Appendix:

Technical Supporting Documentation

This section details the complete technical workflow, rationale, and implementation logic behind the visual and analytical components of the memo.

It documents how the raw data was preprocessed, aggregated, and post-processed for interpretation. Each decision from scaling functions to visualization styling is explained with its analytical justification.

1. Dataset Overview and Cleaning

The dataset `Coffe_sales_with_menu_price` consists of **3,547 transactional records** with columns such as:

- `money` : revenue per transaction (numeric, continuous)
- `hour_of_day` : 24-hour timestamp of purchase
- `Weekday` : day of week (categorical)
- `coffee_name` : product purchased
- `Time_of_Day` : derived categorical variable
- `Weekdaysort` : numeric column for weekday sorting

The dataset contained no missing values in the key variables used for analysis. Currency values were formatted as floats, rounded for readability in visualization. Outliers (very high single-transaction amounts) were retained since they likely correspond to bulk orders operationally relevant for sales volume planning.

2. Feature Engineering

Two key engineered features were created:

- **Time_of_Day** derived from `hour_of_day` to represent broad customer behavior periods (Morning, Afternoon, Evening).
- **Weekdaysort** assigns numeric order to weekdays for consistent plotting.

The cutoffs for `Time_of_Day` were defined as:

- Morning: 0 ≤ hour < 11
- Afternoon: 11 ≤ hour < 17
- Evening: 17 ≤ hour < 24

These bins align with typical coffee consumption and operational patterns (morning commute, midday office breaks, evening social visits).

```
day_bins = [0, 11, 17, 24]
day_labels = ["Morning", "Afternoon", "Evening"]
```

```
df["Time_of_Day"] = pd.cut(df["hour_of_day"], bins=day_bins,
labels=day_labels, right=False)

weekday_order = ["Monday", "Tuesday", "Wednesday", "Thursday",
"Friday", "Saturday", "Sunday"]
df["Weekdaysort"] = df["Weekday"].apply(lambda x:
weekday_order.index(x))
```

3. Aggregation Logic

Several aggregation layers were created to support different visual analyses.
Each aggregation corresponds to a managerial insight discussed in the memo:

Aggregation	Purpose	Analytical Rationale
`sales_by_hour`	Total sales by hour	Identifies intra-day peaks and operational “rush hours.”
`sales_by_weekday`	Total sales by day	Distinguishes weekday vs. weekend trends.
`sales_by_coffee`	Total sales by product	Ranks products by contribution to revenue.
`pivot_sales`	2D pivot (Weekday × Time_of_Day)	Enables heatmap of sales by time and day.
`coffee_heatmap`	2D pivot (Coffee Type × Time_of_Day)	Visualizes product popularity across dayparts.

```
sales_by_hour = df.groupby("hour_of_day", as_index=False)
["money"].sum()
sales_by_weekday = (
    df.groupby(["Weekday", "Weekdaysort"], as_index=False)
["money"].sum().sort_values("Weekdaysort")
)
sales_by_coffee = (
    df.groupby("coffee_name", as_index=False)
["money"].sum().sort_values("money", ascending=False)
)
pivot_sales = df.pivot_table(index="Weekday", columns="Time_of_Day",
values="money", aggfunc="sum", fill_value=0)
coffee_heatmap = df.pivot_table(index="coffee_name",
columns="Time_of_Day", values="money", aggfunc="sum", fill_value=0)
```

4. Post-Processing and Derived Metrics

4.1 Normalization and Staffing Function

After calculating total sales per hour (`sales_by_hour`), a heuristic staffing model was applied to convert hourly revenue into a recommended number of staff members.
This step bridges raw financial data with operational guidance allowing sales intensity to be interpreted as workload intensity.

```python
import math

# Extract hourly sales as a Series indexed by hour
hour_sales = sales_by_hour.set_index("hour_of_day")["money"]

# Normalize hourly sales between 0 and 1
normalized = hour_sales / hour_sales.max()

# Scale and convert normalized values into discrete staff counts
recommended_staff = (normalized * 5).apply(math.ceil) + 1

# Create final DataFrame with hour and staff recommendations
rec_hours = (
    pd.DataFrame({"hour_of_day": range(0, 24)})
    .merge(recommended_staff.rename("recommended_staff"),
on="hour_of_day", how="left")
    .fillna(1)
)
rec_hours["recommended_staff"] =
rec_hours["recommended_staff"].astype(int)
rec_hours.head(10)
```

Explanation of the Transformation

The staffing calculation proceeds in five key steps:

1. `hour_sales` — represents total hourly revenue, e.g.:

   | hour_of_day | money ($) | |--------------|-----------| | 6 | 120 | | 7 | 250 | | 8 | 430 | | 9 | 670 | | 10 | 620 | | 11 | 540 |

   Here, 9–10 AM is clearly the high-demand period.

2. **Normalization:**
   Dividing by `hour_sales.max()` scales all hourly sales to a 0–1 range:
   $[\text{normalized}_i = \frac{\text{sales}_i}{\max(\text{sales})}]$
   For example, if 9 AM = $670 and 6 AM =$120, then:
   $[\text{normalized}(6\text{AM}) = 120/670 \approx 0.18]$ This allows comparison of relative sales intensity across hours.

3. **Scaling:**
   Multiplying by 5 maps the normalized sales into a theoretical range of 0–5.
   This constant (5) represents the **maximum number of employees needed during peak demand** for a small- to mid-sized coffee shop.
   It's a tunable parameter that can be adapted for larger stores.

4. **Ceiling Function (`math.ceil()`):**
   Rounds each scaled value **up** to the nearest integer, ensuring that fractional workloads are represented by whole staff members.
   For example:

   - 9 AM (normalized 1.00 × 5 = 5.00 → ceil = 5)

- 6 AM (normalized 0.18 × 5 = 0.9 → ceil = 1)

5. **Baseline Adjustment (+1):**
   Adds a **minimum coverage of one staff member**, ensuring that even during very low traffic hours (late evenings or early mornings), at least one barista is on duty for safety and customer service.

The final function therefore transforms revenue into operationally interpretable staff counts:

$$[\text{Recommended Staff}_i = \lceil (\text{Sales}_i / \text{Max Sales}) \times 5 \rceil + 1]$$

This is a **nonlinear heuristic**, meaning small increases in sales at lower hours may not proportionally increase staffing, but high-volume hours rapidly reach peak staffing levels.

Example: Inspect calculated recommendations for peak and off-peak hours

```
rec_hours.loc[rec_hours["hour_of_day"].isin([6, 9, 14, 20])]
```

Example Interpretation

Hour	Sales ($)	Normalized	Scaled	Ceil	+1	Recommended Staff
6 AM	120	0.18	0.9	1	+1	2
9 AM	670	1.00	5.0	5	+1	6
2 PM	350	0.52	2.6	3	+1	4
8 PM	190	0.28	1.4	2	+1	3

Hence, the model recommends **6 staff members at peak (9 AM)** and **2–3 during slower hours (6 AM, 8 PM)** consistent with observed transaction volume patterns.

Analytical Rationale

- **Normalization:** Enables comparison across stores and days by removing scale bias.
- **Scaling factor (×5):** Reflects realistic peak staffing capacity; can be recalibrated for store size or regional norms.
- **Ceiling and baseline adjustment:** Prevents fractional staffing and ensures continuous coverage.
- **Interpretability:** The resulting staffing chart aligns visually with transaction and revenue peaks, making it actionable for operations teams.

This transformation is **not a predictive model**, but an **empirical operational heuristic** derived from proportional scaling ideal for translating historical demand patterns into scheduling decisions without requiring regression-based forecasting.

5. Reproducibility and Analytical Assumptions

- **Environment:**
  Python 3.10.

Libraries: `pandas 2.x`, `numpy 1.26+`, `matplotlib 3.8+`, `seaborn 0.13+`.

- **Assumptions:**

  1. Sales volume correlates linearly with staffing demand (sufficient for aggregate-level scheduling).
  2. Customer arrival patterns are consistent across stores in the region.
  3. No external seasonality or promotional data were included; patterns are purely temporal.

- **Reproducibility:**
  Each cell is modular; parameters such as scaling factor (`5` in the staffing heuristic) or top product filter (`K` in product analysis) can be modified to test alternative operational scenarios.

In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from matplotlib.ticker import MaxNLocator, FuncFormatter
import math
```

In [2]:
```
df = pd.read_csv("Coffe_sales_with_menu_price.csv")
```

In [3]:
```
df.head()
```

Out[3]:

	hour_of_day	cash_type	coffee_name	Time_of_Day	Weekday	Month_name
0	10	card	Latte	Morning	Fri	Mar
1	12	card	Hot Chocolate	Afternoon	Fri	Mar
2	12	card	Hot Chocolate	Afternoon	Fri	Mar
3	13	card	Americano	Afternoon	Fri	Mar
4	13	card	Latte	Afternoon	Fri	Mar

In [4]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 3547 entries, 0 to 3546
Data columns (total 11 columns):
 #   Column       Non-Null Count  Dtype  
---  ------       --------------  -----  
 0   hour_of_day  3547 non-null   int64  
 1   cash_type    3547 non-null   object 
 2   coffee_name  3547 non-null   object 
 3   Time_of_Day  3547 non-null   object 
 4   Weekday      3547 non-null   object 
 5   Month_name   3547 non-null   object 
 6   Weekdaysort  3547 non-null   int64  
 7   Monthsort    3547 non-null   int64  
 8   Date         3547 non-null   object 
 9   Time         3547 non-null   object 
 10  money        3547 non-null   float64
dtypes: float64(1), int64(3), object(7)
memory usage: 304.9+ KB
```

In [5]:
```
# convert to datetime
df["Date"] = pd.to_datetime(df["Date"], errors="coerce")
```

```
df["Time"] = pd.to_datetime(df["Time"], errors="coerce")
```

```
/var/folders/mc/2wjfdchj6vsffbrpfbfgqw4w0000gn/T/ipykernel_70053/309375
0455.py:3: UserWarning: Could not infer format, so each element will be
parsed individually, falling back to `dateutil`. To ensure parsing is c
onsistent and as-expected, please specify a format.
  df["Time"] = pd.to_datetime(df["Time"], errors="coerce")
```

In [6]:
```
df
```

Out[6]:

	hour_of_day	cash_type	coffee_name	Time_of_Day	Weekday	Month_n
0	10	card	Latte	Morning	Fri	
1	12	card	Hot Chocolate	Afternoon	Fri	
2	12	card	Hot Chocolate	Afternoon	Fri	
3	13	card	Americano	Afternoon	Fri	
4	13	card	Latte	Afternoon	Fri	
...	...	...	...	...	...	
3542	10	card	Cappuccino	Morning	Sun	
3543	14	card	Cocoa	Afternoon	Sun	
3544	14	card	Cocoa	Afternoon	Sun	
3545	15	card	Americano	Afternoon	Sun	
3546	18	card	Latte	Night	Sun	

3547 rows × 11 columns

In [7]:
```
df[df.duplicated()]
```

Out[7]:

hour_of_day	cash_type	coffee_name	Time_of_Day	Weekday	Month_name

In [8]:
```
df.isnull().any()
```

Out[8]:
```
hour_of_day    False
cash_type      False
coffee_name    False
Time_of_Day    False
Weekday        False
Month_name     False
Weekdaysort    False
Monthsort      False
Date           False
Time           False
money          False
dtype: bool
```

In [9]:
```
df["money"] = pd.to_numeric(df["money"], errors="coerce")
```

In [10]:
```
weekday_order = ["Mon", "Tue", "Wed", "Thu", "Fri", "Sat", "Sun"]
month_order = [
    "Jan",
    "Feb",
    "Mar",
    "Apr",
    "May",
    "Jun",
    "Jul",
    "Aug",
    "Sep",
    "Oct",
    "Nov",
    "Dec",
]

df["Weekday"] = pd.Categorical(df["Weekday"], categories=weekday_order
df["Month_name"] = pd.Categorical(
    df["Month_name"], categories=month_order, ordered=True
)
```

In [11]:
```
df.head()
```

Out[11]:

	hour_of_day	cash_type	coffee_name	Time_of_Day	Weekday	Month_name
0	10	card	Latte	Morning	Fri	Mar
1	12	card	Hot Chocolate	Afternoon	Fri	Mar
2	12	card	Hot Chocolate	Afternoon	Fri	Mar
3	13	card	Americano	Afternoon	Fri	Mar
4	13	card	Latte	Afternoon	Fri	Mar

Question 1

What times of day and days of the week generate the highest sales volume, and how can staffing or store hours be optimized to match customer demand?

Purpose: Helps identify peak operational periods to guide shift scheduling and labor cost efficiency.

In [12]:
```
# general aggregations
sales_by_hour = (
    df.groupby("hour_of_day", as_index=False)["money"].sum().sort_valu
)
count_by_hour = (
    df.groupby("hour_of_day", as_index=False)
    .size()
    .rename(columns={"size": "transactions"})
)
sales_by_timeofday = (
    df.groupby("Time_of_Day", as_index=False)["money"]
    .sum()
    .sort_values("money", ascending=False)
)
sales_by_weekday = (
    df.groupby(["Weekday", "Weekdaysort"], as_index=False)["money"]
    .sum()
    .sort_values("Weekdaysort")
)
sales_by_coffee = (
    df.groupby("coffee_name", as_index=False)["money"]
    .sum()
    .sort_values("money", ascending=False)
)
```

```
/var/folders/mc/2wjfdchj6vsffbrpfbfgqw4w0000gn/T/ipykernel_70053/106961
8463.py:16: FutureWarning: The default of observed=False is deprecated
and will be changed to True in a future version of pandas. Pass observe
d=False to retain current behavior or observed=True to adopt the future
default and silence this warning.
  df.groupby(["Weekday", "Weekdaysort"], as_index=False)["money"]
```

In [13]:
```
pivot_df = df.pivot_table(
    index="hour_of_day", columns="Weekday", values="money", aggfunc="s
)
```

```
/var/folders/mc/2wjfdchj6vsffbrpfbfgqw4w0000gn/T/ipykernel_70053/177229
2445.py:1: FutureWarning: The default value of observed=False is deprec
ated and will change to observed=True in a future version of pandas. Sp
ecify observed=False to silence this warning and retain the current beh
avior
  pivot_df = df.pivot_table(
```

In [14]:
```
pivot_df
```

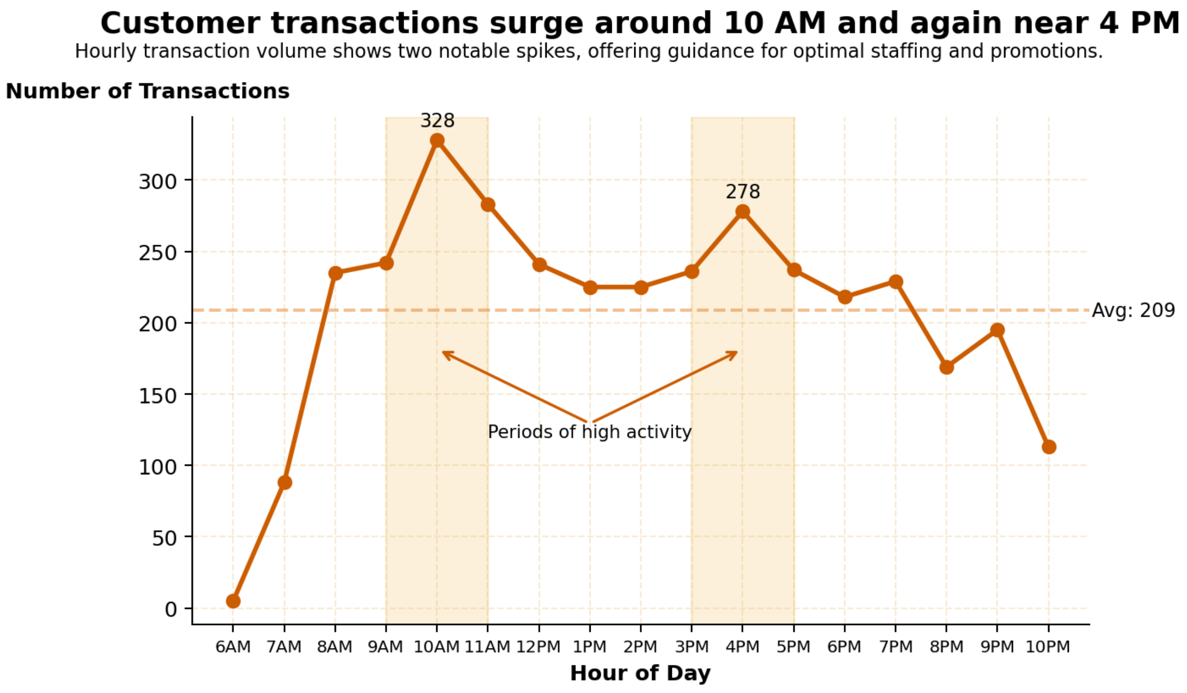
Out[14]:

Weekday hour_of_day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
6	9.70	0.00	0.00	0.00	13.35	0.00	0.00
7	105.45	69.50	84.45	63.45	82.85	9.70	8.90
8	188.25	220.85	131.65	102.20	216.55	107.10	88.70
9	165.80	175.75	117.25	146.70	225.15	149.15	95.05
10	232.90	213.95	211.10	217.55	189.35	183.65	228.05
11	173.25	247.50	203.50	125.65	124.10	242.35	130.50
12	112.15	134.75	149.05	129.25	163.60	207.30	188.75
13	124.95	99.45	195.35	138.75	163.70	147.45	148.20
14	190.90	147.60	68.45	150.85	148.35	169.45	142.85
15	170.15	119.45	141.05	163.90	158.45	168.30	159.35
16	218.65	211.10	194.30	177.55	139.05	193.65	111.55
17	160.55	157.25	156.70	162.25	184.50	129.50	108.70
18	162.70	147.70	155.10	138.25	138.80	85.05	153.20
19	203.10	236.95	164.05	193.05	116.25	89.30	46.45
20	94.40	165.40	108.10	135.05	70.55	103.65	81.50
21	117.70	144.55	140.05	192.80	76.45	52.15	153.50
22	60.65	54.25	45.50	57.95	152.70	95.95	38.80

In [15]:

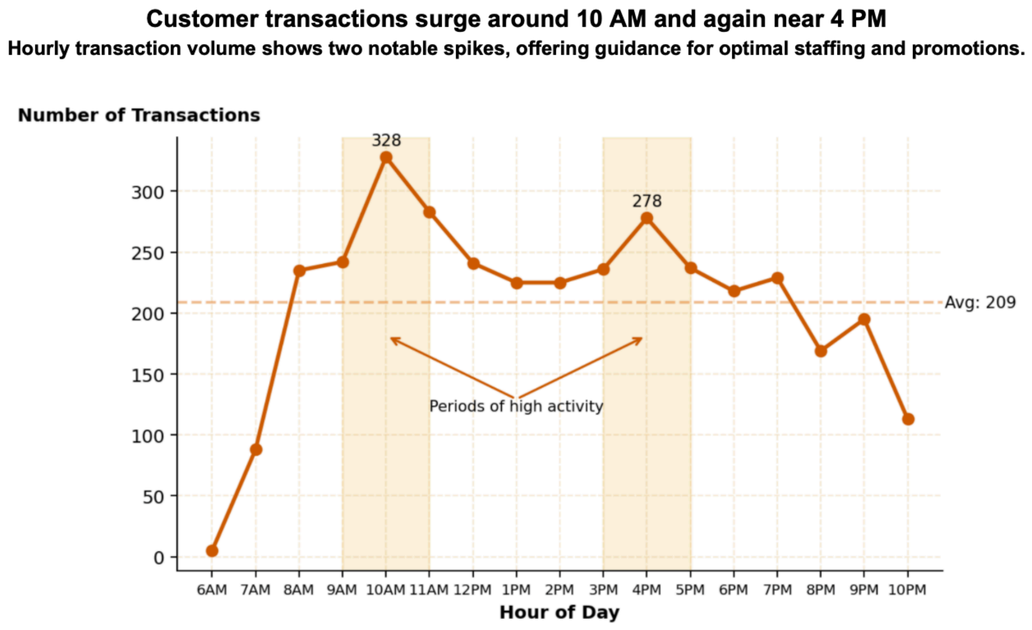
```python
tx_hour = count_by_hour.sort_values("hour_of_day")

fig, ax_tx = plt.subplots(figsize=(8, 5), dpi=180)

main_color = "#cc5c00"
light_color = "#f5c76e"
highlight_color = "#e67e22"

ax_tx.plot(
    tx_hour["hour_of_day"],
    tx_hour["transactions"],
    marker="o",
    linewidth=2.2,
    color=main_color,
)
ax_tx.grid(True, linestyle="--", alpha=0.25, color="#e0b35c")

spacing = tx_hour["transactions"].max() * 0.02
```

```
peak_hours = [10, 16]
for x, y in zip(tx_hour["hour_of_day"], tx_hour["transactions"]):
    if x in peak_hours:
        ax_tx.text(
            x,
            y + spacing,
            f"{y:,.0f}",
            ha="center",
            va="bottom",
            fontsize=9,
            fontweight="medium",
            color="black",
        )

plt.suptitle(
    "Hourly transaction volume shows two notable spikes, offering guid
    fontsize=9,
    fontweight="medium",
    y=0.872,
    x=0.5,
    ha="center",
    color="black",
)

plt.title(
    "Customer transactions surge around 10 AM and again near 4 PM",
    fontsize=14,
    fontweight="bold",
    pad=40,
    loc="center",
    color="black",
)

plt.xlabel("Hour of Day", fontsize=10, fontweight="bold", color="black
plt.ylabel("", fontsize=10, fontweight="bold")

ax_tx.text(
    -0.05,
    1.03,
    "Number of Transactions",
    transform=ax_tx.transAxes,
    ha="center",
    va="bottom",
    fontweight="bold",
    fontsize=10,
    color="black",
)

ax_tx.set_xticks(range(6, 23))
ax_tx.set_xticklabels(
    [f"{h%12 or 12}{'AM' if h < 12 else 'PM'}" for h in range(6, 23)],
    fontsize=8,
    fontweight="medium",
    color="black",
    family="sans-serif",
)

# get the avg line
avg_tx = tx_hour["transactions"].mean()
ax_tx.axhline(avg_tx, color=highlight_color, linestyle="--", alpha=0.5
ax_tx.text(
    x=tx_hour["hour_of_day"].max() + 0.85,
    y=avg_tx,
    s=f"Avg: {avg_tx:,.0f}",
    va="center",
    ha="left",
    fontsize=9,
    color="black",
    fontweight="medium",
)

# highlight windows
ax_tx.axvspan(9, 11, color=light_color, alpha=0.25)
ax_tx.axvspan(15, 17, color=light_color, alpha=0.25)

label_y = avg_tx * 0.62
arrow_y = avg_tx * 0.87

ax_tx.text(
    13,
    label_y,
    "Periods of high activity",
    ha="center",
    va="top",
    fontsize=8.5,
    fontweight="medium",
    color="black",
)

ax_tx.annotate(
    "",
    xy=(10, arrow_y),
    xytext=(13, label_y),
    arrowprops=dict(arrowstyle="->", lw=1.3, color=main_color),
)
ax_tx.annotate(
    "",
    xy=(16, arrow_y),
    xytext=(13, label_y),
    arrowprops=dict(arrowstyle="->", lw=1.3, color=main_color),
)

sns.despine()
plt.tight_layout()
plt.show()
```



We need to post processes this for better labeling for which we move our plot above to a word document and then work on the labels

The is our plot post processing



In [16]:
```
weekday_order = ["Mon", "Tue", "Wed", "Thu", "Fri", "Sat", "Sun"]
pivot_df = pivot_df[weekday_order]

left_data = pivot_df.copy()
```

```
def get_time_of_day(hour):
    if 6 <= hour < 12:
        return "Morning"
    elif 12 <= hour < 17:
        return "Afternoon"
    elif 17 <= hour <= 22:
        return "Evening"
    else:
        return "Other"


df_long = pivot_df.reset_index().melt(
    id_vars="hour_of_day", var_name="Weekday", value_name="Revenue"
)
df_long["TimeOfDay"] = df_long["hour_of_day"].apply(get_time_of_day)
agg = df_long.groupby(["Weekday", "TimeOfDay"])["Revenue"].sum().reset
time_order = ["Morning", "Afternoon", "Evening"]
right_data = (
    agg.pivot(index="Weekday", columns="TimeOfDay", values="Revenue")
    .reindex(index=weekday_order, columns=time_order)
    .fillna(0)
)
```

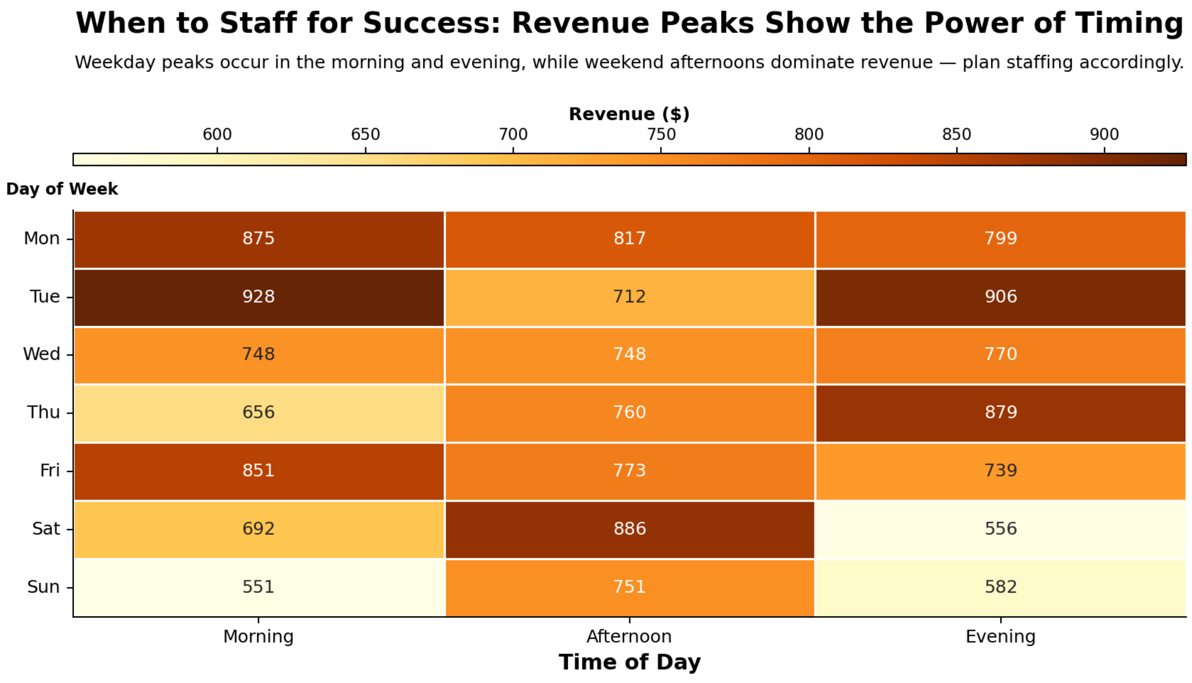
In [17]:
```
# prepare heatmap
td_map = {"Night": "Evening"}
df_for_heatmap = df.assign(Time_of_Day_plot=df["Time_of_Day"].replace(

right_data = (
    df_for_heatmap.pivot_table(
        index="Weekday",
        columns="Time_of_Day_plot",
        values="money",
        aggfunc="sum",
        fill_value=0,
    )
    .reindex(index=weekday_order)
    .reindex(columns=time_order, fill_value=0)
    .astype(float)
)
```

```
/var/folders/mc/2wjfdchj6vsffbrpfbfgqw4w0000gn/T/ipykernel_70053/185310
7675.py:6: FutureWarning: The default value of observed=False is deprec
ated and will change to observed=True in a future version of pandas. Sp
ecify observed=False to silence this warning and retain the current beh
avior
  df_for_heatmap.pivot_table(
```

In [18]:
```
weekday_order = ["Mon", "Tue", "Wed", "Thu", "Fri", "Sat", "Sun"]
time_order = ["Morning", "Afternoon", "Evening"]

fig, ax = plt.subplots(figsize=(10, 6), dpi=180)
```

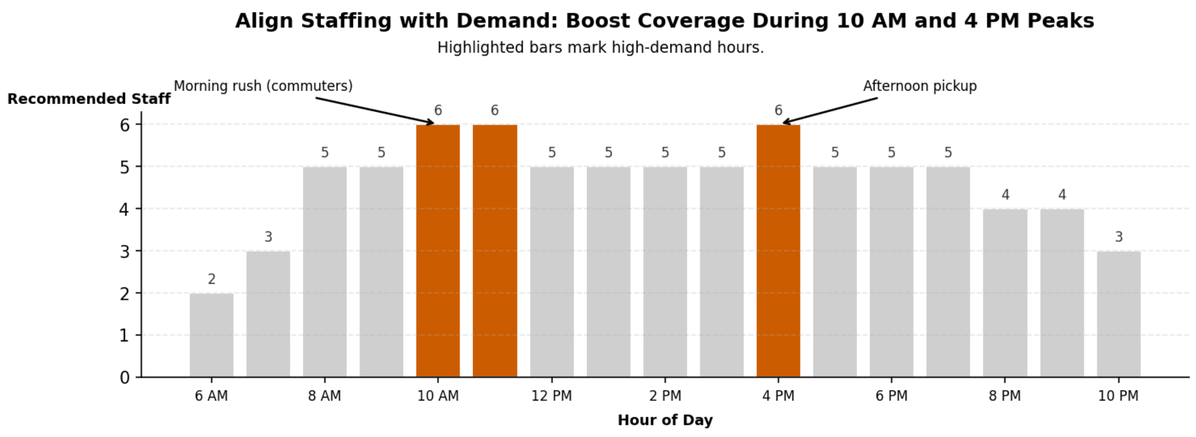
```
heatmap = sns.heatmap(
    right_data,
    ax=ax,
    cmap="YlOrBr",
    annot=True,
    fmt=".0f",
    linewidths=0.5,
    linecolor="white",
    cbar=False,
)

# horizontal colorbar axis just above the heatmap
from mpl_toolkits.axes_grid1 import make_axes_locatable

divider = make_axes_locatable(ax)
cax = divider.append_axes("top", size="3%", pad=0.35)
norm = plt.Normalize(vmin=right_data.values.min(), vmax=right_data.val
sm = plt.cm.ScalarMappable(cmap="YlOrBr", norm=norm)
cbar = fig.colorbar(sm, cax=cax, orientation="horizontal")
cbar.set_label("Revenue ($)", fontsize=10, fontweight="bold", labelpad
cbar.ax.tick_params(labelsize=9, pad=2)
cbar.ax.xaxis.set_ticks_position("top")
cbar.ax.xaxis.set_label_position("top")

ax.set_title(
    "When to Staff for Success: Revenue Peaks Show the Power of Timing
    fontsize=16,
    fontweight="bold",
    pad=100,
)
ax.text(
    0.5,
    1.35,
    "Weekday peaks occur in the morning and evening, while weekend aft
    transform=ax.transAxes,
    ha="center",
    fontsize=10,
)

ax.set_xlabel("Time of Day", fontsize=12, fontweight="bold")
ax.set_ylabel("", fontsize=10, fontweight="bold")
ax.text(
    -0.01,
    1.03,
    "Day of Week",
    transform=ax.transAxes,
    ha="center",
    va="bottom",
    fontweight="bold",
    fontsize=9,
)
```

```
ax.set_xticklabels(ax.get_xticklabels(), rotation=0)
ax.set_yticklabels(ax.get_yticklabels(), rotation=0)

sns.despine()
plt.tight_layout(rect=[0, 0.05, 1, 0.96])
plt.show()
```



In [19]:
```
hour_sales = sales_by_hour.set_index("hour_of_day")["money"]
normalized = hour_sales / hour_sales.max() if hour_sales.max() > 0 els
recommended_staff = (normalized * 5).apply(math.ceil) + 1

recommended_df = recommended_staff.reset_index().rename(
    columns={"money": "recommended_staff"}
)

rec_hours = (
    pd.DataFrame({"hour_of_day": range(6, 23)})
    .merge(recommended_df, on="hour_of_day", how="left")
    .fillna(1)
)
rec_hours["recommended_staff"] = rec_hours["recommended_staff"].astype
```

In [20]:
```
plt.figure(figsize=(10, 4), dpi=150)

non_peak_color = "#cfcfcf"
peak_color = "#cc5c00"

bars = plt.bar(
    rec_hours["hour_of_day"],
    rec_hours["recommended_staff"],
    color=non_peak_color,
    edgecolor="white",
)

for idx, val in enumerate(rec_hours["recommended_staff"]):
    plt.text(
        rec_hours["hour_of_day"].iloc[idx],
        val + 0.15,
        str(val),
        ha="center",
        va="bottom",
        fontsize=8,
        color="#333",
    )

# highlight peak bars
peak_hours = [10, 11, 16]
plt.bar(
    rec_hours.loc[rec_hours["hour_of_day"].isin(peak_hours), "hour_of_
    rec_hours.loc[rec_hours["hour_of_day"].isin(peak_hours), "recommen
    color=peak_color,
    edgecolor="white",
)

plt.title(
    "Align Staffing with Demand: Boost Coverage During 10 AM and 4 PM
    fontsize=12,
    fontweight="bold",
    pad=50,
)
plt.suptitle(
    "Highlighted bars mark high-demand hours.",
    fontsize=9,
    y=0.835,
)

plt.xlabel("Hour of Day", fontsize=8.5, fontweight="bold", labelpad=6)
plt.ylabel("")
plt.text(
    -0.05,
    1.02,
    "Recommended Staff",
    transform=plt.gca().transAxes,
    ha="center",
    va="bottom",
    fontweight="bold",
    fontsize=8.5,
)

ax = plt.gca()
ax.set_xticks(range(6, 23))
ax.set_xticklabels(
    [f"{h%12 or 12} {'AM' if h < 12 else 'PM'}" for h in range(6, 23)]
    rotation=0,
    fontsize=8,
    fontweight="medium",
    family="sans-serif",
)

plt.annotate(
    "Morning rush (commuters)",
    xy=(10, 6),
    xytext=(8.5, 6.8),
    arrowprops=dict(arrowstyle="->", color="black", lw=1.2),
    fontsize=8,
    color="black",
    ha="right",
)

plt.annotate(
    "Afternoon pickup",
    xy=(16, 6),
    xytext=(17.5, 6.8),
    arrowprops=dict(arrowstyle="->", color="black", lw=1.2),
    fontsize=8,
    color="black",
    ha="left",
)

ax.xaxis.set_major_locator(MaxNLocator(integer=True))
ax.grid(axis="y", linestyle="--", alpha=0.3)
ax.spines["top"].set_visible(False)
ax.spines["right"].set_visible(False)

plt.tight_layout()
plt.show()
```



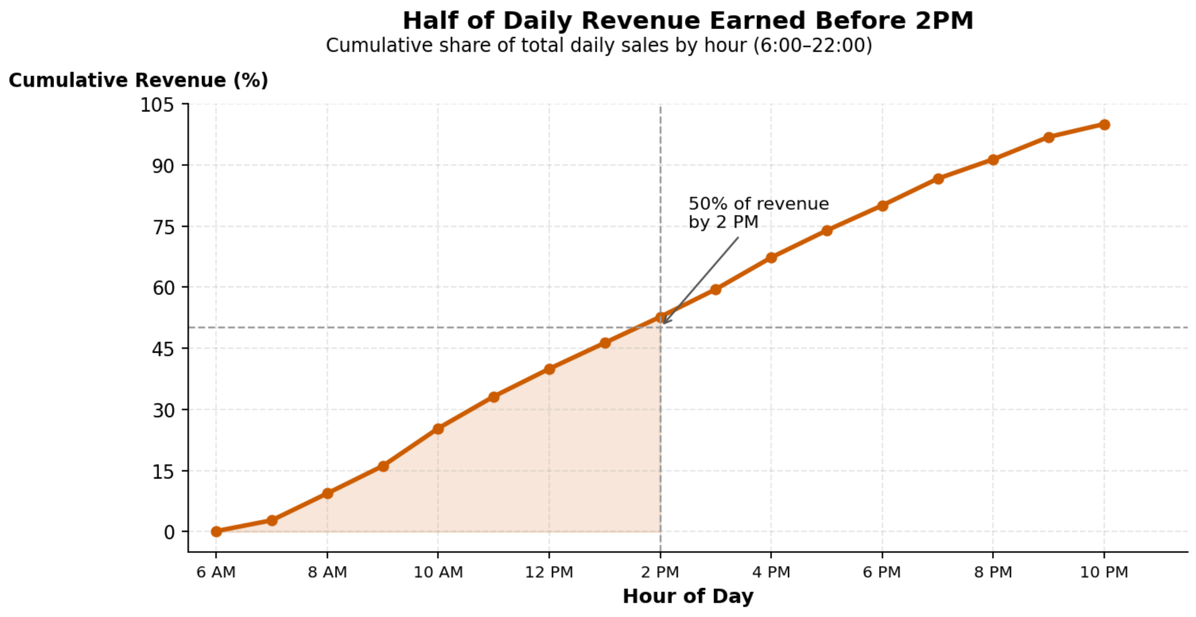
In [21]:
```
rec_open_hours = rec_hours[rec_hours["recommended_staff"] > 1][
    ["hour_of_day", "recommended_staff"]
]
print("Recommended Staff by Hour (hours with >1 staff):")
print(rec_open_hours)
```

```
Recommended Staff by Hour (hours with >1 staff):
    hour_of_day  recommended_staff
0             6                  2
1             7                  3
2             8                  5
3             9                  5
4            10                  6
5            11                  6
6            12                  5
7            13                  5
8            14                  5
9            15                  5
10           16                  6
11           17                  5
12           18                  5
13           19                  5
14           20                  4
15           21                  4
16           22                  3
```

Question 2

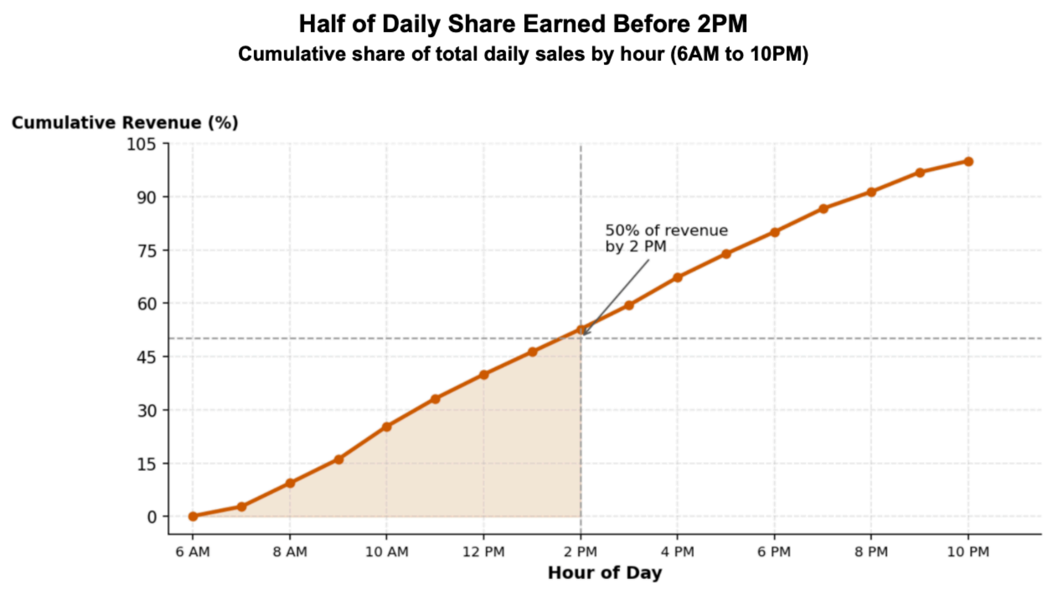
Which types of coffee are most popular during different times of the day, and how should inventory and promotions adjust accordingly? Purpose: Helps managers plan inventory and marketing by matching coffee types to customer habits (e.g., cappuccinos in the morning, iced drinks in the afternoon).

In [22]:
```python
assert {"hour_of_day", "money"} <= set(df.columns), "Missing columns."

OPEN_HOUR = 6
CLOSE_HOUR = 23

h = (
    df.assign(hour_of_day=pd.to_numeric(df["hour_of_day"], errors="coe
    .dropna(subset=["hour_of_day", "money"])
    .query("@OPEN_HOUR <= hour_of_day <= @CLOSE_HOUR")
    .groupby("hour_of_day", dropna=True)["money"]
    .sum()
    .sort_index()
)
if h.empty:
    print("No hourly data to plot within open hours.")
else:
    cum_pct = h.cumsum() / h.sum() * 100
    half_idx = (cum_pct >= 50).idxmax()

    plt.figure(figsize=(9, 5), dpi=170)
    ax = plt.gca()
    plt.plot(
        cum_pct.index,
        cum_pct.values,
        color="#cc5c00",
        lw=2.4,
        marker="o",
        markersize=5,
    )

    plt.fill_between(
        cum_pct.index,
        0,
        cum_pct.values,
        where=cum_pct.index <= half_idx,
        color="#cc5c00",
        alpha=0.15,
    )

    plt.axhline(50, ls="--", c="#999", lw=1)
    plt.axvline(half_idx, ls="--", c="#999", lw=1)

    hour_12 = half_idx % 12
    hour_12 = 12 if hour_12 == 0 else hour_12
    period = "AM" if half_idx < 12 else "PM"

    plt.annotate(
        f"50% of revenue\nby {hour_12} {period}",
        xy=(half_idx, 50),
        xytext=(half_idx + 0.5, 78),
        arrowprops=dict(arrowstyle="->", color="#555", lw=1),
        fontsize=9.5,
        ha="left",
        va="center",
    )

    plt.title(
        "Half of Daily Revenue Earned Before 2PM",
        fontsize=13,
        fontweight="bold",
        pad=40,
    )
    plt.suptitle(
        f"Cumulative share of total daily sales by hour ({OPEN_HOUR}:0
        fontsize=10,
        y=0.873,
    )

    ax.set_xlabel("Hour of Day", fontsize=10.5, fontweight="bold")

    ax.text(
        -0.05,
        1.03,
        "Cumulative Revenue (%)",
        transform=ax.transAxes,
        ha="center",
        va="bottom",
        fontweight="bold",
        fontsize=10,
    )

    ax.set_xlim(OPEN_HOUR - 0.5, CLOSE_HOUR + 0.5)
    ax.set_xticks(range(OPEN_HOUR, CLOSE_HOUR + 1, 2))
    ax.set_xticklabels(
        [
            f"{h%12 or 12} {'AM' if h < 12 else 'PM'}"
            for h in range(OPEN_HOUR, CLOSE_HOUR + 1, 2)
        ],
        fontsize=8.5,
    )

    ax.yaxis.set_major_locator(MaxNLocator(integer=True))
    ax.grid(axis="both", linestyle="--", alpha=0.3)
    ax.spines["top"].set_visible(False)
    ax.spines["right"].set_visible(False)

    plt.tight_layout()
    plt.show()
```



We need to post processes this for better labeling for which we move our plot above to a word document and then work on the labels

The is our plot post processing

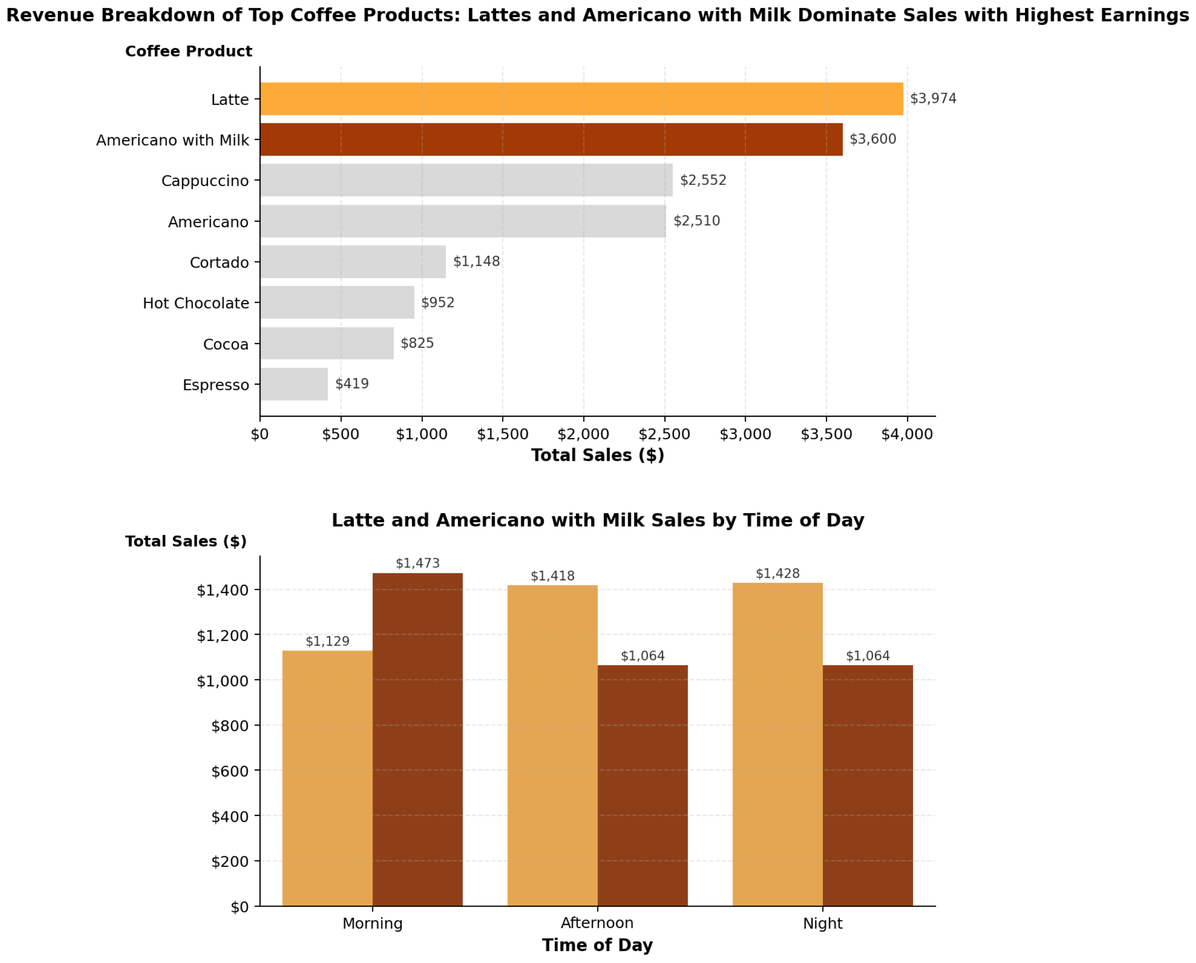


In [23]:
```
DAYPART_ORDER = ["Morning", "Afternoon", "Night"]
DAYPART_DESC = {"Morning": "Open–10am", "Afternoon": "10am–2pm", "Nigh
TOP_N = 8
CMAP = "Blues"
CURRENCY = FuncFormatter(lambda x, p: f"${x:,.0f}")

sales_by_coffee_ord = sales_by_coffee.sort_values("money", ascending=T
overall_top = sales_by_coffee_ord.iloc[-1]["coffee_name"]
overall_top_amt = sales_by_coffee_ord.iloc[-1]["money"]

coffee_heatmap = (
    df[df["coffee_name"].isin(sales_by_coffee_ord["coffee_name"])]
    .pivot_table(
        index="coffee_name",
        columns="Time_of_Day",
        values="money",
        aggfunc="sum",
        fill_value=0,
    )
    .reindex(index=sales_by_coffee_ord["coffee_name"].tolist())
    .reindex(columns=[d for d in DAYPART_ORDER if d in df["Time_of_Day
)

daypart_leads = coffee_heatmap.idxmax(axis=0)
lead_morn = daypart_leads.get("Morning", None)
lead_aft = daypart_leads.get("Afternoon", None)
lead_night = daypart_leads.get("Night", None)
```

In [24]:
```
cmap = plt.cm.YlOrBr
latte_color = cmap(0.45)
americano_color = cmap(0.85)

fig, (ax1, ax2) = plt.subplots(
    2, 1, figsize=(8, 10), dpi=180, gridspec_kw={"hspace": 0.4}
)

y = np.arange(len(sales_by_coffee_ord))
colors = []
for name in sales_by_coffee_ord["coffee_name"]:
    if name == "Latte":
        colors.append(latte_color)
    elif name == "Americano with Milk":
        colors.append(americano_color)
    else:
        colors.append("#D9D9D9")

bars = ax1.barh(y, sales_by_coffee_ord["money"].values, color=colors)

xmax = sales_by_coffee_ord["money"].max()
for yi, v in zip(y, sales_by_coffee_ord["money"].values):
    ax1.text(v + xmax * 0.01, yi, f"${v:,.0f}", va="center", fontsize=

ax1.set_yticks(y)
ax1.set_yticklabels(sales_by_coffee_ord["coffee_name"])
ax1.set_xlabel("Total Sales ($)", fontsize=11, fontweight="bold")
ax1.set_ylabel("")
ax1.xaxis.set_major_formatter(CURRENCY)
ax1.grid(axis="x", linestyle="--", alpha=0.3)
ax1.spines["top"].set_visible(False)
ax1.spines["right"].set_visible(False)

ax1.set_title(
    "Revenue Breakdown of Top Coffee Products: Lattes and Americano wi
    fontsize=12,
    fontweight="bold",
    pad=30,
)
ax1.text(
    -0.2,
    1.02,
    "Coffee Product",
    transform=ax1.transAxes,
    fontsize=10,
    ha="left",
    va="bottom",
    fontweight="bold",
)

focus_products = ["Latte", "Americano with Milk"]
focus_df = coffee_heatmap.loc[focus_products]

focus_long = focus_df.reset_index().melt(
    id_vars="coffee_name", var_name="Time of Day", value_name="Sales (
)
focus_long.rename(columns={"coffee_name": "Coffee"}, inplace=True)
```

```
sns.barplot(
    data=focus_long,
    x="Time of Day",
    y="Sales ($)",
    hue="Coffee",
    ax=ax2,
    palette=[latte_color, americano_color],
)

for container in ax2.containers:
    ax2.bar_label(
        container,
        labels=[f"${h.get_height():,.0f}" for h in container],
        fmt="%d",
        label_type="edge",
        padding=2,
        fontsize=8.5,
        color="#333",
    )

ax2.set_title(
    "Latte and Americano with Milk Sales by Time of Day",
    fontsize=12,
    fontweight="bold",
    pad=20,
)
ax2.text(
    -0.2,
    1.02,
    "Total Sales ($)",
    transform=ax2.transAxes,
    fontsize=10,
    ha="left",
    va="bottom",
    fontweight="bold",
)

ax2.set_xlabel("Time of Day", fontsize=11, fontweight="bold")
ax2.set_ylabel("")
ax2.yaxis.set_major_formatter(CURRENCY)
ax2.grid(axis="y", linestyle="--", alpha=0.3)
ax2.spines["top"].set_visible(False)
ax2.spines["right"].set_visible(False)

ax2.legend_.remove()

fig.tight_layout(rect=[0, 0, 1, 0.97], pad=2.0)
plt.show()
```

```
/var/folders/mc/2wjfdchj6vsffbrpfbfgqw4w0000gn/T/ipykernel_70053/346913
3764.py:105: UserWarning: This figure includes Axes that are not compat
ible with tight_layout, so results might be incorrect.
  fig.tight_layout(rect=[0, 0, 1, 0.97], pad=2.0)
```



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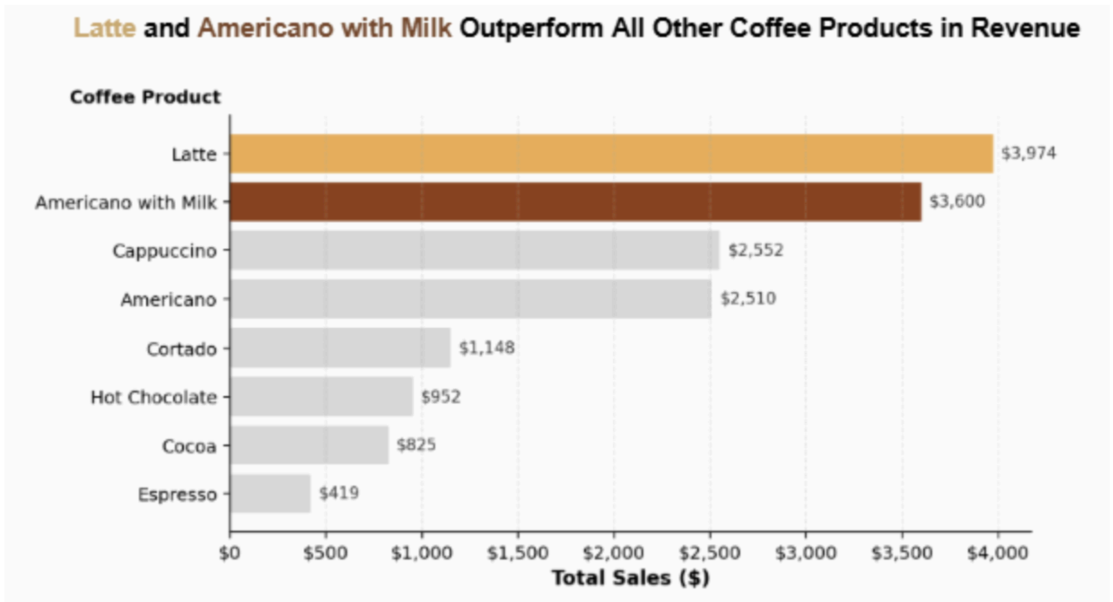
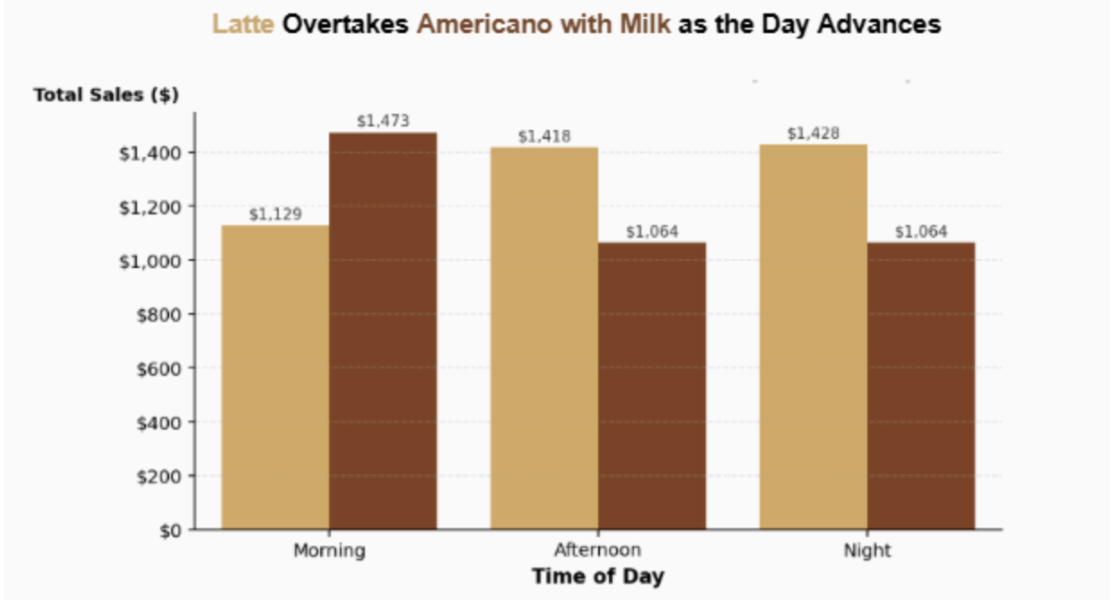
The is our plot post processing


Latte and Americano with Milk Outperform All Other Coffee Products in Revenue
Coffee Product
Latte
Americano with Milk
Cappuccino
Americano
Cortado
Hot Chocolate
Cocoa
Espresso
$3,974
$3,600
$2,552
$2,510
$1,148
$952
$825
$419
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
$4,000
Total Sales ($)


Latte Overtakes Americano with Milk as the Day Advances
Total Sales ($)
$1,129
$1,473
$1,418
$1,064
$1,428
$1,064
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
Morning
Afternoon
Night
Time of Day