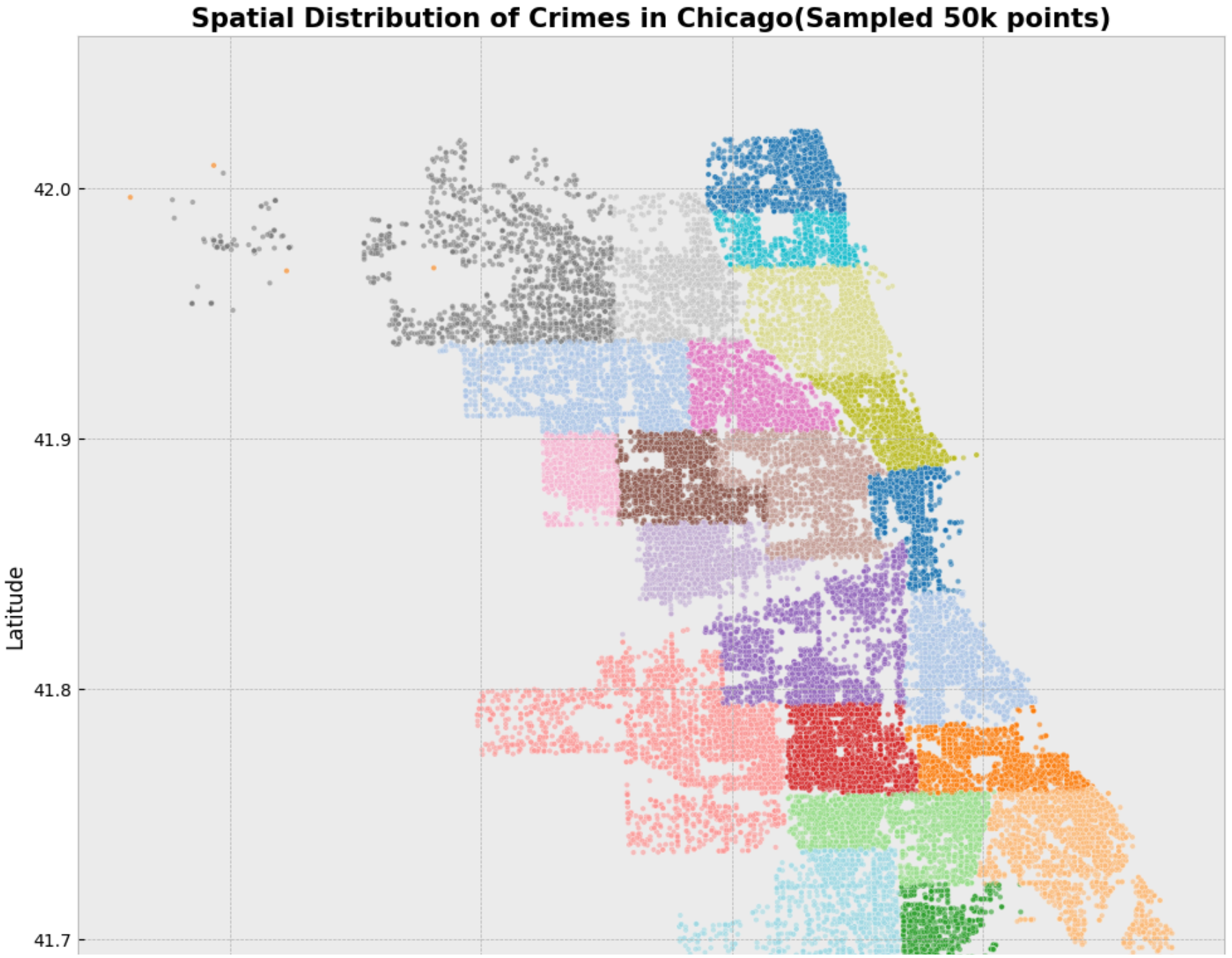
```
sns.barplot(y=top_locations.index, x=top_locations.values, palette="mako")
plt.title("Top 15 Most Common Crime Locations in Chicago(2015-2025)", fontsize=15,fontweight='bold')
plt.xlabel("Number of Incidents", fontsize=12)
plt.ylabel("Location Description", fontsize=12)

plt.tight_layout()
```

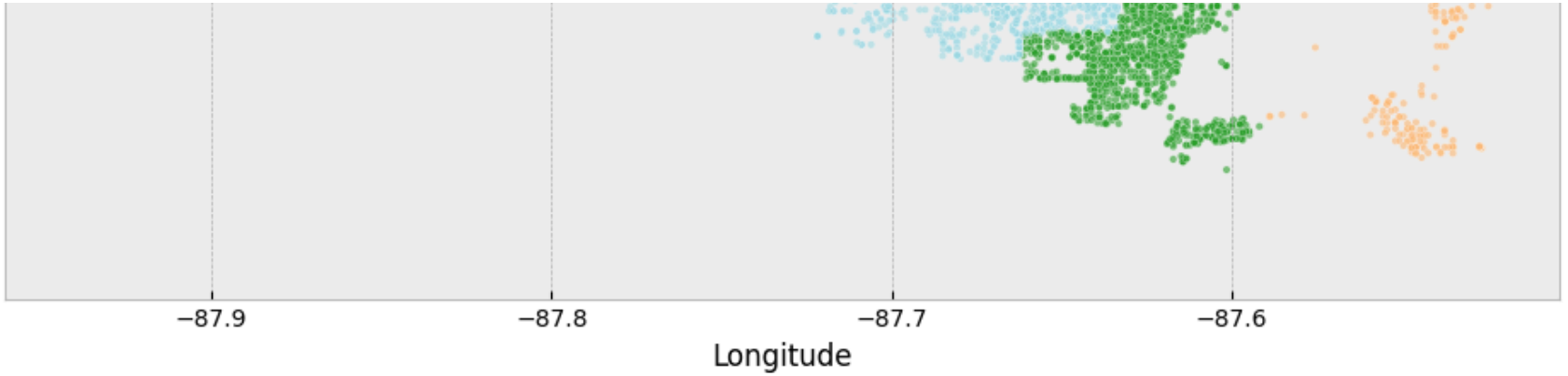


In [273…

```
plt.figure(figsize=(10, 10))

sample_df = df.sample(n=50000, random_state=42)
```

```
sns.scatterplot(
    data=sample_df,
    x='Longitude',
    y='Latitude',
    hue='District',
    palette='tab20',
    s=10,
    legend=False,
    alpha=0.6
)

plt.title("Spatial Distribution of Crimes in Chicago(Sampled 50k points)", fontsize=15,fontweight='bold')
plt.xlabel("Longitude", fontsize=12)
plt.ylabel("Latitude", fontsize=12)

plt.axis('equal')

plt.tight_layout()
```


Spatial Distribution of Crimes in Chicago(Sampled 50k points)
Latitude
42.0
41.9
41.8
41.7



Crime Correlation Analysis

This section examines relationships between crime type, arrests, district patterns, and temporal behavior. It supports actionable insights and downstream predictive modeling decisions.

Objectives

- Explore arrest dynamics over time
- Compare crime vs arrest trends
- Examine how crime types and districts interact

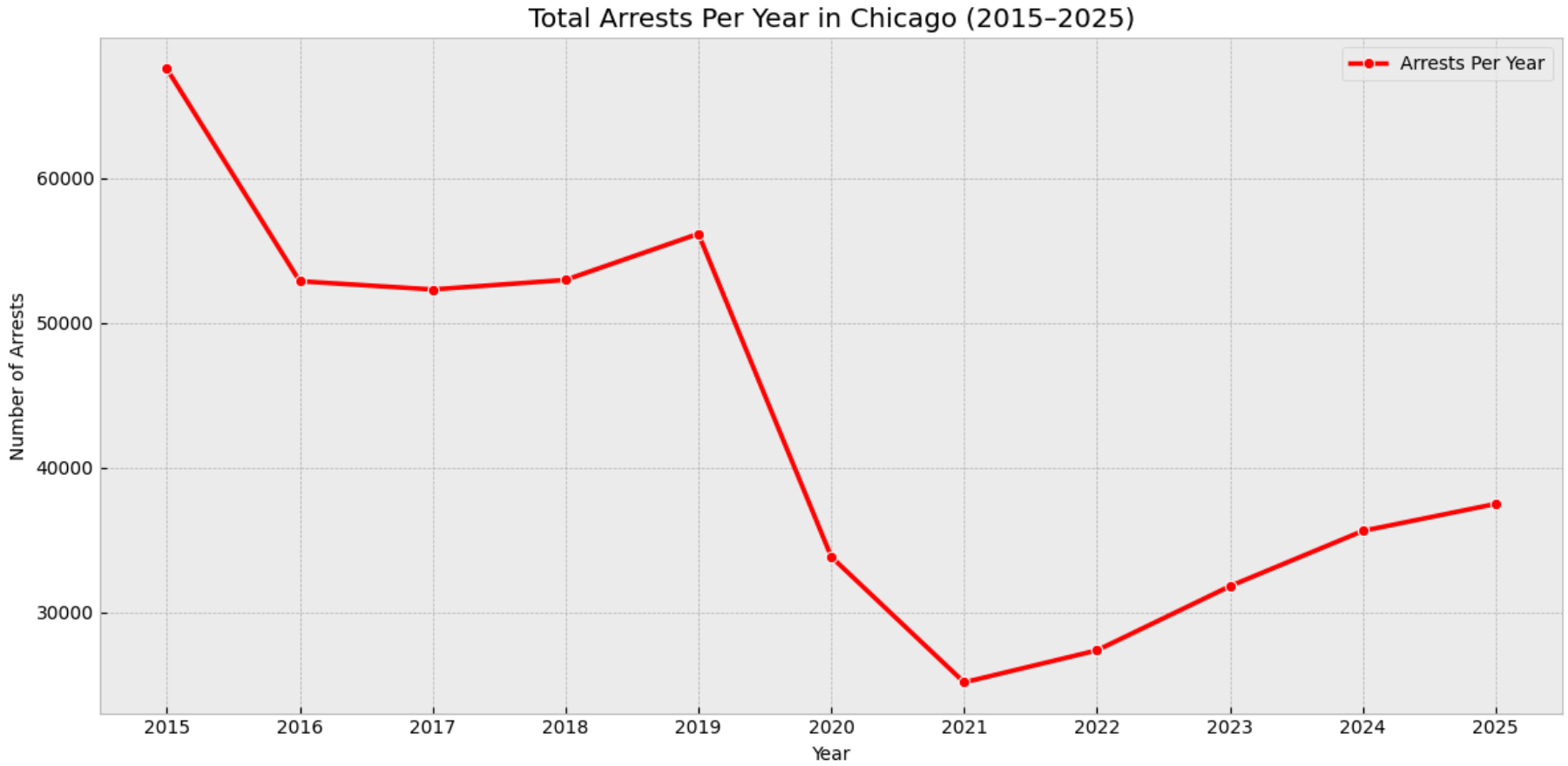
In [187…
```
total_arrests = df['Arrest'].sum()
print(f"Total Arrests in the Dataset: {total_arrests:,}")
```

```
Total Arrests in the Dataset: 473,192
```

In [188…
```
arrests_per_year = df[df['Arrest'] == True].groupby('Year').size()
arrests_per_year
```

Out[188]:
```
Year
2015    67534
2016    52872
2017    52302
2018    52961
2019    56147
2020    33849
2021    25179
2022    27391
2023    31821
2024    35635
2025    37501
dtype: int64
```

In [ ]:
```
plt.figure(figsize=(12, 6))

sns.lineplot(
    x=arrests_per_year.index,
    y=arrests_per_year.values,
    marker='o',
    linewidth=2.5,
    color='r',
    label="Arrests Per Year"

plt.xlabel("Year")
plt.ylabel("Number of Arrests")
plt.title("Total Arrests Per Year in Chicago (2015–2025)")

plt.xticks(arrests_per_year.index)
plt.legend()

plt.tight_layout()
```

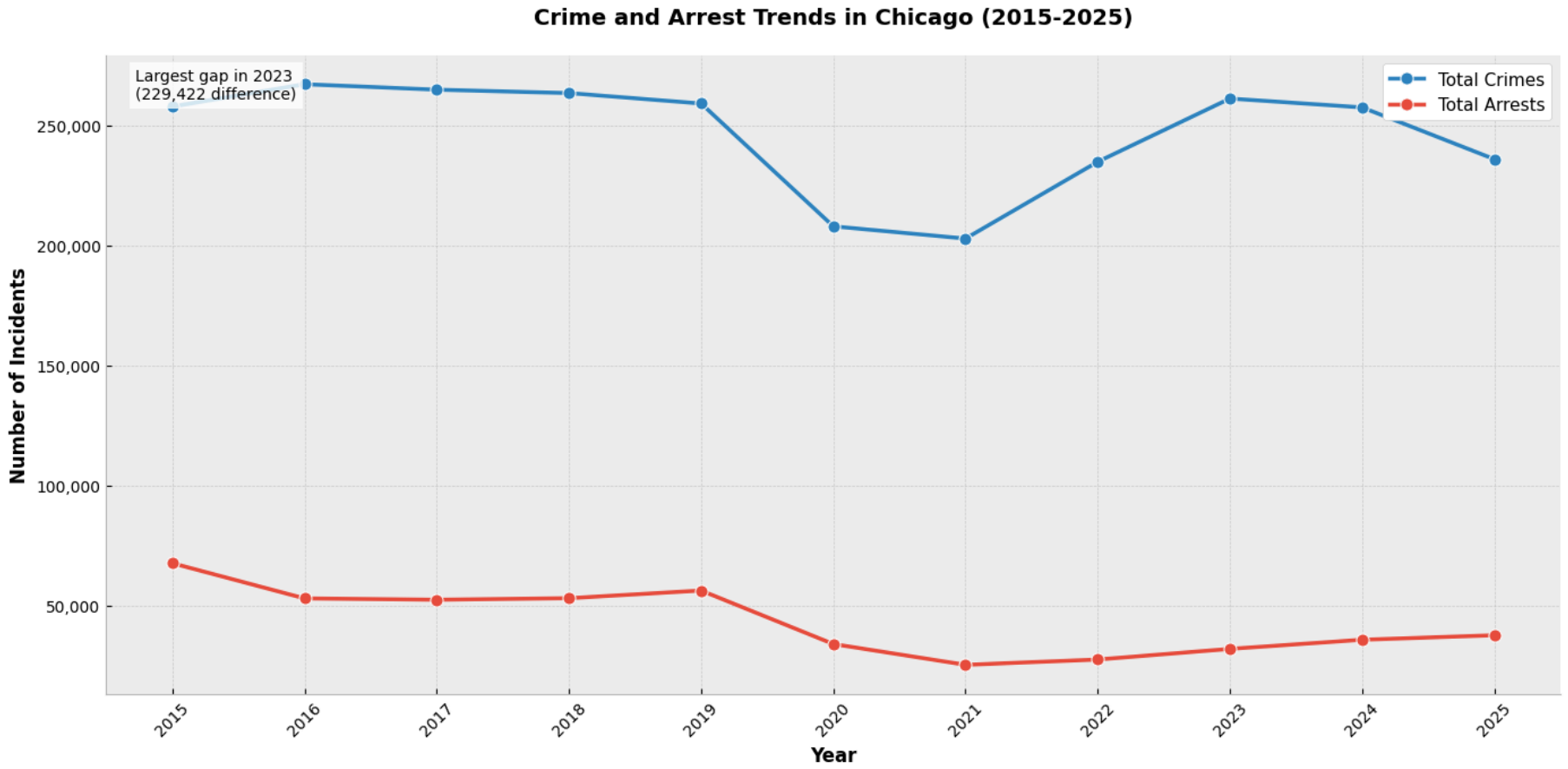


In [293…

```
plt.style.use('bmh')
plt.figure(figsize=(14, 7))

sns.lineplot(
    x=crimes_per_year.index,
    y=crimes_per_year.values,
    marker='o',
    linewidth=2.5,
    markersize=8,
    color='#2E86C1',
    label="Total Crimes"
)
```

```
sns.lineplot(
    x=arrests_per_year.index,
    y=arrests_per_year.values,
    marker='o',
    linewidth=2.5,
    markersize=8,
    color='#E74C3C',
    label="Total Arrests"
)

plt.xlabel("Year", fontsize=12, fontweight='bold')
plt.ylabel("Number of Incidents", fontsize=12, fontweight='bold')
plt.title("Crime and Arrest Trends in Chicago (2015-2025)",
          fontsize=14,
          fontweight='bold',
          pad=20)

plt.gca().yaxis.set_major_formatter(plt.FuncFormatter(lambda x, p: f"{int(x):,}"))

plt.legend(fontsize=11,
           frameon=True,
           facecolor='white',
           framealpha=1,
           loc='upper right')

plt.grid(True, linestyle='--', alpha=0.6)
plt.gca().spines['top'].set_visible(False)
plt.gca().spines['right'].set_visible(False)

plt.xticks(crimes_per_year.index, rotation=45)

plt.tight_layout()

max_year_diff = (crimes_per_year - arrests_per_year).idxmax()
max_diff = (crimes_per_year - arrests_per_year).max()
plt.text(0.02, 0.98,
         f'Largest gap in {max_year_diff}\n({max_diff:,.0f} difference)',
         transform=plt.gca().transAxes,
         bbox=dict(facecolor='white', alpha=0.8, edgecolor='none'),
         verticalalignment='top',
         fontsize=10)
```

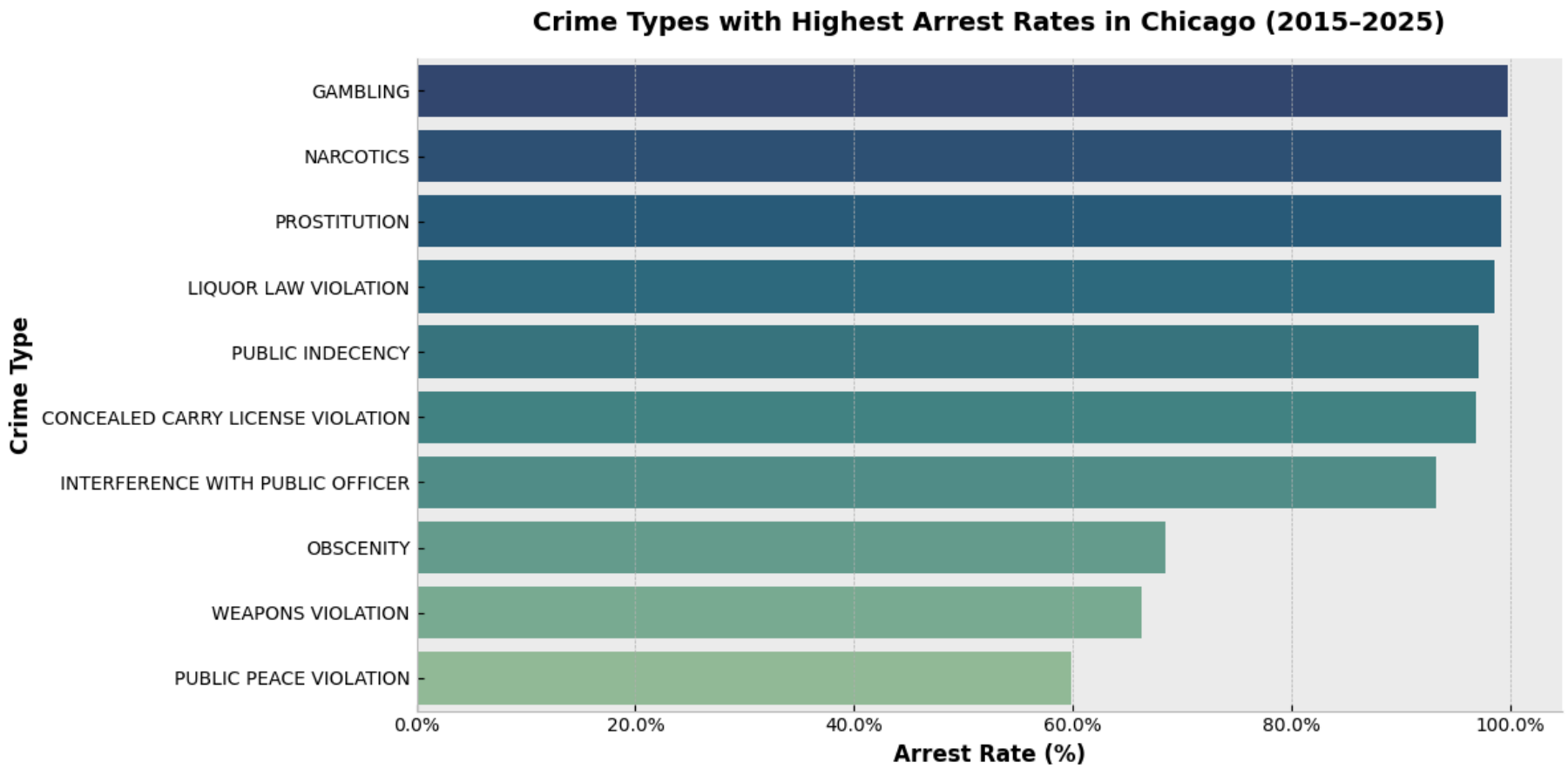
```
plt.show()
```



In [299…

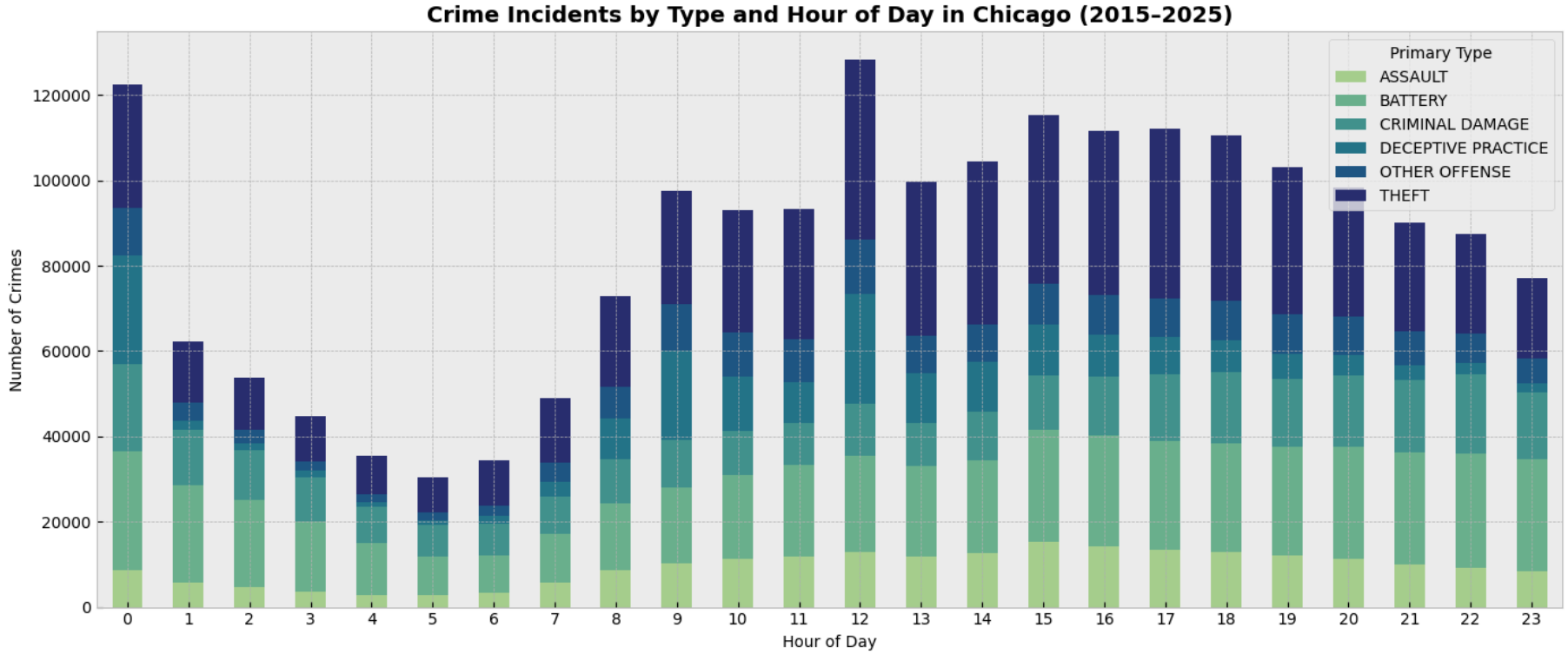
```
crime_arrest_counts = df[df['Arrest'] == True]['Primary Type'].value_counts()
crime_total_counts = df['Primary Type'].value_counts()
crime_arrest_rate = (crime_arrest_counts / crime_total_counts).sort_values(ascending=False)

top_10_most_arrested = crime_arrest_rate.head(10)
top_10_least_arrested = crime_arrest_rate.tail(10)



plt.style.use('bmh')
```

```
plt.figure(figsize=(12, 6))

sns.barplot(
    y=top_10_most_arrested.index,
    x=top_10_most_arrested.values * 100,
    palette='crest_r'
)

plt.xlabel("Arrest Rate (%)", fontsize=12, fontweight='bold')
plt.ylabel("Crime Type", fontsize=12, fontweight='bold')
plt.title("Crime Types with Highest Arrest Rates in Chicago (2015–2025)",
          fontsize=14, fontweight='bold', pad=15)

plt.gca().xaxis.set_major_formatter(plt.FuncFormatter(lambda x, p: f"{x:.1f}%"))
sns.despine()
plt.tight_layout()
plt.show()
```



In [ ]:
```
top_types = df['Primary Type'].value_counts().head(6).index

temp = df[df['Primary Type'].isin(top_types)].copy()
temp['Hour'] = pd.to_datetime(temp['Time'], format='%H:%M:%S', errors='coerce').dt.hour

type_hour = pd.crosstab(temp['Hour'], temp['Primary Type'])

type_hour.plot(
    kind='bar',
    stacked=True,
    figsize=(14,6),
    colormap='crest'
)
```

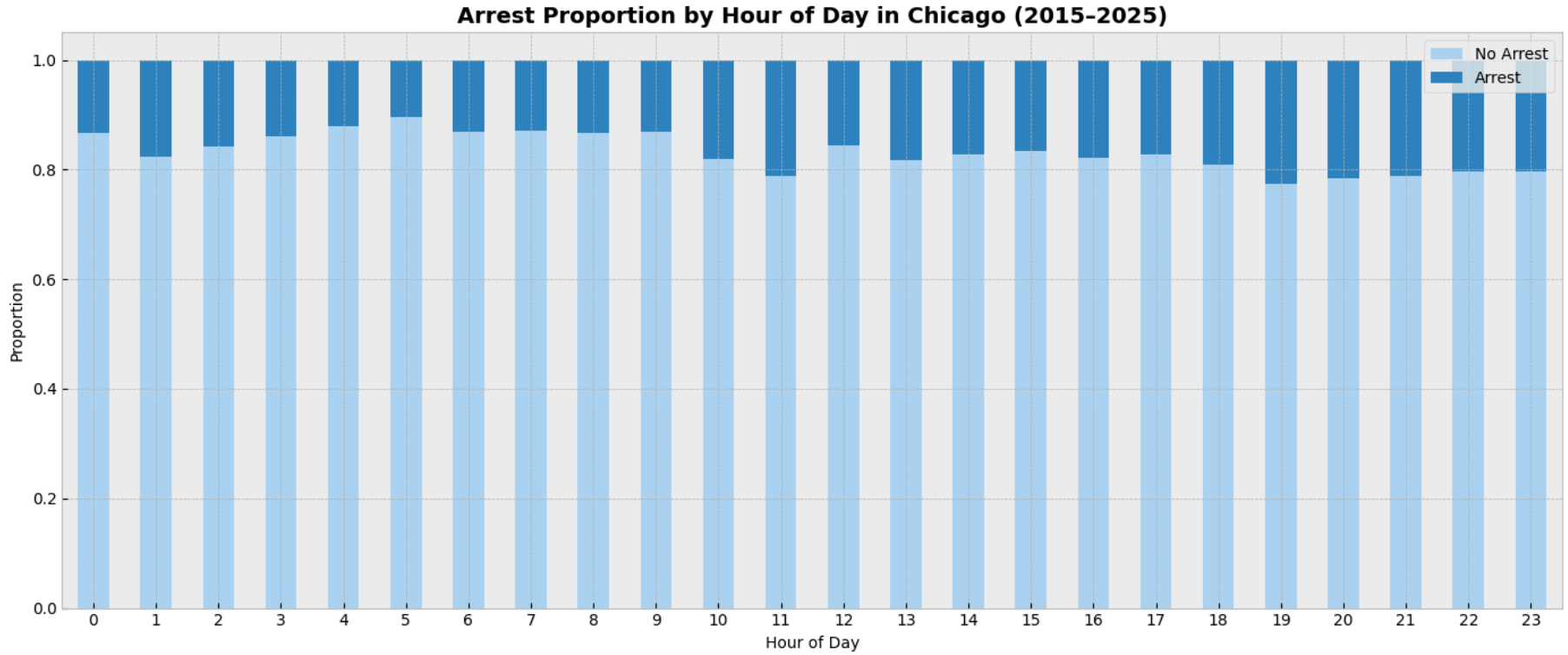
```
plt.title('Crime Incidents by Type and Hour of Day in Chicago (2015–2025)', fontsize=14, fontweight='bold')
plt.xlabel('Hour of Day')
plt.ylabel('Number of Crimes')
plt.xticks(rotation=0)
plt.tight_layout()
plt.show()
```



In [275…

```
df['Hour'] = pd.to_datetime(df['Time'], format='%H:%M:%S', errors='coerce').dt.hour

arrest_hour = pd.crosstab(df['Hour'], df['Arrest'], normalize='index')

arrest_hour.plot(
    kind='bar',
    stacked=True,
    figsize=(14,6),
    color=['#AED6F1', '#2E86C1']
```

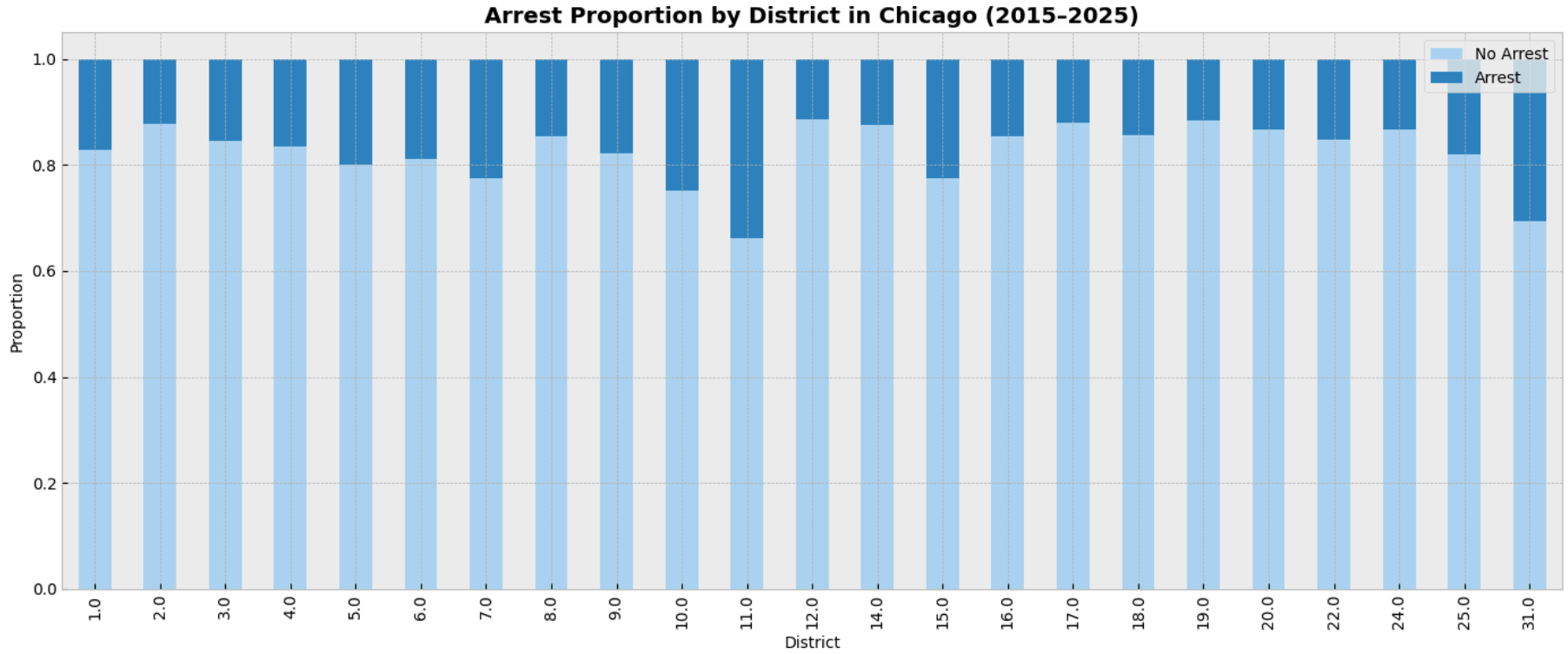
```
)

plt.title('Arrest Proportion by Hour of Day in Chicago (2015–2025)', fontsize=14, fontweight='bold')
plt.xlabel('Hour of Day')
plt.ylabel('Proportion')
plt.xticks(rotation=0)
plt.legend(['No Arrest', 'Arrest'])
plt.tight_layout()
plt.show()
```



In [276…

```
arrest_district = pd.crosstab(df['District'], df['Arrest'], normalize='index')

arrest_district.plot(
    kind='bar',
    stacked=True,
    figsize=(14,6),
    color=['#AED6F1', '#2E86C1']
```

```
)

plt.title('Arrest Proportion by District in Chicago (2015–2025)', fontsize=14, fontweight='bold')
plt.xlabel('District')
plt.ylabel('Proportion')
plt.legend(['No Arrest', 'Arrest'])
plt.tight_layout()
plt.show()
```

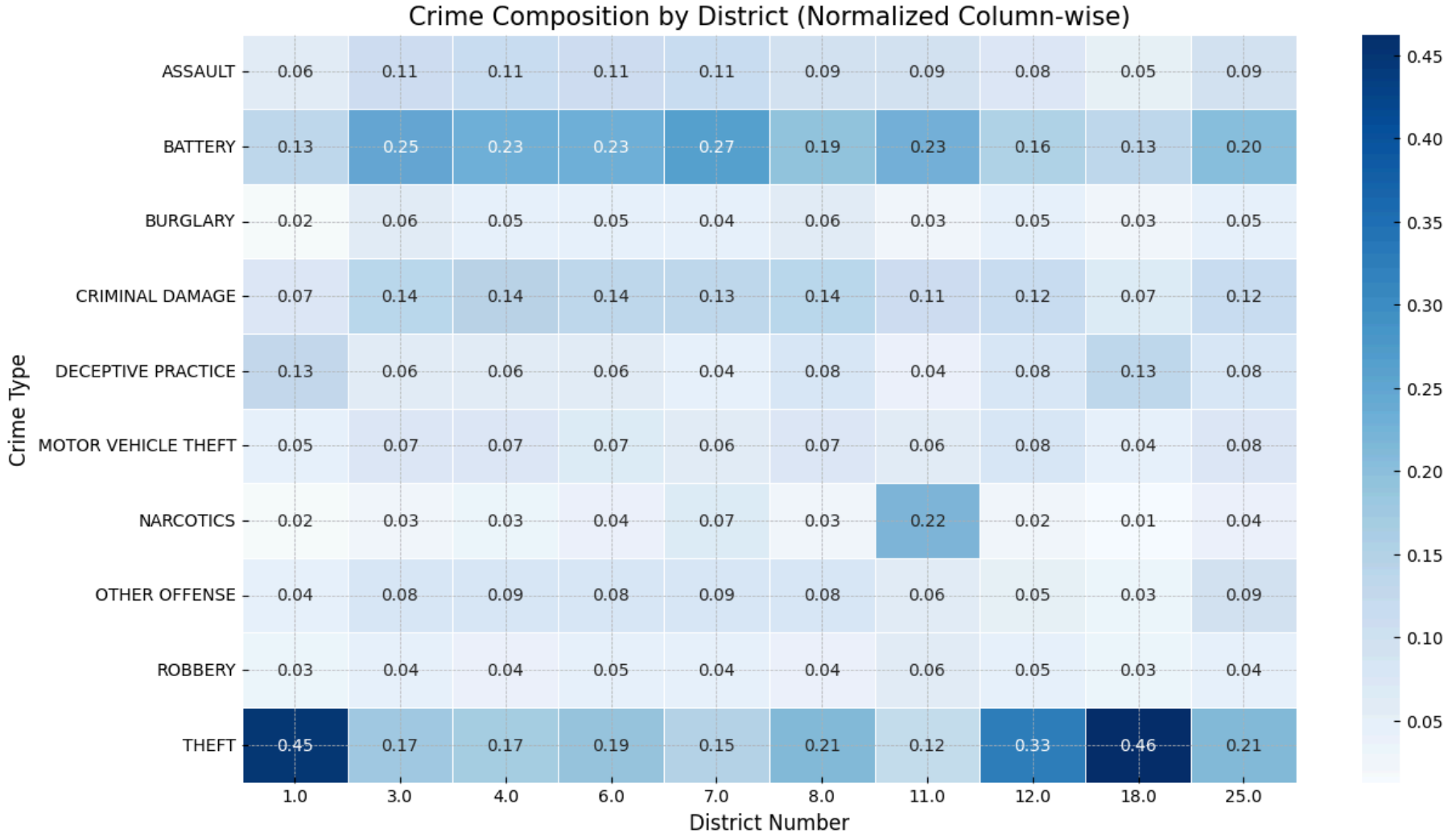


In [304…

```
# Crime Type vs District correlation
plt.figure(figsize=(14, 8))
#Select the top 10 crime types and the top 10 busiest areas to see what the relationship is between them.
top_10_crimes = df['Primary Type'].value_counts().head(10).index
top_10_districts = df['District'].value_counts().head(10).index

matrix_df = df[
    (df['Primary Type'].isin(top_10_crimes)) &
```

```
    (df['District'].isin(top_10_districts))
]

crime_district_matrix = pd.crosstab(matrix_df['Primary Type'], matrix_df['District'])

crime_district_matrix_norm = crime_district_matrix.div(crime_district_matrix.sum(axis=0), axis=1)

sns.heatmap(crime_district_matrix_norm, cmap="Blues", linewidths=0.5, annot=True, fmt=".2f")
plt.title("Crime Composition by District (Normalized Column-wise)", fontsize=15)
plt.xlabel("District Number", fontsize=12)
plt.ylabel("Crime Type", fontsize=12)
```

Out[304]: Text(150.58333333333334, 0.5, 'Crime Type')


Crime Composition by District (Normalized Column-wise)
Crime Type
ASSAULT 0.06 0.11 0.11 0.11 0.11 0.09 0.09 0.08 0.05 0.09
BATTERY 0.13 0.25 0.23 0.23 0.27 0.19 0.23 0.16 0.13 0.20
BURGLARY 0.02 0.06 0.05 0.05 0.04 0.06 0.03 0.05 0.03 0.05
CRIMINAL DAMAGE 0.07 0.14 0.14 0.14 0.13 0.14 0.11 0.12 0.07 0.12
DECEPTIVE PRACTICE 0.13 0.06 0.06 0.06 0.04 0.08 0.04 0.08 0.13 0.08
MOTOR VEHICLE THEFT 0.05 0.07 0.07 0.07 0.06 0.07 0.06 0.08 0.04 0.08
NARCOTICS 0.02 0.03 0.03 0.04 0.07 0.03 0.22 0.02 0.01 0.04
OTHER OFFENSE 0.04 0.08 0.09 0.08 0.09 0.08 0.06 0.05 0.03 0.09
ROBBERY 0.03 0.04 0.04 0.05 0.04 0.04 0.06 0.05 0.03 0.04
THEFT 0.45 0.17 0.17 0.19 0.15 0.21 0.12 0.33 0.46 0.21
1.0 3.0 4.0 6.0 7.0 8.0 11.0 12.0 18.0 25.0
District Number
0.45 0.40 0.35 0.30 0.25 0.20 0.15 0.10 0.05