

```
In [1]: #Import Data and necessary libraries
import os
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import math
import statsmodels.api as sm
from statsmodels.formula.api import ols
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import TimeSeriesSplit, RandomizedSearchCV
from sklearn.ensemble import RandomForestRegressor
from xgboost import XGBRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
from scipy.stats import randint, uniform

import warnings

warnings.simplefilter(action = "ignore", category = FutureWarning)
```

Business Problem:

Rossmann drug stores has asked to predict 6 weeks of daily sales for 1,115 stores located across Germany. Reliable sales forecasts enable store managers to create effective staff schedules that increase productivity and motivation. By helping Rossmann create a robust prediction model, you will help store managers stay focused on what's most important to them: their customers and their teams!

Historical sales data for 1,115 Rossmann stores is provided. The task is to forecast the "Sales" column for the test set. Note that some stores in the dataset were temporarily closed for refurbishment.

Files

train.csv - historical data including Sales

test.csv - historical data excluding Sales

sample_submission.csv - a sample submission file in the correct format

store.csv - supplemental information about the stores

Data fields

Most of the fields are self-explanatory. The following are descriptions for those that aren't.

Id - an Id that represents a (Store, Date) duple within the test set

Store - a unique Id for each store

Sales - the turnover for any given day (this is what you are predicting)

Customers - the number of customers on a given day

Open - an indicator for whether the store was open: 0 = closed, 1 = open

StateHoliday - indicates a state holiday. Normally all stores, with few exceptions, are closed on state holidays. Note that all schools are closed on public holidays and weekends. a = public holiday, b = Easter holiday, c = Christmas, 0 = None

SchoolHoliday - indicates if the (Store, Date) was affected by the closure of public schools

StoreType - differentiates between 4 different store models: a, b, c, d

Assortment - describes an assortment level: a = basic, b = extra, c = extended

CompetitionDistance - distance in meters to the nearest competitor store

CompetitionOpenSince[Month/Year] - gives the approximate year and month of the time the nearest competitor was opened

Promo - indicates whether a store is running a promo on that day

Promo2 - Promo2 is a continuing and consecutive promotion for some stores: 0 = store is not participating, 1 = store is participating

Promo2Since[Year/Week] - describes the year and calendar week when the store started participating in Promo2

PromoInterval - describes the consecutive intervals Promo2 is started, naming the months the promotion is started anew. E.g. "Feb,May,Aug,Nov" means each round starts in February, May, August, November of any given year for that store

```
In [3]: #Load data from csv files

base_path = "/Users/sanchijain/Desktop/Data_Analytics_Science/MSDS_Colorado/"

#Using os.path.join() (cross-platform safe)
train_path = os.path.join(base_path, "train.csv")
store_path = os.path.join(base_path, "store.csv")
test_path = os.path.join(base_path, "test.csv")

#Loading train csv, 'StateHoliday' column has str and int dtype so low_memory
train = pd.read_csv(train_path, low_memory = False)
print("train dataset")
print(train.head())

#Loading store csv
```

```
store = pd.read_csv(store_path)
print("store dataset")
print(store.head())

#Loading test csv
test = pd.read_csv(test_path)
print("test dataset")
print(test.head())
```

```

train dataset
    Store DayOfWeek      Date  Sales  Customers  Open  Promo  StateHoliday
\ 
 0     1         5 2015-07-31   5263       555     1     1       0
 1     2         5 2015-07-31   6064       625     1     1       0
 2     3         5 2015-07-31   8314       821     1     1       0
 3     4         5 2015-07-31  13995      1498     1     1       0
 4     5         5 2015-07-31   4822       559     1     1       0

    SchoolHoliday
 0             1
 1             1
 2             1
 3             1
 4             1

store dataset
    Store StoreType Assortment  CompetitionDistance  CompetitionOpenSinceMont
h \
 0     1         c           a                  1270.0          9.
 0
 1     2         a           a                  570.0          11.
 0
 2     3         a           a                 14130.0         12.
 0
 3     4         c           c                  620.0          9.
 0
 4     5         a           a                 29910.0         4.
 0

    CompetitionOpenSinceYear  Promo2  Promo2SinceWeek  Promo2SinceYear \
 0            2008.0        0        NaN            NaN
 1            2007.0        1        13.0          2010.0
 2            2006.0        1        14.0          2011.0
 3            2009.0        0        NaN            NaN
 4            2015.0        0        NaN            NaN

    PromoInterval
 0              NaN
 1  Jan,Apr,Jul,Oct
 2  Jan,Apr,Jul,Oct
 3              NaN
 4              NaN

test dataset
    Id  Store DayOfWeek      Date  Open  Promo  StateHoliday  SchoolHoliday
 0   1     1         4 2015-09-17  1.0     1       0             0
 1   2     3         4 2015-09-17  1.0     1       0             0
 2   3     7         4 2015-09-17  1.0     1       0             0
 3   4     8         4 2015-09-17  1.0     1       0             0
 4   5     9         4 2015-09-17  1.0     1       0             0

```

```
In [4]: print(train.info())
print(store.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1017209 entries, 0 to 1017208
Data columns (total 9 columns):
 #   Column            Non-Null Count  Dtype  
--- 
 0   Store              1017209 non-null   int64  
 1   DayOfWeek          1017209 non-null   int64  
 2   Date               1017209 non-null   object  
 3   Sales              1017209 non-null   int64  
 4   Customers          1017209 non-null   int64  
 5   Open                1017209 non-null   int64  
 6   Promo               1017209 non-null   int64  
 7   StateHoliday        1017209 non-null   object  
 8   SchoolHoliday       1017209 non-null   int64  
dtypes: int64(7), object(2)
memory usage: 69.8+ MB
None
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1115 entries, 0 to 1114
Data columns (total 10 columns):
 #   Column            Non-Null Count  Dtype  
--- 
 0   Store              1115 non-null    int64  
 1   StoreType          1115 non-null    object  
 2   Assortment         1115 non-null    object  
 3   CompetitionDistance 1112 non-null   float64 
 4   CompetitionOpenSinceMonth 761 non-null   float64 
 5   CompetitionOpenSinceYear 761 non-null   float64 
 6   Promo2              1115 non-null    int64  
 7   Promo2SinceWeek     571 non-null    float64 
 8   Promo2SinceYear     571 non-null    float64 
 9   PromoInterval       571 non-null    object  
dtypes: float64(5), int64(2), object(3)
memory usage: 87.2+ KB
None
```

```
In [5]: #Check for the missing values
print("Number of missing values in each column of store dataset")

for col in store.columns:
    print(col, ":", store[col].isna().sum())
```

```
Number of missing values in each column of store dataset
Store : 0
StoreType : 0
Assortment : 0
CompetitionDistance : 3
CompetitionOpenSinceMonth : 354
CompetitionOpenSinceYear : 354
Promo2 : 0
Promo2SinceWeek : 544
Promo2SinceYear : 544
PromoInterval : 544
```

```
In [6]: #Merging train and store df on 'store' column
store_df = pd.merge(train, store, how = "left", on = "Store")
```

```
store_df.head()
```

	Store	DayOfWeek	Date	Sales	Customers	Open	Promo	StateHoliday	SchoolH
0	1	5	2015-07-31	5263	555	1	1	0	0
1	2	5	2015-07-31	6064	625	1	1	0	0
2	3	5	2015-07-31	8314	821	1	1	0	0
3	4	5	2015-07-31	13995	1498	1	1	0	0
4	5	5	2015-07-31	4822	559	1	1	0	0

Inspecting the dataset

```
In [16]: store_df.shape
```

#1.01 million records and 18 features in the dataset

```
Out[16]: (1017209, 18)
```

```
In [18]: store_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1017209 entries, 0 to 1017208
Data columns (total 18 columns):
 #   Column           Non-Null Count  Dtype  
 --- 
 0   Store            1017209 non-null   int64  
 1   DayOfWeek        1017209 non-null   int64  
 2   Date             1017209 non-null   object 
 3   Sales            1017209 non-null   int64  
 4   Customers        1017209 non-null   int64  
 5   Open              1017209 non-null   int64  
 6   Promo             1017209 non-null   int64  
 7   StateHoliday     1017209 non-null   object 
 8   SchoolHoliday    1017209 non-null   int64  
 9   StoreType         1017209 non-null   object 
 10  Assortment        1017209 non-null   object 
 11  CompetitionDistance 1014567 non-null   float64
 12  CompetitionOpenSinceMonth 693861 non-null   float64
 13  CompetitionOpenSinceYear 693861 non-null   float64
 14  Promo2            1017209 non-null   int64  
 15  Promo2SinceWeek   509178 non-null   float64
 16  Promo2SinceYear   509178 non-null   float64
 17  PromoInterval     509178 non-null   object 

dtypes: float64(5), int64(8), object(5)
memory usage: 139.7+ MB
```

In [20]: `store_df.describe()`

Out[20]:

	Store	DayOfWeek	Sales	Customers	Open
count	1.017209e+06	1.017209e+06	1.017209e+06	1.017209e+06	1.017209e+06
mean	5.584297e+02	3.998341e+00	5.773819e+03	6.331459e+02	8.301067e-01
std	3.219087e+02	1.997391e+00	3.849926e+03	4.644117e+02	3.755392e-01
min	1.000000e+00	1.000000e+00	0.000000e+00	0.000000e+00	0.000000e+00
25%	2.800000e+02	2.000000e+00	3.727000e+03	4.050000e+02	1.000000e+00
50%	5.580000e+02	4.000000e+00	5.744000e+03	6.090000e+02	1.000000e+00
75%	8.380000e+02	6.000000e+00	7.856000e+03	8.370000e+02	1.000000e+00
max	1.115000e+03	7.000000e+00	4.155100e+04	7.388000e+03	1.000000e+00

In [21]: `store_df.head()`

Out[21]:

	Store	DayOfWeek	Date	Sales	Customers	Open	Promo	StateHoliday	SchoolH
0	1	5	2015-07-31	5263	555	1	1	0	0
1	2	5	2015-07-31	6064	625	1	1	0	0
2	3	5	2015-07-31	8314	821	1	1	0	0
3	4	5	2015-07-31	13995	1498	1	1	0	0
4	5	5	2015-07-31	4822	559	1	1	0	0

In [24]: `#Make all column headers to lower case and making all names to snake case from camel case`
`import re`
`store_df.columns = [re.sub(r'(?<!^)(?=[A-Z])', '_', col).lower() for col in store_df]`
`print(store_df.columns)`

```
Index(['store', 'day_of_week', 'date', 'sales', 'customers', 'open', 'promo',
       'state_holiday', 'school_holiday', 'store_type', 'assortment',
       'competition_distance', 'competition_open_since_month',
       'competition_open_since_year', 'promo2', 'promo2_since_week',
       'promo2_since_year', 'promo_interval'],
      dtype='object')
```

In [26]: `#Converting 'date' column from object to date datatype`
`store_df['date']= pd.to_datetime(store_df['date'])`

```
In [28]: #Segregating month and year from 'date' into separate columns
store_df['month'] = store_df['date'].dt.month
store_df['year'] = store_df['date'].dt.year
```

Check for unique values

```
In [31]: #Number of unique values in each column of the df
print("Number of unique values in each column")
for col in store_df.columns:
    print(col, ":", store_df[col].nunique())
```

Number of unique values in each column

store	:	1115
day_of_week	:	7
date	:	942
sales	:	21734
customers	:	4086
open	:	2
promo	:	2
state_holiday	:	4
school_holiday	:	2
store_type	:	4
assortment	:	3
competition_distance	:	654
competition_open_since_month	:	12
competition_open_since_year	:	23
promo2	:	2
promo2_since_week	:	24
promo2_since_year	:	7
promo_interval	:	3
month	:	12
year	:	3

```
In [33]: #Unique values in each of the categorical features
unique_val_col_list = ['day_of_week', 'open', 'promo', 'state_holiday', 'sch
    'competition_open_since_month', 'competition_open_si
    'promo2_since_year', 'promo_interval', 'month', 'year

print("Unique values for each categorical column")
for col in unique_val_col_list:
    print(col, ":", store_df[col].unique())
```

```
Unique values for each categorical column
day_of_week : [5 4 3 2 1 7 6]
open : [1 0]
promo : [1 0]
state_holiday : ['0' 'a' 'b' 'c']
school_holiday : [1 0]
store_type : ['c' 'a' 'd' 'b']
assortment : ['a' 'c' 'b']
competition_open_since_month : [ 9. 11. 12. 4. 10. 8. nan 3. 6. 5. 1.
2. 7.]
competition_open_since_year : [2008. 2007. 2006. 2009. 2015. 2013. 2014. 200
0. 2011. nan 2010. 2005.
1999. 2003. 2012. 2004. 2002. 1961. 1995. 2001. 1990. 1994. 1900. 1998.]
promo2 : [0 1]
promo2_since_week : [nan 13. 14. 1. 45. 40. 26. 22. 5. 6. 10. 31. 37. 9.
39. 27. 18. 35.
23. 48. 36. 50. 44. 49. 28.]
promo2_since_year : [ nan 2010. 2011. 2012. 2009. 2014. 2015. 2013.]
promo_interval : [nan 'Jan,Apr,Jul,Oct' 'Feb,May,Aug,Nov' 'Mar,Jun,Sept,De
c']
month : [ 7 6 5 4 3 2 1 12 11 10 9 8]
year : [2015 2014 2013]
```

Check for Missing Values

```
In [36]: #Check for the missing values
print("Number of missing values in each column")

for col in store_df.columns:
    print(col, ":", store_df[col].isna().sum())
```

```
Number of missing values in each column
store : 0
day_of_week : 0
date : 0
sales : 0
customers : 0
open : 0
promo : 0
state_holiday : 0
school_holiday : 0
store_type : 0
assortment : 0
competition_distance : 2642
competition_open_since_month : 323348
competition_open_since_year : 323348
promo2 : 0
promo2_since_week : 508031
promo2_since_year : 508031
promo_interval : 508031
month : 0
year : 0
```

```
In [38]: #Filter all rows where 'competition_distance' has missing values
store_df[store_df['competition_distance'].isna()]
```

Out[38]:

	store	day_of_week	date	sales	customers	open	promo	state_holiday
290	291	5	2015-07-31	10052	973	1	1	0
621	622	5	2015-07-31	6306	540	1	1	0
878	879	5	2015-07-31	6000	466	1	1	0
1405	291	4	2015-07-30	9030	883	1	1	0
1736	622	4	2015-07-30	5412	406	1	1	0
...
1015601	622	3	2013-01-02	4080	451	1	0	0
1015858	879	3	2013-01-02	3077	326	1	0	0
1016385	291	2	2013-01-01	0	0	0	0	a
1016716	622	2	2013-01-01	0	0	0	0	a
1016973	879	2	2013-01-01	0	0	0	0	a

2642 rows × 20 columns

In [40]:

```
#All the unique values of 'store', 'store_type', 'assortment' where 'competition_distance' is null
competition_missing_rows = store_df[store_df['competition_distance'].isna()]

print("Unique Stores:", competition_missing_rows['store'].unique())
print("Unique Store_type:", competition_missing_rows['store_type'].unique())
print("Unique assortment:", competition_missing_rows['assortment'].unique())
```

Unique Stores: [291 622 879]
 Unique Store_type: ['d' 'a']
 Unique assortment: ['a' 'c']

```
In [42]: #There are 3 stores (291, 622, 879) Stores with missing competition distance
#Lets replace the 'competition_distance' missing values with a large value (1000)

#define a large value to indicate 'no nearby competition'
large_distance = store_df['competition_distance'].max() + 1000

#Apply conditional update only to rows with missing competition_distance
store_df.loc[store_df['competition_distance'].isna(), 'competition_distance'] = large_distance
```

```
In [44]: #Viewing competition_open_since_month's missing values

store_df[store_df['competition_open_since_month'].isna()]
```

Out[44]:

	store	day_of_week	date	sales	customers	open	promo	state_holiday
11	12		5 2015-07-31	8959	962	1	1	0
12	13		5 2015-07-31	8821	568	1	1	0
15	16		5 2015-07-31	10231	979	1	1	0
18	19		5 2015-07-31	8234	718	1	1	0
21	22		5 2015-07-31	6566	633	1	1	0
...
1017189	1096		2 2013-01-01	0	0	0	0	a
1017193	1100		2 2013-01-01	0	0	0	0	a
1017206	1113		2 2013-01-01	0	0	0	0	a
1017207	1114		2 2013-01-01	0	0	0	0	a
1017208	1115		2 2013-01-01	0	0	0	0	a

323348 rows × 20 columns

```
In [48]: #Replacing missing values in 'competition_open_since_month' and 'competition_since_store_magic'
#As for cases where there is no competition around them there won't be any negative impact.
#no historical impact. And for cases, where the opening date is not available, we can use the latest date

#Finding the max date in the dataframe
latest_date = store_df['date'].max()

print("latest date:", latest_date)
```

```
latest date: 2015-07-31 00:00:00
```

```
In [50]: #Replace missing values with latest date
store_df['competition_open_since_month'].fillna(latest_date.month, inplace = True)
store_df['competition_open_since_year'].fillna(latest_date.year, inplace = True)

store_df.isna().sum()
```

```
Out[50]: store          0
day_of_week      0
date            0
sales           0
customers       0
open             0
promo            0
state_holiday    0
school_holiday   0
store_type       0
assortment       0
competition_distance  0
competition_open_since_month  0
competition_open_since_year   0
promo2           0
promo2_since_week  508031
promo2_since_year 508031
promo_interval     508031
month            0
year             0
dtype: int64
```

```
In [52]: #Converting the columns to int datatype
store_df['competition_open_since_month'] = store_df['competition_open_since_month'].astype(int)
store_df['competition_open_since_year'] = store_df['competition_open_since_year'].astype(int)

store_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1017209 entries, 0 to 1017208
Data columns (total 20 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   store            1017209 non-null   int64  
 1   day_of_week      1017209 non-null   int64  
 2   date             1017209 non-null   datetime64[ns] 
 3   sales            1017209 non-null   int64  
 4   customers        1017209 non-null   int64  
 5   open              1017209 non-null   int64  
 6   promo             1017209 non-null   int64  
 7   state_holiday    1017209 non-null   object  
 8   school_holiday   1017209 non-null   int64  
 9   store_type        1017209 non-null   object  
 10  assortment       1017209 non-null   object  
 11  competition_distance 1017209 non-null   float64 
 12  competition_open_since_month 1017209 non-null   int64  
 13  competition_open_since_year   1017209 non-null   int64  
 14  promo2            1017209 non-null   int64  
 15  promo2_since_week 509178 non-null   float64  
 16  promo2_since_year 509178 non-null   float64  
 17  promo_interval    509178 non-null   object  
 18  month             1017209 non-null   int32  
 19  year              1017209 non-null   int32  
dtypes: datetime64[ns](1), float64(3), int32(2), int64(10), object(4)
memory usage: 147.5+ MB
```

In [54]: `store_df[store_df['promo2_since_week'].isna()]['promo2'].unique()`
#This gives us the rows where promo2_since_week info is missing, the corresponding rows
#Let's see wherever the value of promo2 is 0, the corresponding promo2_since

Out[54]: `array([0])`

In [56]: `#Number of rows with missing 'promo2_since_week' values- 508,031`
`store_df['promo2_since_week'].isna().sum()`

Out[56]: `508031`

In [58]: `#So if a store didn't have promo2, then it didn't have promo2_since_week, means it has missing values`
#Replacing all the missing values of those columns with corresponding latest
`store_df['promo2_since_week'].fillna(1, inplace = True)`
`store_df['promo2_since_year'].fillna(latest_date.year, inplace = True)`
`store_df['promo_interval'].fillna(0, inplace = True)`

In [60]: `#Cleaning promo2_since_week and promo2_since_year column`
`#Convert to int`
`store_df['promo2_since_week'] = store_df['promo2_since_week'].astype(int)`
`store_df['promo2_since_year'] = store_df['promo2_since_year'].astype(int)`

In [62]: `store_df.isna().sum()`
#Viola!!! We have a dataset with 0 missing values

```
Out[62]: store          0
day_of_week        0
date              0
sales             0
customers         0
open               0
promo              0
state_holiday      0
school_holiday     0
store_type         0
assortment         0
competition_distance 0
competition_open_since_month 0
competition_open_since_year 0
promo2              0
promo2_since_week    0
promo2_since_year    0
promo_interval       0
month               0
year                0
dtype: int64
```

Data type check

```
In [64]: store_df.info()
```

#	Column	Non-Null Count	Dtype
0	store	1017209 non-null	int64
1	day_of_week	1017209 non-null	int64
2	date	1017209 non-null	datetime64[ns]
3	sales	1017209 non-null	int64
4	customers	1017209 non-null	int64
5	open	1017209 non-null	int64
6	promo	1017209 non-null	int64
7	state_holiday	1017209 non-null	object
8	school_holiday	1017209 non-null	int64
9	store_type	1017209 non-null	object
10	assortment	1017209 non-null	object
11	competition_distance	1017209 non-null	float64
12	competition_open_since_month	1017209 non-null	int64
13	competition_open_since_year	1017209 non-null	int64
14	promo2	1017209 non-null	int64
15	promo2_since_week	1017209 non-null	int64
16	promo2_since_year	1017209 non-null	int64
17	promo_interval	1017209 non-null	object
18	month	1017209 non-null	int32
19	year	1017209 non-null	int32

dtypes: datetime64[ns](1), float64(1), int32(2), int64(12), object(4)
memory usage: 147.5+ MB

```
In [66]: #Combine competition_open_since_month and competition_open_since_year and convert them to date
store_df['competition_open_since_date'] = pd.to_datetime(store_df['competition_open_since_month'].astype(str) + '-' + store_df['competition_open_since_year'].astype(str))
store_df['competition_open_since_date'] = pd.to_datetime(store_df['competition_open_since_date'])

In [68]: #Drop 'competition_open_since_month' and 'competition_open_since_year' columns
store_df.drop(['competition_open_since_month', 'competition_open_since_year'], axis=1, inplace=True)

In [72]: #Convert year + week to a date (Monday of that week)
store_df['promo2_since_date'] = pd.to_datetime(store_df['promo2_since_year'].astype(str) + '-' + store_df['promo2_since_week'].astype(str), format = '%Y-%W-%w') #%Y-Year
store_df['promo2_since_date'] = pd.to_datetime(store_df['promo2_since_date'].dt.strftime('%Y-%m-%d'))

In [74]: #Drop promo2_since_week and year columns
store_df.drop(['promo2_since_week', 'promo2_since_year'], axis=1, inplace=True)

In [78]: #Creating new columns: competition_open_since = (date - competition_open_since_date)
#promo2_since = (date - promo2_since_date)
#It will tell the number of days passed since the competition opened and promo 2 began
#competition_open_since = date - competition_open_since_date
#promo2_since = date - promo2_since_date
#competition_open_since = store_df['date'] - store_df['competition_open_since_date']
#promo2_since = store_df['date'] - store_df['promo2_since_date']

store_df['competition_open_since'] = store_df['date'] - store_df['competition_open_since_date']
store_df['promo2_since'] = store_df['date'] - store_df['promo2_since_date']

store_df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1017209 entries, 0 to 1017208
Data columns (total 20 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   store            1017209 non-null   int64  
 1   day_of_week      1017209 non-null   int64  
 2   date             1017209 non-null   datetime64[ns]
 3   sales            1017209 non-null   int64  
 4   customers        1017209 non-null   int64  
 5   open              1017209 non-null   int64  
 6   promo             1017209 non-null   int64  
 7   state_holiday    1017209 non-null   object  
 8   school_holiday   1017209 non-null   int64  
 9   store_type        1017209 non-null   object  
 10  assortment        1017209 non-null   object  
 11  competition_distance 1017209 non-null   float64 
 12  promo2            1017209 non-null   int64  
 13  promo_interval    1017209 non-null   object  
 14  month             1017209 non-null   int32  
 15  year              1017209 non-null   int32  
 16  competition_open_since_date 1017209 non-null   datetime64[ns]
 17  promo2_since_date 1017209 non-null   datetime64[ns]
 18  competition_open_since 1017209 non-null   timedelta64[ns]
 19  promo2_since      1017209 non-null   timedelta64[ns]
dtypes: datetime64[ns](3), float64(1), int32(2), int64(8), object(4), timedelta64[ns](2)
memory usage: 147.5+ MB
```

```
In [82]: #Modifying state_holiday to 'is_holiday' binary feature

#Converting state_holiday to str dtype and then 'is_holiday' to binary
store_df['is_holiday'] = store_df['state_holiday'].astype(str).apply(lambda
```

```
In [84]: #Creating 'is_weekend' binary feature from 'day_of_week' column

store_df['is_weekend'] = store_df['day_of_week'].apply(lambda x: 1 if x in |
```

Exploratory Data Analysis

```
In [87]: # Lets segregate categorical, numerical but categorical and numerical columns

def col_names(data, cat = 15):
    cat_cols_1 = [col for col in data if data[col].dtype == 'O' or data[col]
num_but_cat = [col for col in data if data[col].dtype not in ['category'
cat_cols = cat_cols_1 + num_but_cat

    num_cols = [col for col in data if data[col].dtype not in ['category', 'O']

    date_cols = [col for col in data if data[col].dtype == 'datetime64[ns]']

    print(f"\nOnly category columns: {cat_cols_1} and length: {len(cat_cols_1)}
print("\nNumeric but category columns:", num_but_cat,"and length: ", len(num_but_cat))
print("\nAll categorical columns:", cat_cols, "and length: ", len(cat_cols))
print("\nAll numerical columns:", num_cols, "and length: ", len(num_cols))
print("\nAll date columns:", date_cols, "and length: ", len(date_cols))

    return cat_cols_1, num_but_cat, cat_cols, num_cols, date_cols
```

```
In [89]: result = col_names(store_df)
cat_cols_1, num_but_cat, cat_cols, num_cols, date_cols = result[0], result[1]
```

Only category columns: ['state_holiday', 'store_type', 'assortment', 'promo_interval'] and length: 4

Numeric but category columns: ['day_of_week', 'open', 'promo', 'school_holiday', 'promo2', 'month', 'year', 'is_holiday', 'is_weekend'] and length: 9

All categorical columns: ['state_holiday', 'store_type', 'assortment', 'promo_interval', 'day_of_week', 'open', 'promo', 'school_holiday', 'promo2', 'month', 'year', 'is_holiday', 'is_weekend'] and length: 13

All numerical columns: ['store', 'sales', 'customers', 'competition_distance', 'competition_open_since', 'promo2_since'] and length: 6

All date columns: ['date', 'competition_open_since_date', 'promo2_since_date'] and length: 3

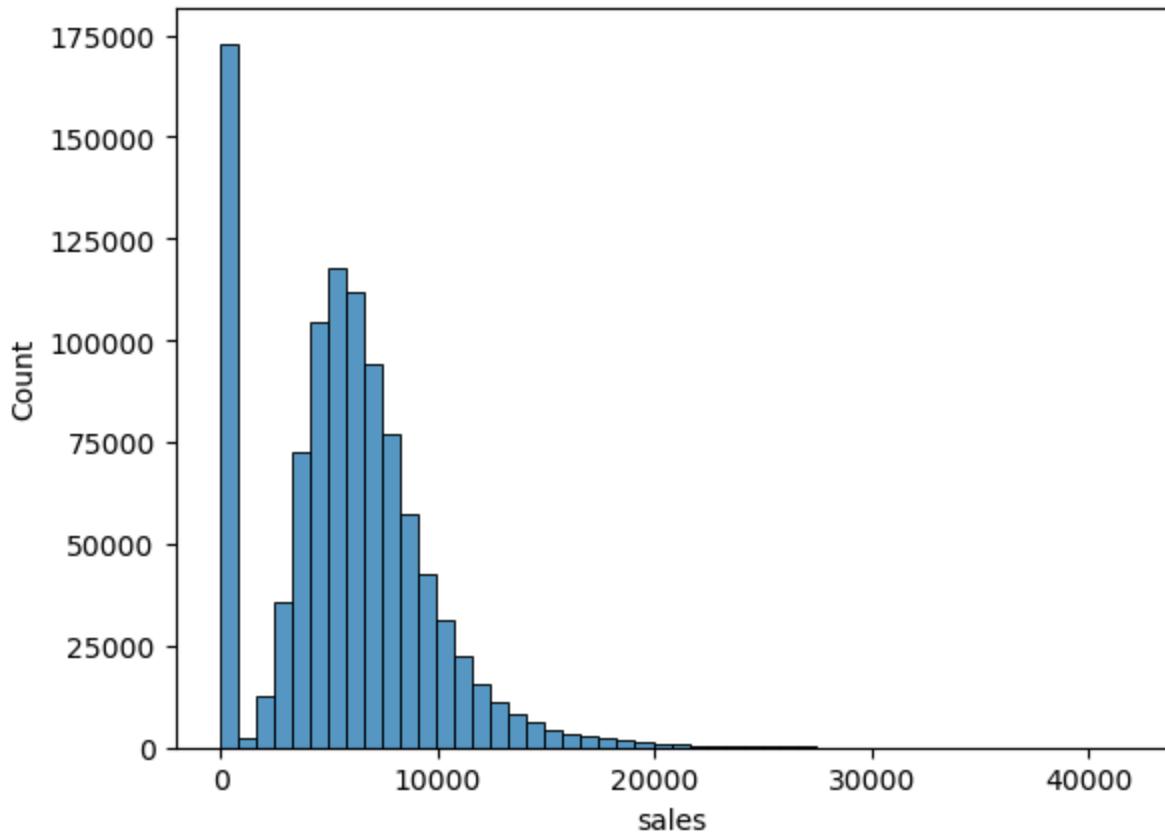
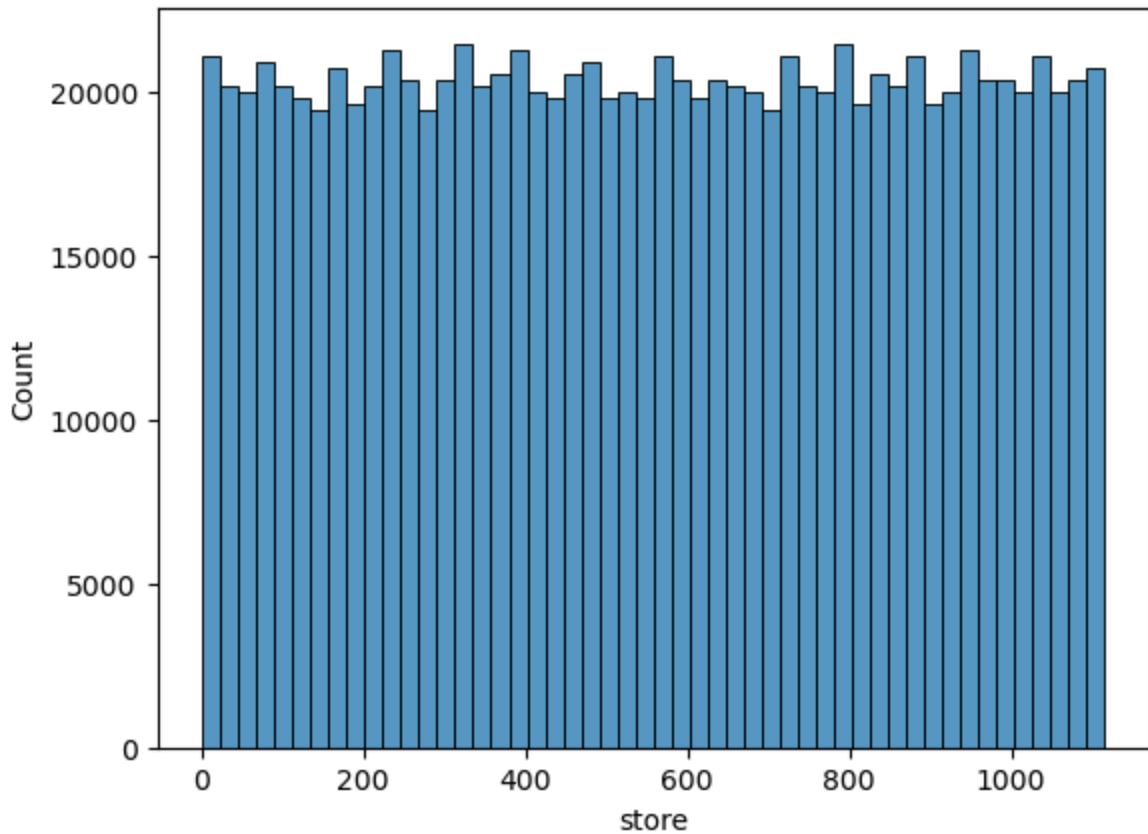
```
In [91]: #Let's look at the distributions of numerical columns except 'competition_open_since_date'

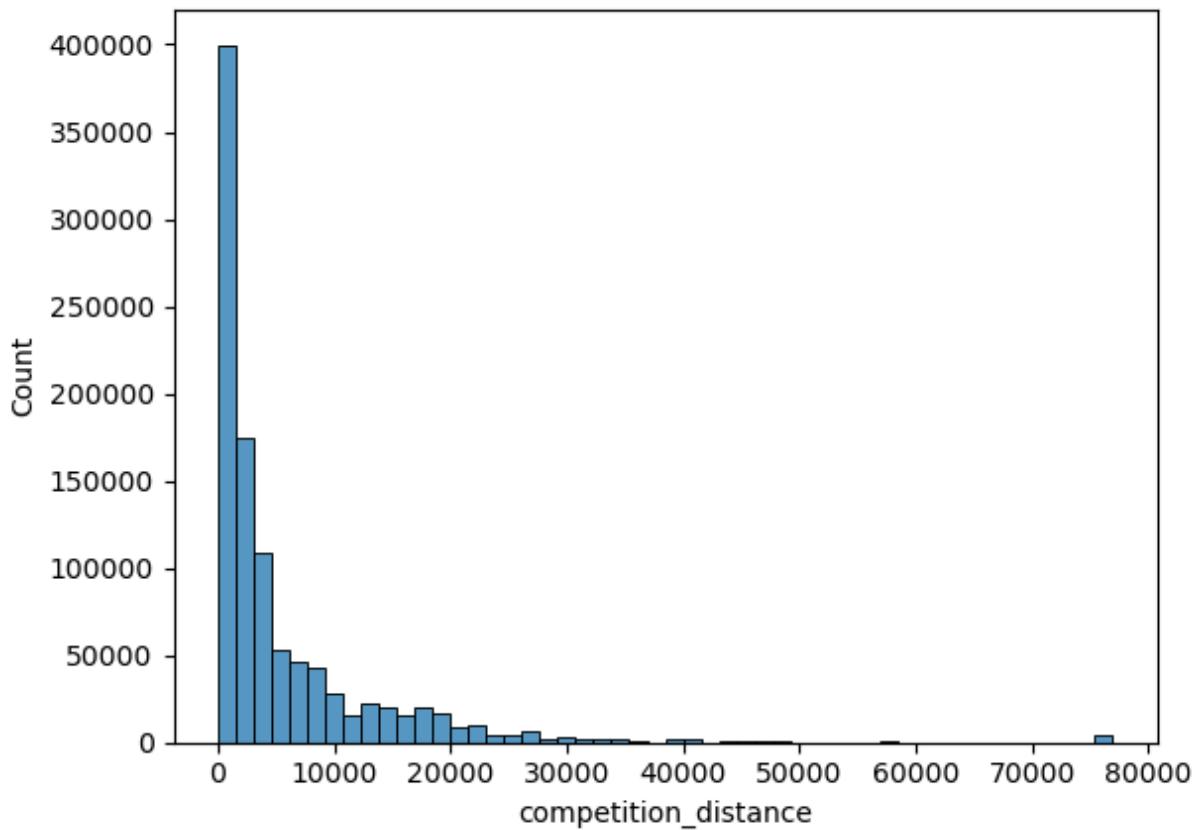
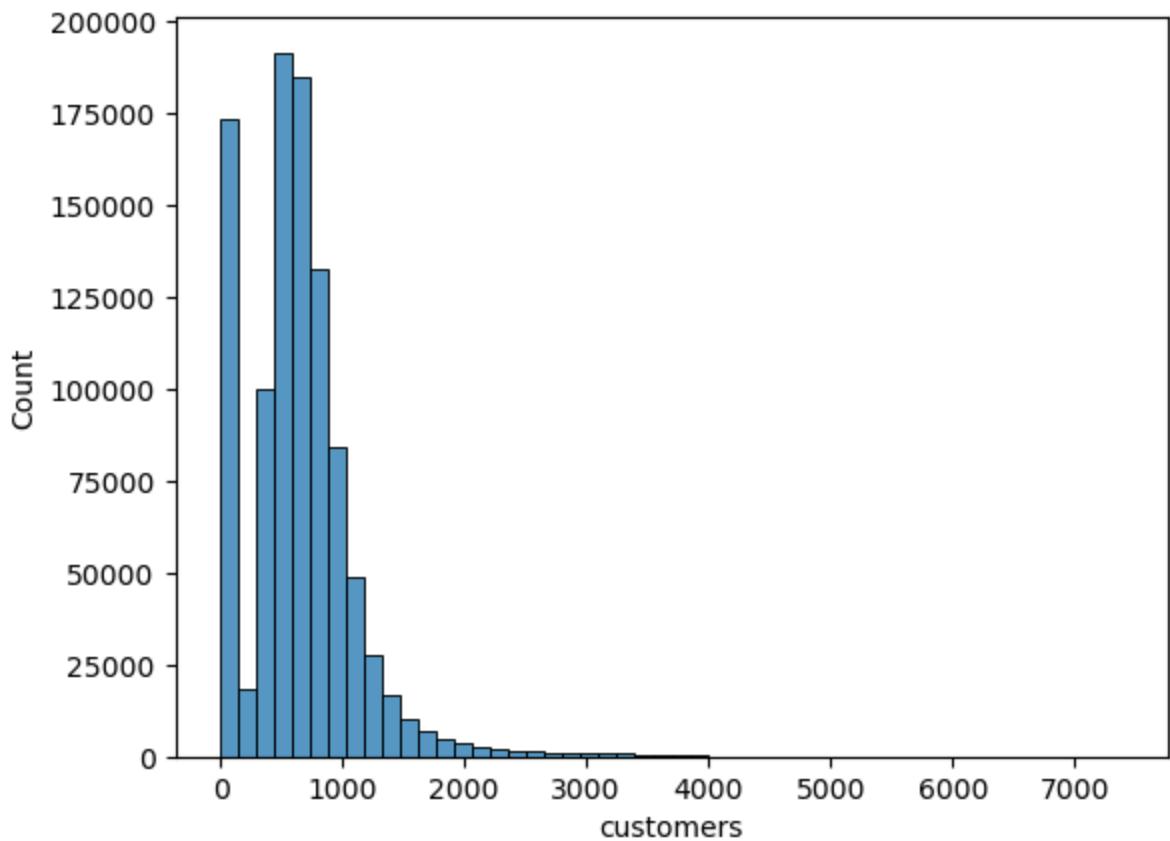
num_cols_list = ['store', 'sales', 'customers', 'competition_distance']

for col in num_cols_list:
```

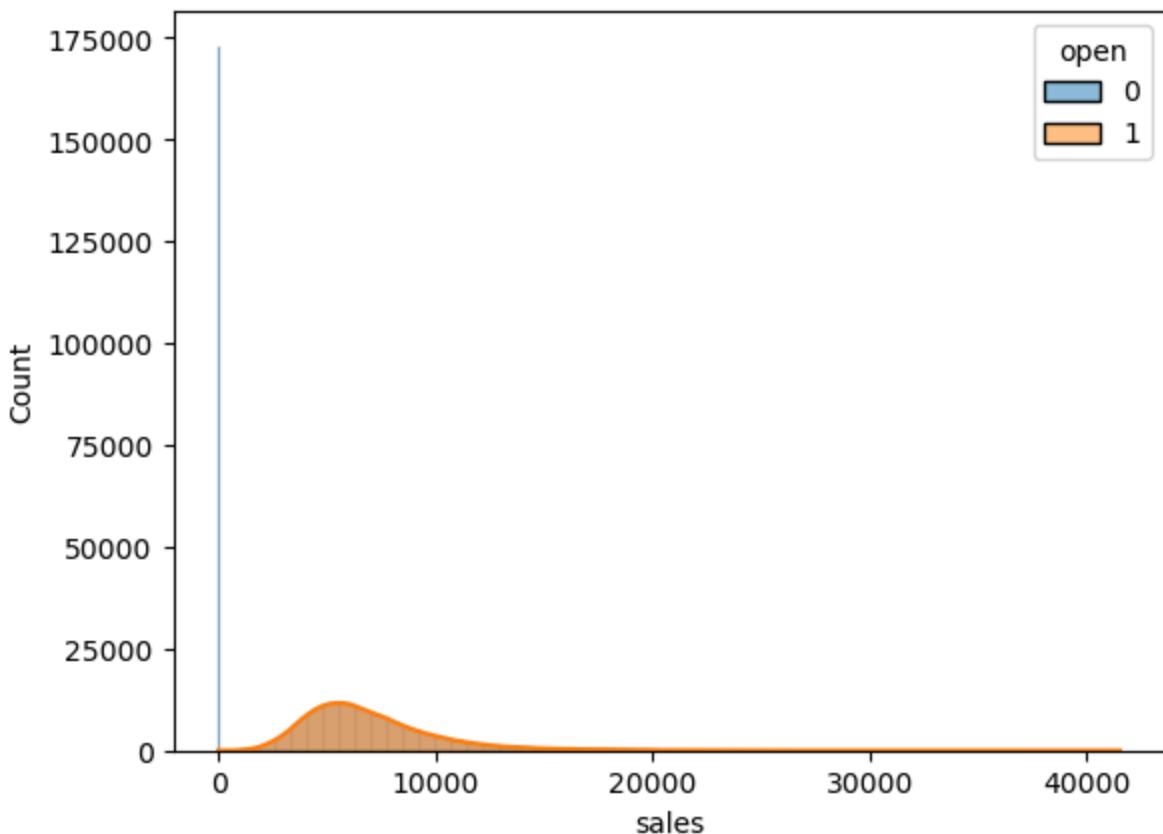
```
sns.histplot(store_df, x = col, bins = 50, stat = 'count')  
plt.show()
```

#A lot of points with Sales = 0, let's inspect them further





```
In [93]: #histogram of sales wrt to store being open  
sns.histplot(store_df, x = 'sales', hue = 'open', stat = 'count', kde = True  
plt.show()
```



```
In [97]: #Looking at days where Sales = 0
zero_sales = store_df[store_df['sales'] == 0]

#172871 rows - majorly sales = 0 when open = 0 ie the store was closed, so i
```

```
In [99]: zero_sales[zero_sales['open'] == 1].info()
#54 rows where sales = 0 even when the store was open
```

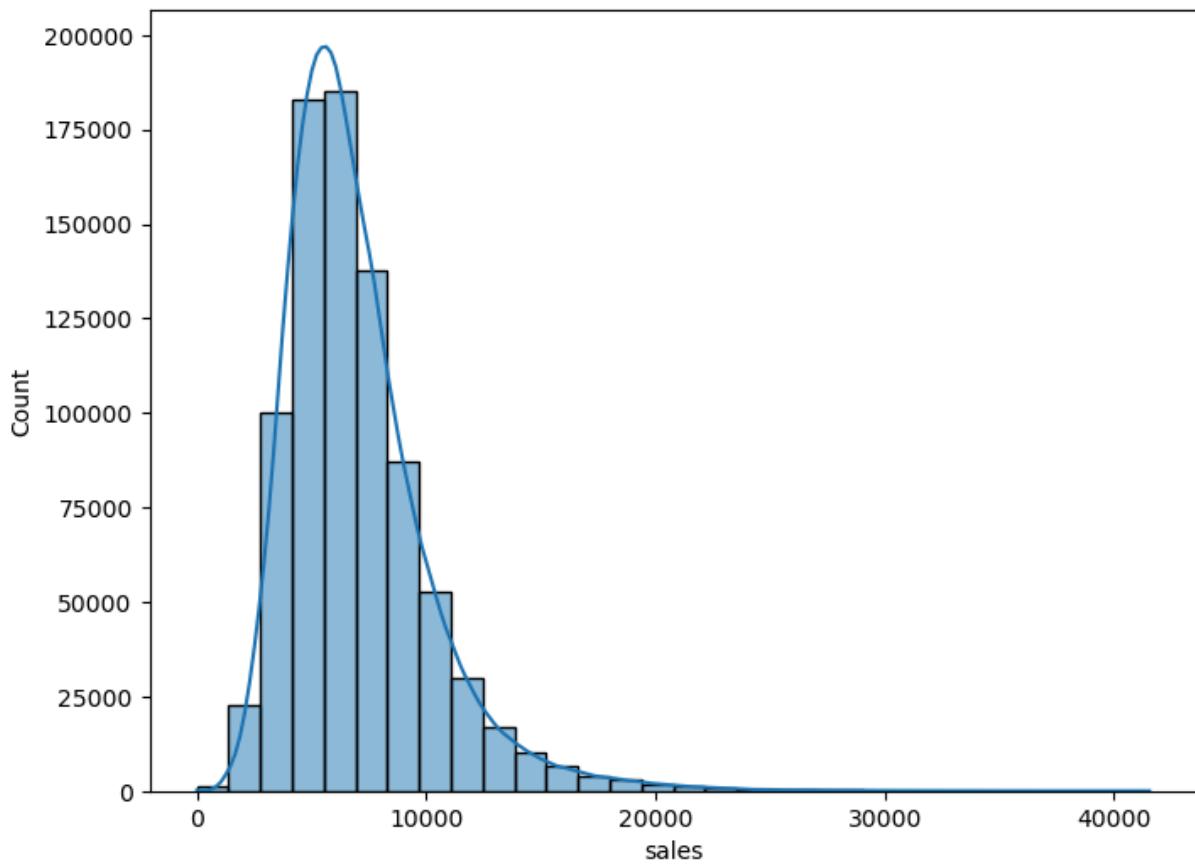
```
<class 'pandas.core.frame.DataFrame'>
Index: 54 entries, 86825 to 999016
Data columns (total 22 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   store            54 non-null      int64  
 1   day_of_week      54 non-null      int64  
 2   date             54 non-null      datetime64[ns]
 3   sales            54 non-null      int64  
 4   customers        54 non-null      int64  
 5   open              54 non-null      int64  
 6   promo             54 non-null      int64  
 7   state_holiday    54 non-null      object  
 8   school_holiday   54 non-null      int64  
 9   store_type        54 non-null      object  
 10  assortment        54 non-null      object  
 11  competition_distance 54 non-null      float64 
 12  promo2            54 non-null      int64  
 13  promo_interval    54 non-null      object  
 14  month             54 non-null      int32  
 15  year              54 non-null      int32  
 16  competition_open_since_date 54 non-null      datetime64[ns]
 17  promo2_since_date 54 non-null      datetime64[ns]
 18  competition_open_since 54 non-null      timedelta64[ns]
 19  promo2_since     54 non-null      timedelta64[ns]
 20  is_holiday        54 non-null      int64  
 21  is_weekend        54 non-null      int64  
dtypes: datetime64[ns](3), float64(1), int32(2), int64(10), object(4), timedelta64[ns](2)
memory usage: 9.3+ KB
```

```
In [101...]: #Dropping all rows where Sales = 0 and Open = 0, as there won't be any sales
rows_to_drop = store_df[store_df['open'] == 0].index

#Drop the rows
store_df = store_df.drop(index = rows_to_drop)

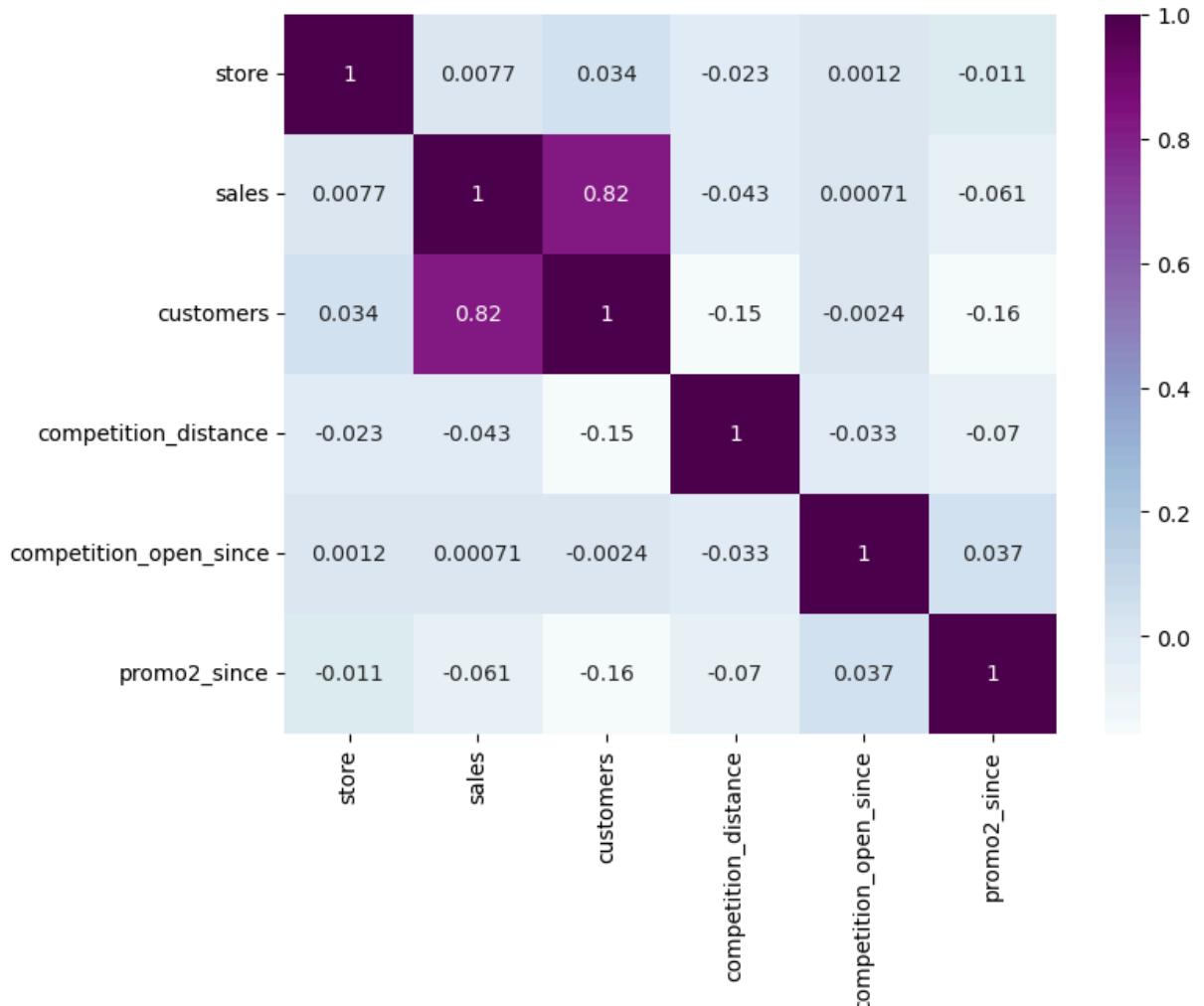
#Reset index
store_df = store_df.reset_index(drop = True)
```

```
In [103...]: #histogram of sales wrt to store being open
plt.figure(figsize = (8,6))
sns.histplot(store_df, x = 'sales', bins = 30, stat = 'count', kde = True)
plt.show()
```



```
In [105...]: #Heatmap to see correlation of all numerical variables  
plt.figure(figsize = (8,6))  
sns.heatmap(store_df[num_cols].corr(), annot = True, cmap = "BuPu")
```

```
Out[105...]: <Axes: >
```



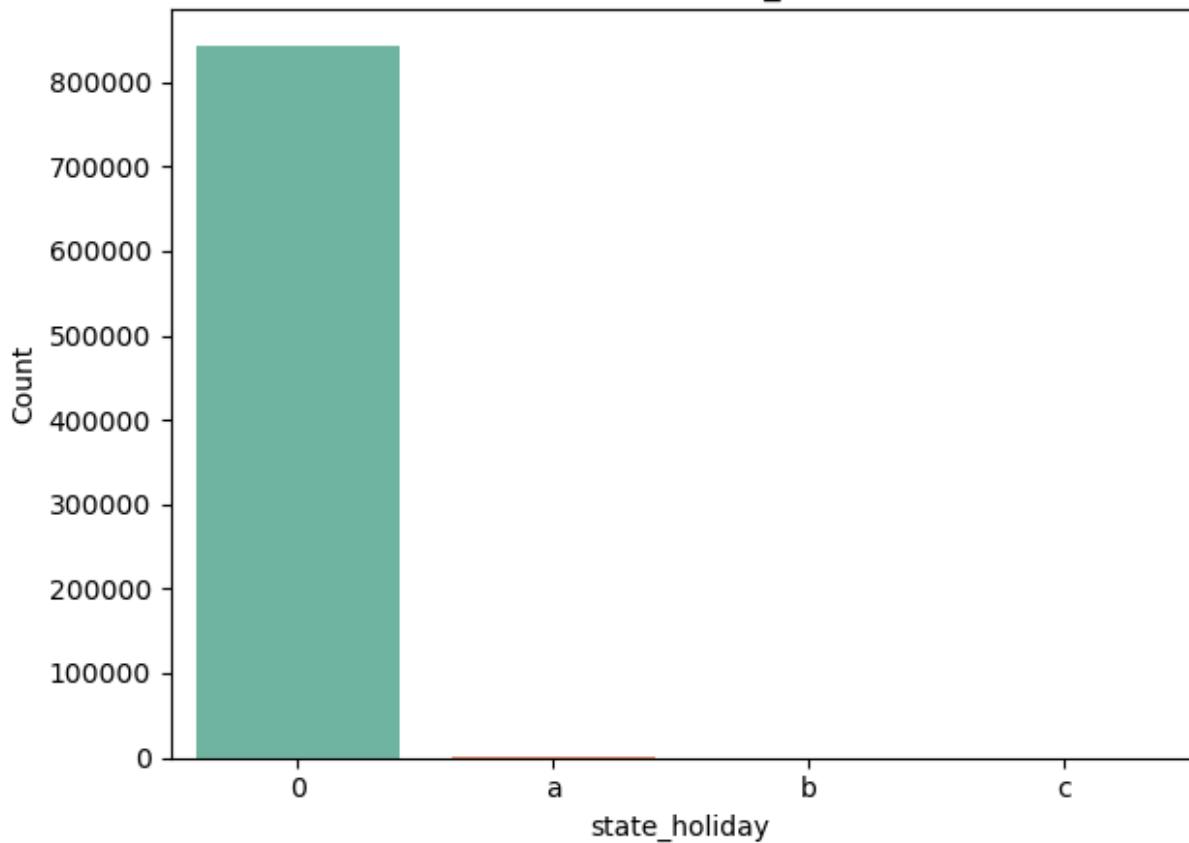
In [109]: #Lets look at the distribution of all the categorical variables using countplot

```

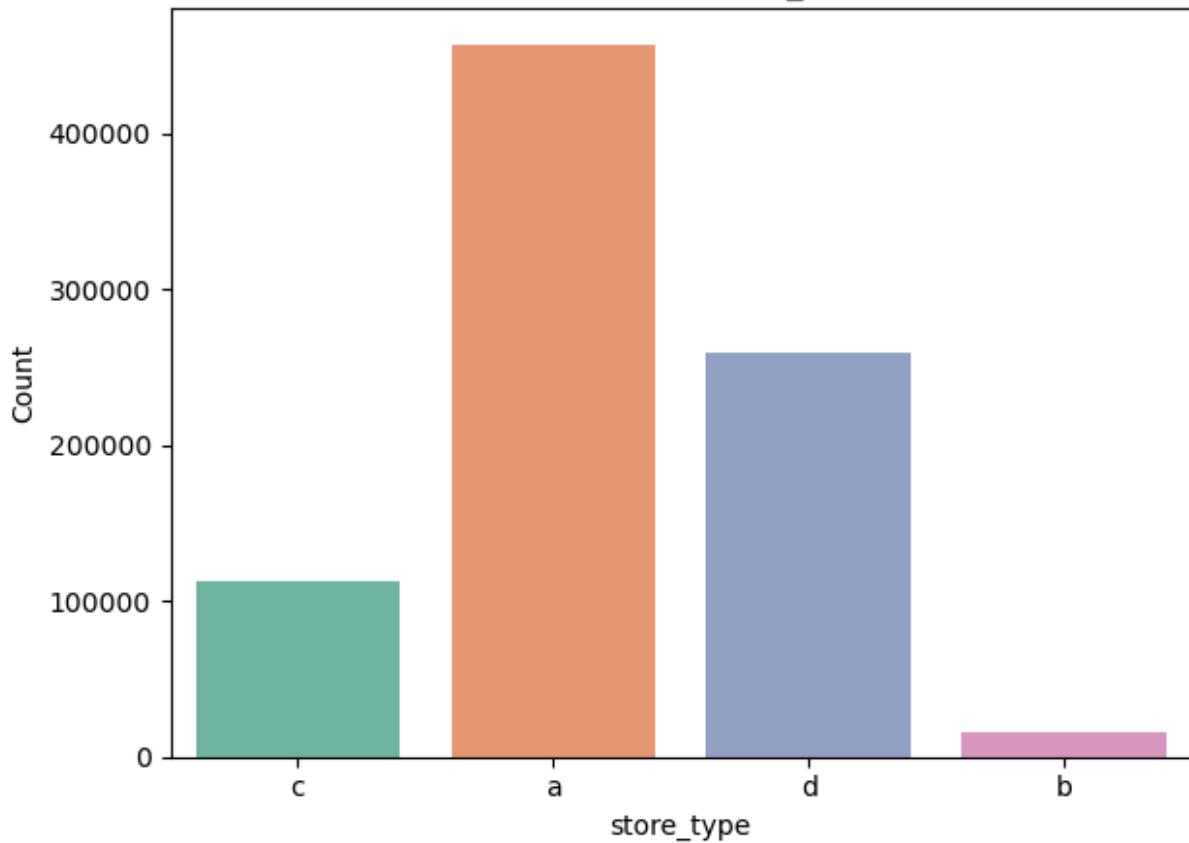
for col in cat_cols:
    sns.countplot(store_df, x = col, palette = "Set2")
    plt.title("Count Plot of " + col)
    plt.ylabel("Count")
    plt.xlabel(col)
    plt.tight_layout()
    plt.show()

```

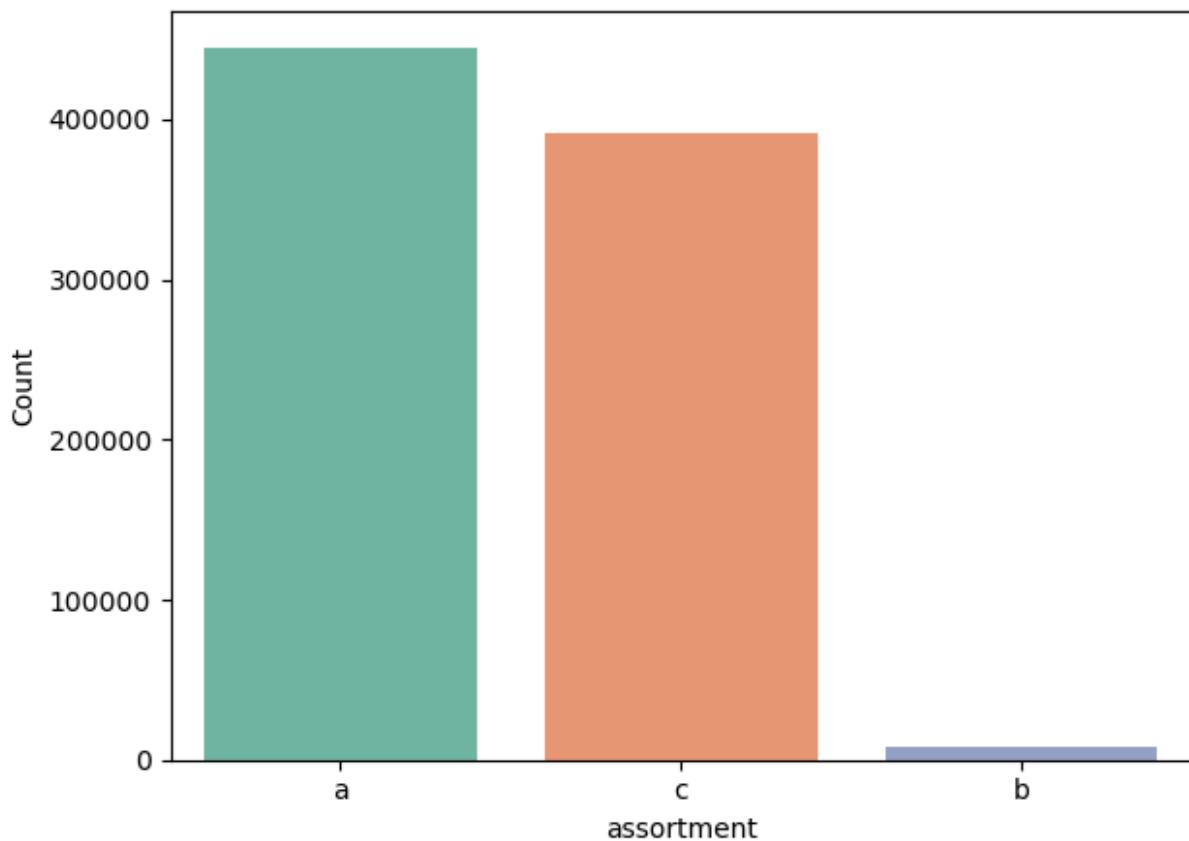
Count Plot of state_holiday



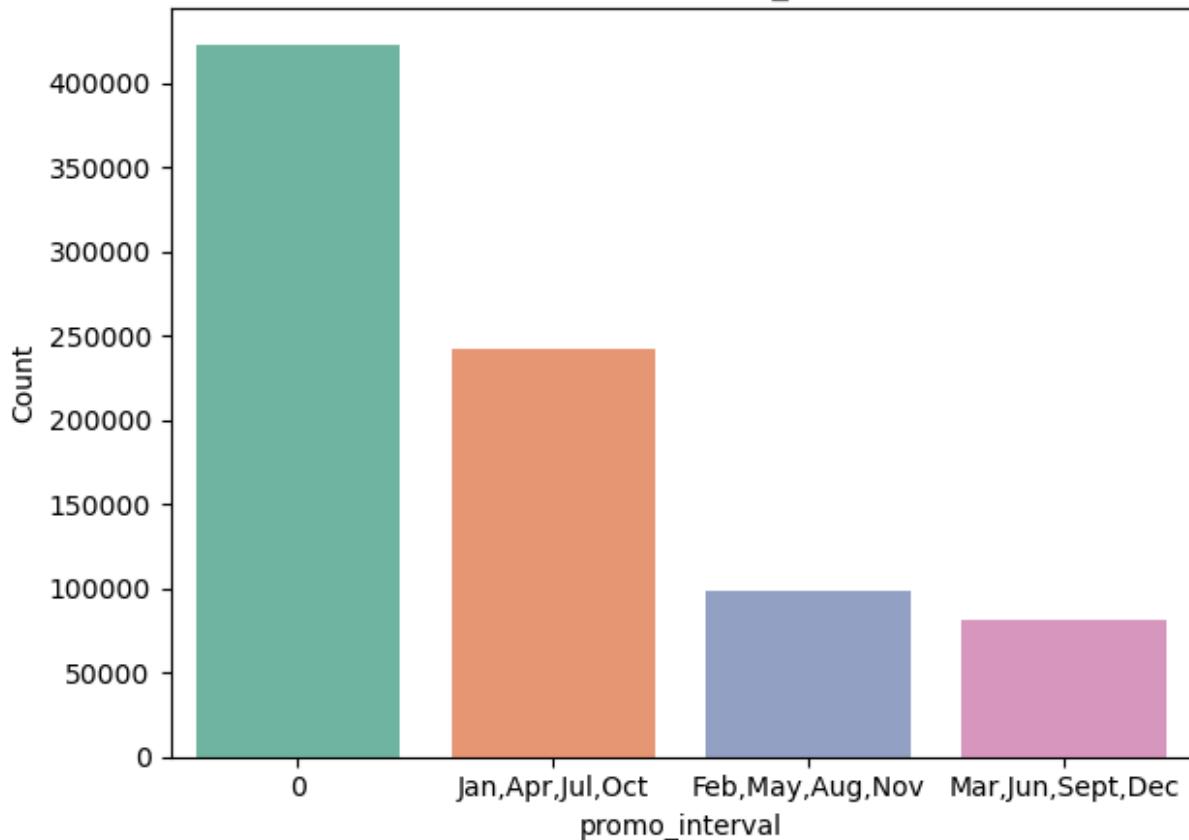
Count Plot of store_type

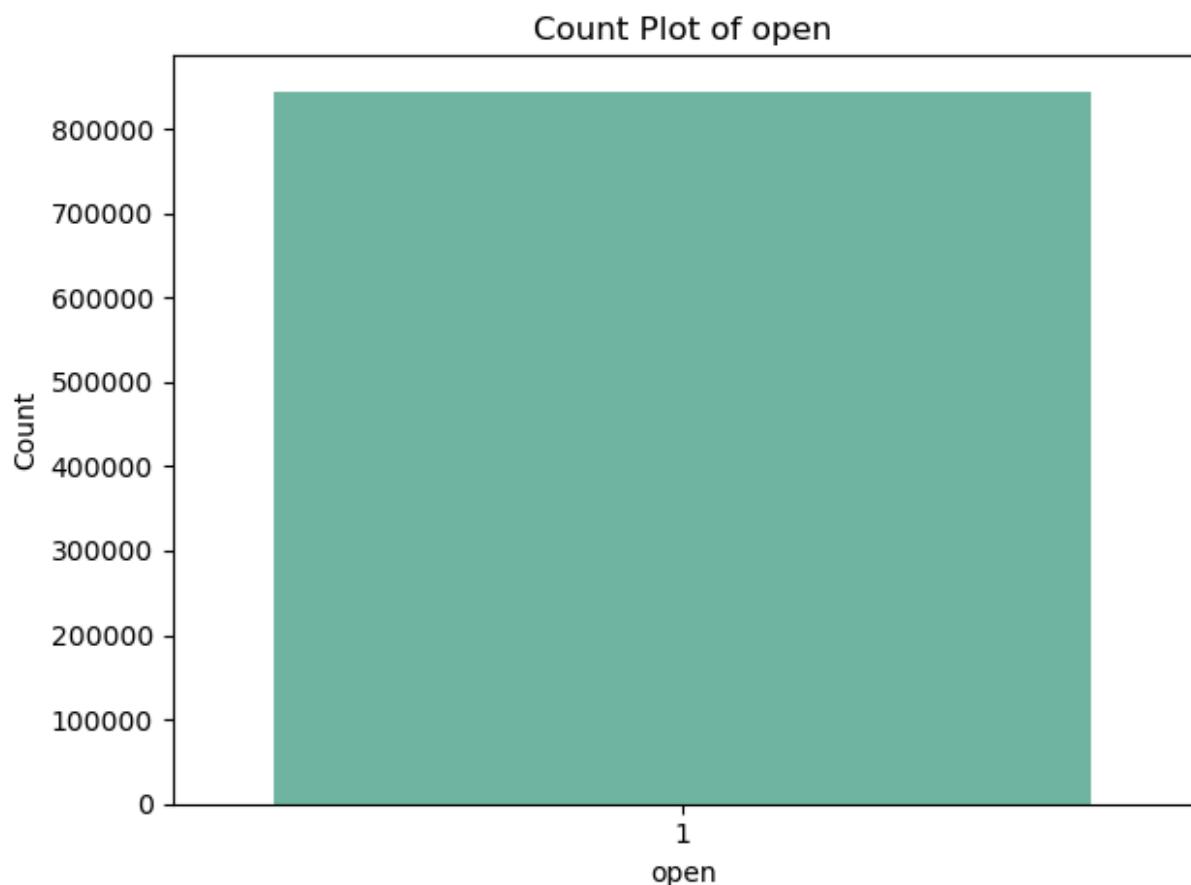
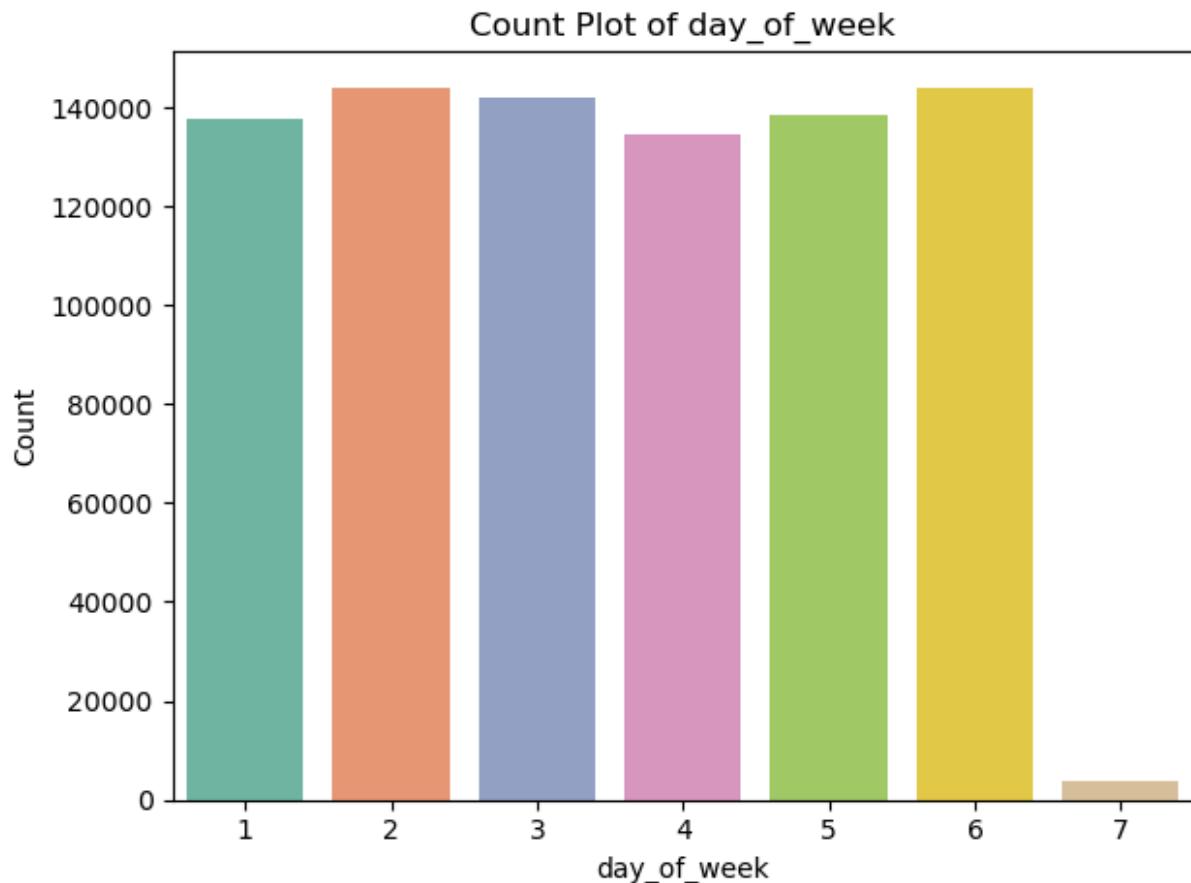


Count Plot of assortment

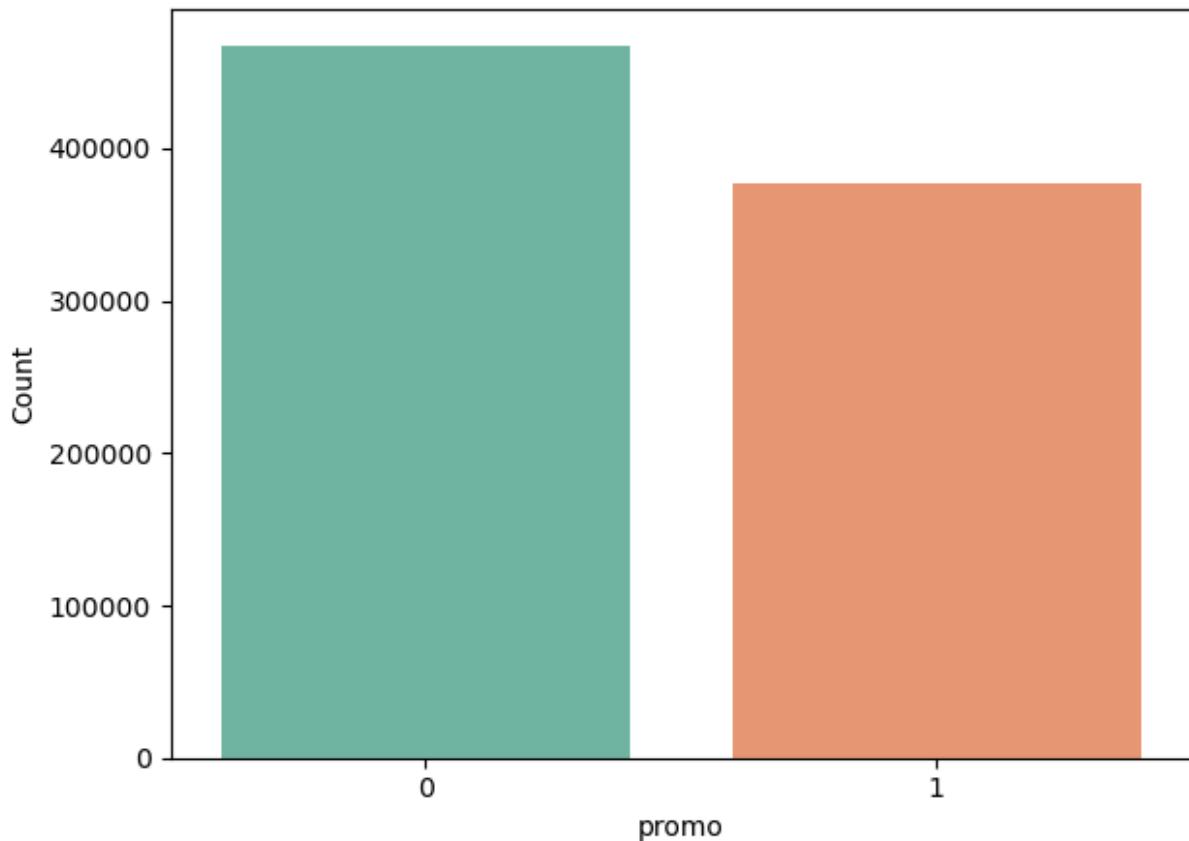


Count Plot of promo_interval

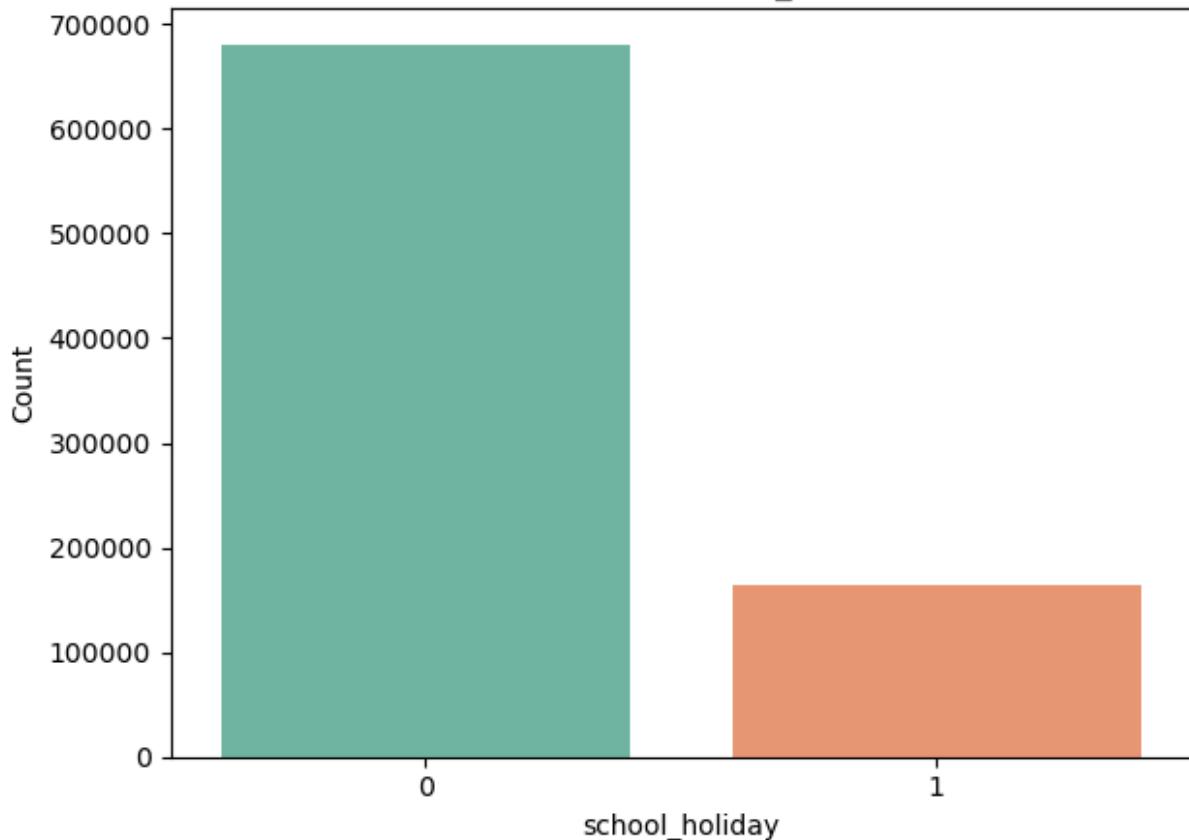




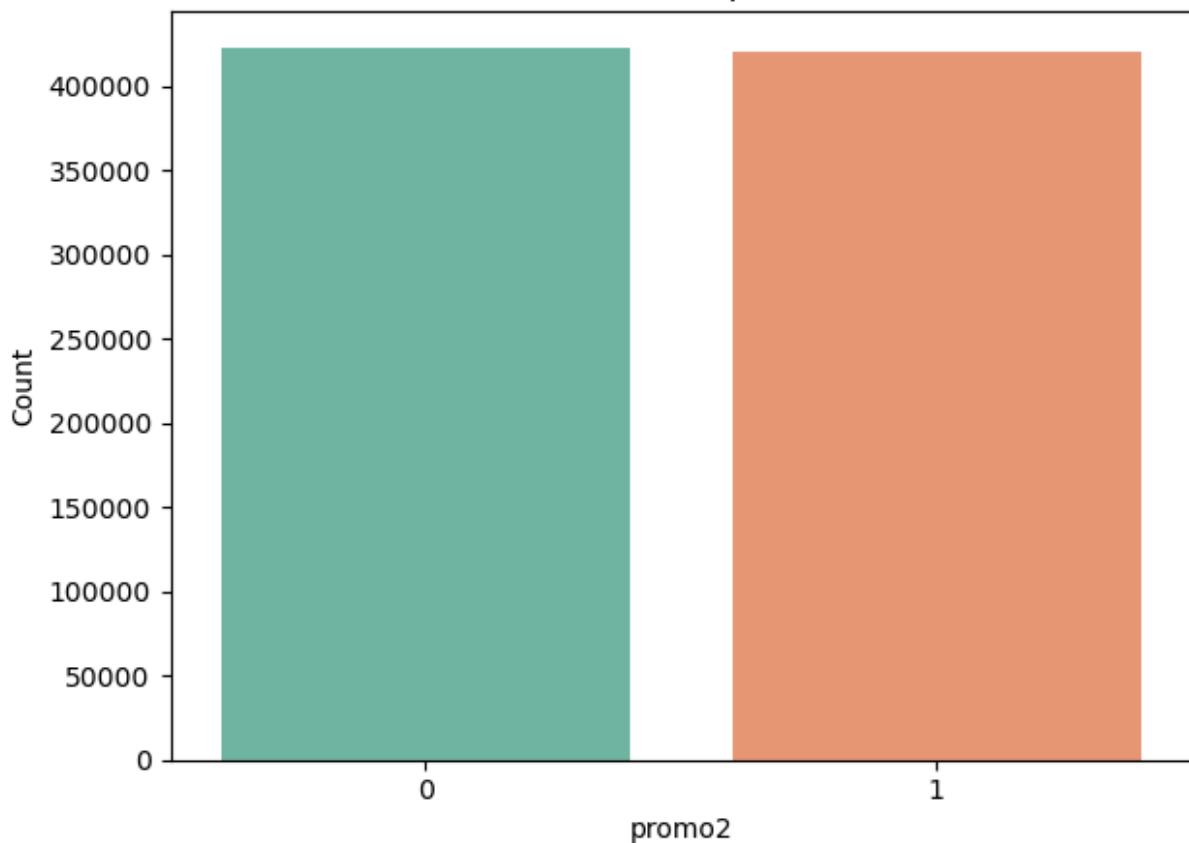
Count Plot of promo



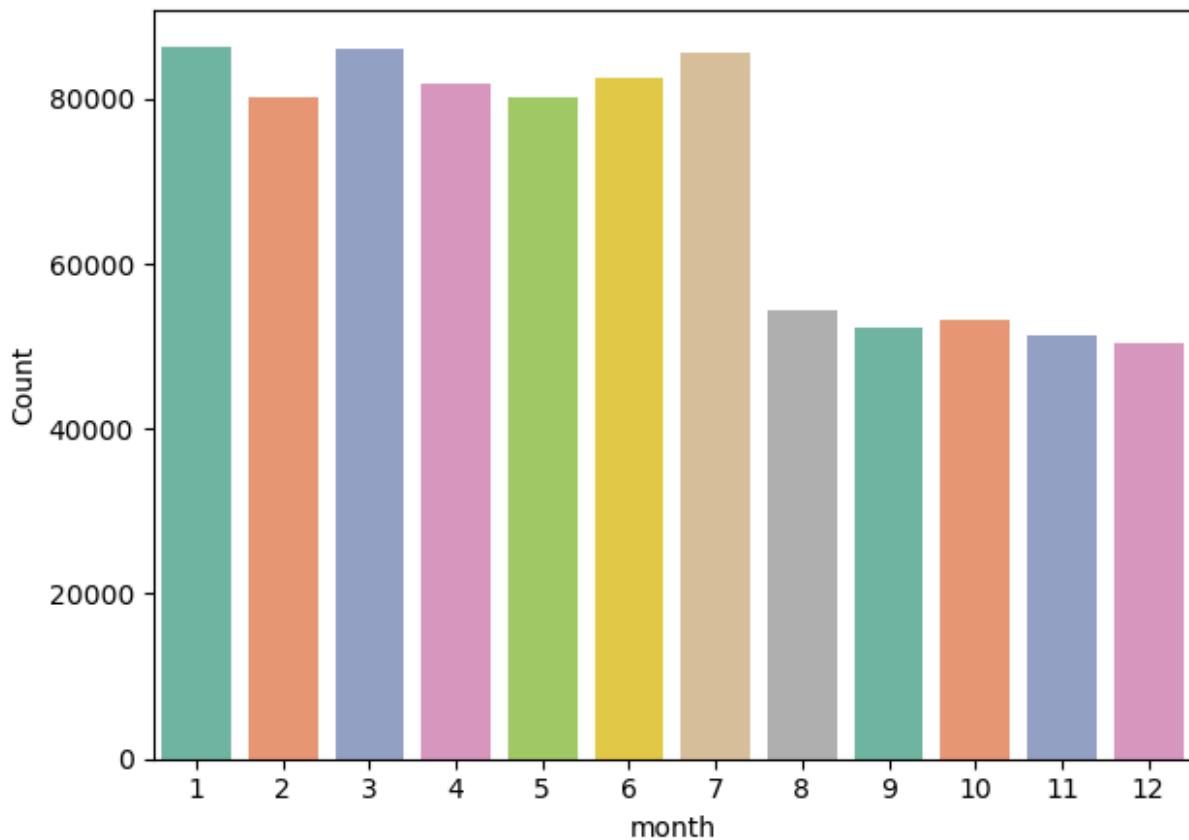
Count Plot of school_holiday

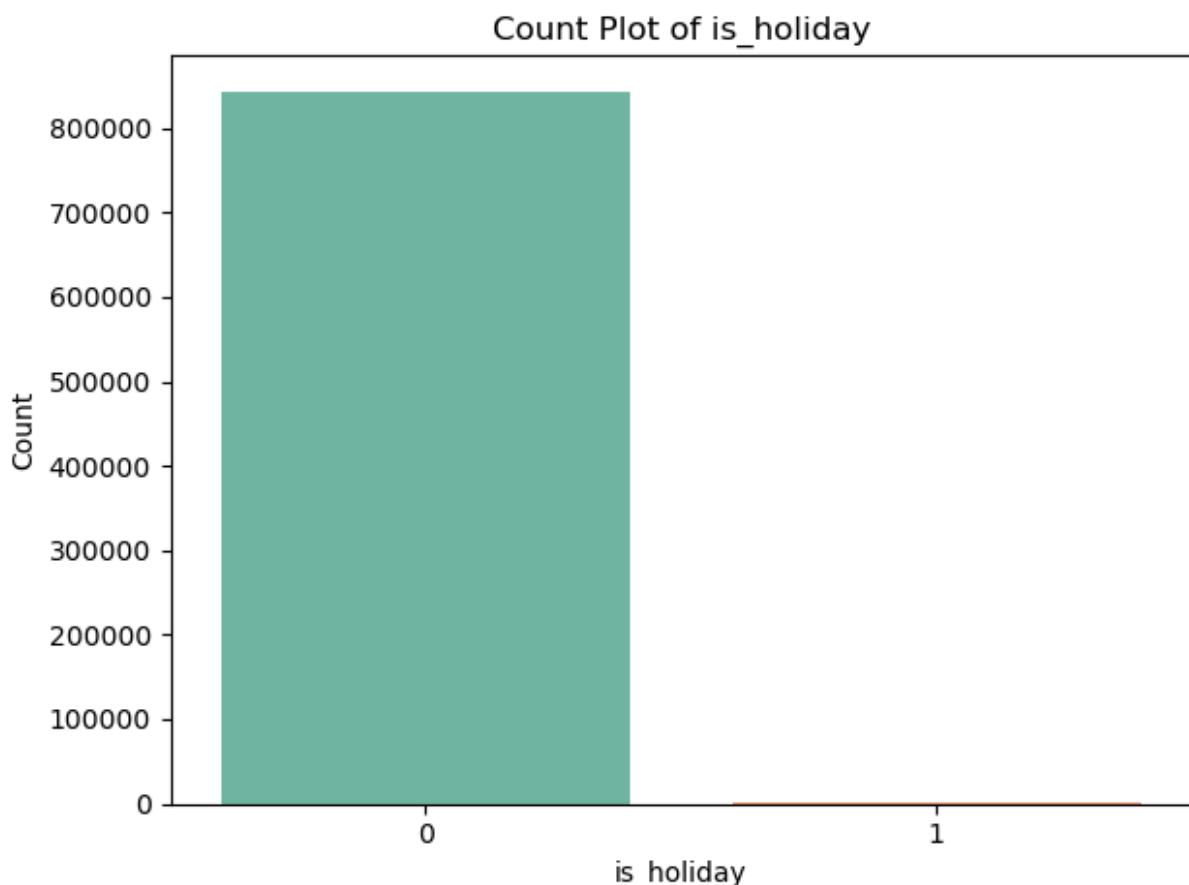
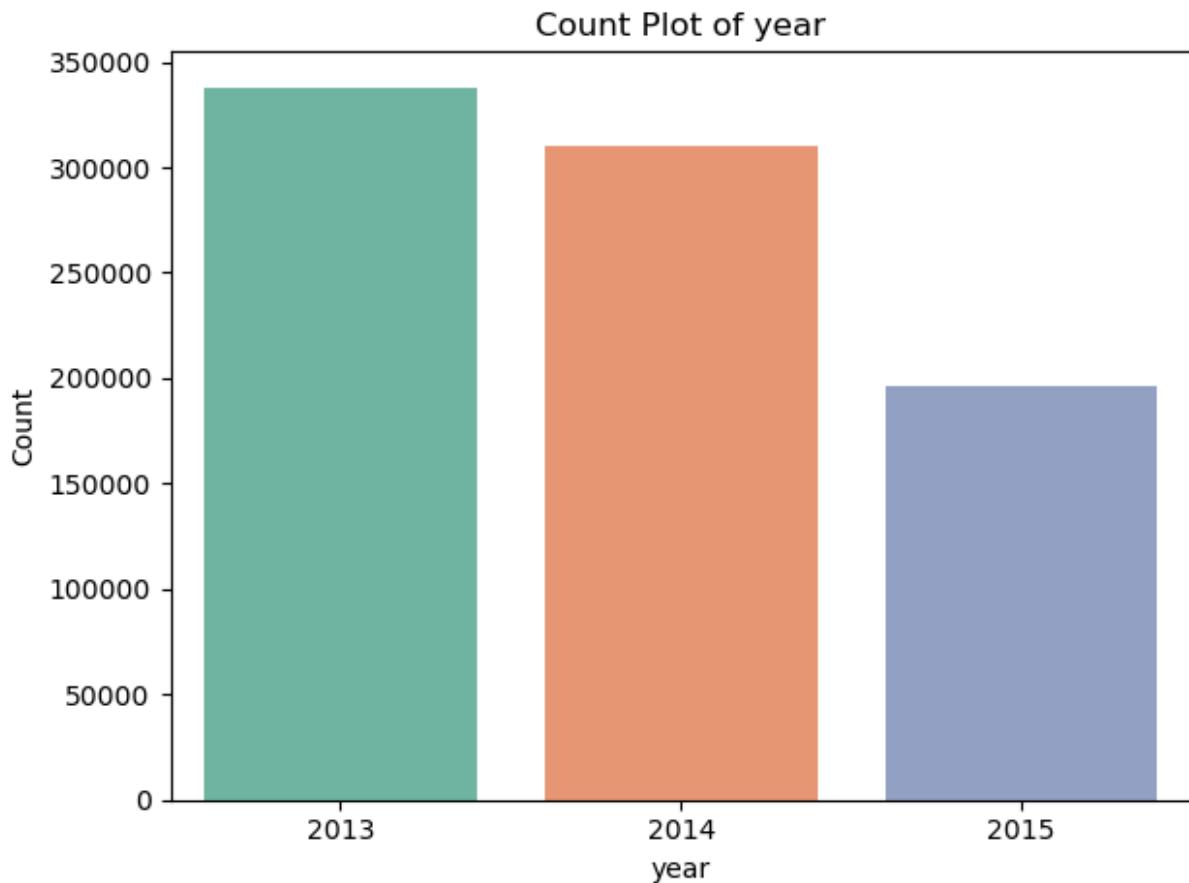


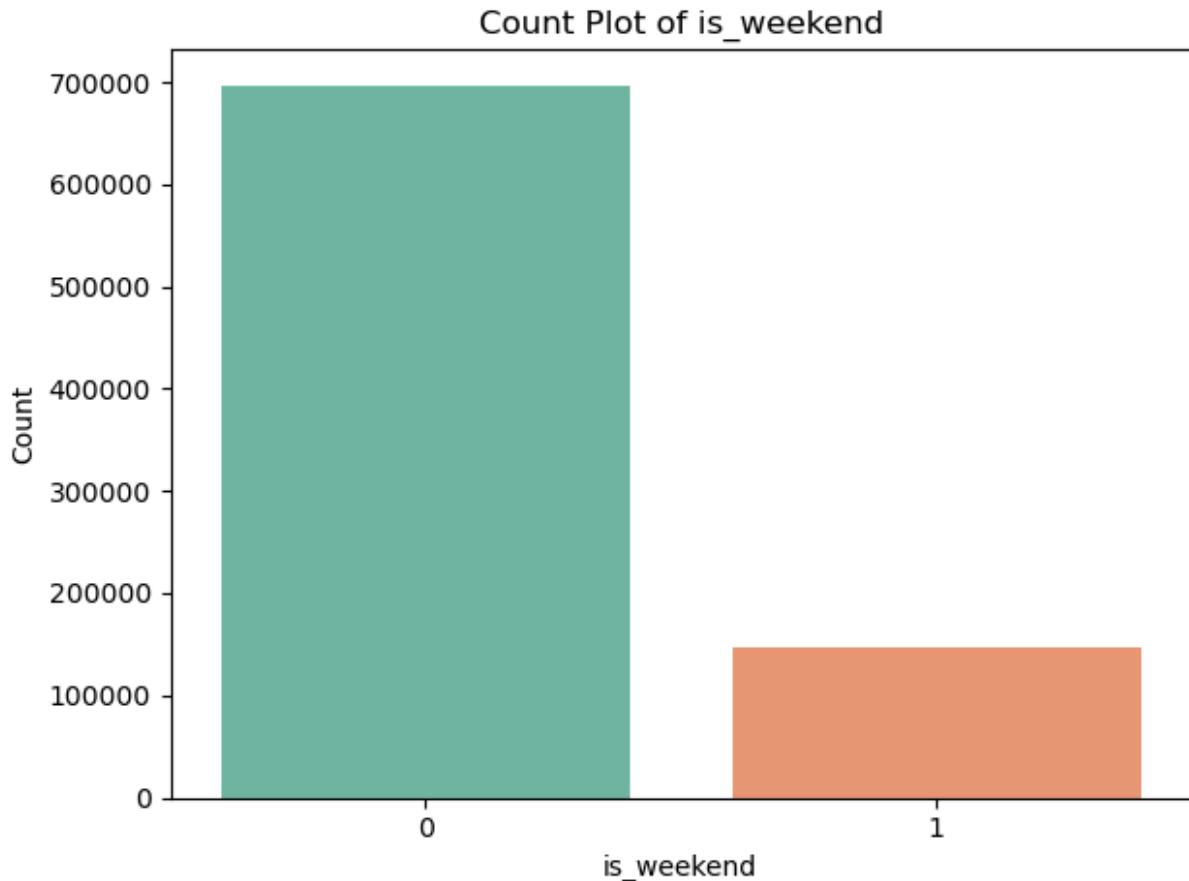
Count Plot of promo2



Count Plot of month





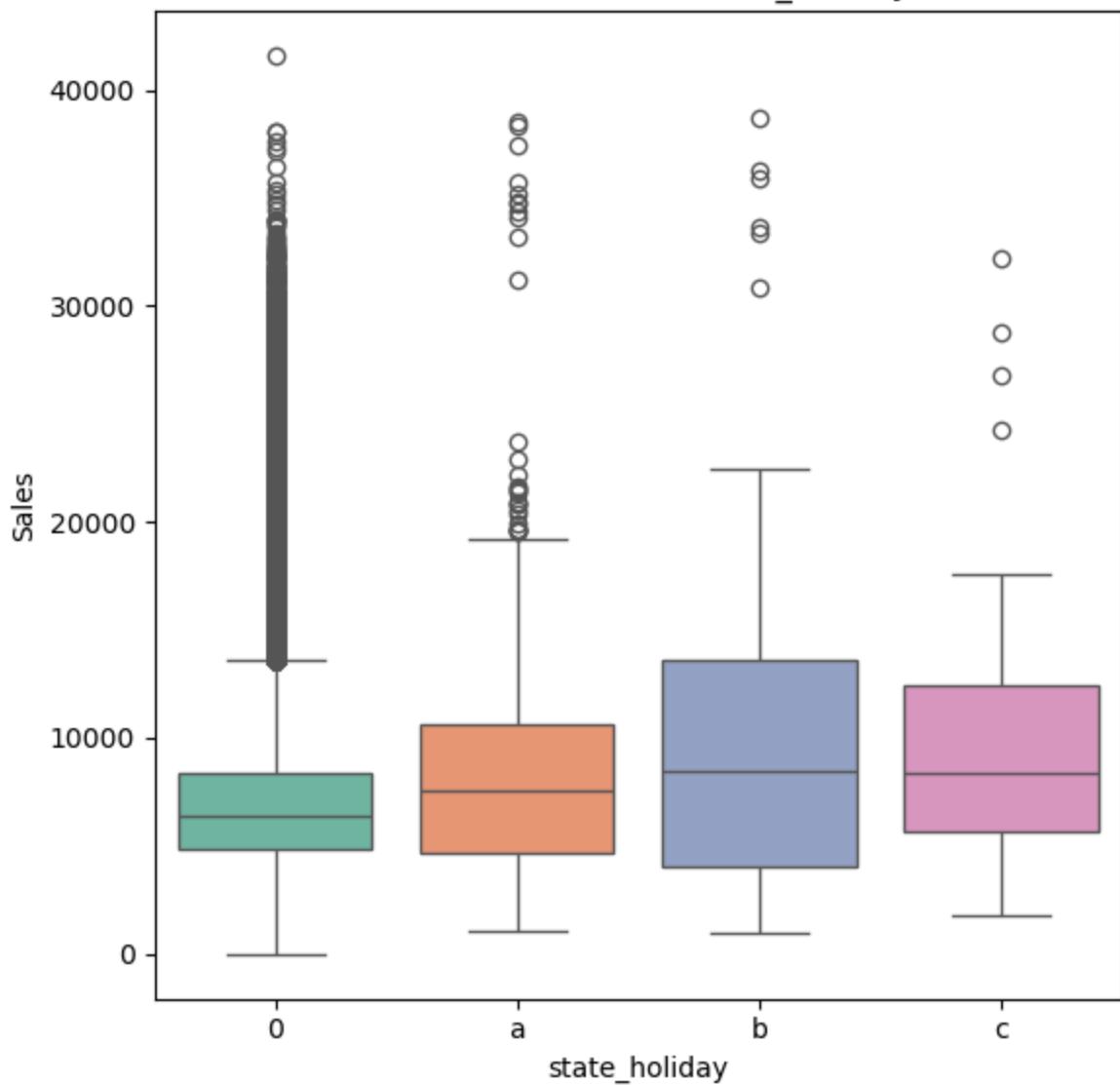


```
In [111]: #Box plot of categorical columns vs sales
for col in cat_cols:
    plt.figure(figsize = (6,6))
    sns.boxplot(store_df, y = 'sales', x = col, palette = "Set2")
    plt.title("Box Plot of " + 'Sales' + " vs " + col)
    plt.ylabel("Sales")
    plt.xlabel(col)
    plt.tight_layout()
    plt.show()

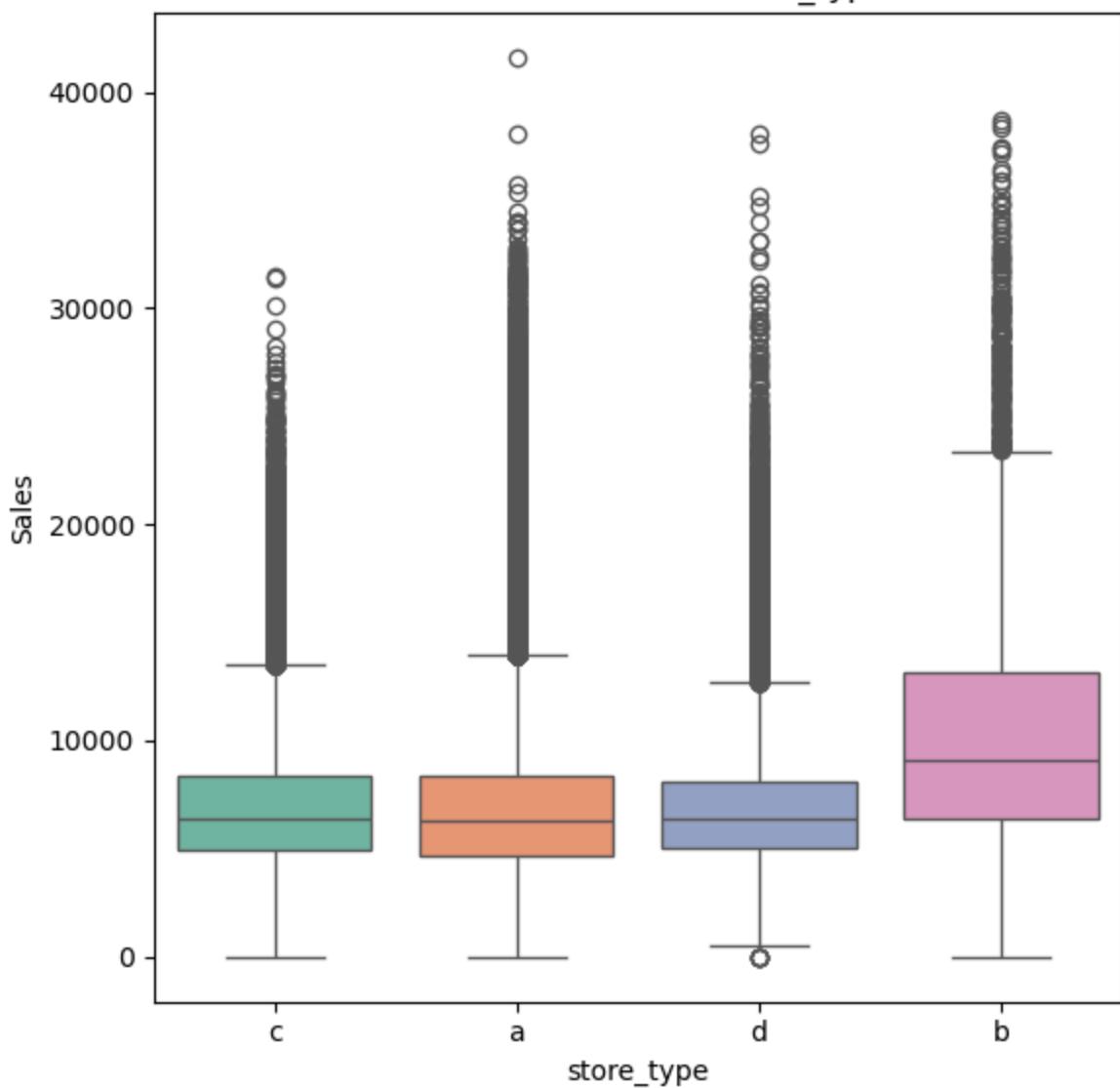
#Outliers occurring in every month, whether promo on or no, whether weekend or not
#so no relation to seasonality or special event like promo or flash sale, so ignore

#The training dataset contains values of 2.5 years (01-Jan-2013 to 31-Jul-2015)
#across each month and year are similarly spread. This tells us that sales
#In other words, seasonality and central tendencies like median sales were
#Monthly sales behavior is predictable and not dependent on full-year coverage
#2015's partial data (Jan-Jul) still mirrors full years.
```

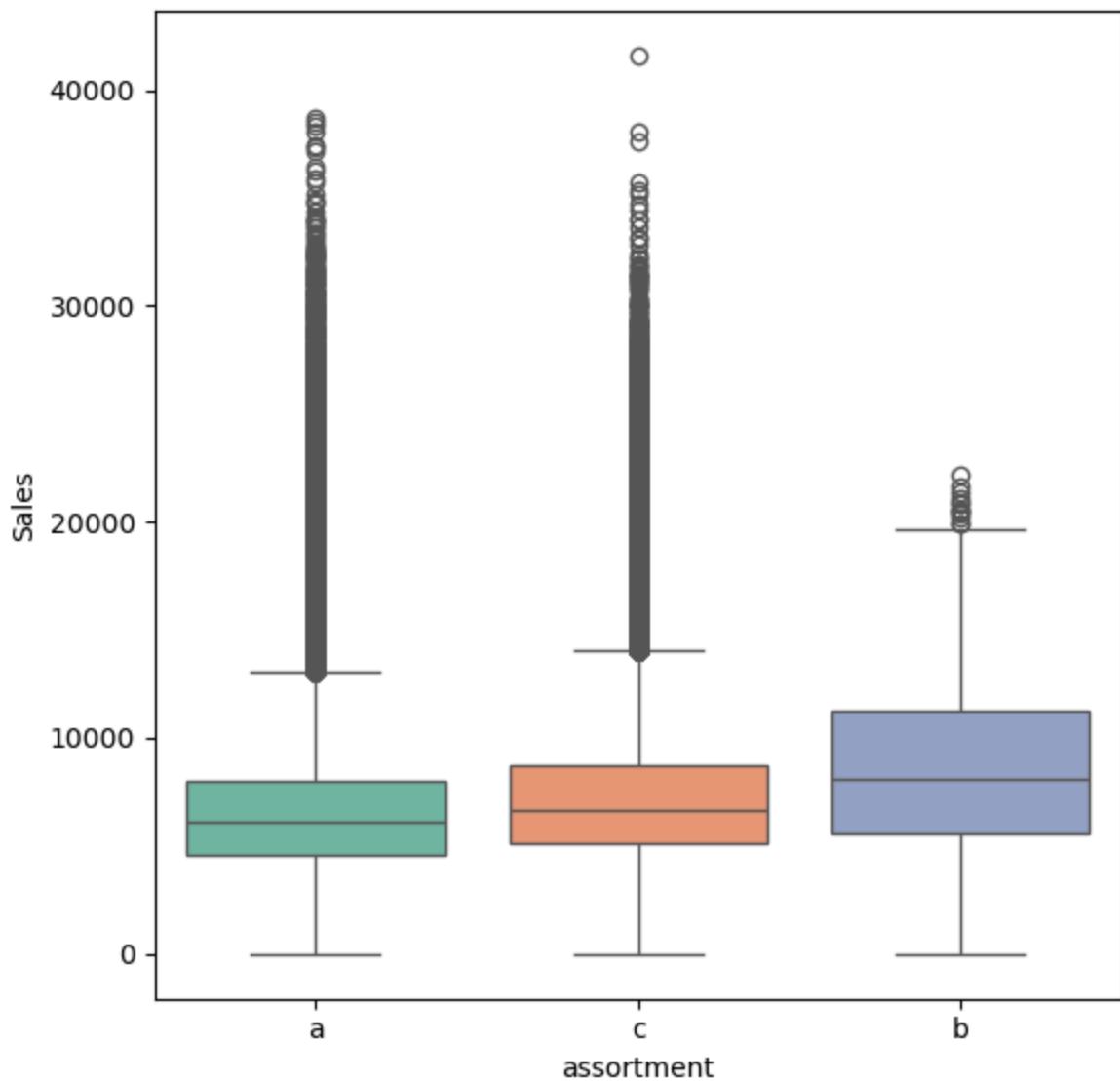
Box Plot of Sales vs state_holiday

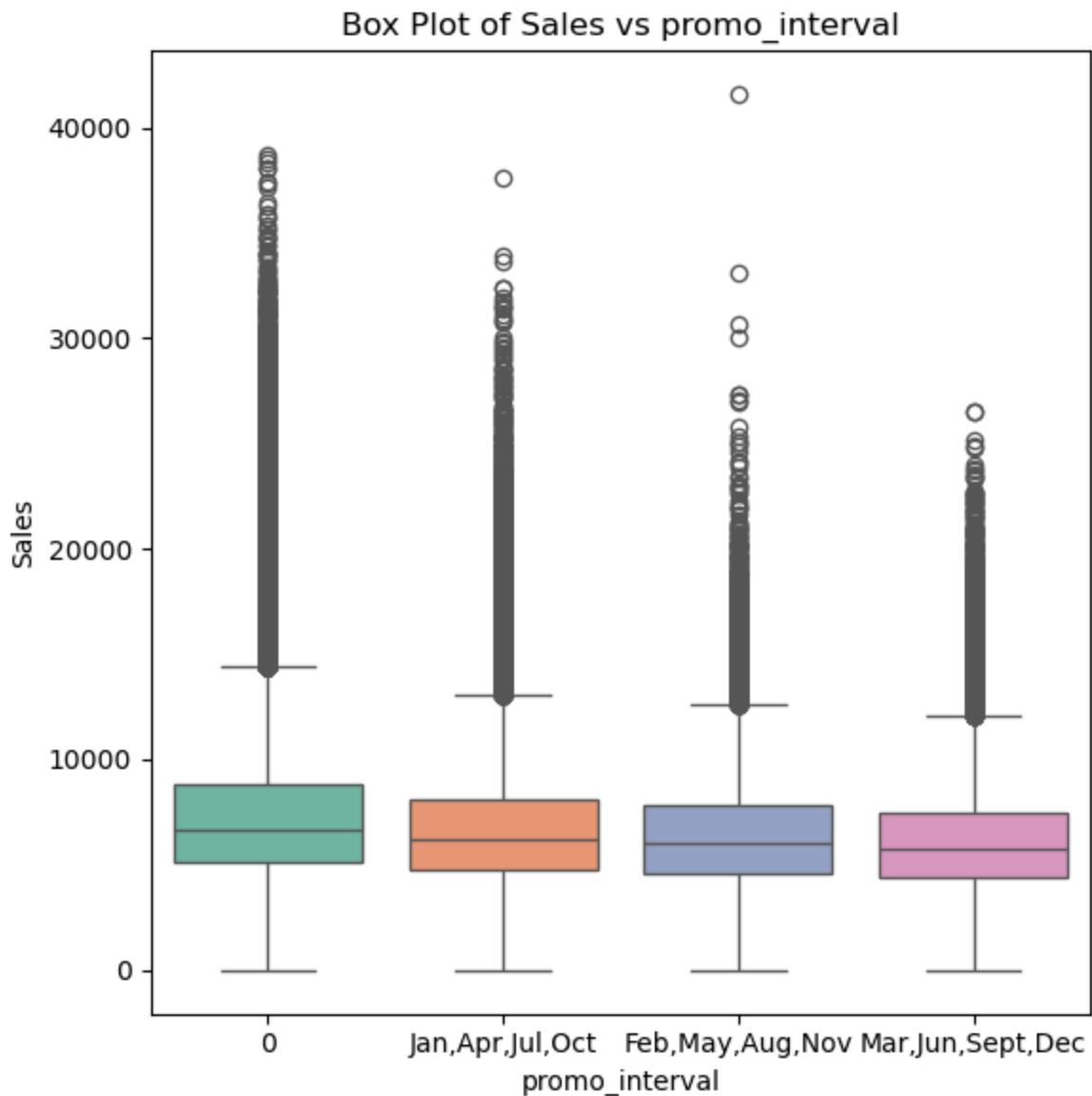


Box Plot of Sales vs store_type

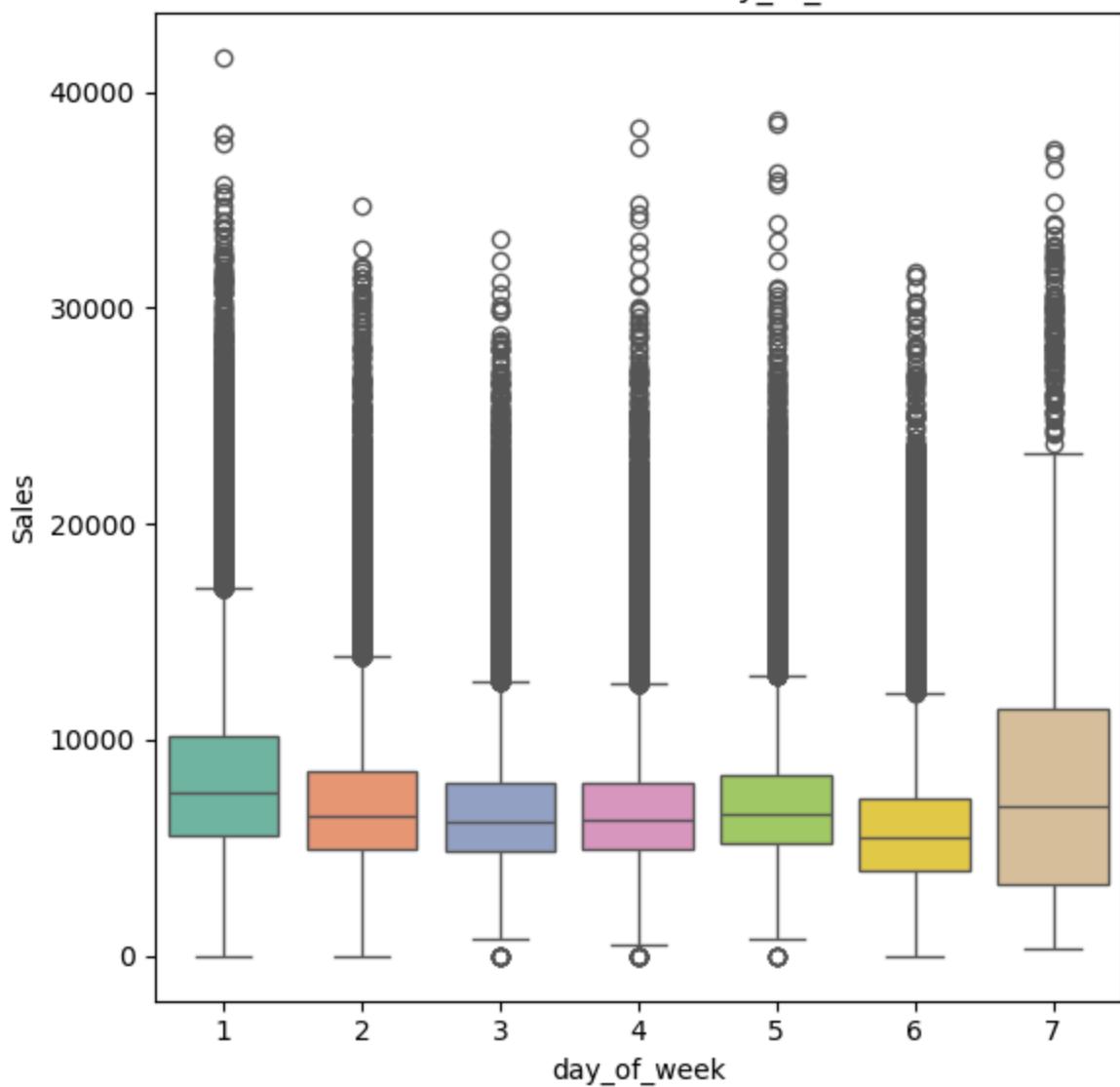


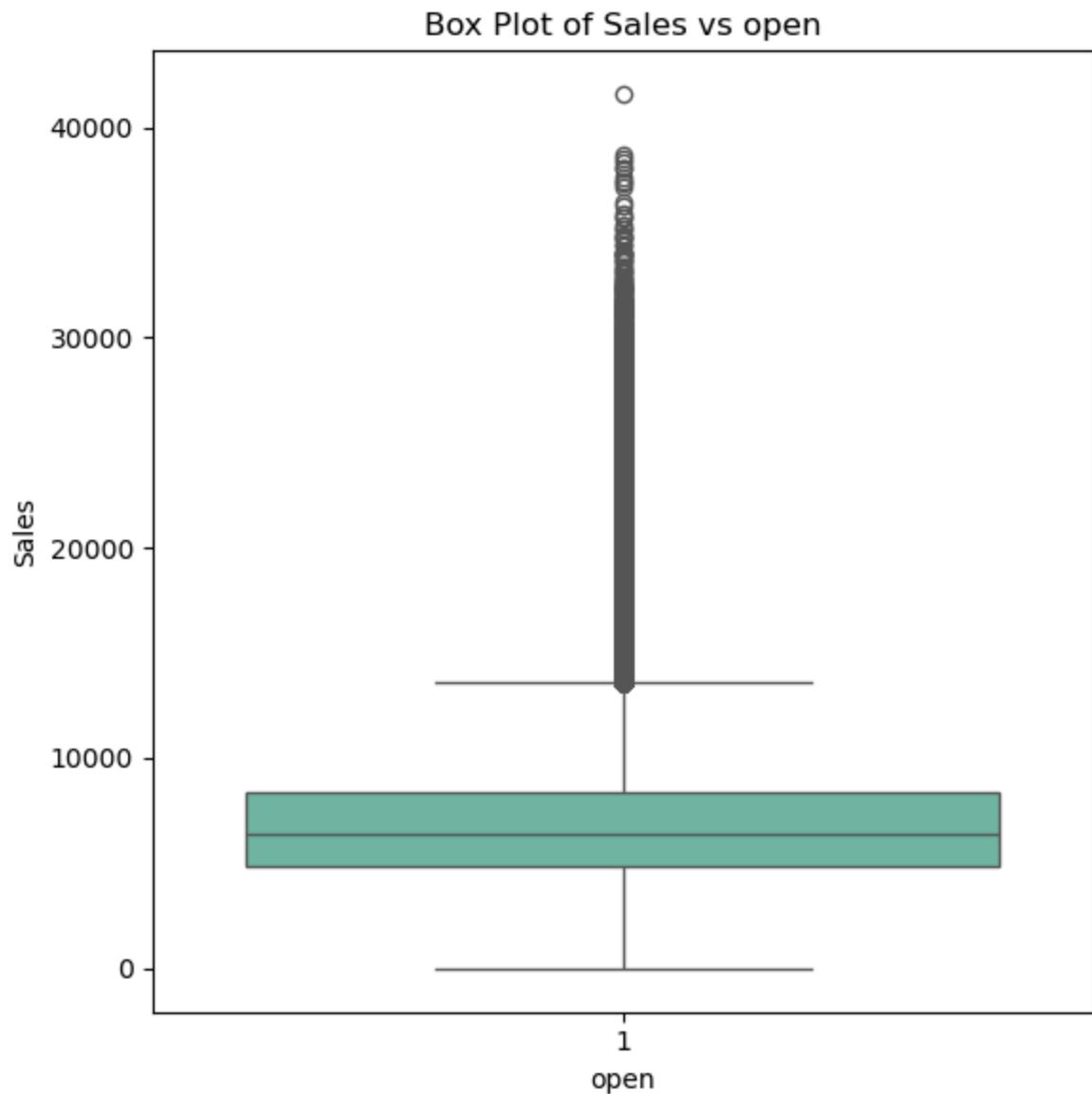
Box Plot of Sales vs assortment



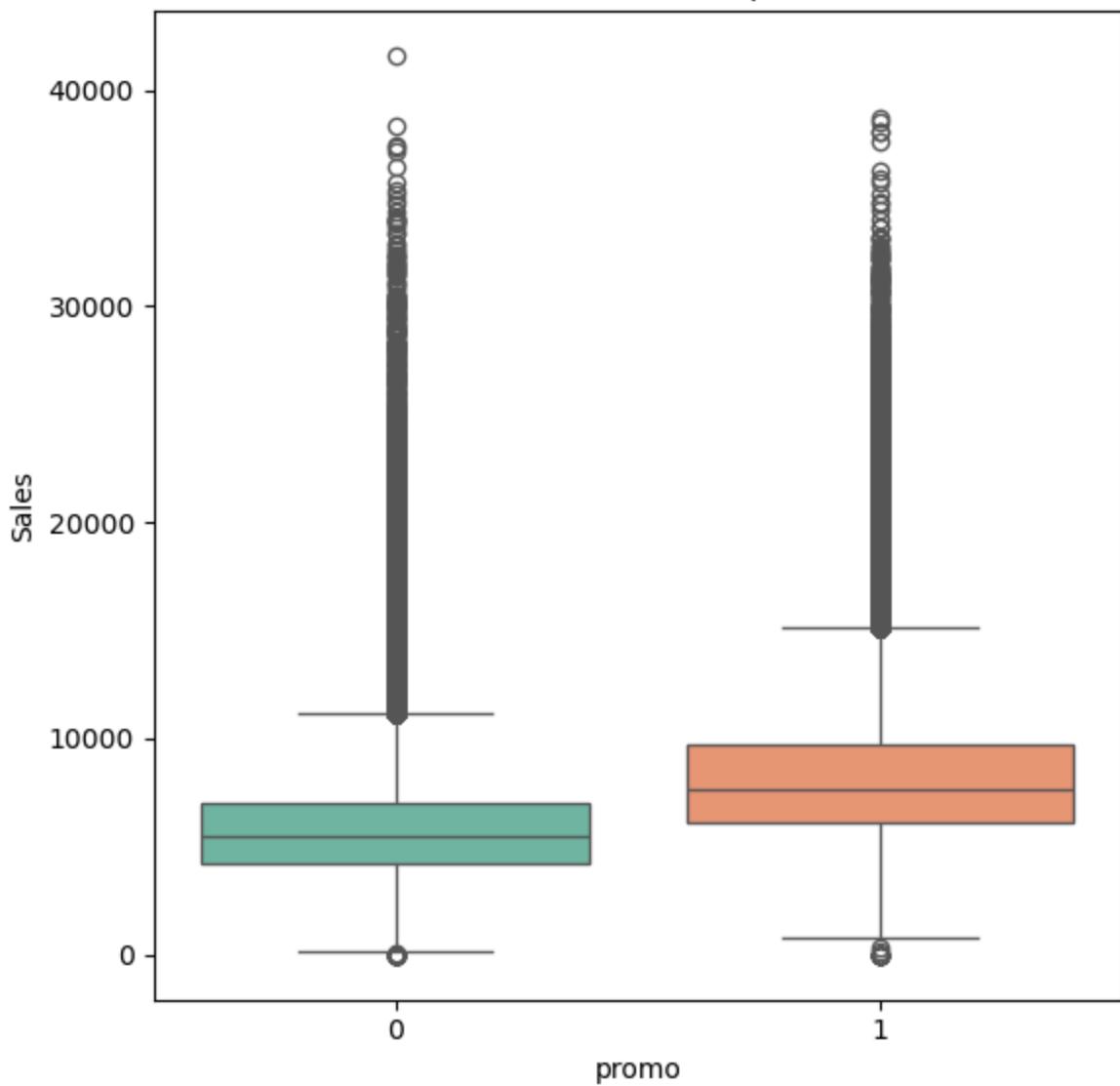


Box Plot of Sales vs day_of_week

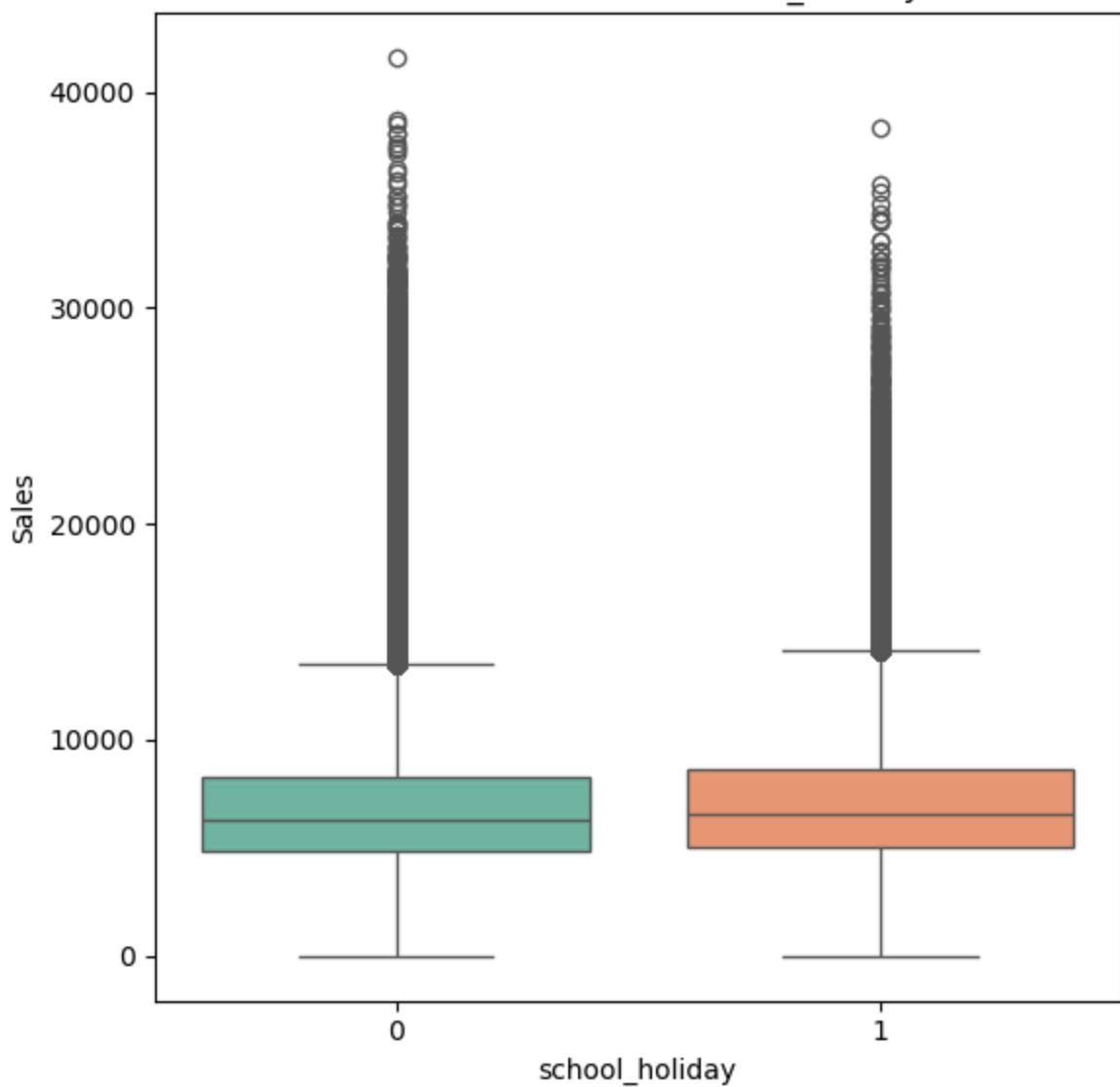




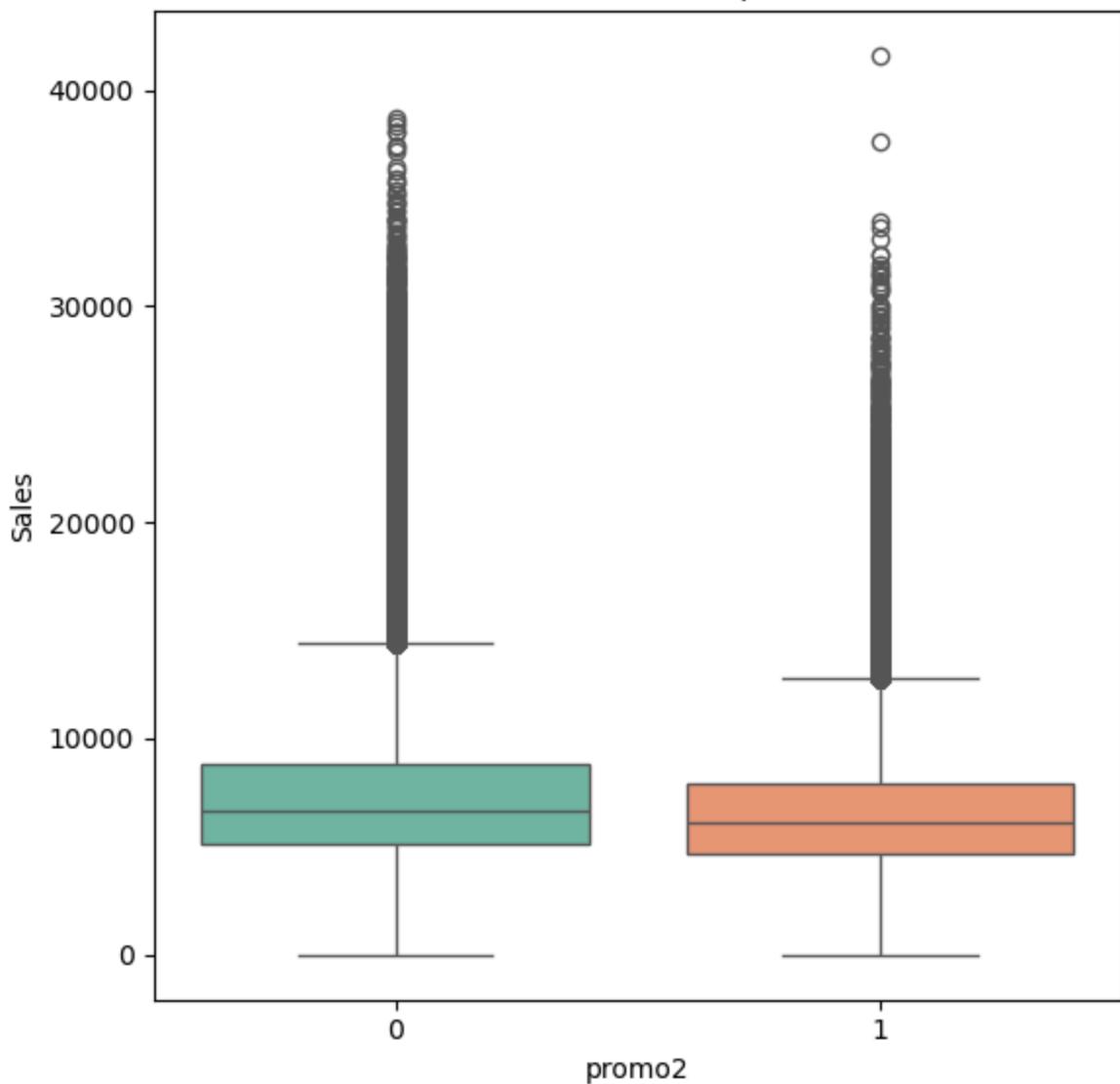
Box Plot of Sales vs promo



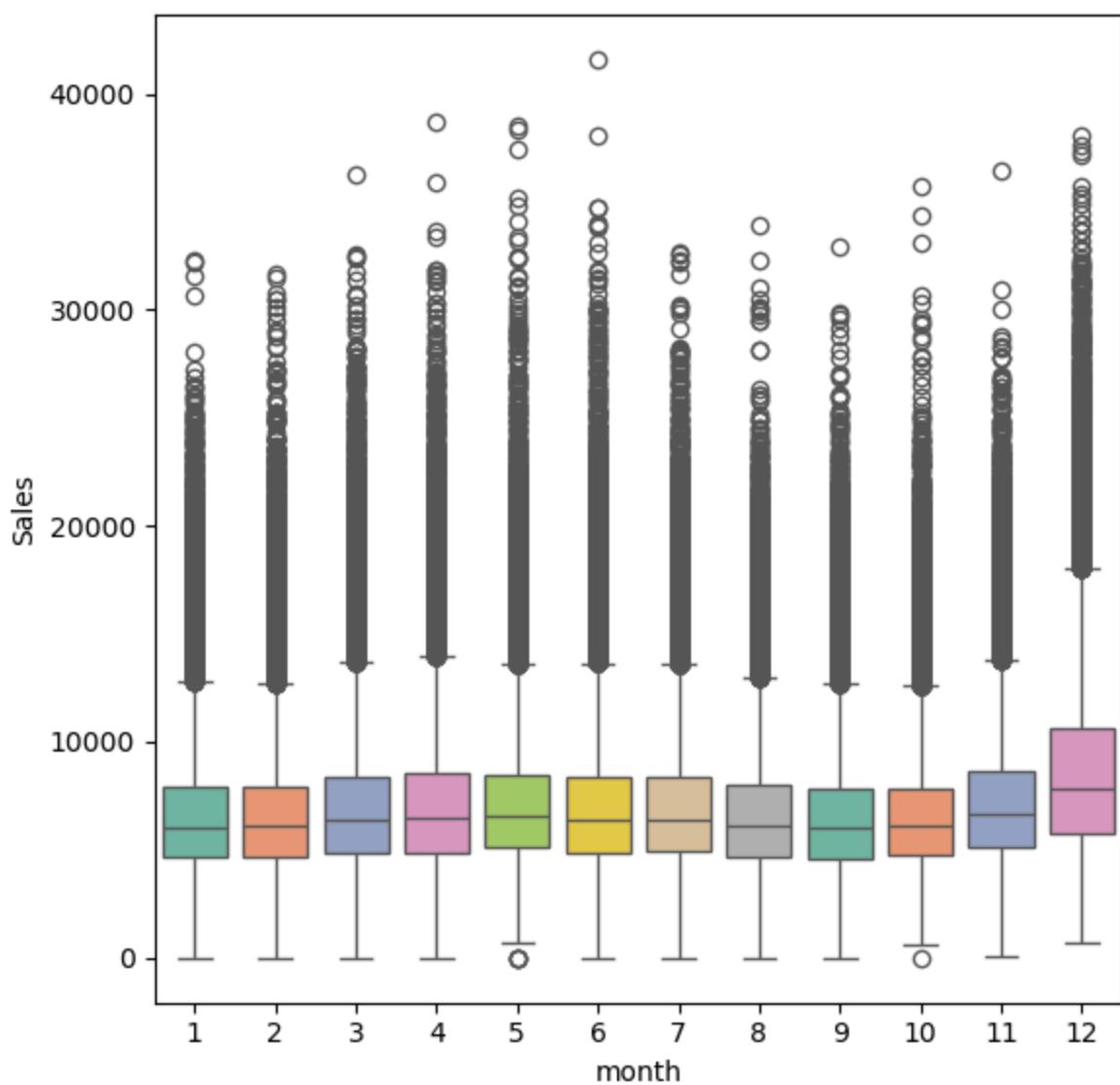
Box Plot of Sales vs school_holiday



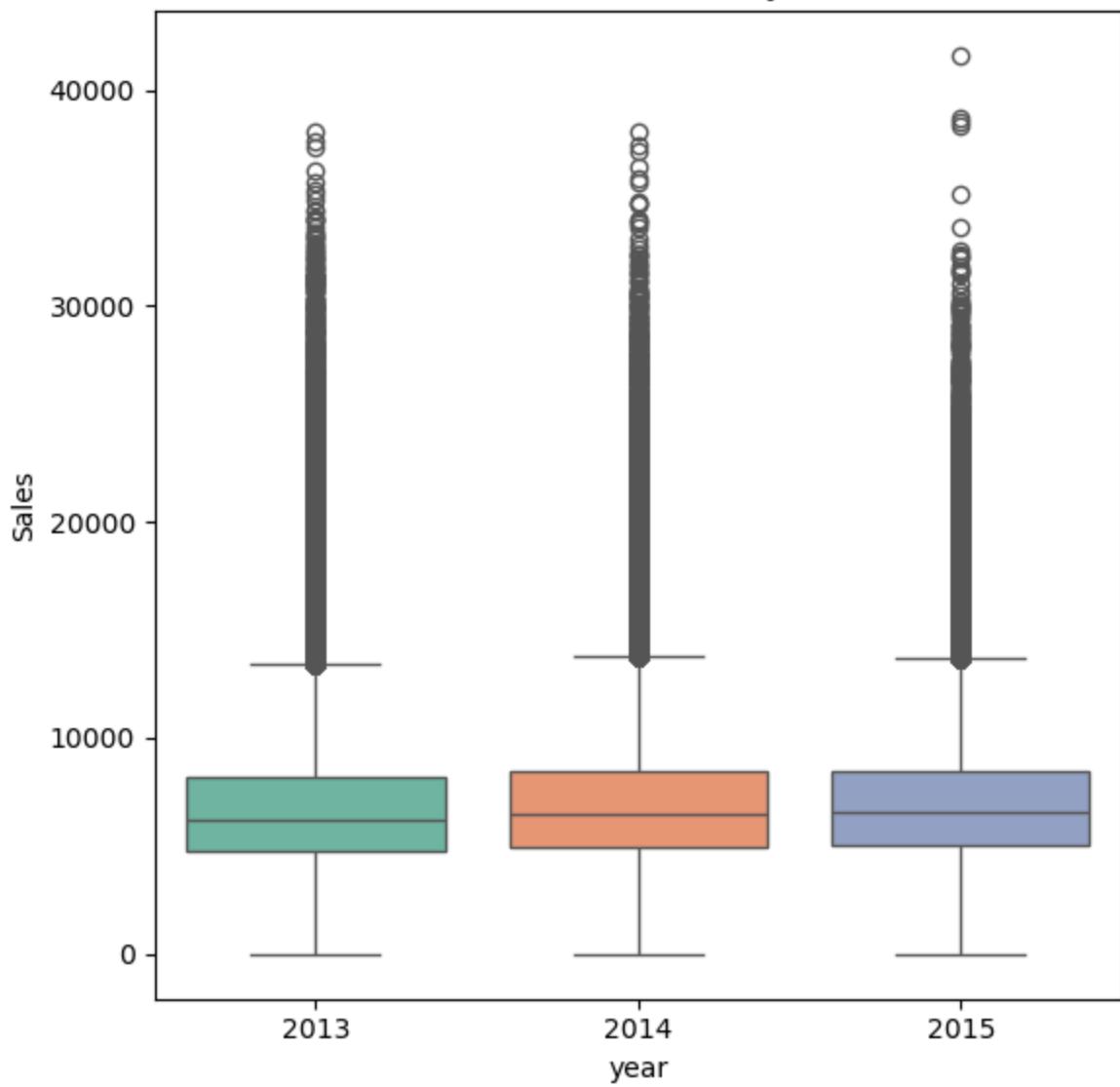
Box Plot of Sales vs promo2



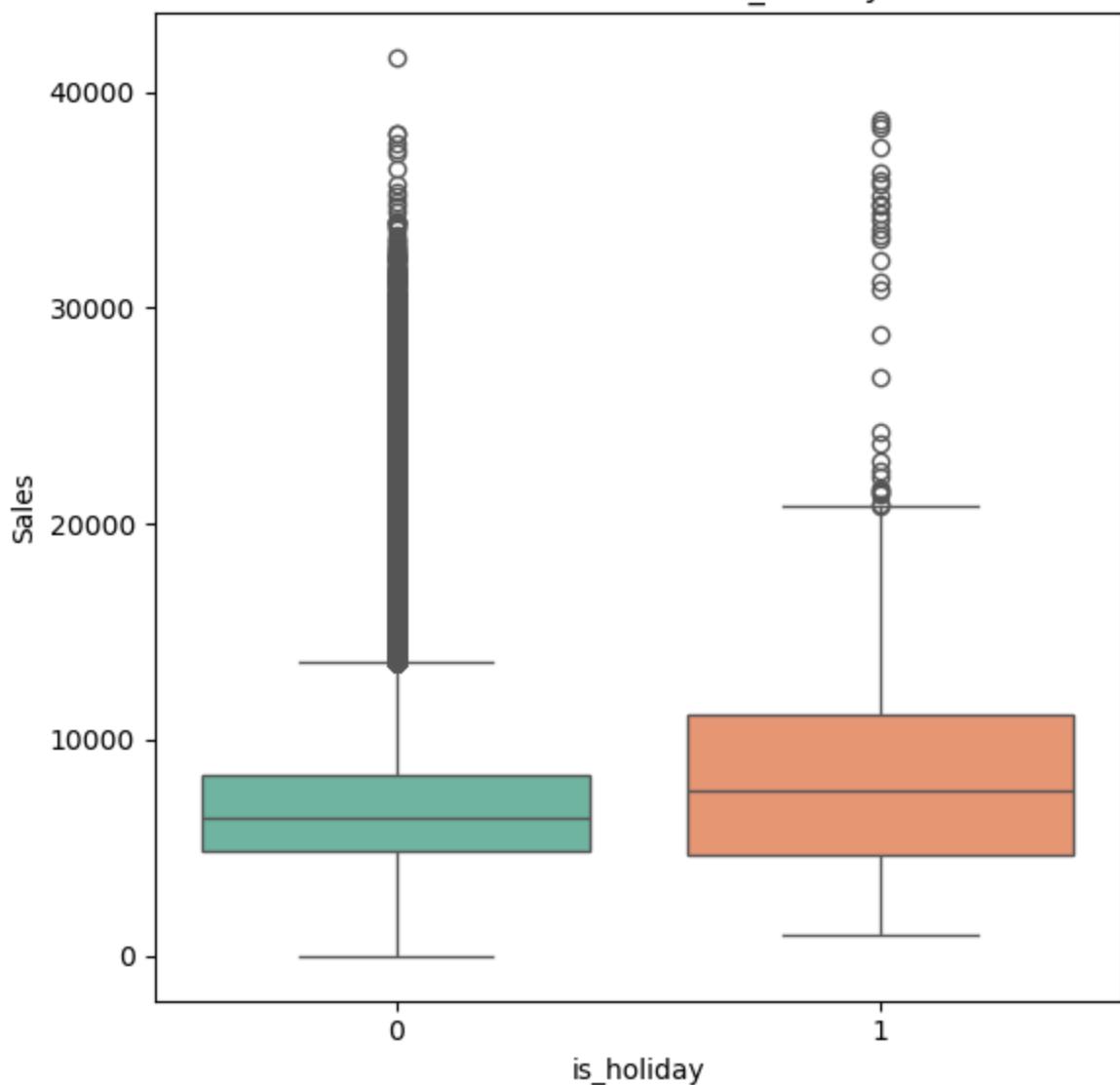
Box Plot of Sales vs month



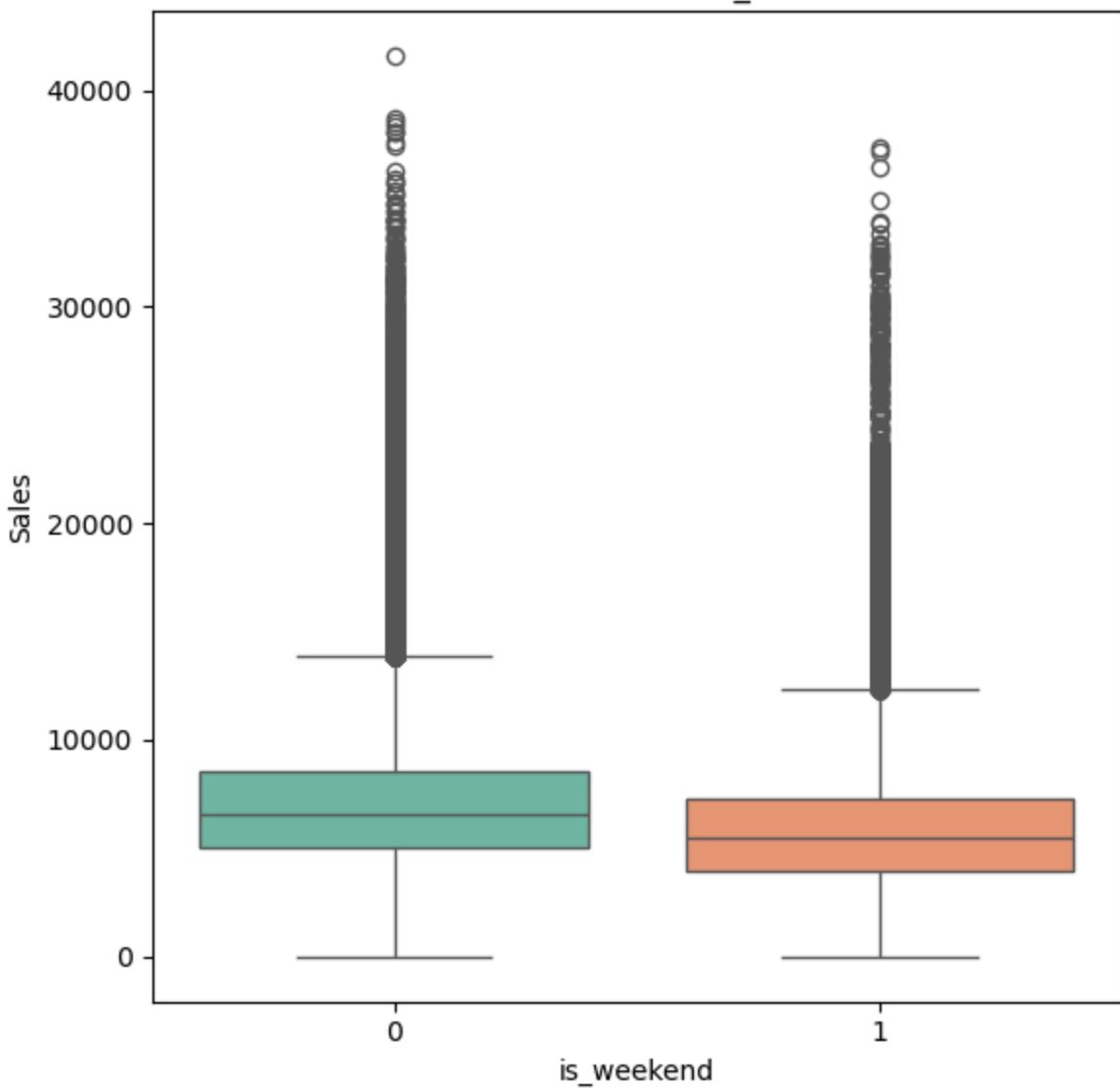
Box Plot of Sales vs year



Box Plot of Sales vs is_holiday



Box Plot of Sales vs is_weekend



```
In [113]: #Lets look at the distribution of Sales (avg) vs all the categorical variables

for col in cat_cols:
    sns.barplot(store_df, x = col, y = 'sales', palette = "Set2")
    plt.title("Distribution of Average Sales vs " + col)
    plt.ylabel("Average Sales")
    plt.xlabel(col)
    plt.tight_layout()
    plt.show()

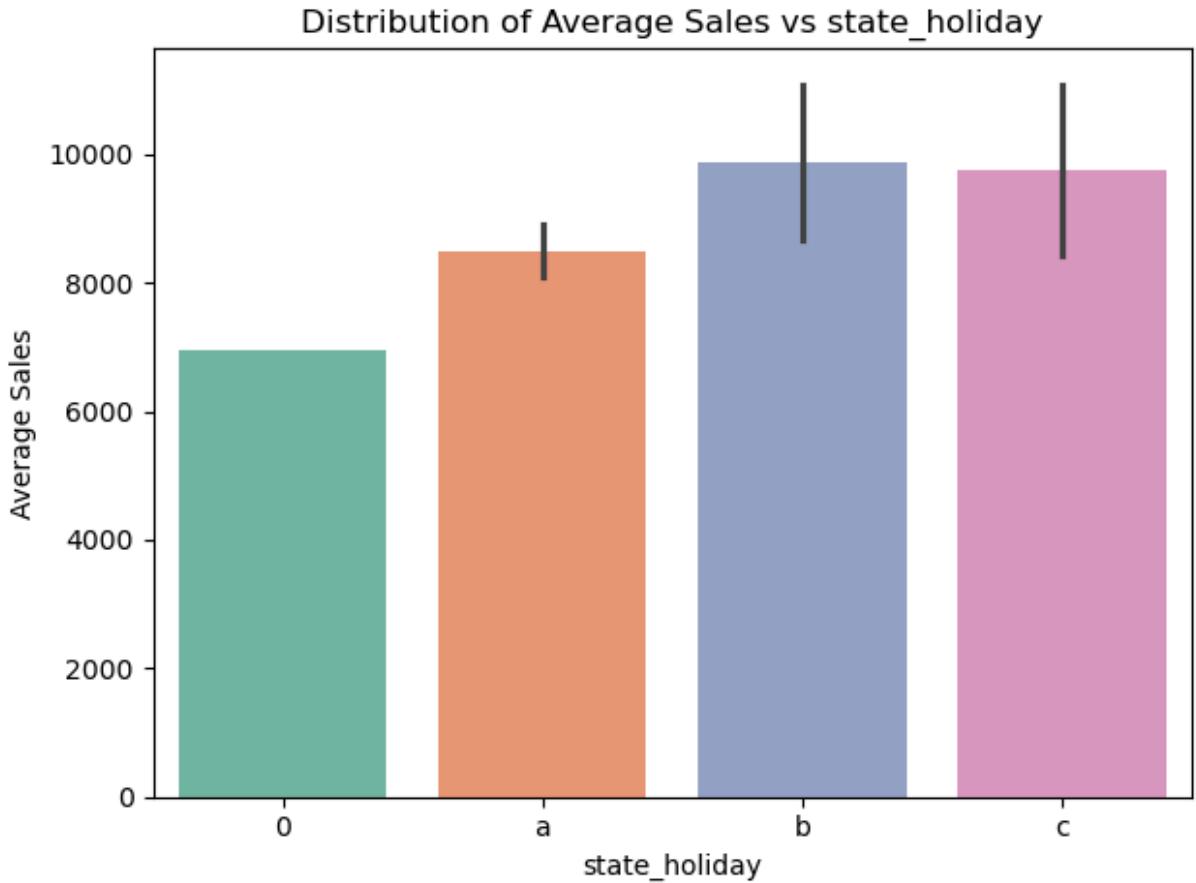
#Average sales for state_holidays is high compared to days without state hol
#maybe because number of holidays are less hence the average is higher

#Average sales for b store_type is highest compared to others though its tot
#because the number of b store_type is very low

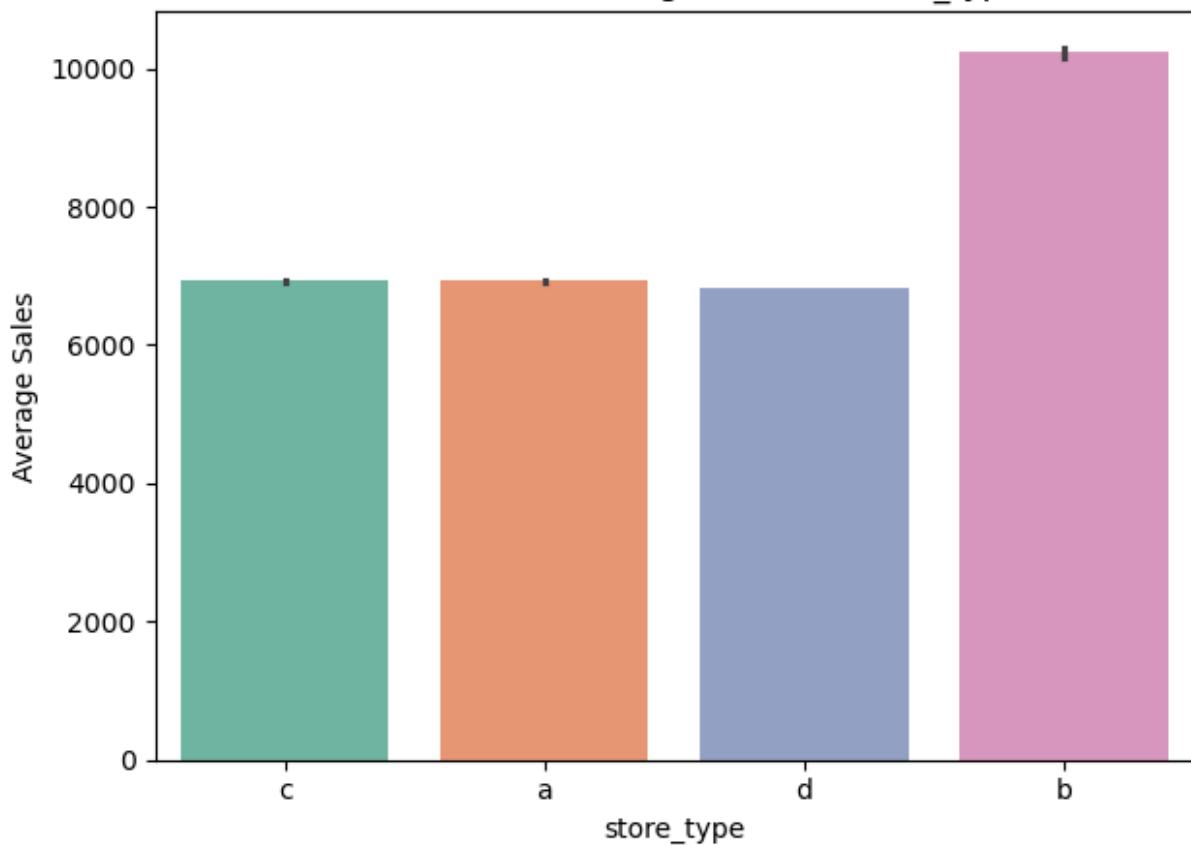
#Average sales for b assortment is highest compared to others though its tot
#because the number of b assortment stores is very low

#Average sales for day_of_week 7 is highest compared to others though its to
```

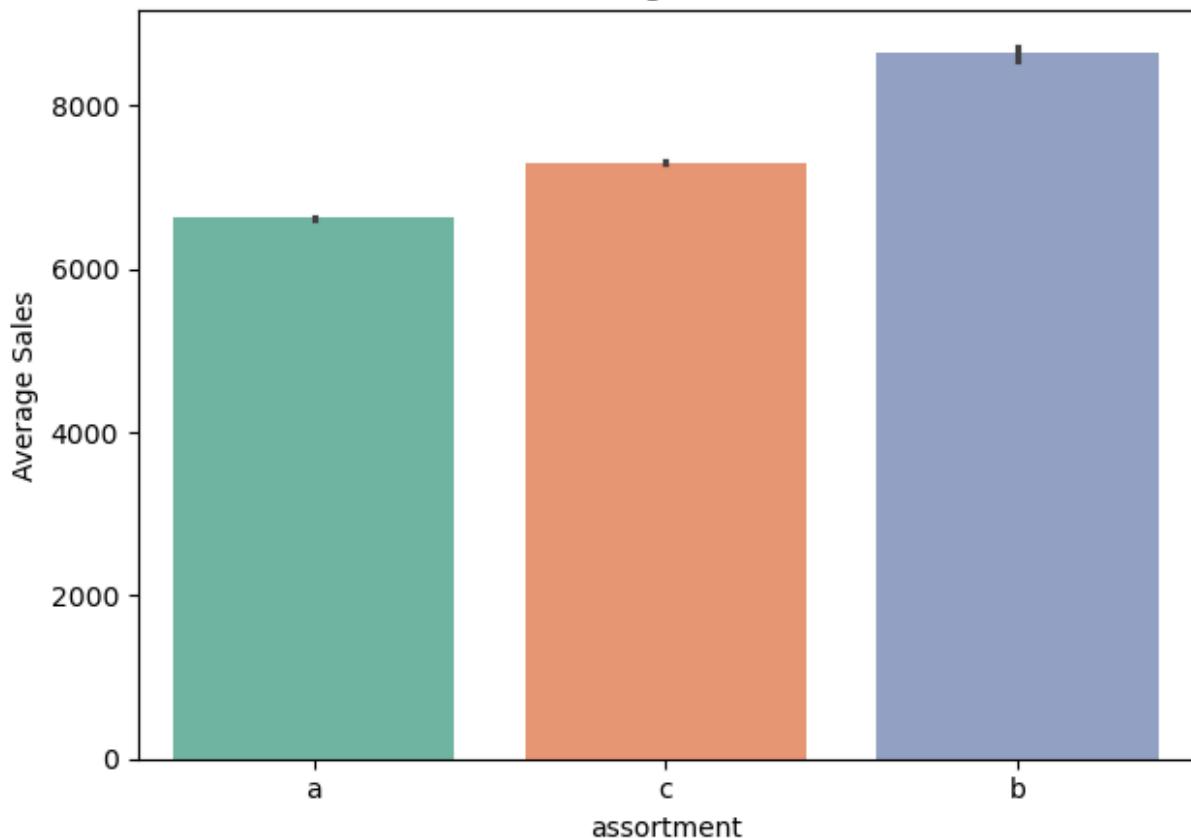
```
#As in many cases stores are closed on Sunday (day 7) so the number of day 7  
#Average sales for month 12 is highest compared to others though its total s  
#because Dec days were less as Dec 2015 data is not provided.  
  
#Average sales for year 2015 is similar to others though its total sales was  
  
#Average sales on a holiday is higher than that of no holiday whereas total  
#maybe because number of holidays are less hence the average is higher  
  
#Average sales on a weekend is higher than that of no weekend whereas total  
#maybe because number of weekends are less hence the average is higher
```

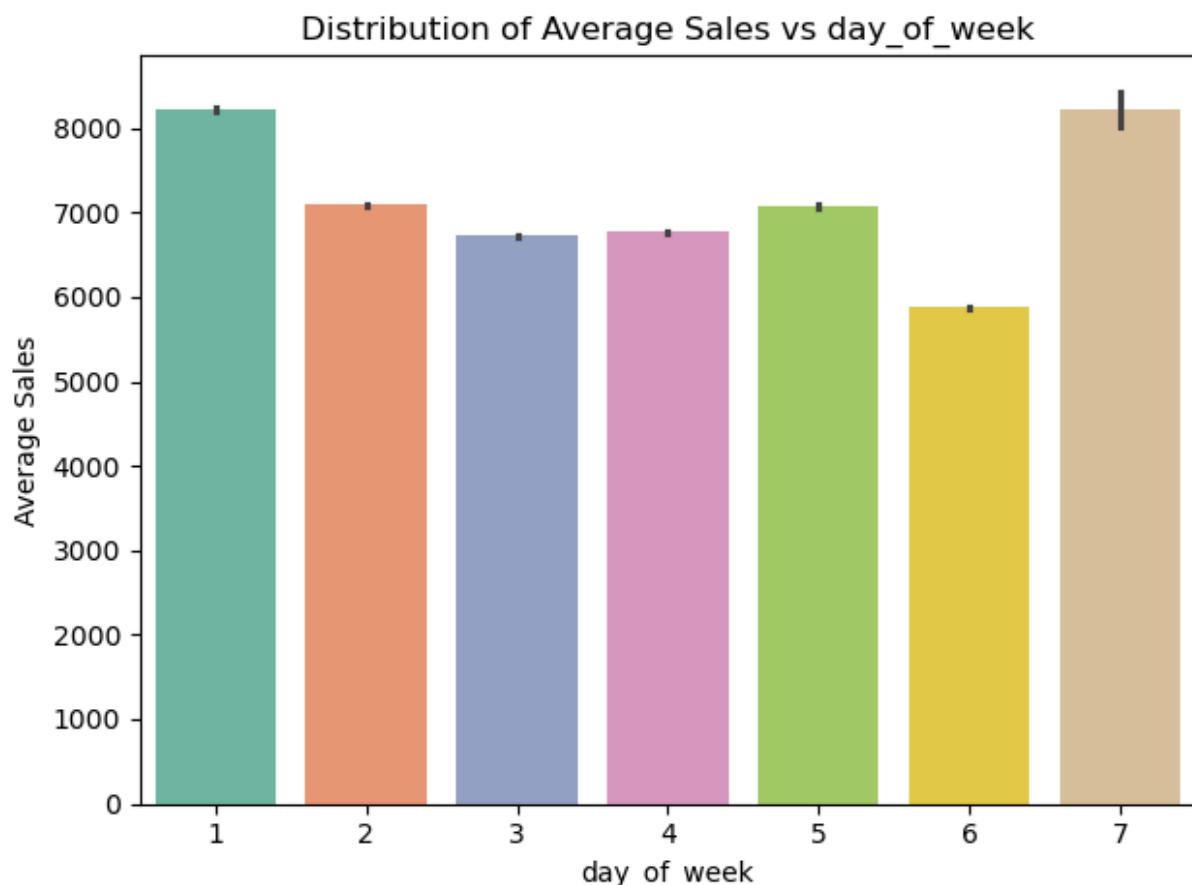
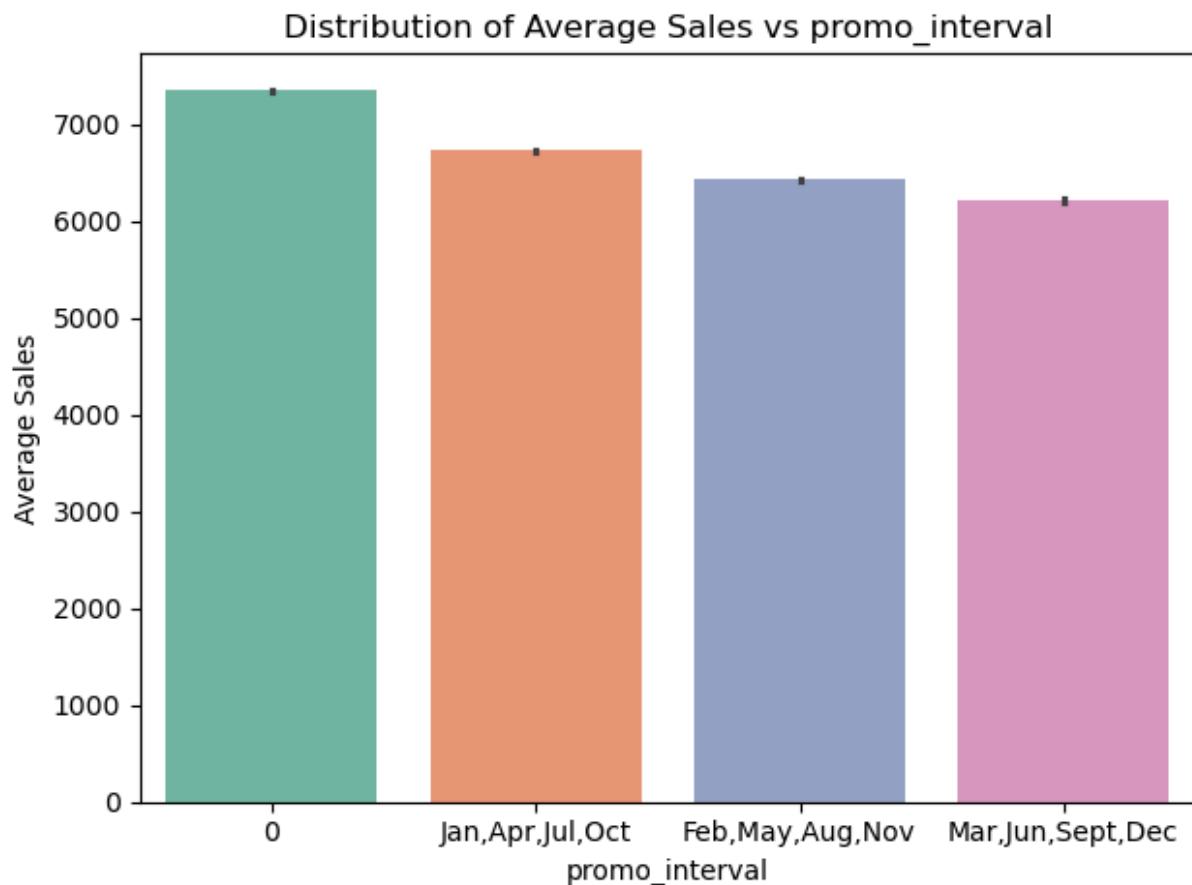


Distribution of Average Sales vs store_type

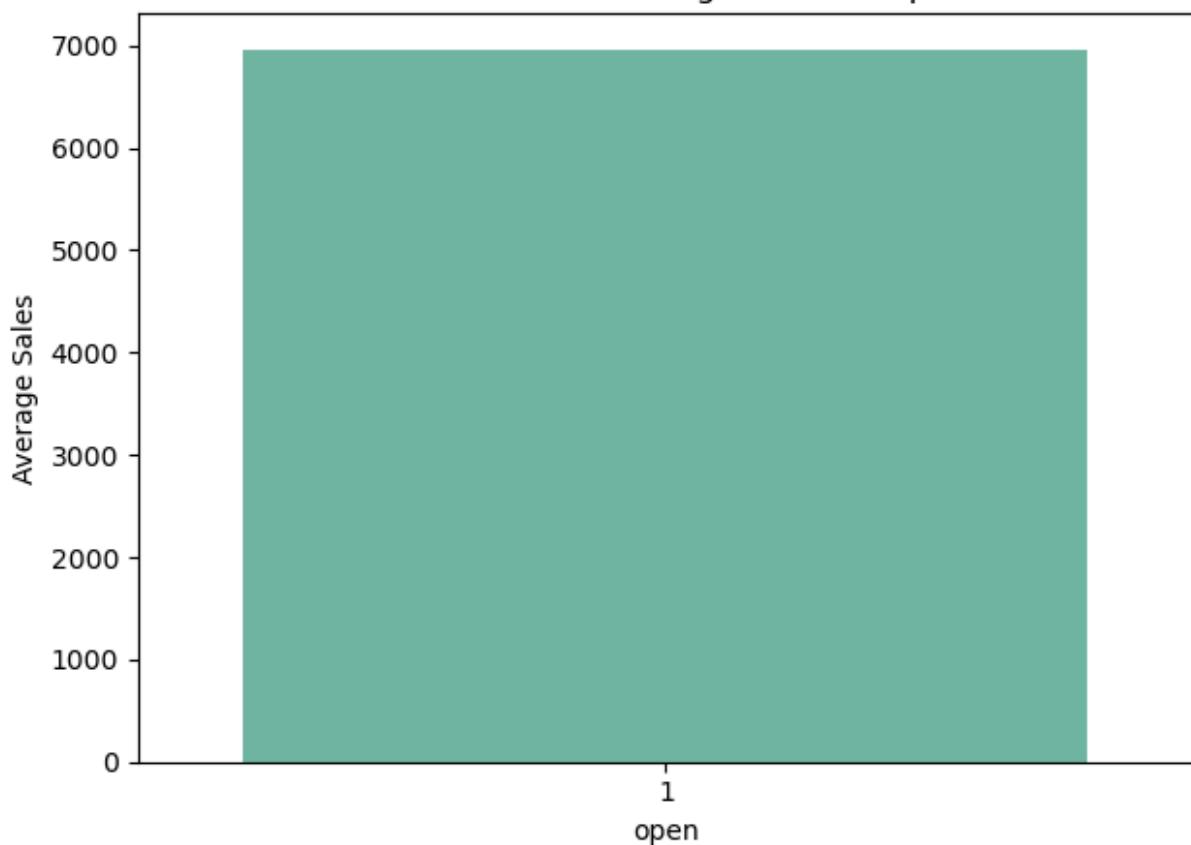


Distribution of Average Sales vs assortment

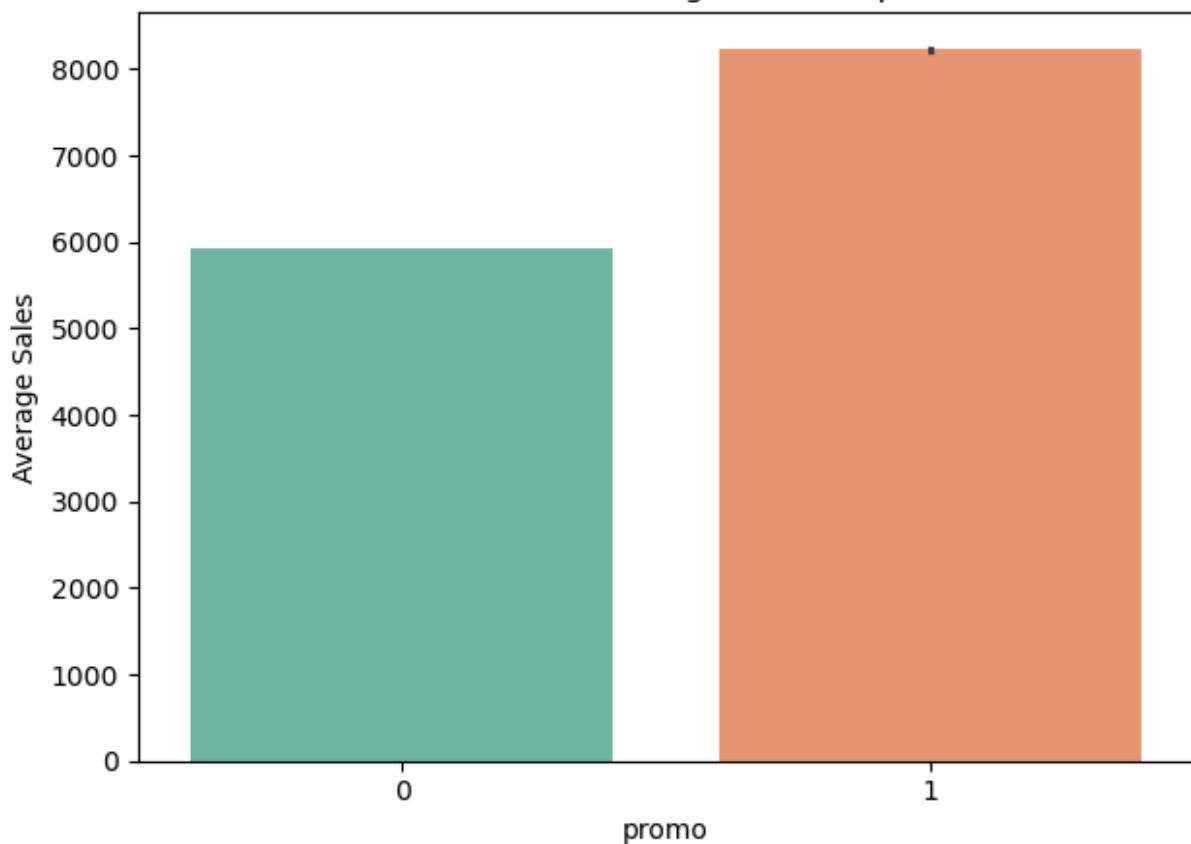




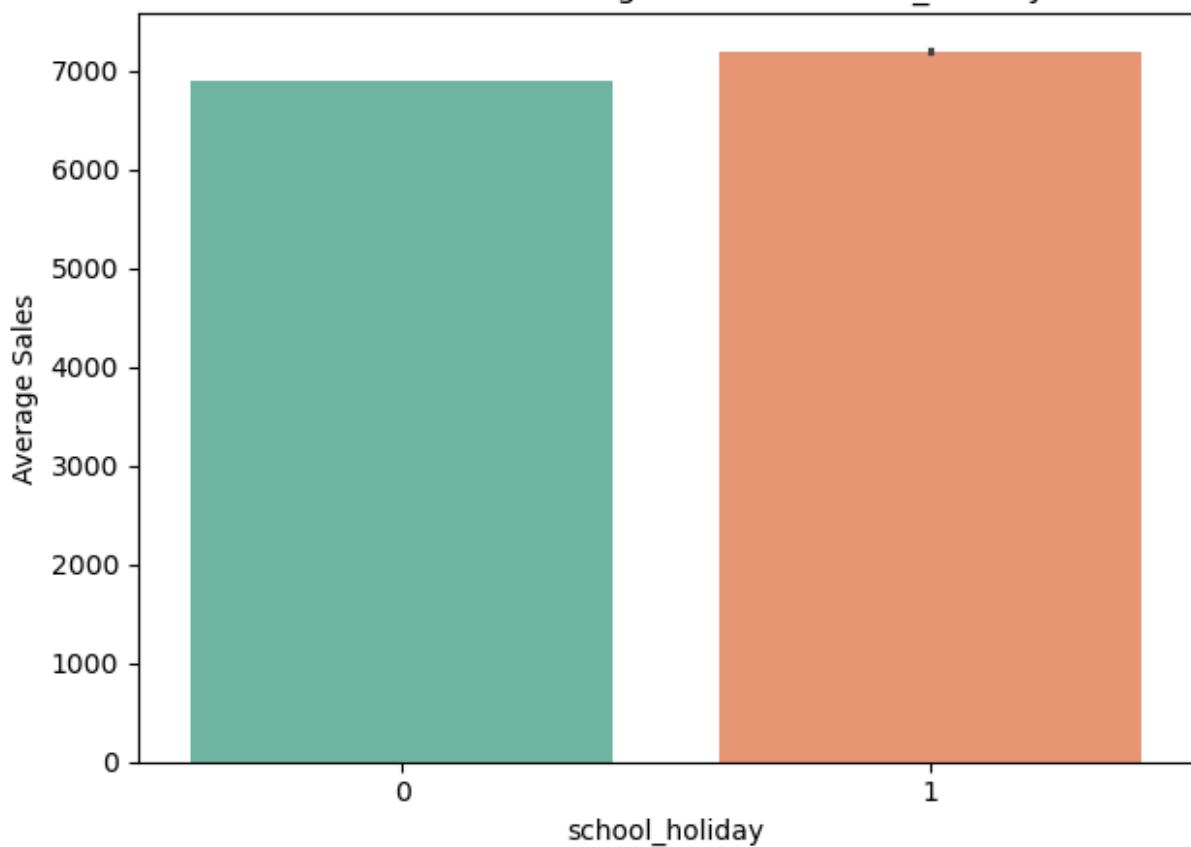
Distribution of Average Sales vs open



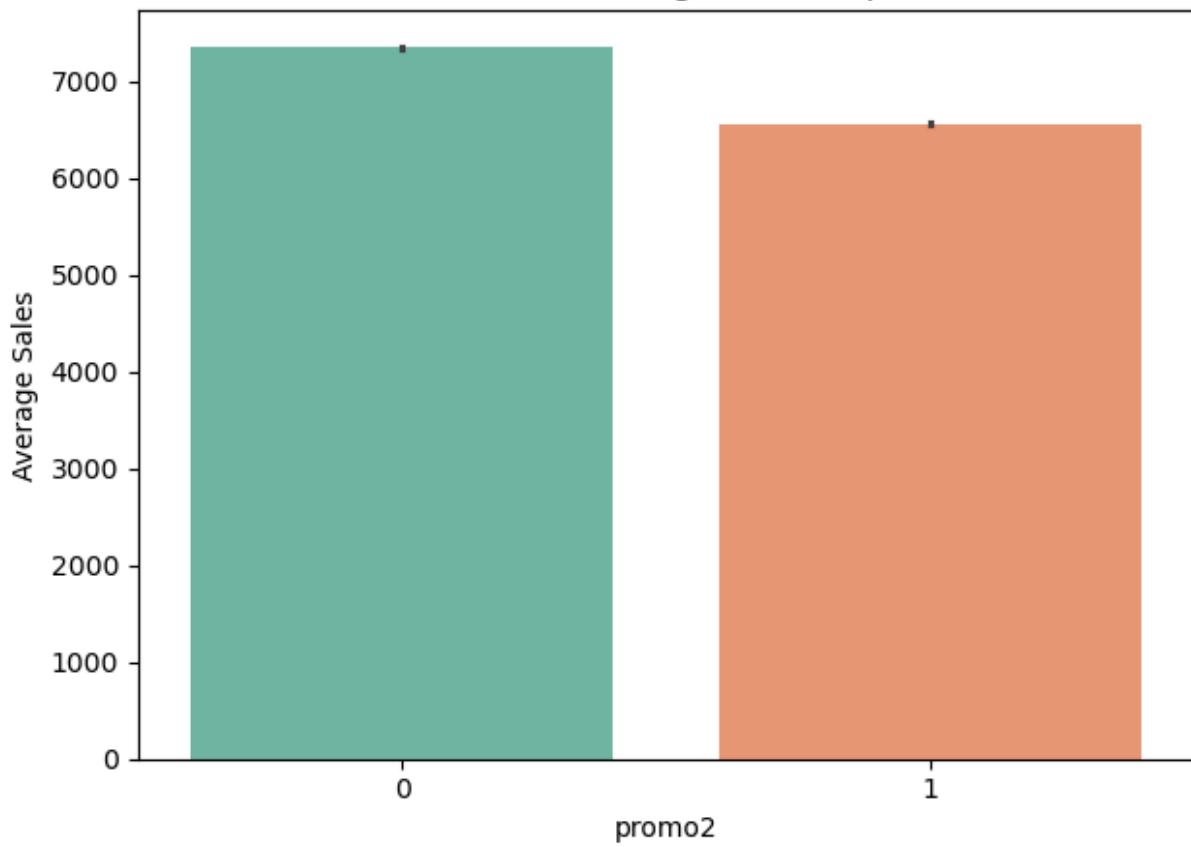
Distribution of Average Sales vs promo



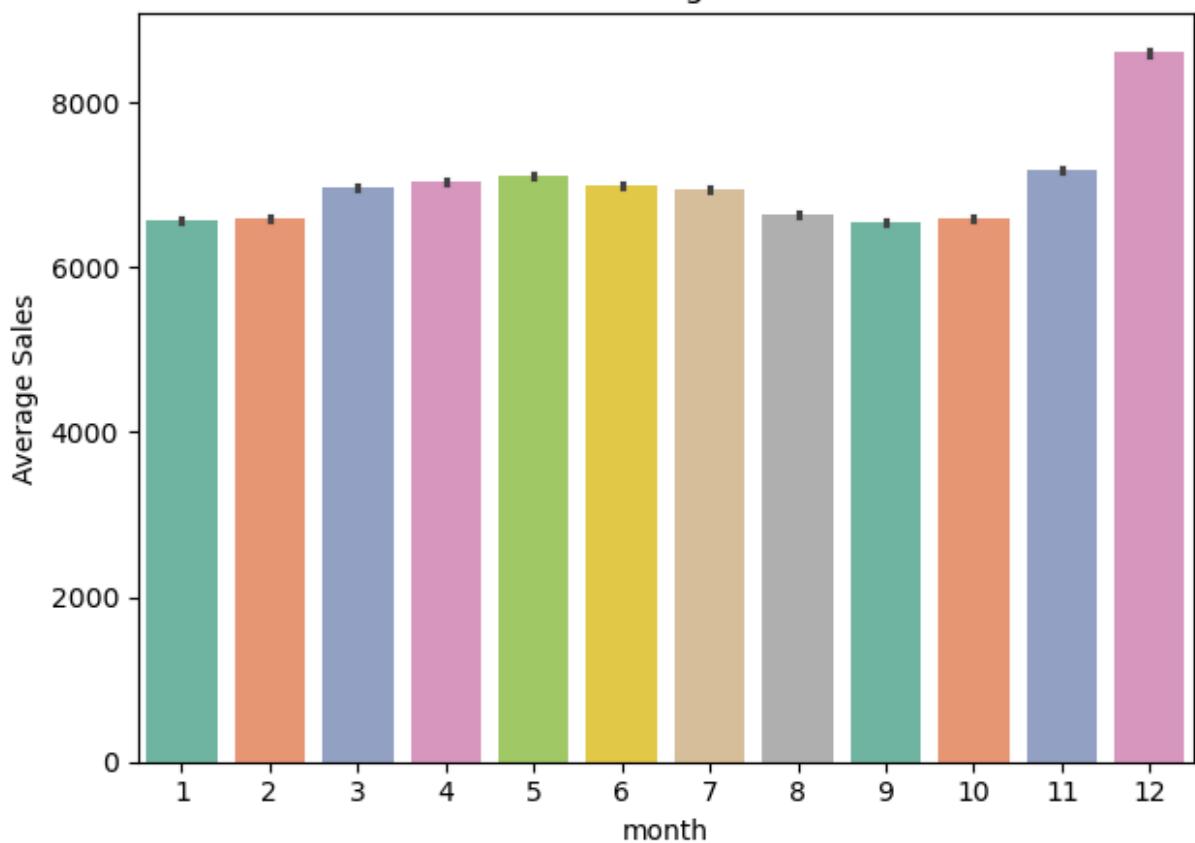
Distribution of Average Sales vs school_holiday



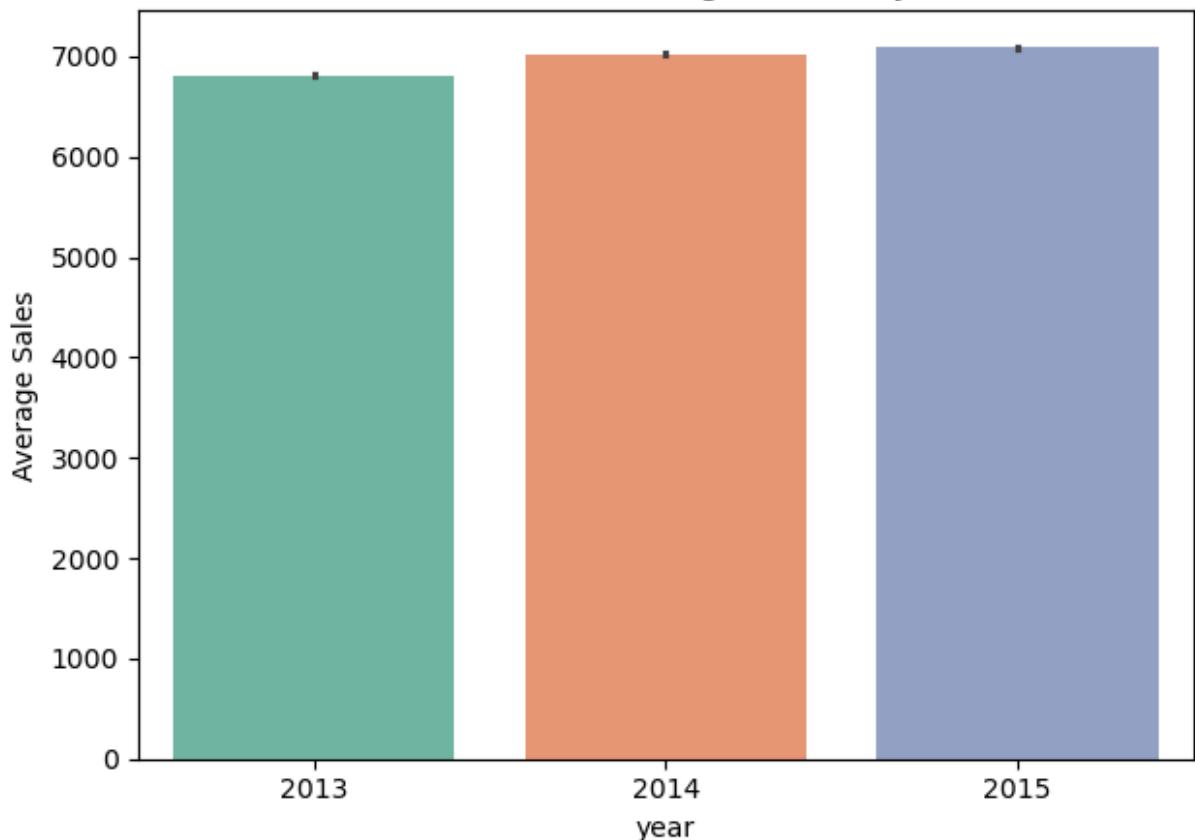
Distribution of Average Sales vs promo2



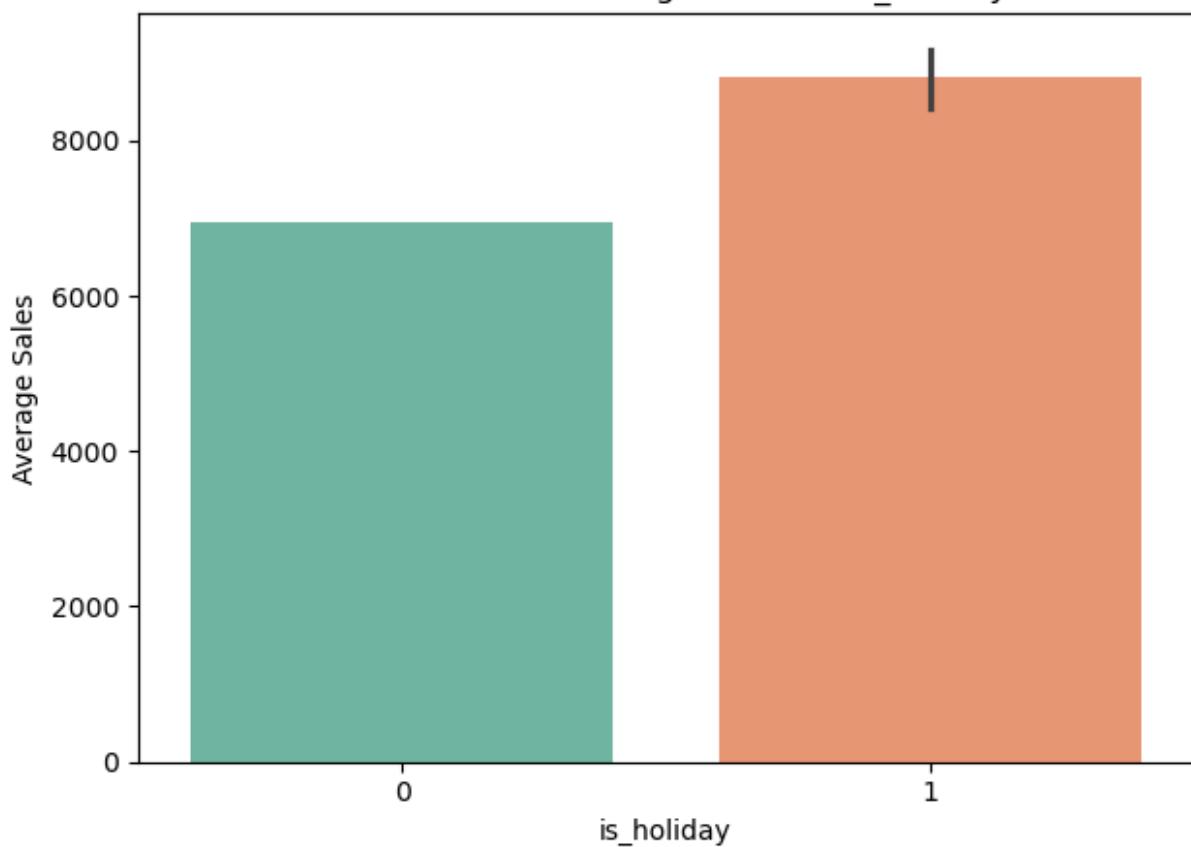
Distribution of Average Sales vs month



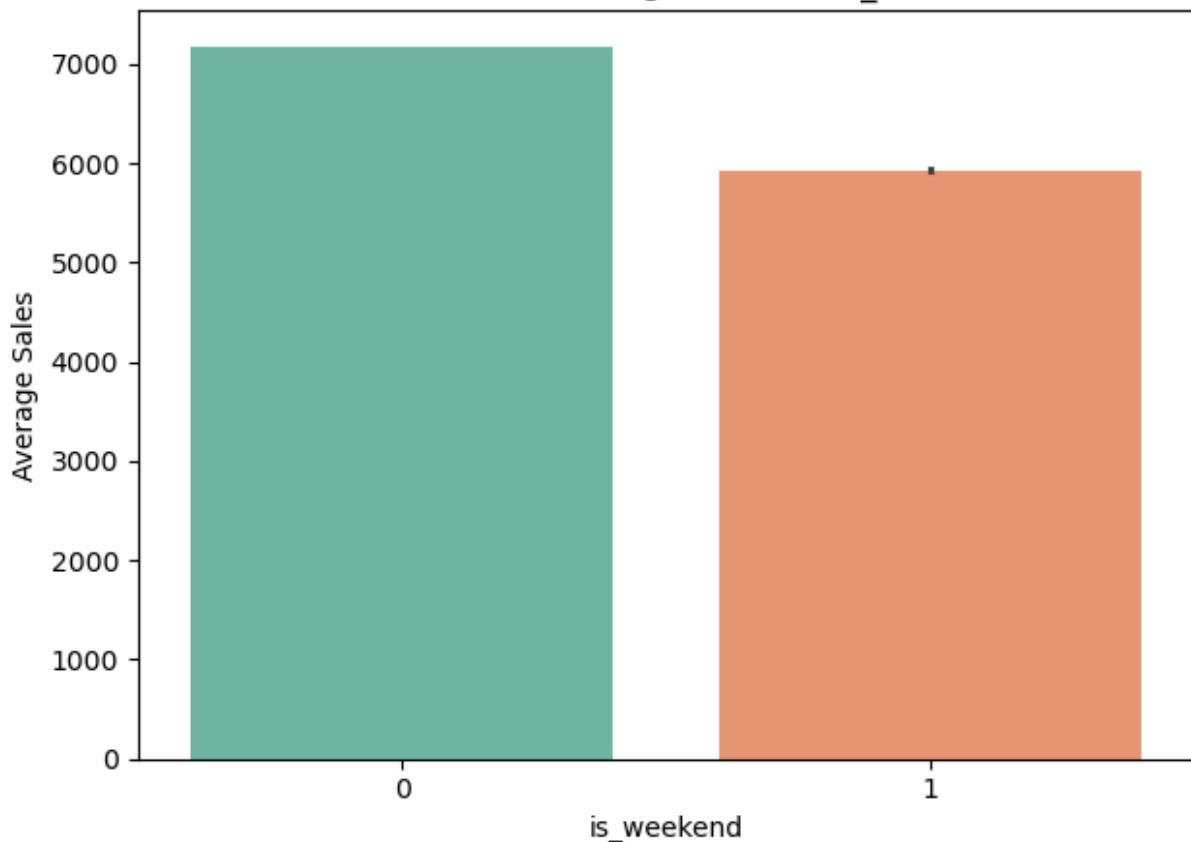
Distribution of Average Sales vs year



Distribution of Average Sales vs is_holiday

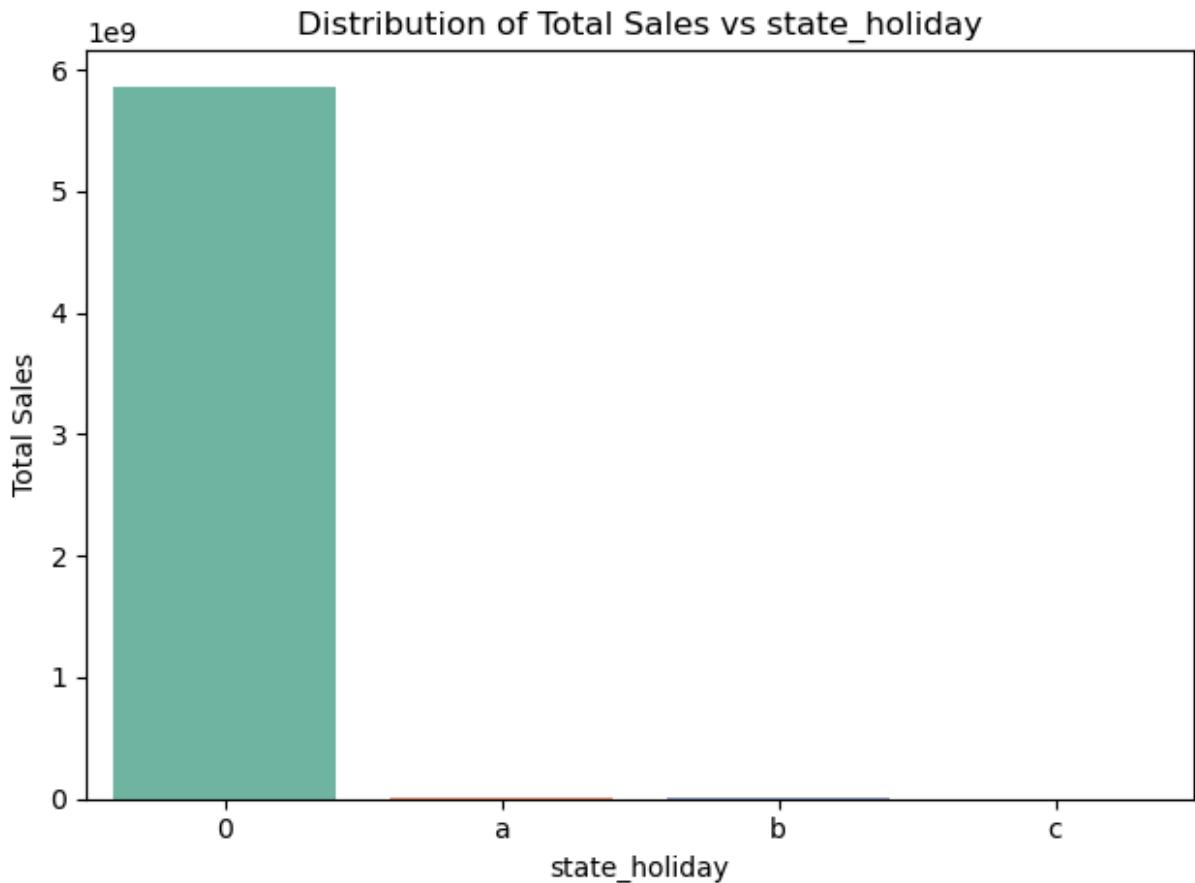


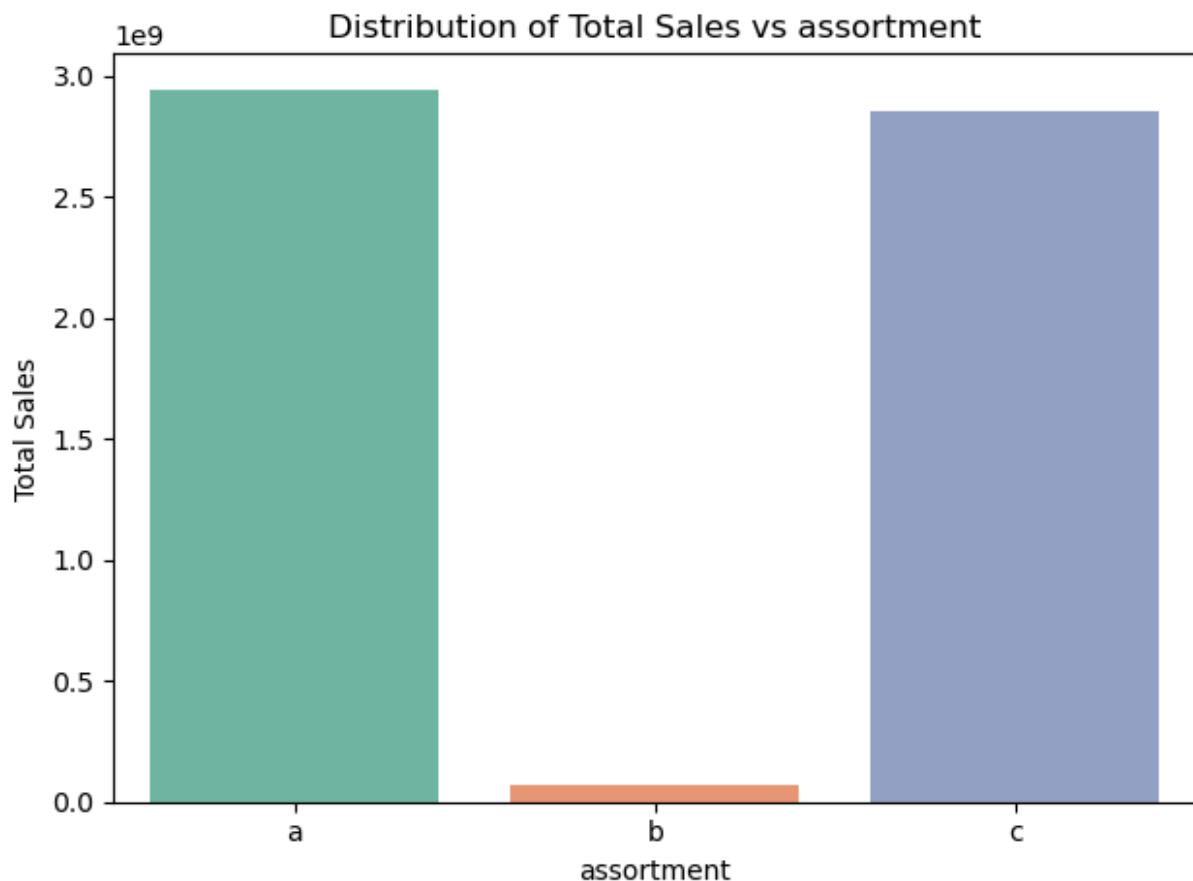
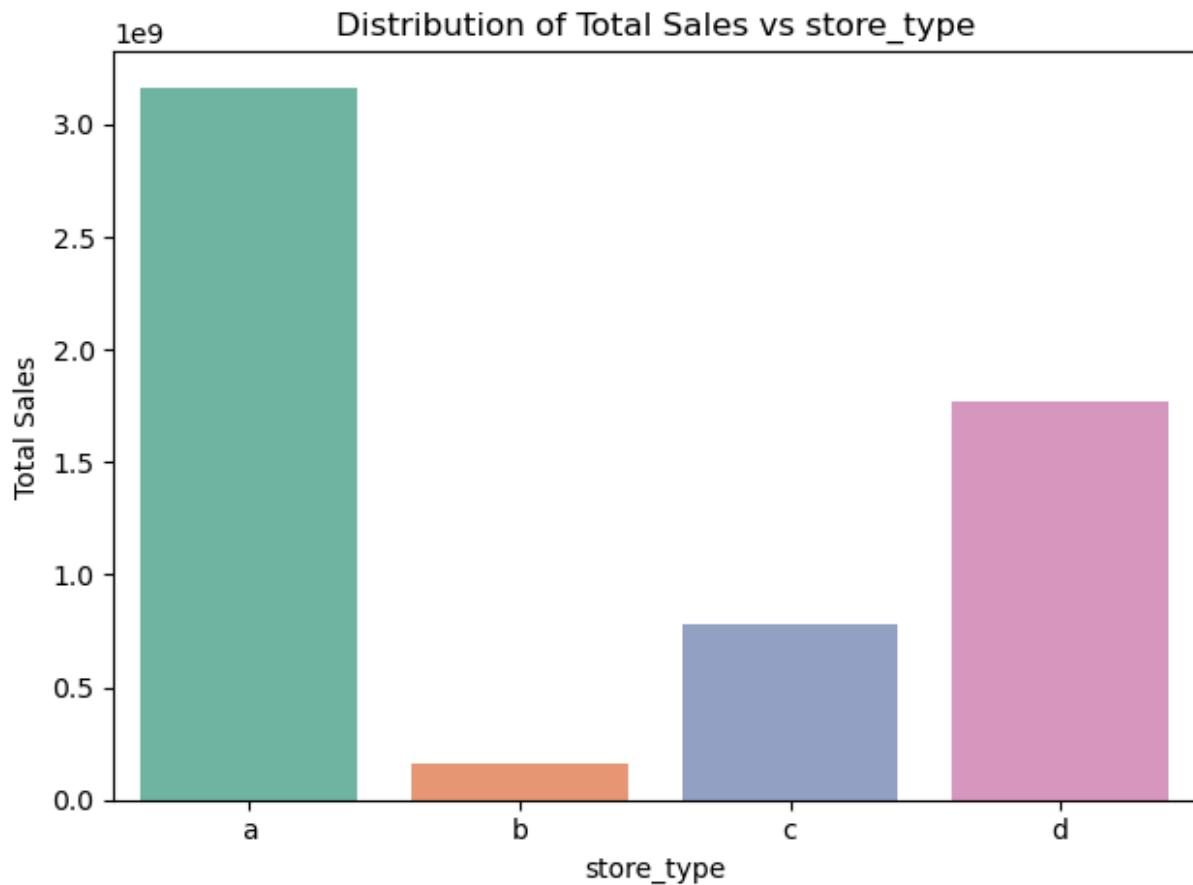
Distribution of Average Sales vs is_weekend

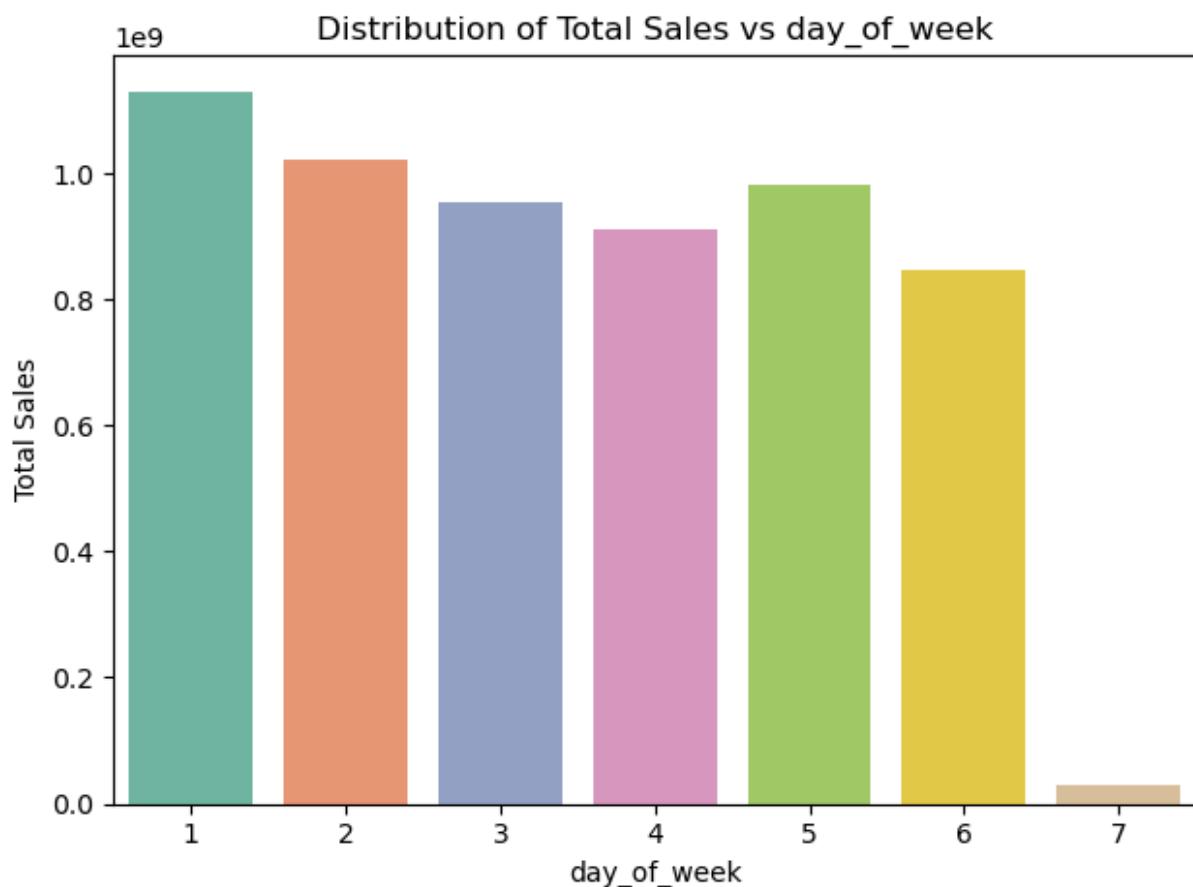
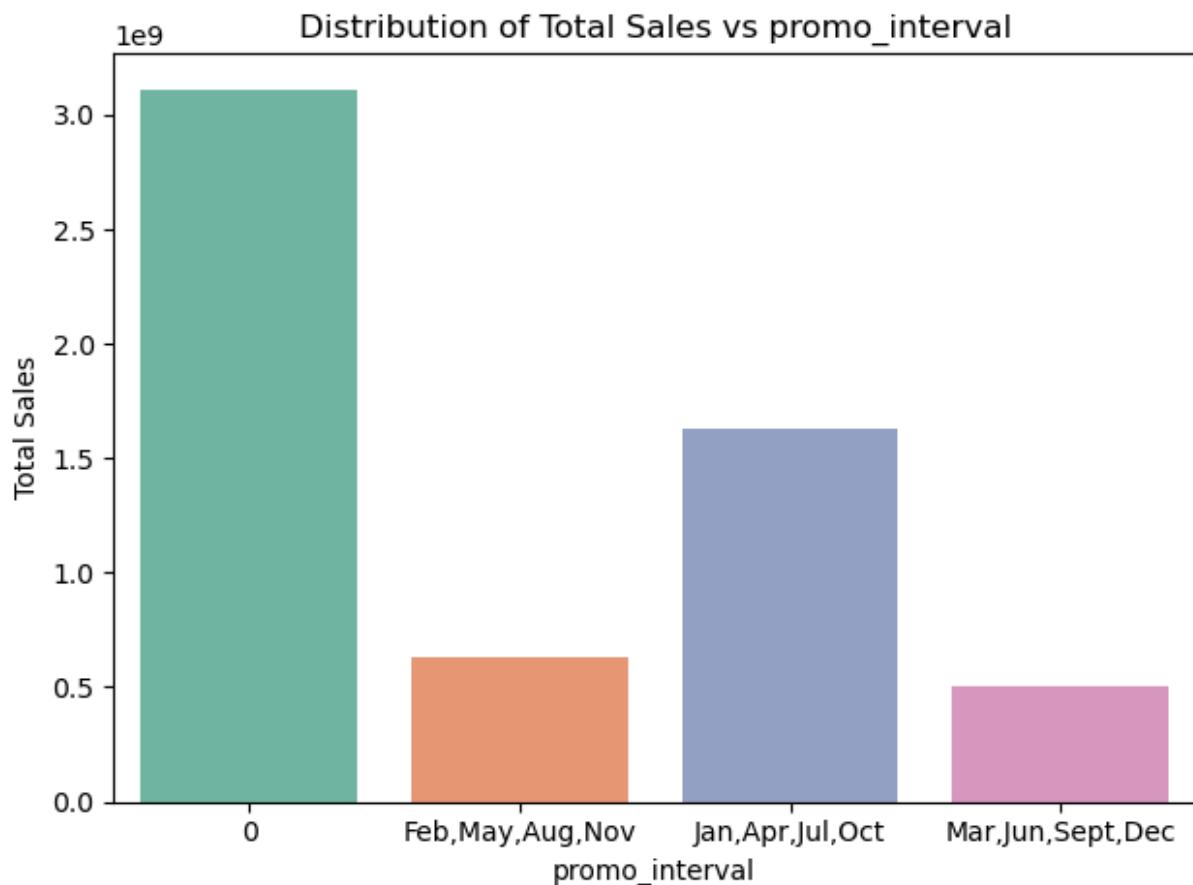


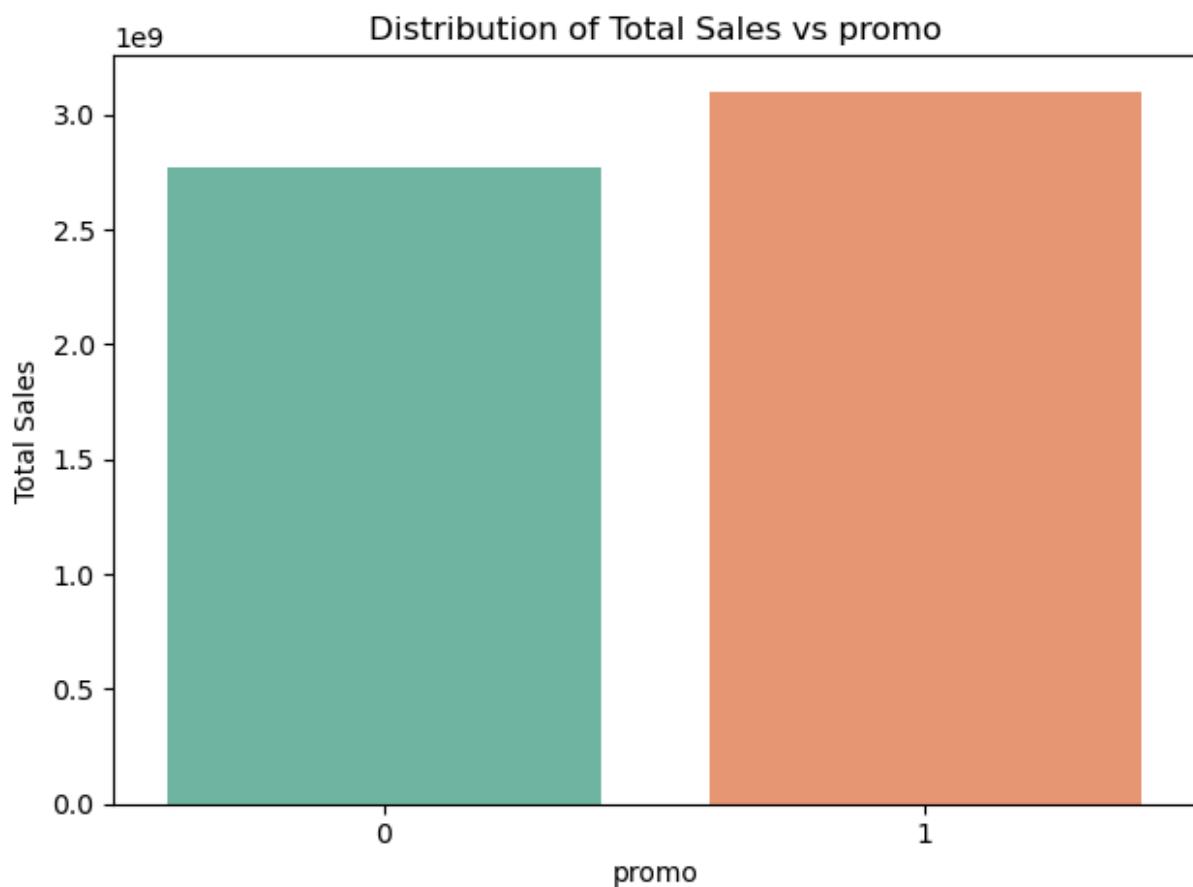
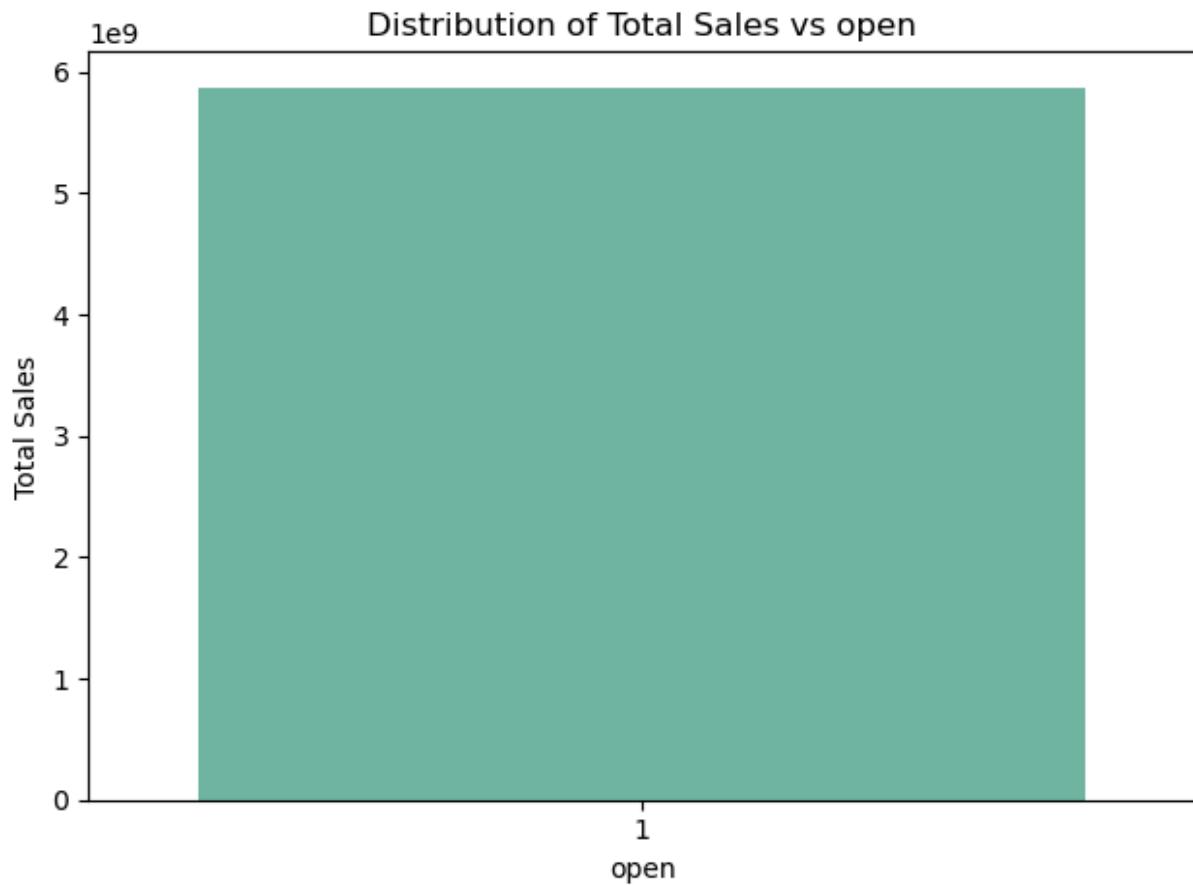
```
In [114]: #Bar Plot of total sales vs categorical columns
```

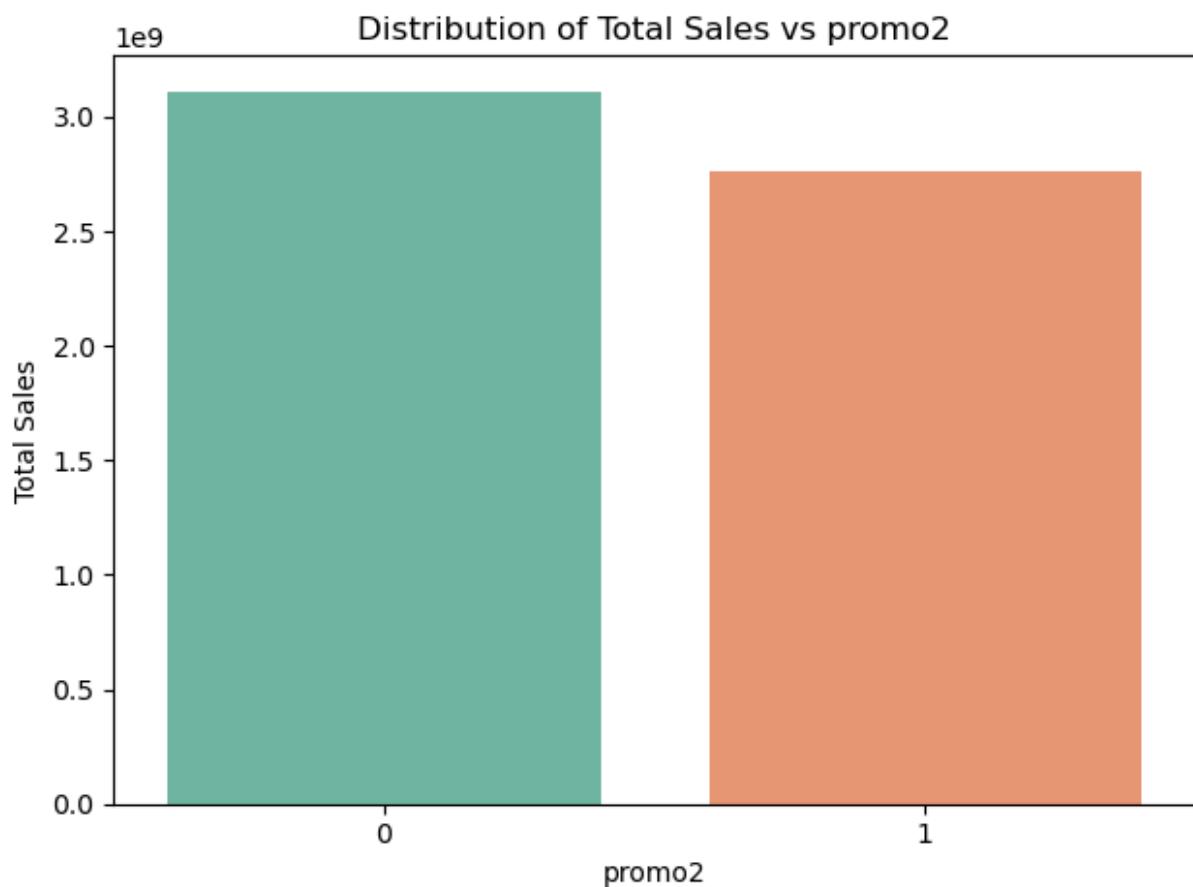
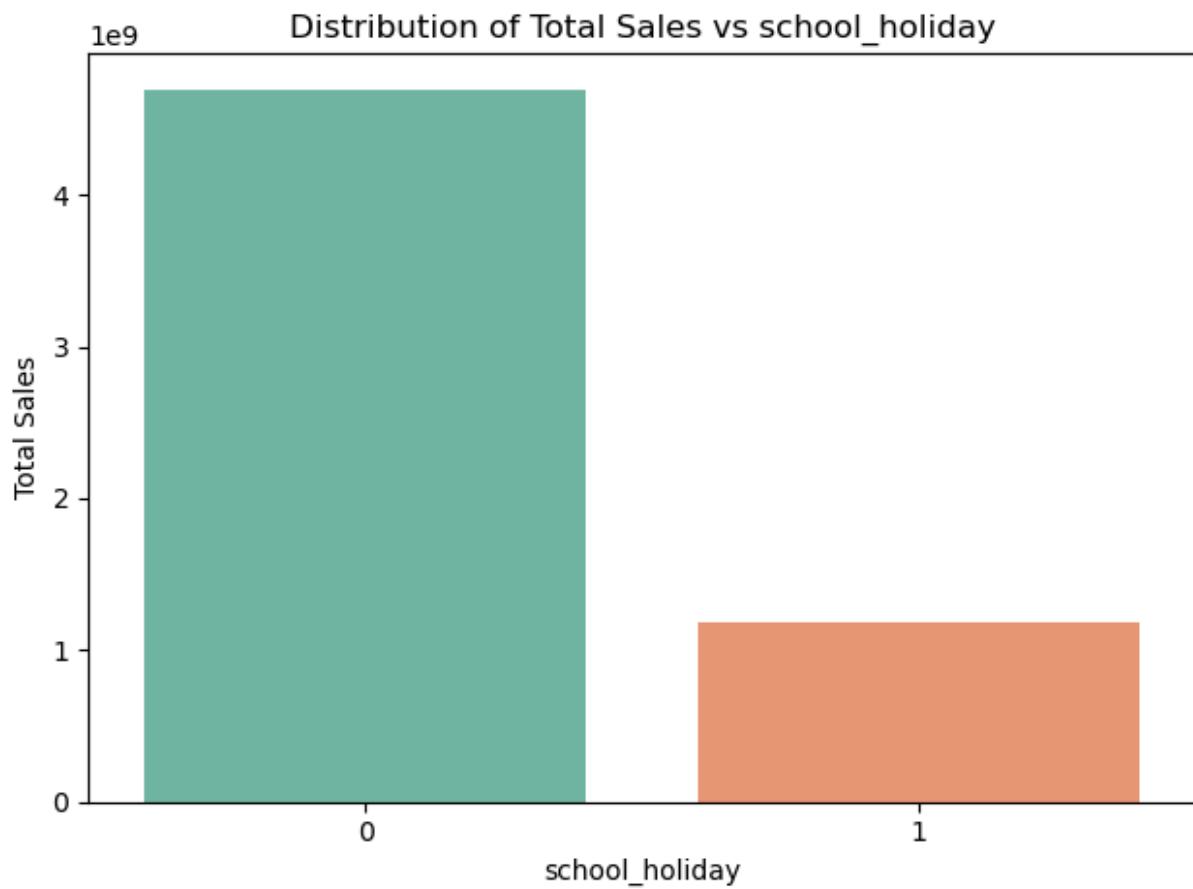
```
for col in cat_cols:  
    sales_sum = store_df.groupby(col)['sales'].sum().reset_index()  
    sns.barplot(sales_sum, y = 'sales', x = col, palette = 'Set2')  
    plt.title("Distribution of Total Sales vs " + col)  
    plt.ylabel("Total Sales")  
    plt.xlabel(col)  
    plt.tight_layout()  
    plt.show()  
  
# Total sales on Sunday (#7) is the lowest.  
# Months 8 to 12 have low total Sales as these months' data is not available  
# Year 2015 has low total Sales as only 7 months data of that year is available  
# Store type b and assortment b also had lowest total sales.  
# Similar trend seen here as that of in count plot, meaning if the number of  
#total sales of those instance also was less.
```

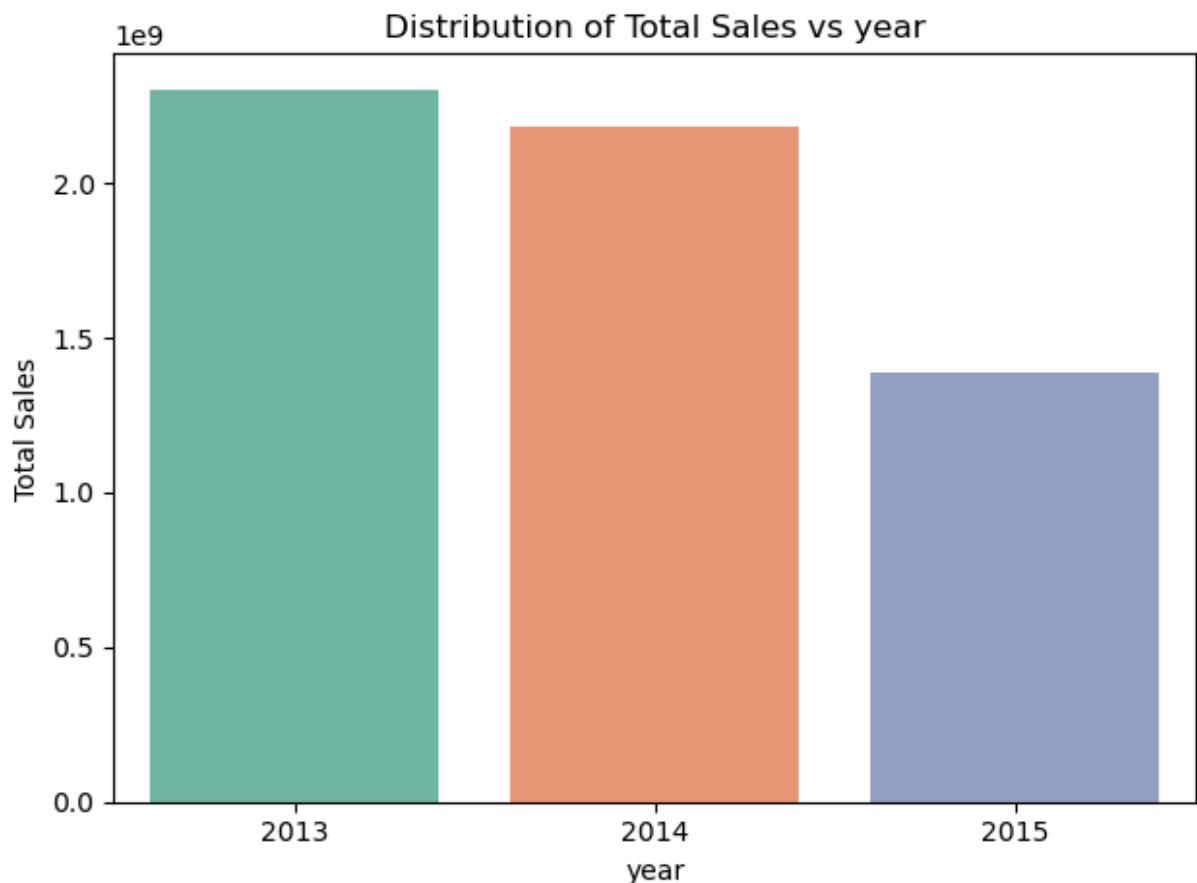
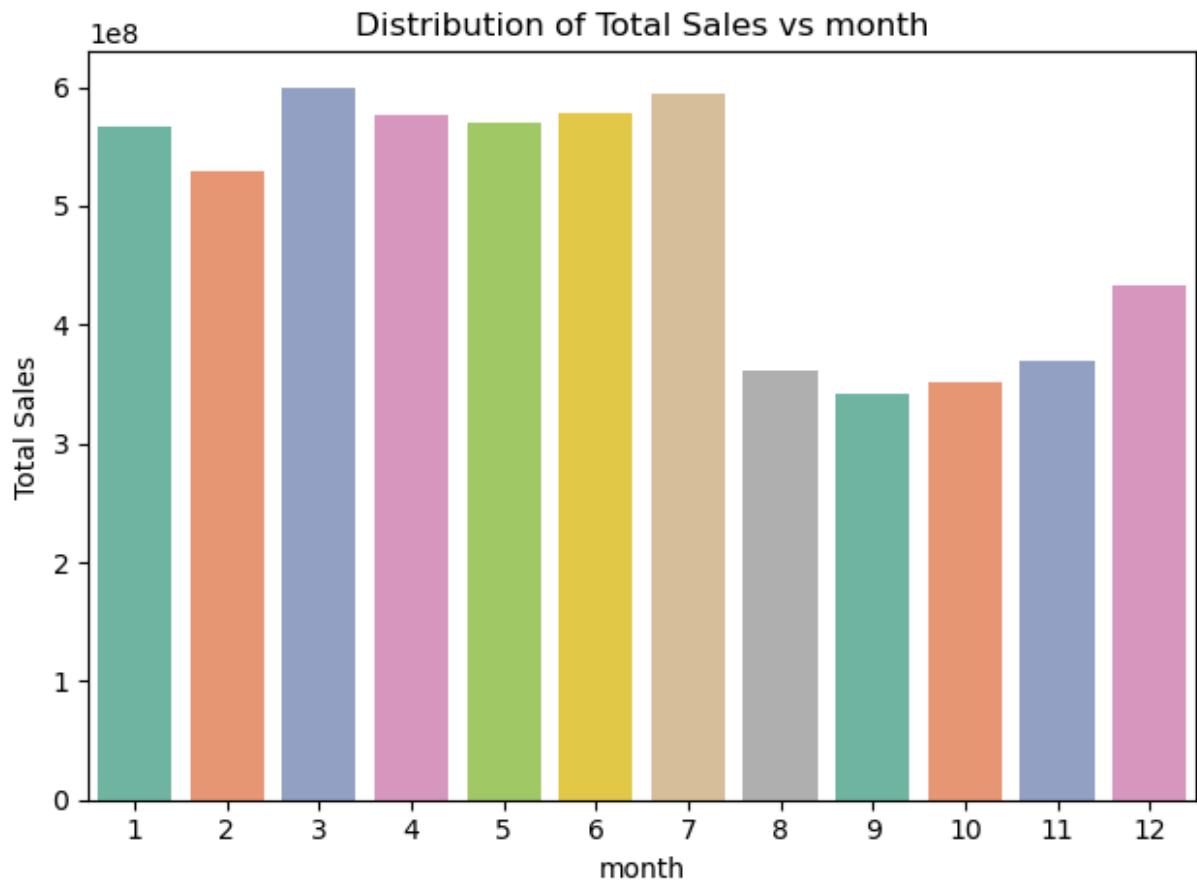


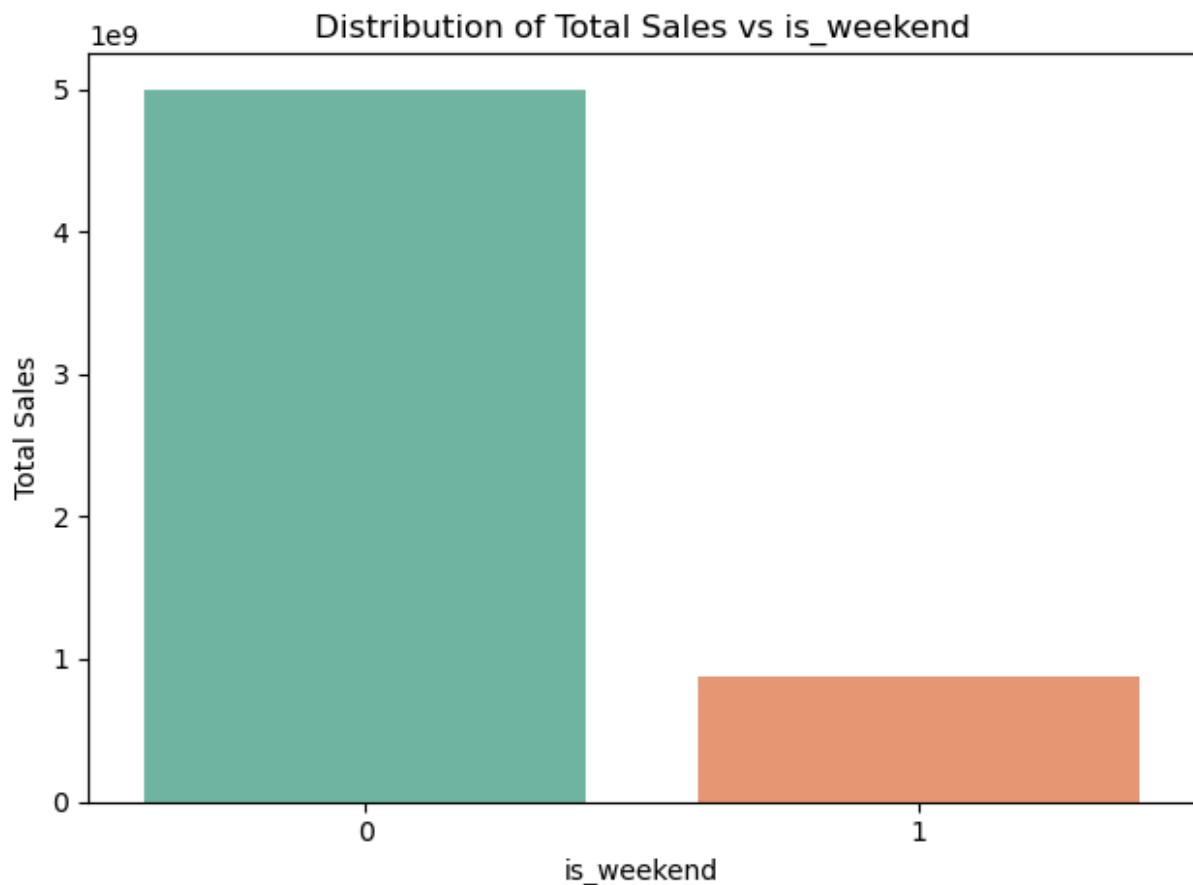
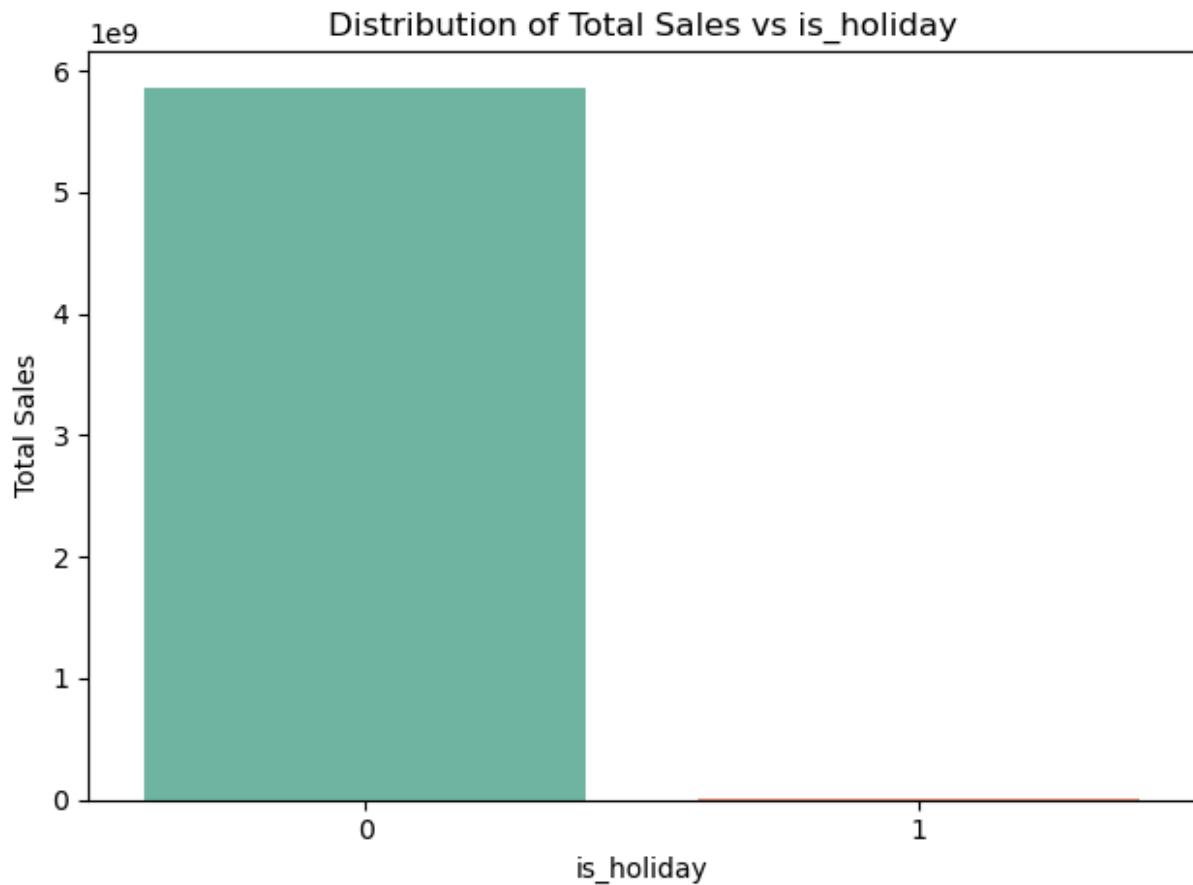






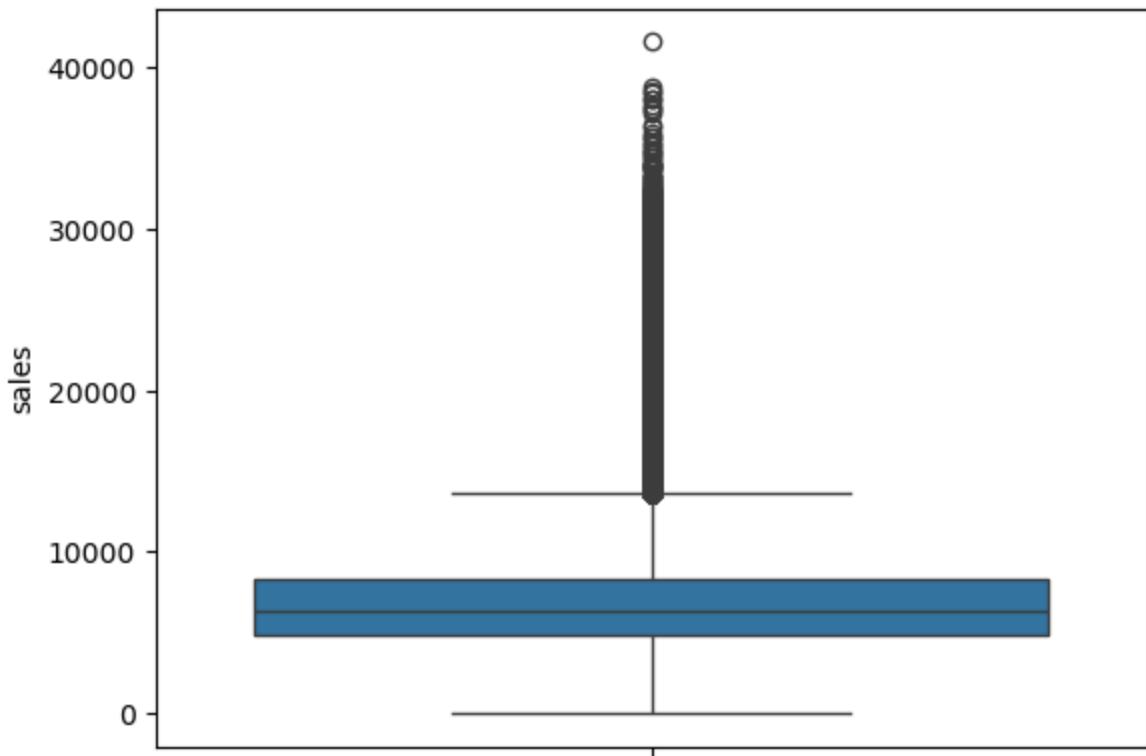
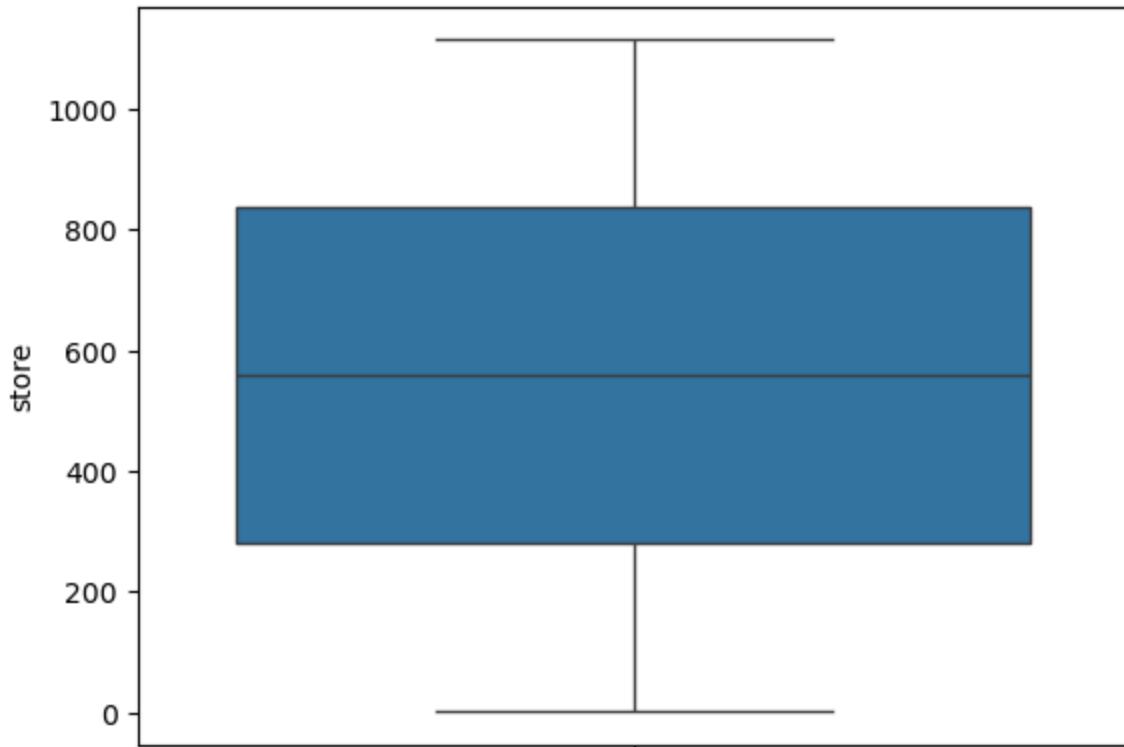


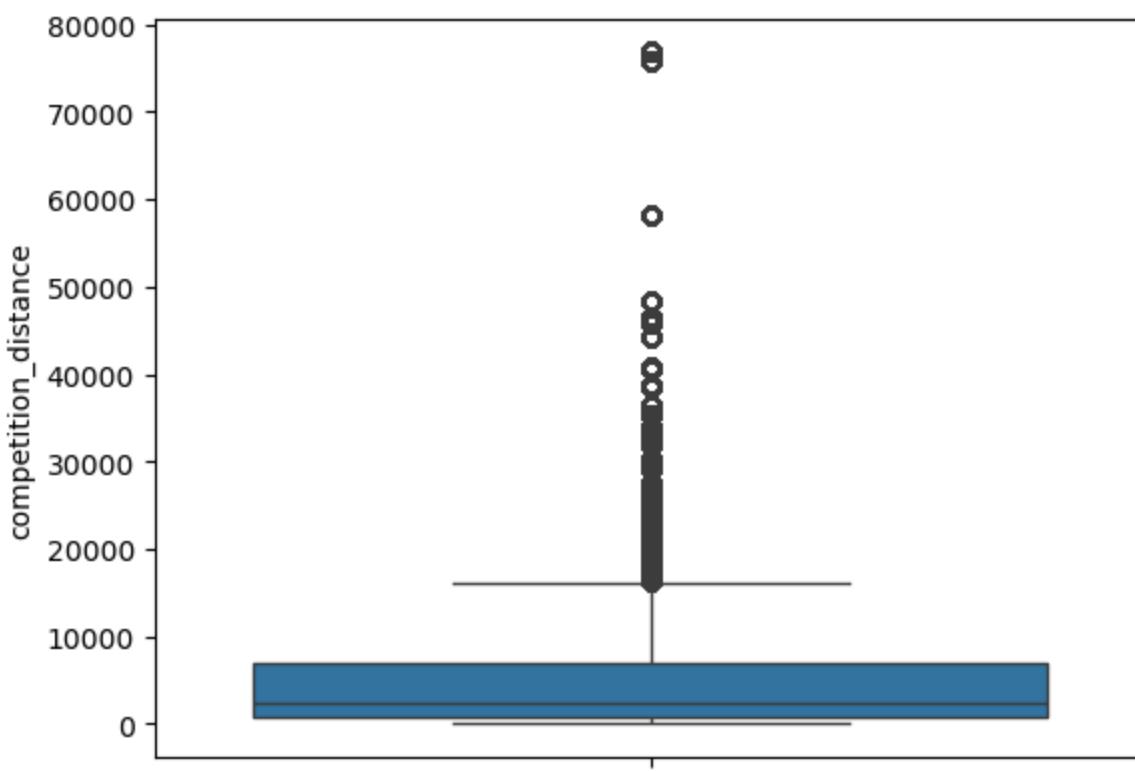
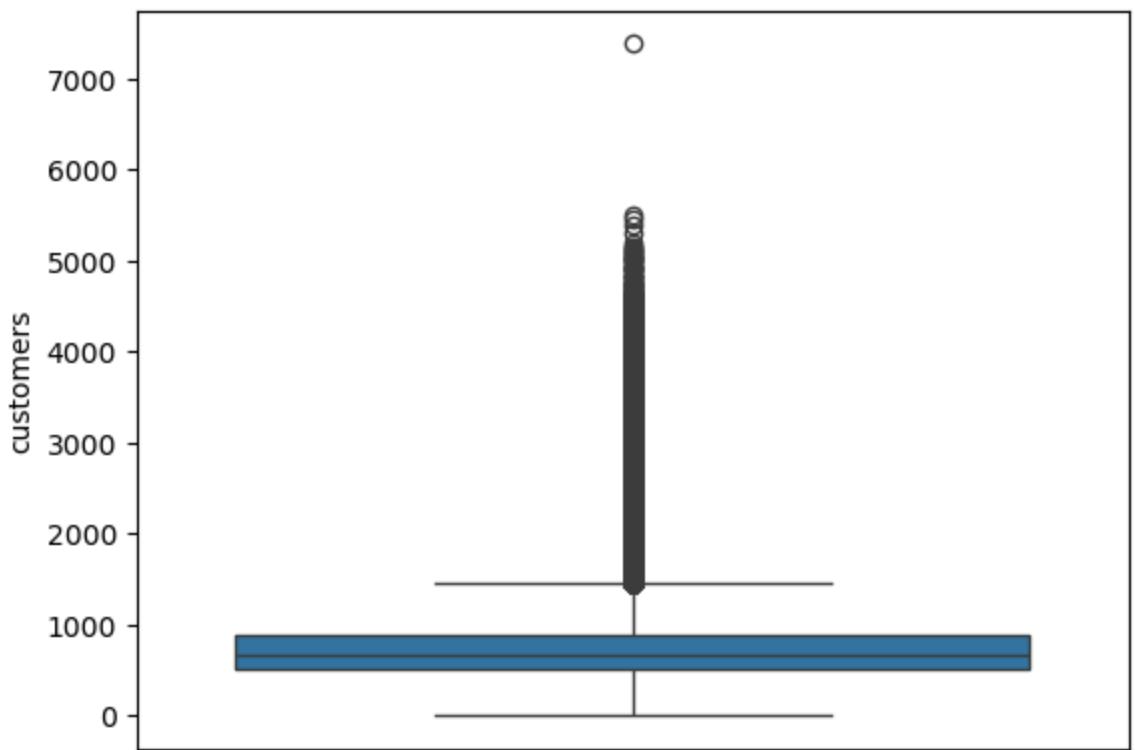


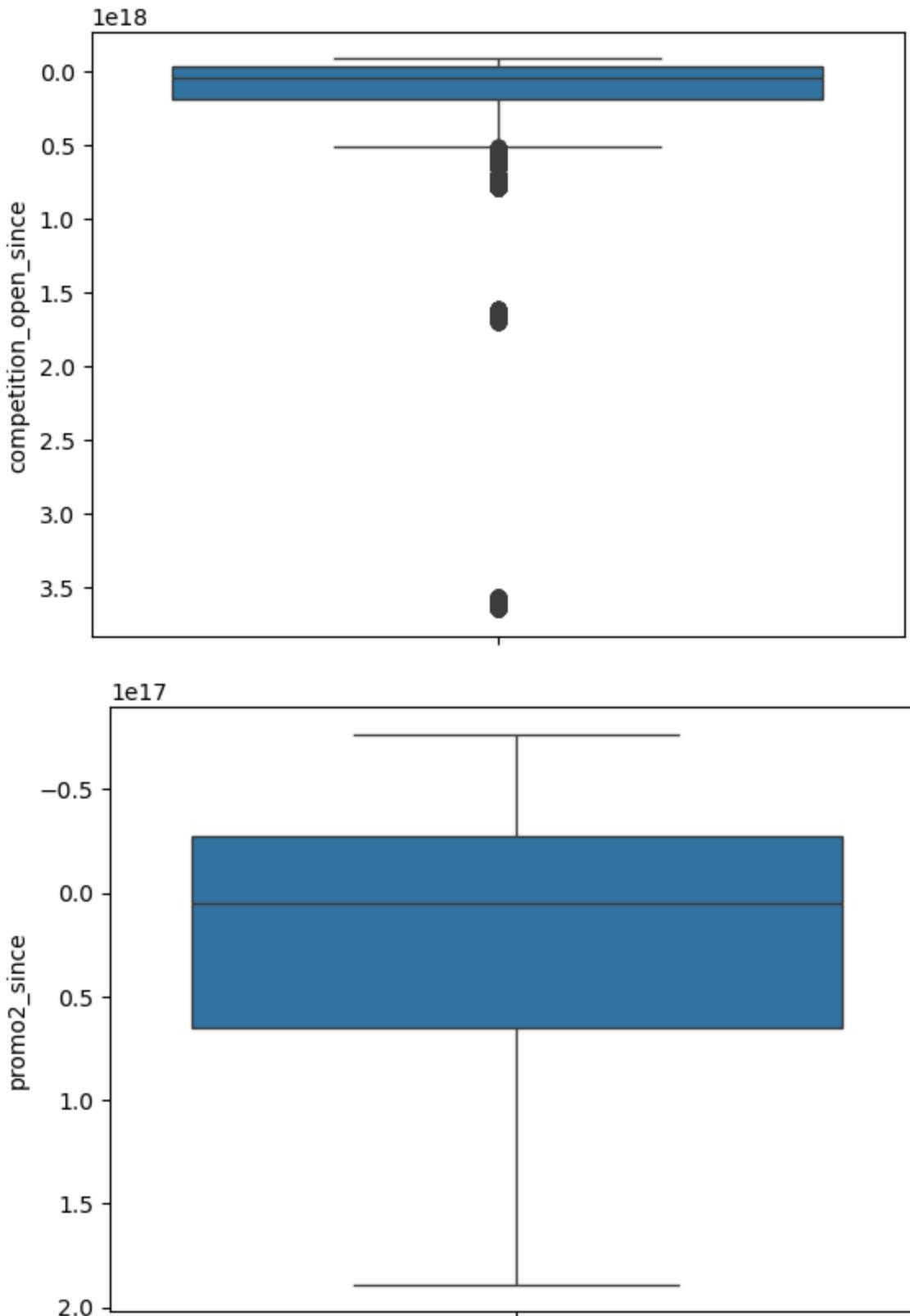


```
In [117]: #Let's look at the box plot of numerical columns
```

```
for col in num_cols:  
    sns.boxplot(store_df, y = col)  
    plt.show()
```

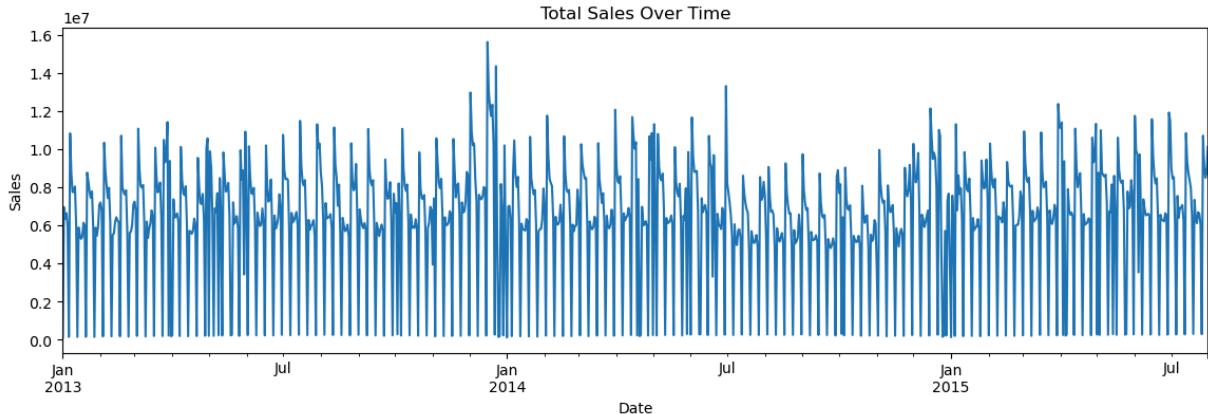






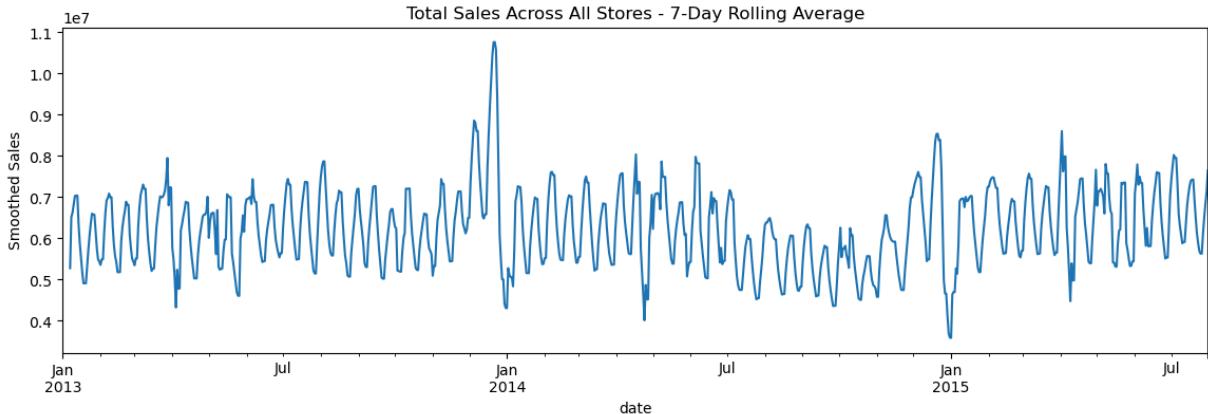
```
In [119]: #Overall Sales trend over time: if sales are generally rising, falling, or stable
store_df.groupby('date')['sales'].sum().plot(figsize=(14, 4))
plt.title("Total Sales Over Time")
plt.ylabel("Sales")
plt.xlabel("Date")
plt.show()
```

#This shows there are spikes during year end indicating holiday season and other factors



```
In [121]: # Sum total sales per calendar date across all stores
daily_sales = store_df.groupby('date')['sales'].sum()
```

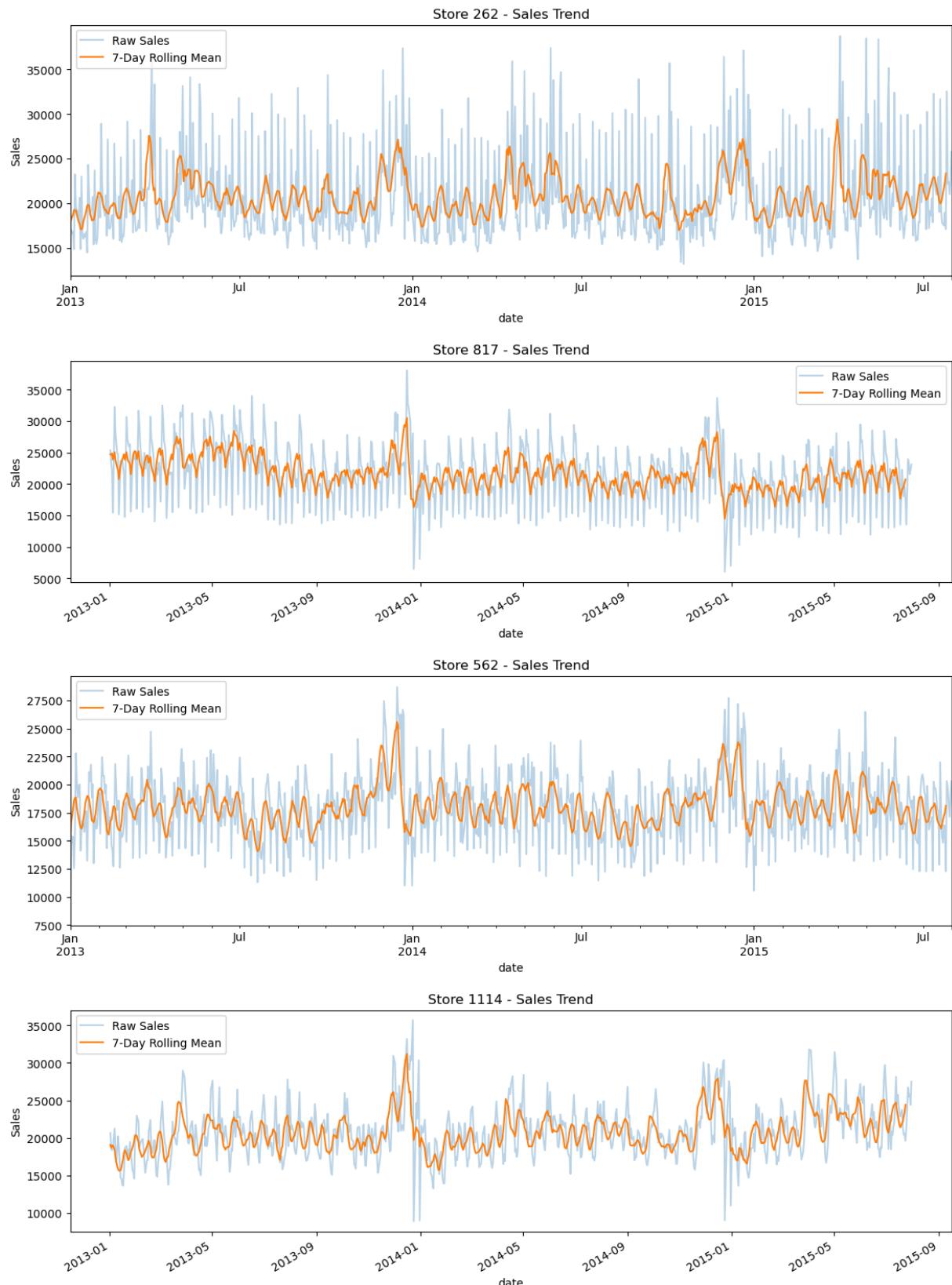
```
#Apply 7-day rolling average
daily_sales.rolling(window = 7).mean().plot(figsize=(14,4))
plt.title("Total Sales Across All Stores - 7-Day Rolling Average")
plt.ylabel("Smoothed Sales")
plt.show()
```

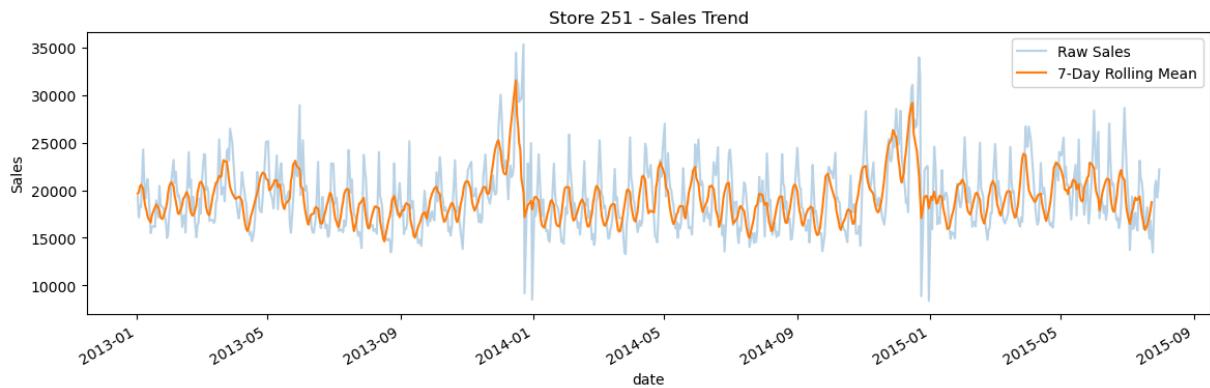


```
In [123]: top_stores = store_df.groupby('store')['sales'].sum().sort_values(ascending=False)

for store_id in top_stores:
    store_subset = store_df[store_df['store'] == store_id].set_index('date')

    plt.figure(figsize=(14, 4))
    store_subset['sales'].plot(alpha=0.3, label='Raw Sales')
    store_subset['sales'].rolling(window=7).mean().plot(label='7-Day Rolling')
    plt.title(f"Store {store_id} - Sales Trend")
    plt.ylabel("Sales")
    plt.legend()
    plt.show()
```





```
In [125...]: # Analyzing store level trends

store_df['tier'] = pd.qcut(
    store_df.groupby('store')['sales'].transform('sum'),
    q = 4,
    labels = ['low', 'medium-low', 'medium-high', 'high']
)

#Create a list of unique stores with their tier
store_tiers = store_df[['store', 'tier']].drop_duplicates()

#Sample 3 stores per tier
sampled_stores = store_tiers.groupby('tier').sample(n = 3, random_state = 5)
sampled_stores
```

```
Out[125...]: [204, 407, 1038, 511, 45, 537, 685, 116, 925, 421, 595, 562]
```

```
In [127...]: # Now use these sampled stores in the FacetGrid plot to see sales trend of i

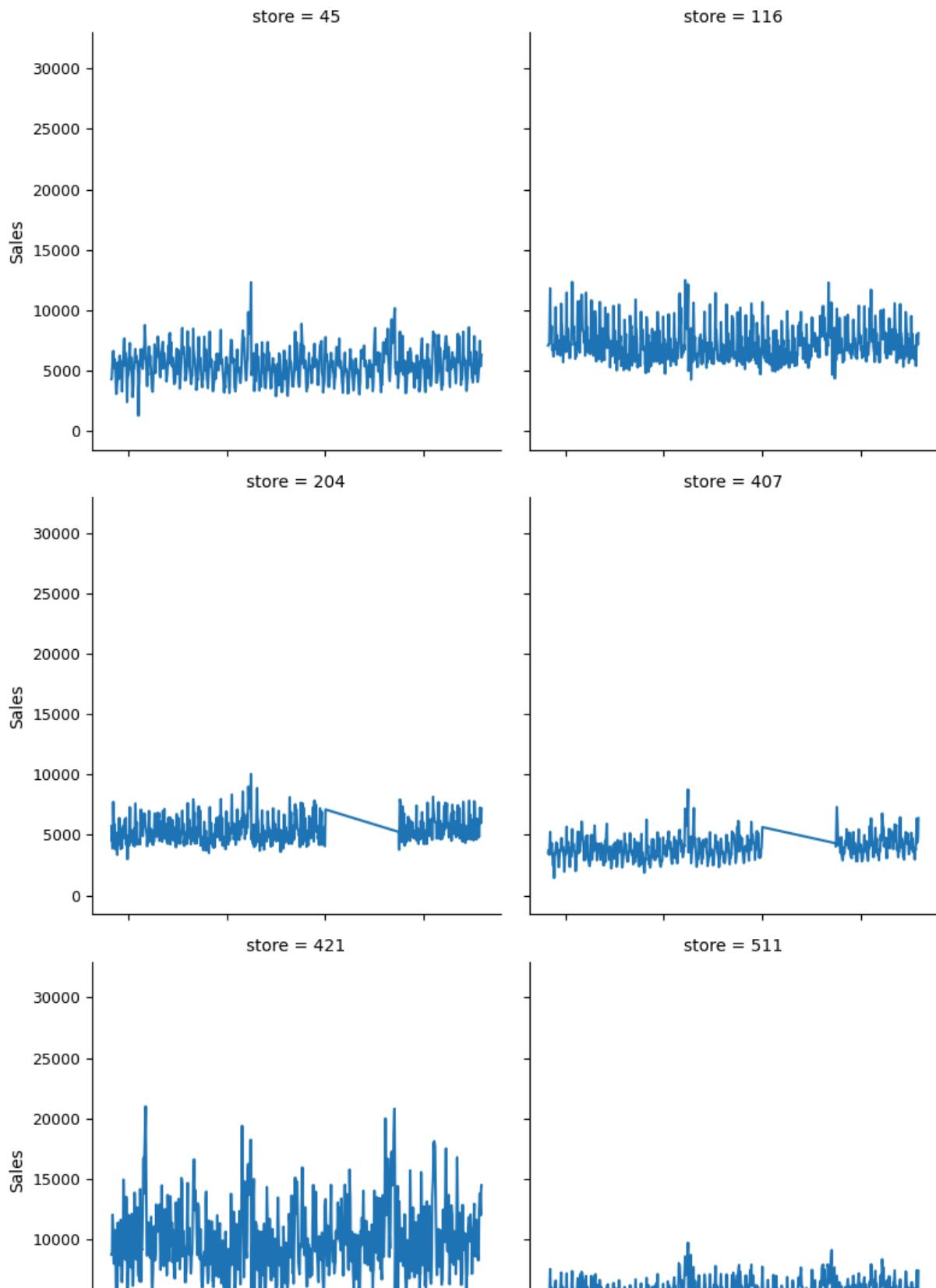
g = sns.FacetGrid(store_df[store_df['store'].isin(sampled_stores)], col = 's
g.map(sns.lineplot, 'date', 'sales')

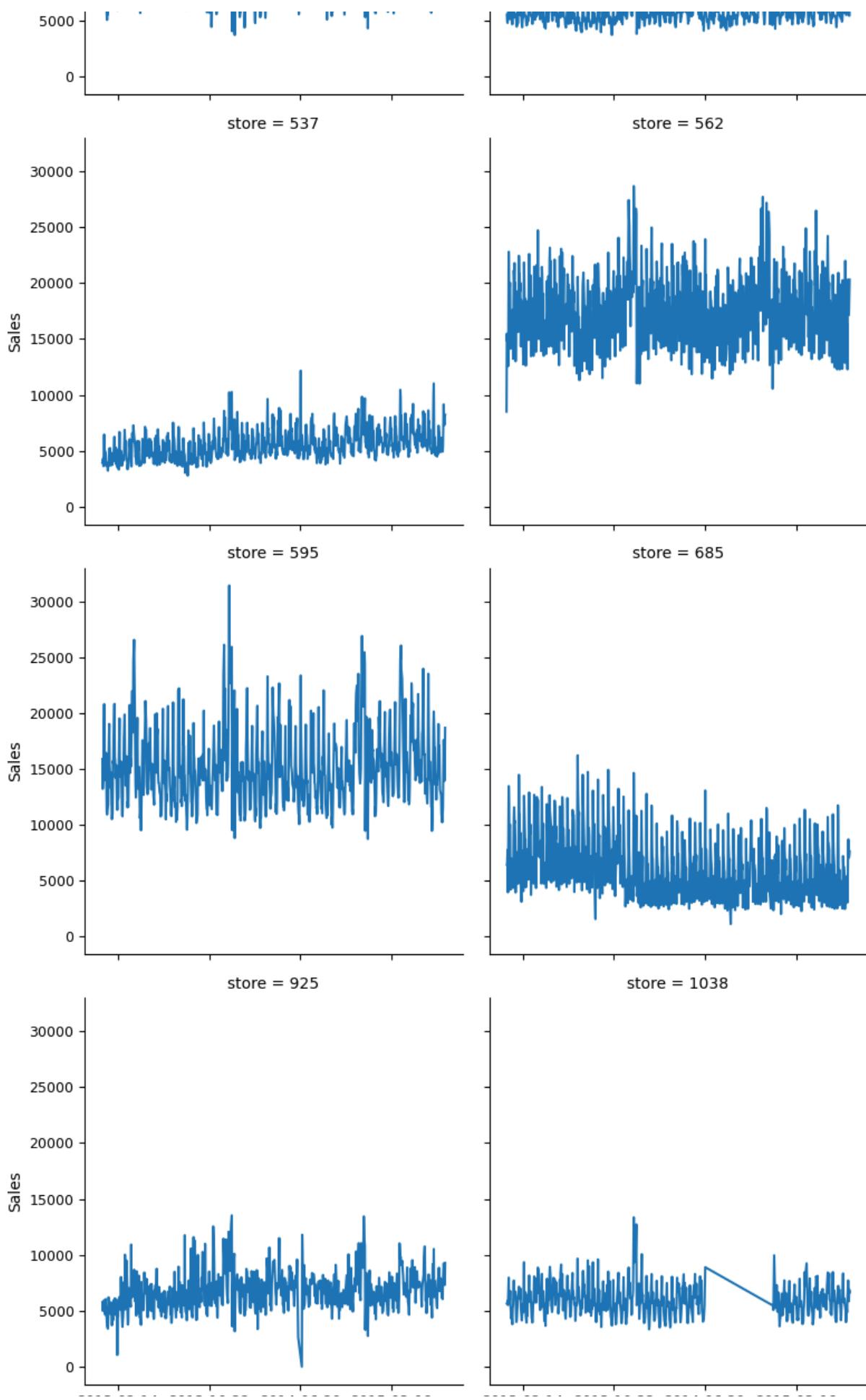
for ax in g.axes.flatten():
    ax.xaxis.set_major_locator(plt.MaxNLocator(5)) # ~ spread-out ticks
    ax.tick_params(axis='y', labelsize=9)
    ax.tick_params(axis='x', labelsize=9)
    ax.set_ylabel("Sales", fontsize=10)
    ax.set_xlabel("Date", fontsize=10)

g.fig.suptitle("Sales Trend per Sampled Store", y = 1.05, fontsize = 14)
plt.tight_layout()
plt.show()

#Sudden drops from the facet grid indicates that for some stores the sales o
#It could be those days when stores were closed for refurbishment as mention
```

Sales Trend per Sampled Store





2013-02-14 2013-10-22 2014-06-29 2015-03-06
Date

2013-02-14 2013-10-22 2014-06-29 2015-03-06
Date

Feature Engineering

```
In [136...]: # Columns to encode
encoding_cols = ['state_holiday', 'store_type', 'assortment', 'promo_interval']

#Copy of the dataframe
df_encoded = store_df.copy()

#Apply Label Encoders
label_encoders = {}

for col in encoding_cols:
    le = LabelEncoder()
    df_encoded[col] = le.fit_transform(df_encoded[col].astype(str))
    label_encoders[col] = le # Save the encoder in case you need to inverse

#Cyclic features: month, day_of_week
# Encode month (1 to 12)
df_encoded['month_sin'] = np.sin(2 * np.pi * df_encoded['month'] / 12)
df_encoded['month_cos'] = np.cos(2 * np.pi * df_encoded['month'] / 12)

# Encode day_of_week (1 to 7 or 0 to 6 depending on your dataset)
df_encoded['dow_sin'] = np.sin(2 * np.pi * df_encoded['day_of_week'] / 7)
df_encoded['dow_cos'] = np.cos(2 * np.pi * df_encoded['day_of_week'] / 7)

df_encoded.drop(['tier'], axis = 1, inplace = True)
```

```
In [138...]: check_set = df_encoded.copy()
check_set.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 844392 entries, 0 to 844391
Data columns (total 26 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   store            844392 non-null   int64  
 1   day_of_week      844392 non-null   int64  
 2   date             844392 non-null   datetime64[ns]
 3   sales            844392 non-null   int64  
 4   customers        844392 non-null   int64  
 5   open              844392 non-null   int64  
 6   promo             844392 non-null   int64  
 7   state_holiday    844392 non-null   int64  
 8   school_holiday   844392 non-null   int64  
 9   store_type        844392 non-null   int64  
 10  assortment       844392 non-null   int64  
 11  competition_distance 844392 non-null   float64 
 12  promo2            844392 non-null   int64  
 13  promo_interval    844392 non-null   int64  
 14  month             844392 non-null   int32  
 15  year              844392 non-null   int32  
 16  competition_open_since_date 844392 non-null   datetime64[ns]
 17  promo2_since_date 844392 non-null   datetime64[ns]
 18  competition_open_since 844392 non-null   timedelta64[ns]
 19  promo2_since     844392 non-null   timedelta64[ns]
 20  is_holiday        844392 non-null   int64  
 21  is_weekend        844392 non-null   int64  
 22  month_sin         844392 non-null   float64 
 23  month_cos         844392 non-null   float64 
 24  dow_sin            844392 non-null   float64 
 25  dow_cos            844392 non-null   float64 
dtypes: datetime64[ns](3), float64(5), int32(2), int64(14), timedelta64[ns](2)
memory usage: 161.1 MB
```

```
In [140]: #Converting timedelta cols to numeric
timedelta_cols = check_set.select_dtypes(include = 'timedelta').columns

for col in timedelta_cols:
    check_set[col] = check_set[col].dt.days
```

```
In [142]: #Has unnecessary features
check_set.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 844392 entries, 0 to 844391
Data columns (total 26 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   store            844392 non-null   int64  
 1   day_of_week      844392 non-null   int64  
 2   date             844392 non-null   datetime64[ns]
 3   sales            844392 non-null   int64  
 4   customers        844392 non-null   int64  
 5   open              844392 non-null   int64  
 6   promo             844392 non-null   int64  
 7   state_holiday    844392 non-null   int64  
 8   school_holiday   844392 non-null   int64  
 9   store_type        844392 non-null   int64  
 10  assortment        844392 non-null   int64  
 11  competition_distance 844392 non-null   float64 
 12  promo2            844392 non-null   int64  
 13  promo_interval    844392 non-null   int64  
 14  month             844392 non-null   int32  
 15  year              844392 non-null   int32  
 16  competition_open_since_date 844392 non-null   datetime64[ns]
 17  promo2_since_date 844392 non-null   datetime64[ns]
 18  competition_open_since 844392 non-null   int64  
 19  promo2_since      844392 non-null   int64  
 20  is_holiday        844392 non-null   int64  
 21  is_weekend        844392 non-null   int64  
 22  month_sin         844392 non-null   float64 
 23  month_cos         844392 non-null   float64 
 24  dow_sin            844392 non-null   float64 
 25  dow_cos            844392 non-null   float64 
dtypes: datetime64[ns](3), float64(5), int32(2), int64(16)
memory usage: 161.1 MB
```

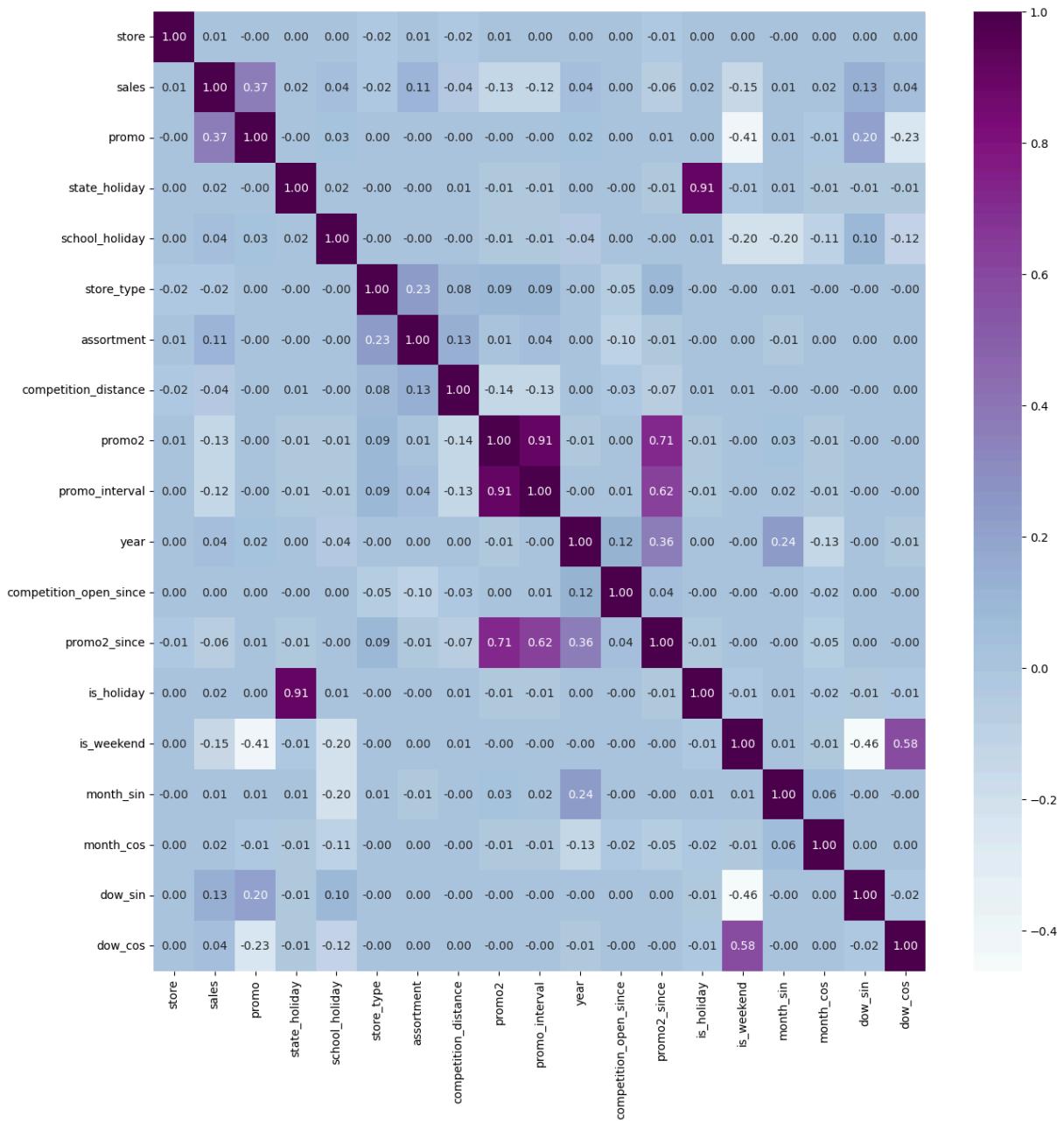
```
In [144]: remove_cols = ['customers', 'open', 'month', 'competition_open_since_date',
check_set_df = check_set.drop(columns = remove_cols)
check_set_df.info()

#Check_set_df contains timedelta64 cols converted to int and it doesn't have
#test set or not needed in test
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 844392 entries, 0 to 844391
Data columns (total 20 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   store            844392 non-null   int64  
 1   date             844392 non-null   datetime64[ns]
 2   sales            844392 non-null   int64  
 3   promo             844392 non-null   int64  
 4   state_holiday    844392 non-null   int64  
 5   school_holiday   844392 non-null   int64  
 6   store_type        844392 non-null   int64  
 7   assortment        844392 non-null   int64  
 8   competition_distance 844392 non-null   float64 
 9   promo2            844392 non-null   int64  
 10  promo_interval   844392 non-null   int64  
 11  year              844392 non-null   int32  
 12  competition_open_since 844392 non-null   int64  
 13  promo2_since     844392 non-null   int64  
 14  is_holiday       844392 non-null   int64  
 15  is_weekend       844392 non-null   int64  
 16  month_sin        844392 non-null   float64 
 17  month_cos        844392 non-null   float64 
 18  dow_sin          844392 non-null   float64 
 19  dow_cos          844392 non-null   float64 
dtypes: datetime64[ns](1), float64(5), int32(1), int64(13)
memory usage: 125.6 MB
```

```
In [146...]: #Heatmap to see correlation of all variables
#Correlation coefficient of 2 variables is independent of the presence of other variables
plt.figure(figsize = (15,15))
sns.heatmap(check_set_df.select_dtypes(include = 'number').corr(), annot = True)
```

```
Out[146...]: <Axes: >
```



Train & Validation Set

```
In [149...]: check_train_val_full = check_set_df[check_set_df['date'] < '2015-08-01'].sort_index()
check_train_val_len = len(check_train_val_full)
check_train_size = int(check_train_val_len * 0.8)

check_train_set = check_train_val_full.iloc[:check_train_size]
check_val_set = check_train_val_full.iloc[check_train_size:]
```

```
In [151...]: check_X_train = check_train_set.drop(columns=['date', 'sales'])
check_y_train = check_train_set['sales']

check_X_val = check_val_set.drop(columns=['date', 'sales'])
check_y_val = check_val_set['sales']
```

Developing the test set

```
In [156... #Make all column headers to lower case and making all names to snake case fr
import re
test.columns = [re.sub(r'(?<!^)(?=[A-Z])', '_', col).lower() for col in test.

print(test.columns)
```

```
Index(['id', 'store', 'day_of_week', 'date', 'open', 'promo', 'state_holiday',
       'school_holiday'],
      dtype='object')
```

```
In [158... #Make all column headers to lower case and making all names to snake case fr
import re
store.columns = [re.sub(r'(?<!^)(?=[A-Z])', '_', col).lower() for col in stor

print(store.columns)
```

```
Index(['store', 'store_type', 'assortment', 'competition_distance',
       'competition_open_since_month', 'competition_open_since_year', 'promo
2',
       'promo2_since_week', 'promo2_since_year', 'promo_interval'],
      dtype='object')
```

```
In [160... test_store_df = pd.merge(test, store, how = 'left', on = 'store')
test_store_df.head()
```

	<u>id</u>	<u>store</u>	<u>day_of_week</u>	<u>date</u>	<u>open</u>	<u>promo</u>	<u>state_holiday</u>	<u>school_holiday</u>	<u>store_</u>
0	1	1		4 2015-09-17	1.0	1	0		0
1	2	3		4 2015-09-17	1.0	1	0		0
2	3	7		4 2015-09-17	1.0	1	0		0
3	4	8		4 2015-09-17	1.0	1	0		0
4	5	9		4 2015-09-17	1.0	1	0		0

```
In [162... #Convert date column to datatype
test_store_df['date'] = pd.to_datetime(test_store_df['date'])

#Columns to add: month, year, is_weekend
test_store_df['month'] = pd.to_datetime(test_store_df['date']).dt.month
test_store_df['year'] = pd.to_datetime(test_store_df['date']).dt.year
test_store_df['is_weekend'] = test_store_df['day_of_week'].apply(lambda x: 1 if x in [6, 7] else 0)
test_store_df['is_holiday'] = test_store_df['state_holiday'].astype(str).apply(lambda x: 1 if x != '0' else 0)

test_store_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 41088 entries, 0 to 41087
Data columns (total 21 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   id               41088 non-null   int64  
 1   store             41088 non-null   int64  
 2   day_of_week       41088 non-null   int64  
 3   date              41088 non-null   datetime64[ns]
 4   open              41077 non-null   float64 
 5   promo              41088 non-null   int64  
 6   state_holiday     41088 non-null   object  
 7   school_holiday    41088 non-null   int64  
 8   store_type         41088 non-null   object  
 9   assortment         41088 non-null   object  
 10  competition_distance 40992 non-null   float64 
 11  competition_open_since_month 25872 non-null   float64 
 12  competition_open_since_year  25872 non-null   float64 
 13  promo2             41088 non-null   int64  
 14  promo2_since_week 23856 non-null   float64 
 15  promo2_since_year 23856 non-null   float64 
 16  promo_interval     23856 non-null   object  
 17  month              41088 non-null   int32  
 18  year               41088 non-null   int32  
 19  is_weekend         41088 non-null   int64  
 20  is_holiday          41088 non-null   int64  
dtypes: datetime64[ns](1), float64(6), int32(2), int64(8), object(4)
memory usage: 6.3+ MB
```

```
In [164...]: #Define a large value to indicate 'no nearby competition'
long_distance = test_store_df['competition_distance'].max() + 1000

#Apply conditional update only to rows with missing competition_distance
test_store_df.loc[test_store_df['competition_distance'].isna(), 'competition_distance'] = long_distance

In [166...]: #Finding the max date in the test_store_df dataframe
current_date = pd.to_datetime(test_store_df['date'].max())

print("current date:", current_date)

current date: 2015-09-17 00:00:00

In [168...]: #Fill na competition_open_since_month and competition_open_since_year
test_store_df['competition_open_since_month'].fillna(current_date.month, inplace=True)
test_store_df['competition_open_since_year'].fillna(current_date.year, inplace=True)

In [170...]: test_store_df['competition_open_since_year'] = test_store_df['competition_open_since_year'].apply(lambda x: x.fillna(current_date.year))
test_store_df['competition_open_since_month'] = test_store_df['competition_open_since_month'].apply(lambda x: x.fillna(current_date.month))

In [172...]: test_store_df['competition_open_since_date'] = pd.to_datetime(test_store_df['date'])
test_store_df['competition_open_since_date'] = test_store_df['competition_open_since_date'].apply(lambda x: x.fillna(current_date))

In [174...]: test_store_df['competition_open_since'] = test_store_df['date'] - test_store_df['competition_open_since_date']
```

```
In [176... #Fill na promo2_since_week and promo2_since_year
    test_store_df['promo2_since_week'].fillna(1, inplace = True)
    test_store_df['promo2_since_year'].fillna(current_date.year, inplace = True)
    test_store_df['promo_interval'].fillna(0, inplace = True)

In [178... test_store_df['promo2_since_week'] = test_store_df['promo2_since_week'].astype('int64')
test_store_df['promo2_since_year'] = test_store_df['promo2_since_year'].astype('int64')

In [180... test_store_df['promo2_since_date'] = pd.to_datetime(test_store_df['promo2_since_date'],
    test_store_df['promo2_since_date'].dt.strftime = '%Y-%W-%w')

In [182... test_store_df['promo2_since'] = test_store_df['date'] - test_store_df['promo2_since_date']

In [184... test_store_df.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 41088 entries, 0 to 41087
Data columns (total 25 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   id               41088 non-null   int64  
 1   store             41088 non-null   int64  
 2   day_of_week       41088 non-null   int64  
 3   date              41088 non-null   datetime64[ns]
 4   open              41077 non-null   float64
 5   promo              41088 non-null   int64  
 6   state_holiday     41088 non-null   object 
 7   school_holiday    41088 non-null   int64  
 8   store_type         41088 non-null   object 
 9   assortment         41088 non-null   object 
 10  competition_distance 41088 non-null   float64
 11  competition_open_since_month 41088 non-null   int64  
 12  competition_open_since_year   41088 non-null   int64  
 13  promo2             41088 non-null   int64  
 14  promo2_since_week    41088 non-null   int64  
 15  promo2_since_year    41088 non-null   int64  
 16  promo_interval      41088 non-null   object 
 17  month              41088 non-null   int32  
 18  year               41088 non-null   int32  
 19  is_weekend          41088 non-null   int64  
 20  is_holiday          41088 non-null   int64  
 21  competition_open_since_date 41088 non-null   datetime64[ns]
 22  competition_open_since   41088 non-null   timedelta64[ns]
 23  promo2_since_date     41088 non-null   datetime64[ns]
 24  promo2_since          41088 non-null   timedelta64[ns]
dtypes: datetime64[ns](3), float64(2), int32(2), int64(12), object(4), timedelta64[ns](2)
memory usage: 7.5+ MB

In [190... test_store_df.drop(['competition_open_since_date', 'promo2_since_date', 'competition_open_since',
    'promo2_since_week', 'promo2_since_year', 'open'], axis=1)
```

```
In [186...]: #Converting timedelta cols to numeric
timedelta_cols = test_store_df.select_dtypes(include = 'timedelta').columns

for col in timedelta_cols:
    test_store_df[col] = test_store_df[col].dt.days
```

```
In [192...]: #Encoding categorical features and adding modifying 'month' and 'dow' column

# Columns to encode
test_encoding_cols = ['state_holiday', 'store_type', 'assortment', 'promo_inten

#Copy of the dataframe
test_store_df_encoded = test_store_df.copy()

#Apply Label Encoders
label_encoders = {}

for col in test_encoding_cols:
    le = LabelEncoder()
    test_store_df_encoded[col] = le.fit_transform(test_store_df_encoded[col])
    label_encoders[col] = le # Save the encoder in case you need to inverse

#Cyclic features: month, day_of_week
# Encode month (1 to 12)
test_store_df_encoded['month_sin'] = np.sin(2 * np.pi * test_store_df_encoded['month'])
test_store_df_encoded['month_cos'] = np.cos(2 * np.pi * test_store_df_encoded['month'])

# Encode day_of_week (1 to 7 or 0 to 6 depending on your dataset)
test_store_df_encoded['dow_sin'] = np.sin(2 * np.pi * test_store_df_encoded['dow'])
test_store_df_encoded['dow_cos'] = np.cos(2 * np.pi * test_store_df_encoded['dow'])
```

```
In [194...]: test_store_df_encoded.drop(['day_of_week', 'month'], axis = 1, inplace = True)
```

```
In [198...]: start_date = pd.to_datetime('2015-08-01')
end_date = pd.to_datetime('2015-09-17')

test_set = test_store_df_encoded[
    (test_store_df_encoded['date'] >= start_date) &
    (test_store_df_encoded['date'] <= end_date)
].sort_values('date')

# Step 4: Confirm date boundaries
print("Min date:", test_set['date'].min())
print("Max date:", test_set['date'].max())
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 41088 entries, 41087 to 0
Data columns (total 20 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   id               41088 non-null    int64  
 1   store             41088 non-null    int64  
 2   date              41088 non-null    datetime64[ns]
 3   promo              41088 non-null    int64  
 4   state_holiday     41088 non-null    int64  
 5   school_holiday    41088 non-null    int64  
 6   store_type         41088 non-null    int64  
 7   assortment         41088 non-null    int64  
 8   competition_distance 41088 non-null    float64
 9   promo2             41088 non-null    int64  
 10  promo_interval    41088 non-null    int64  
 11  year              41088 non-null    int32  
 12  is_weekend        41088 non-null    int64  
 13  is_holiday         41088 non-null    int64  
 14  competition_open_since 41088 non-null    int64  
 15  promo2_since       41088 non-null    int64  
 16  month_sin          41088 non-null    float64
 17  month_cos          41088 non-null    float64
 18  dow_sin            41088 non-null    float64
 19  dow_cos            41088 non-null    float64
dtypes: datetime64[ns](1), float64(5), int32(1), int64(13)
memory usage: 6.4 MB
Min date: 2015-08-01 00:00:00
Max date: 2015-09-17 00:00:00
```

```
In [200]: test_set.drop(columns= ['id', 'date'], axis = 1, inplace = True )
```

```
In [202]: train_columns = check_X_train.columns.tolist()

# Step 2: Reorder test set columns to match
test_set = test_set[train_columns]
test_set.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 41088 entries, 41087 to 0
Data columns (total 18 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   store            41088 non-null   int64  
 1   promo             41088 non-null   int64  
 2   state_holiday    41088 non-null   int64  
 3   school_holiday   41088 non-null   int64  
 4   store_type        41088 non-null   int64  
 5   assortment        41088 non-null   int64  
 6   competition_distance 41088 non-null   float64 
 7   promo2            41088 non-null   int64  
 8   promo_interval    41088 non-null   int64  
 9   year              41088 non-null   int32  
 10  competition_open_since 41088 non-null   int64  
 11  promo2_since     41088 non-null   int64  
 12  is_holiday       41088 non-null   int64  
 13  is_weekend       41088 non-null   int64  
 14  month_sin        41088 non-null   float64 
 15  month_cos        41088 non-null   float64 
 16  dow_sin           41088 non-null   float64 
 17  dow_cos           41088 non-null   float64 
dtypes: float64(5), int32(1), int64(12)
memory usage: 5.8 MB
```

```
In [204...]: print("Train:", check_train_set['date'].min(), "→", check_train_set['date'].max())
print("Val: ", check_val_set['date'].min(), "→", check_val_set['date'].max())
print("Test: ", test['date'].min(), "→", test['date'].max())
```

Train: 2013-01-01 00:00:00 → 2015-01-30 00:00:00
 Val: 2015-01-30 00:00:00 → 2015-07-31 00:00:00
 Test: 2015-08-01 → 2015-09-17

Model Training and Selection

```
In [295...]: def rmspe(y_true, y_pred):
    y_true = np.array(y_true)
    y_pred = np.array(y_pred)

    # Avoid division by zero by filtering out zeros
    non_zero_idx = y_true != 0
    y_true = y_true[non_zero_idx]
    y_pred = y_pred[non_zero_idx]

    return np.sqrt(np.mean(((y_true - y_pred) / (y_true)) ** 2))
```

```
In [290...]: #Hyperparameter tuning the model using RandomizedSearchCV and TimeSeriesSplit

param_dist = { 'n_estimators': [100, 200, 300],
               'max_depth': [5, 10, 20, None],
               'min_samples_split': [2, 5, 10],
               'min_samples_leaf': [1, 2, 4],
               'max_features': [None, 'sqrt', 'log2', 0.3, 0.5]}
```

```
}

tscv = TimeSeriesSplit(n_splits = 3)

rf = RandomForestRegressor(random_state = 42)

#RandomizedSearchCV for hyperparameter tuning

random_search_7 = RandomizedSearchCV(rf, param_distributions = param_dist, r
                                      verbose = 2, n_jobs = -1)

#Fit the model
random_search_7.fit(check_X_train, check_y_train)

print("Best parameters: ", random_search_7.best_params_)
print("Best RMSE: ", (-random_search_7.best_score_) ** 0.5)
```

Fitting 3 folds for each of 20 candidates, totalling 60 fits

[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time= 1.9min

[CV] END max_depth=None, max_features=None, min_samples_leaf=4, min_samples_split=10, n_estimators=200; total time= 4.6min

[CV] END max_depth=20, max_features=0.5, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time= 8.3min

[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=2, min_samples_split=2, n_estimators=300; total time= 5.3min

[CV] END max_depth=20, max_features=None, min_samples_leaf=4, min_samples_split=2, n_estimators=200; total time=11.7min

[CV] END max_depth=10, max_features=log2, min_samples_leaf=1, min_samples_split=5, n_estimators=100; total time= 19.4s

[CV] END max_depth=10, max_features=sqrt, min_samples_leaf=2, min_samples_split=10, n_estimators=300; total time= 1.1min

[CV] END max_depth=5, max_features=0.5, min_samples_leaf=4, min_samples_split=2, n_estimators=100; total time= 22.2s

[CV] END max_depth=5, max_features=0.5, min_samples_leaf=4, min_samples_split=2, n_estimators=100; total time= 1.1min

[CV] END max_depth=5, max_features=sqrt, min_samples_leaf=4, min_samples_split=10, n_estimators=200; total time= 1.2min

[CV] END max_depth=None, max_features=None, min_samples_leaf=4, min_samples_split=10, n_estimators=200; total time=17.9min

[CV] END max_depth=5, max_features=log2, min_samples_leaf=4, min_samples_split=5, n_estimators=100; total time= 11.9s

[CV] END max_depth=5, max_features=log2, min_samples_leaf=4, min_samples_split=5, n_estimators=100; total time= 23.5s

[CV] END max_depth=5, max_features=log2, min_samples_leaf=4, min_samples_split=5, n_estimators=100; total time= 39.6s

[CV] END max_depth=10, max_features=log2, min_samples_leaf=2, min_samples_split=2, n_estimators=100; total time= 1.0min

[CV] END max_depth=None, max_features=0.3, min_samples_leaf=2, min_samples_split=5, n_estimators=300; total time= 9.3min

[CV] END max_depth=10, max_features=log2, min_samples_leaf=1, min_samples_split=5, n_estimators=100; total time= 1.2min

[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time= 6.3min

[CV] END max_depth=20, max_features=0.5, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time= 4.0min

[CV] END max_depth=None, max_features=0.5, min_samples_leaf=1, min_samples_split=5, n_estimators=200; total time= 3.2min

[CV] END max_depth=10, max_features=0.5, min_samples_leaf=1, min_samples_split=5, n_estimators=200; total time= 4.5min

[CV] END max_depth=10, max_features=None, min_samples_leaf=1, min_samples_split=2, n_estimators=100; total time= 4.8min

[CV] END max_depth=10, max_features=log2, min_samples_leaf=2, min_samples_split=2, n_estimators=100; total time= 7.8min

[CV] END max_depth=5, max_features=sqrt, min_samples_leaf=2, min_samples_split=10, n_estimators=200; total time= 25.1s

[CV] END max_depth=5, max_features=sqrt, min_samples_leaf=2, min_samples_split=10, n_estimators=200; total time= 49.0s

[CV] END max_depth=10, max_features=log2, min_samples_leaf=1, min_samples_split=5, n_estimators=100; total time= 43.9s

[CV] END max_depth=10, max_features=sqrt, min_samples_leaf=2, min_samples_split=10, n_estimators=300; total time= 1.9min

[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_split=10, n_estimators=200; total time= 4.5min

```
lit=10, n_estimators=300; total time= 4.1min
[CV] END max_depth=20, max_features=0.3, min_samples_leaf=4, min_samples_split=2, n_estimators=200; total time= 3.4min
[CV] END max_depth=20, max_features=0.5, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time=12.6min
[CV] END max_depth=5, max_features=0.3, min_samples_leaf=4, min_samples_split=2, n_estimators=300; total time= 2.8min
[CV] END max_depth=10, max_features=log2, min_samples_leaf=2, min_samples_split=2, n_estimators=100; total time= 7.4min
[CV] END max_depth=None, max_features=0.3, min_samples_leaf=2, min_samples_split=5, n_estimators=300; total time= 5.2min
[CV] END max_depth=5, max_features=0.5, min_samples_leaf=4, min_samples_split=2, n_estimators=100; total time= 45.3s
[CV] END max_depth=5, max_features=sqrt, min_samples_leaf=4, min_samples_split=10, n_estimators=200; total time= 24.6s
[CV] END max_depth=5, max_features=sqrt, min_samples_leaf=4, min_samples_split=10, n_estimators=200; total time= 47.3s
[CV] END max_depth=None, max_features=None, min_samples_leaf=4, min_samples_split=10, n_estimators=200; total time=11.2min
[CV] END max_depth=10, max_features=0.5, min_samples_leaf=1, min_samples_split=5, n_estimators=200; total time= 3.0min
[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=2, min_samples_split=2, n_estimators=300; total time=15.5min
[CV] END max_depth=5, max_features=sqrt, min_samples_leaf=2, min_samples_split=10, n_estimators=200; total time= 1.2min
[CV] END max_depth=10, max_features=sqrt, min_samples_leaf=2, min_samples_split=10, n_estimators=300; total time= 2.7min
[CV] END max_depth=None, max_features=0.3, min_samples_leaf=1, min_samples_split=2, n_estimators=300; total time= 8.0min
[CV] END max_depth=20, max_features=0.3, min_samples_leaf=2, min_samples_split=2, n_estimators=100; total time= 47.8s
[CV] END max_depth=20, max_features=0.3, min_samples_leaf=2, min_samples_split=2, n_estimators=100; total time= 1.8min
[CV] END max_depth=None, max_features=0.5, min_samples_leaf=1, min_samples_split=5, n_estimators=200; total time= 6.9min
[CV] END max_depth=10, max_features=None, min_samples_leaf=1, min_samples_split=2, n_estimators=100; total time= 2.7min
[CV] END max_depth=20, max_features=None, min_samples_leaf=4, min_samples_split=2, n_estimators=200; total time=15.8min
[CV] END max_depth=None, max_features=0.3, min_samples_leaf=1, min_samples_split=2, n_estimators=300; total time=12.6min
[CV] END max_depth=None, max_features=0.5, min_samples_leaf=1, min_samples_split=5, n_estimators=200; total time=17.7min
[CV] END max_depth=None, max_features=0.3, min_samples_leaf=2, min_samples_split=5, n_estimators=300; total time= 6.7min
[CV] END max_depth=None, max_features=0.3, min_samples_leaf=1, min_samples_split=2, n_estimators=300; total time= 3.5min
[CV] END max_depth=20, max_features=0.3, min_samples_leaf=4, min_samples_split=2, n_estimators=200; total time= 1.4min
[CV] END max_depth=20, max_features=0.3, min_samples_leaf=4, min_samples_split=2, n_estimators=200; total time= 5.3min
[CV] END max_depth=20, max_features=0.3, min_samples_leaf=2, min_samples_split=2, n_estimators=100; total time= 2.7min
[CV] END max_depth=10, max_features=0.5, min_samples_leaf=1, min_samples_split=5, n_estimators=200; total time= 1.5min
[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=2, min_samples_
```

```
split=2, n_estimators=300; total time= 2.5min
[CV] END max_depth=10, max_features=None, min_samples_leaf=1, min_samples_split=2, n_estimators=100; total time= 1.3min
[CV] END max_depth=5, max_features=0.3, min_samples_leaf=4, min_samples_split=2, n_estimators=300; total time= 40.7s
[CV] END max_depth=5, max_features=0.3, min_samples_leaf=4, min_samples_split=2, n_estimators=300; total time= 1.4min
[CV] END max_depth=20, max_features=None, min_samples_leaf=4, min_samples_split=2, n_estimators=200; total time=18.4min
Best parameters: {'n_estimators': 200, 'min_samples_split': 5, 'min_samples_leaf': 1, 'max_features': 0.5, 'max_depth': None}
Best RMSE: 1761.0746797243892
```

In [297...]

```
best_model_rf_7 = random_search_7.best_estimator_

#Prediction of Validation Set:
check_y_val_pred = best_model_rf_7.predict(check_X_val)

#Calculate performance metrics
mae = mean_absolute_error(check_y_val, check_y_val_pred)
rmse = mean_squared_error(check_y_val, check_y_val_pred, squared = False)
r2 = r2_score(check_y_val, check_y_val_pred)
rmspe_score = rmspe(check_y_val, check_y_val_pred)

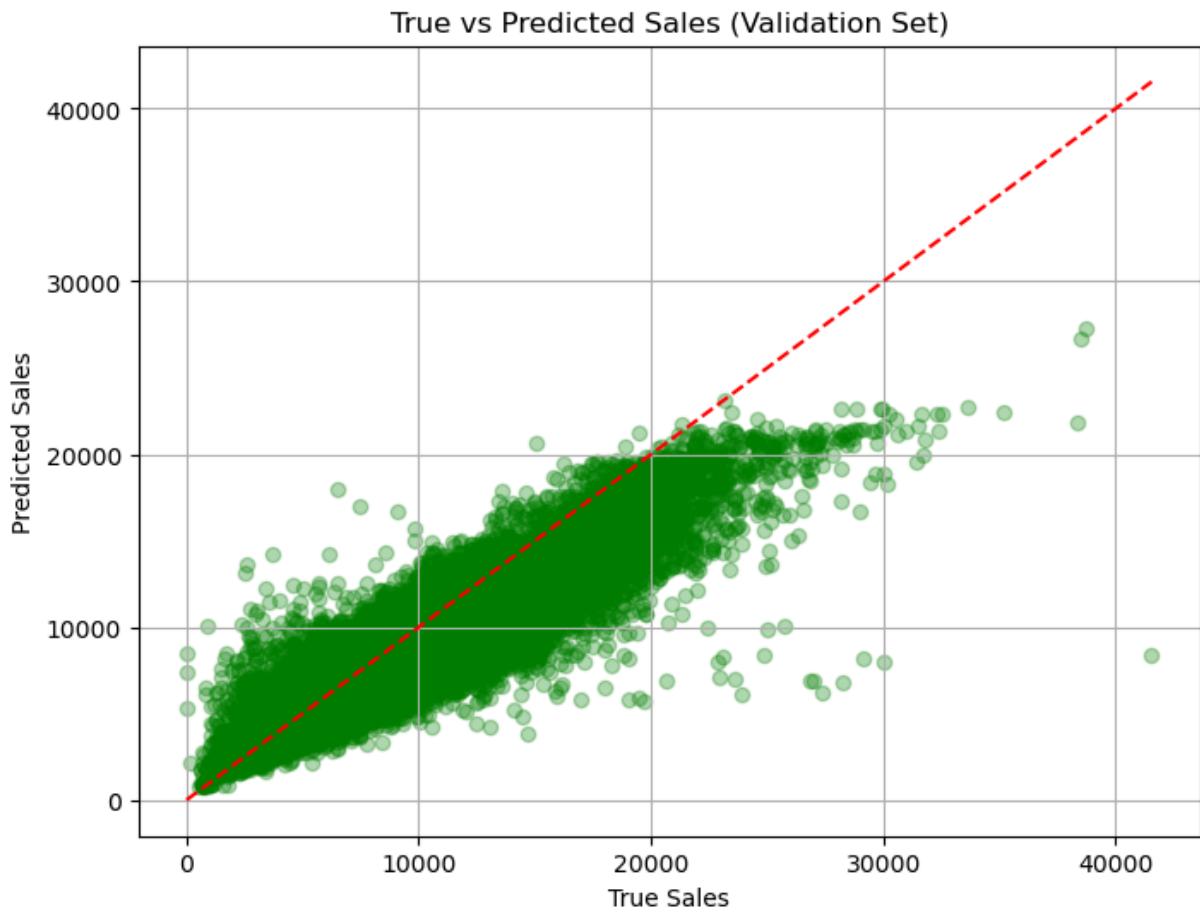
print(f"MAE: {mae:.2f}")
print(f"RMSE: {rmse:.2f}")
print(f"R2 Score: {r2: .4f}")
print(f"RMSPE: {rmspe_score: .4f}")
```

MAE: 863.01
RMSE: 1277.93
R2 Score: 0.8260
RMSPE: 0.1783

In [299...]

```
#Scatter Plot: True vs Predicted

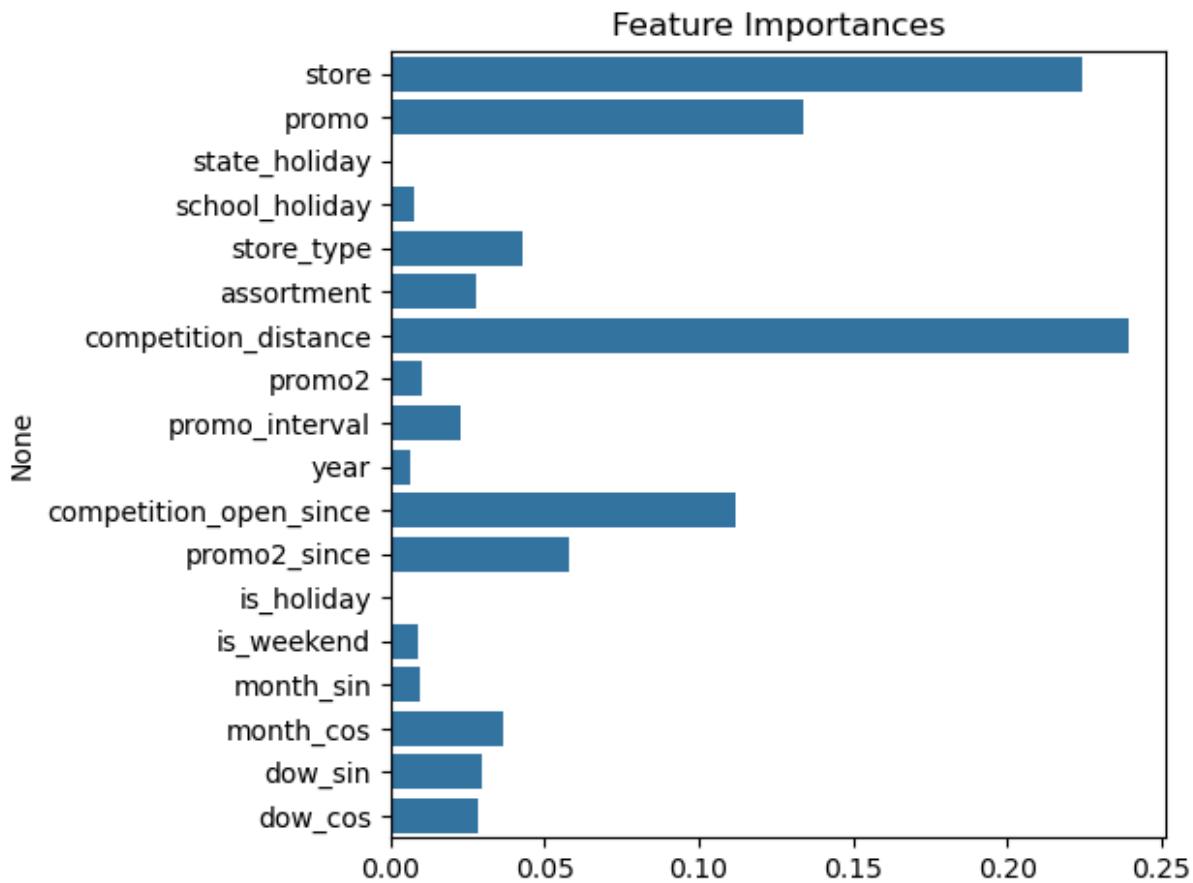
plt.figure(figsize=(8,6))
plt.scatter(check_y_val, check_y_val_pred, alpha=0.3, color='green')
plt.xlabel("True Sales")
plt.ylabel("Predicted Sales")
plt.title("True vs Predicted Sales (Validation Set)")
plt.plot([check_y_val.min(), check_y_val.max()], [check_y_val.min(), check_y_val.max()])
plt.grid()
plt.show()
```



In [301]: #Feature importance Check of best_model_rf_7

```
importances = best_model_rf_7.feature_importances_
features = check_X_train.columns

sns.barplot(x = importances, y = features)
plt.title("Feature Importances")
plt.tight_layout()
plt.show()
```



The r² of best_model_rf_7 is 0.78 which is low so let's eliminate features that are no important

```
In [304]: #Removing features which are least important in the above graph: ('state_holiday', 'school_holiday', 'year', 'is_holiday', 'is_weekend', 'month_sin', 'dow_sin', 'dow_cos')

feature_importance_series = pd.Series(best_model_rf_7.feature_importances_, #feature_importance_series

# Sort importances in descending order
sorted_importances = feature_importance_series.sort_values(ascending=False) #sorted_importances

# Set threshold (e.g., 1% importance)
threshold = 0.01

# Select features above the threshold
selected_features_rf = feature_importance_series[feature_importance_series > threshold]
selected_features_rf
```

```
Out[304... ['store',
 'promo',
 'store_type',
 'assortment',
 'competition_distance',
 'promo2',
 'promo_interval',
 'competition_open_since',
 'promo2_since',
 'month_cos',
 'dow_sin',
 'dow_cos']
```

```
In [271... #Hyperparameter tuning the model using RandomizedSearchCV and TimeSeriesSplit
#with (check_X_train, check_X_val)

param_dist = { 'n_estimators': [100, 200, 300],
               'max_depth': [5, 10, 20, None],
               'min_samples_split': [2, 5, 10],
               'min_samples_leaf': [1, 2, 4],
               'max_features': [None,'sqrt', 'log2', 0.3, 0.5] #Use of auto here
             }

selected_features_rf = ['store','promo','store_type','assortment','competition_distance',
                        'promo2_since','month_cos','dow_sin','dow_cos']

tscv = TimeSeriesSplit(n_splits = 3)

rf = RandomForestRegressor(random_state = 42)

#RandomizedSearchCV for hyperparameter tuning

random_search_8 = RandomizedSearchCV(rf, param_distributions = param_dist, n_iter = 10,
                                      verbose = 2, n_jobs = -1)

random_search_8.fit(check_X_train[selected_features_rf], check_y_train)

print("Best parameters: ", random_search_8.best_params_)
print("Best RMSE: ", (-random_search_8.best_score_) ** 0.5)
```

Fitting 3 folds for each of 20 candidates, totalling 60 fits

[CV] END max_depth=None, max_features=log2, min_samples_leaf=1, min_samples_split=2, n_estimators=200; total time= 4.5min

[CV] END max_depth=10, max_features=None, min_samples_leaf=4, min_samples_split=5, n_estimators=300; total time=56.2min

[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_split=2, n_estimators=200; total time= 1.5min

[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_split=2, n_estimators=200; total time= 4.2min

[CV] END max_depth=5, max_features=None, min_samples_leaf=4, min_samples_split=2, n_estimators=100; total time= 32.0s

[CV] END max_depth=5, max_features=None, min_samples_leaf=4, min_samples_split=2, n_estimators=100; total time= 1.9min

[CV] END max_depth=5, max_features=log2, min_samples_leaf=1, min_samples_split=2, n_estimators=100; total time= 12.3s

[CV] END max_depth=5, max_features=log2, min_samples_leaf=1, min_samples_split=2, n_estimators=100; total time= 23.0s

[CV] END max_depth=5, max_features=0.5, min_samples_leaf=4, min_samples_split=5, n_estimators=300; total time= 59.4s

[CV] END max_depth=10, max_features=None, min_samples_leaf=4, min_samples_split=5, n_estimators=300; total time=49.2min

[CV] END max_depth=5, max_features=log2, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time= 33.3s

[CV] END max_depth=5, max_features=log2, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time= 1.1min

[CV] END max_depth=10, max_features=log2, min_samples_leaf=4, min_samples_split=10, n_estimators=300; total time= 1.0min

[CV] END max_depth=None, max_features=None, min_samples_leaf=1, min_samples_split=10, n_estimators=100; total time= 4.3min

[CV] END max_depth=20, max_features=0.5, min_samples_leaf=2, min_samples_split=10, n_estimators=300; total time= 6.3min

[CV] END max_depth=None, max_features=log2, min_samples_leaf=1, min_samples_split=2, n_estimators=200; total time= 2.2min

[CV] END max_depth=5, max_features=0.5, min_samples_leaf=2, min_samples_split=10, n_estimators=300; total time= 2.0min

[CV] END max_depth=10, max_features=None, min_samples_leaf=4, min_samples_split=5, n_estimators=300; total time=52.7min

[CV] END max_depth=None, max_features=None, min_samples_leaf=1, min_samples_split=10, n_estimators=100; total time= 7.1min

[CV] END max_depth=10, max_features=0.5, min_samples_leaf=2, min_samples_split=5, n_estimators=300; total time= 3.4min

[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=1, min_samples_split=5, n_estimators=200; total time= 1.6min

[CV] END max_depth=5, max_features=0.3, min_samples_leaf=1, min_samples_split=2, n_estimators=100; total time= 38.8s

[CV] END max_depth=5, max_features=0.5, min_samples_leaf=2, min_samples_split=10, n_estimators=300; total time= 3.0min

[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=2, min_samples_split=10, n_estimators=300; total time=47.8min

[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_split=10, n_estimators=200; total time= 2.4min

[CV] END max_depth=10, max_features=log2, min_samples_leaf=4, min_samples_split=10, n_estimators=300; total time= 3.2min

[CV] END max_depth=20, max_features=0.5, min_samples_leaf=1, min_samples_split=10, n_estimators=300; total time= 9.2min

[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=1, min_samples_

```

split=5, n_estimators=200; total time= 5.4min
[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=2, min_samples_
split=10, n_estimators=300; total time=50.0min
[CV] END max_depth=10, max_features=log2, min_samples_leaf=4, min_samples_sp
lit=10, n_estimators=300; total time= 2.1min
[CV] END max_depth=20, max_features=log2, min_samples_leaf=4, min_samples_sp
lit=5, n_estimators=200; total time= 2.4min
[CV] END max_depth=20, max_features=0.5, min_samples_leaf=2, min_samples_sp
lit=10, n_estimators=300; total time= 3.0min
[CV] END max_depth=10, max_features=0.5, min_samples_leaf=2, min_samples_sp
lit=5, n_estimators=300; total time= 1.8min
[CV] END max_depth=None, max_features=None, min_samples_leaf=4, min_samples_
split=5, n_estimators=100; total time= 3.7min
[CV] END max_depth=5, max_features=None, min_samples_leaf=4, min_samples_sp
lit=2, n_estimators=100; total time= 1.2min
[CV] END max_depth=5, max_features=0.3, min_samples_leaf=1, min_samples_sp
lit=2, n_estimators=100; total time= 12.2s
[CV] END max_depth=5, max_features=0.3, min_samples_leaf=1, min_samples_sp
lit=2, n_estimators=100; total time= 24.3s
[CV] END max_depth=5, max_features=0.5, min_samples_leaf=2, min_samples_sp
lit=10, n_estimators=300; total time= 1.0min
[CV] END max_depth=5, max_features=log2, min_samples_leaf=1, min_samples_sp
lit=2, n_estimators=100; total time= 36.2s
[CV] END max_depth=5, max_features=0.5, min_samples_leaf=4, min_samples_sp
lit=5, n_estimators=300; total time= 2.0min
[CV] END max_depth=None, max_features=sqrt, min_samples_leaf=2, min_samples_
split=10, n_estimators=300; total time=52.2min
[CV] END max_depth=20, max_features=log2, min_samples_leaf=4, min_samples_sp
lit=5, n_estimators=200; total time= 3.7min
[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_sp
lit=2, n_estimators=200; total time= 2.9min
[CV] END max_depth=10, max_features=0.5, min_samples_leaf=2, min_samples_sp
lit=5, n_estimators=300; total time= 4.5min
[CV] END max_depth=None, max_features=log2, min_samples_leaf=1, min_samples_
split=2, n_estimators=200; total time=52.5min
[CV] END max_depth=5, max_features=sqrt, min_samples_leaf=4, min_samples_sp
lit=2, n_estimators=100; total time= 24.2s
[CV] END max_depth=20, max_features=sqrt, min_samples_leaf=1, min_samples_sp
lit=10, n_estimators=200; total time= 1.2min
[CV] END max_depth=5, max_features=log2, min_samples_leaf=1, min_samples_sp
lit=10, n_estimators=300; total time= 1.8min
[CV] END max_depth=None, max_features=None, min_samples_leaf=1, min_samples_
split=10, n_estimators=100; total time= 1.9min
[CV] END max_depth=20, max_features=0.5, min_samples_leaf=1, min_samples_sp
lit=10, n_estimators=300; total time= 2.9min
[CV] END max_depth=20, max_features=0.5, min_samples_leaf=2, min_samples_sp
lit=10, n_estimators=300; total time= 8.4min
Best parameters: {'n_estimators': 200, 'min_samples_split': 2, 'min_samples
_leaf': 1, 'max_features': 'log2', 'max_depth': None}
Best RMSE: 1798.1790049481633

```

In [274...]: best_model_rf_8 = random_search_8.best_estimator_

```

#Prediction of Validation Set:
check_y_val_pred = best_model_rf_8.predict(check_X_val[selected_features_rf]

```

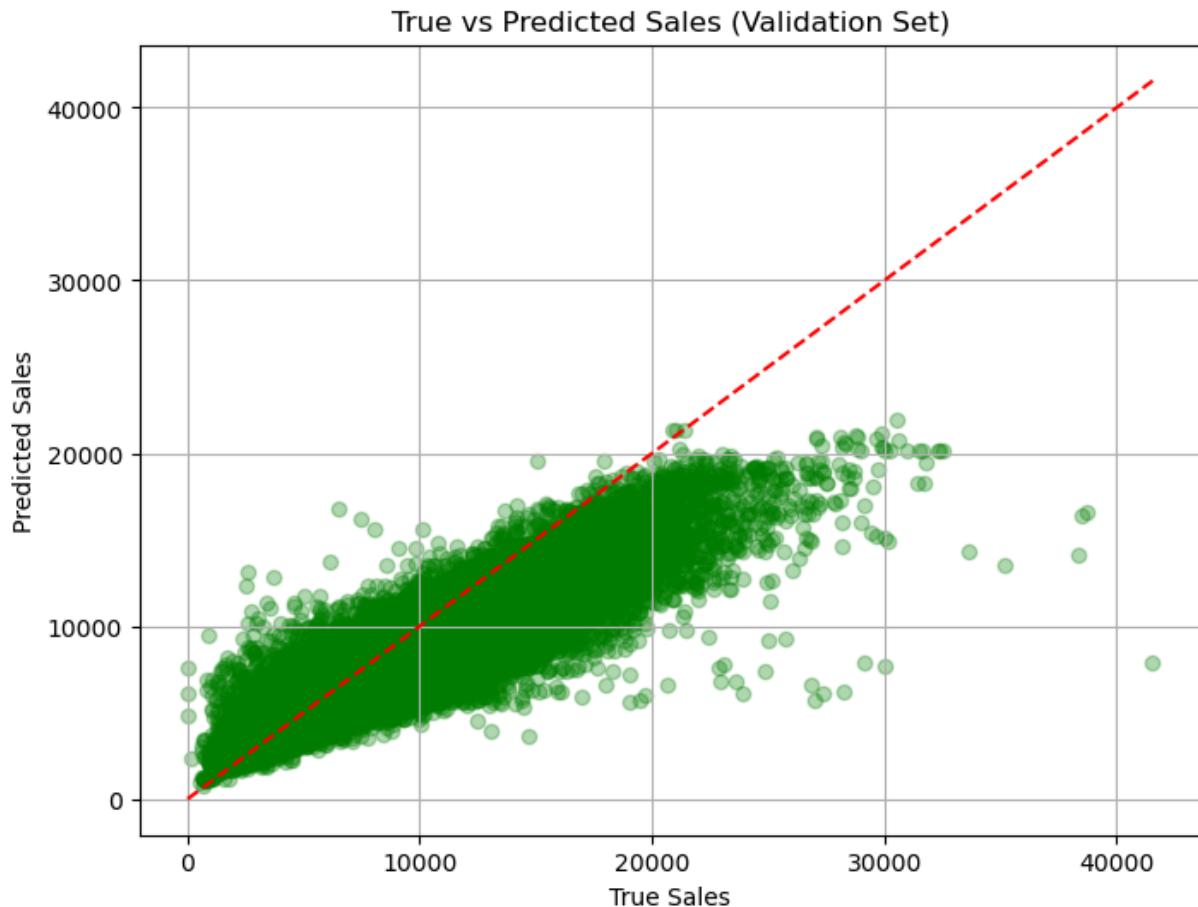
```
#Calculate performance metrics
mae = mean_absolute_error(check_y_val, check_y_val_pred)
rmse = mean_squared_error(check_y_val, check_y_val_pred, squared = False)
r2 = r2_score(check_y_val, check_y_val_pred)
rmspe_score = rmspe(check_y_val, check_y_val_pred)

print(f"MAE: {mae:.2f}")
print(f"RMSE: {rmse:.2f}")
print(f"R2 Score: {r2: .4f}")
print(f"RMSPE: {rmspe_score: .4f}")
```

MAE: 1022.62
 RMSE: 1511.50
 R2 Score: 0.7566
 RMSPE: 0.2125

In [276...]

```
#Scatter Plot: True vs Predicted
plt.figure(figsize=(8,6))
plt.scatter(check_y_val, check_y_val_pred, alpha=0.3, color='green')
plt.xlabel("True Sales")
plt.ylabel("Predicted Sales")
plt.title("True vs Predicted Sales (Validation Set)")
plt.plot([check_y_val.min(), check_y_val.max()], [check_y_val.min(), check_y_val.max()])
plt.grid()
plt.show()
```

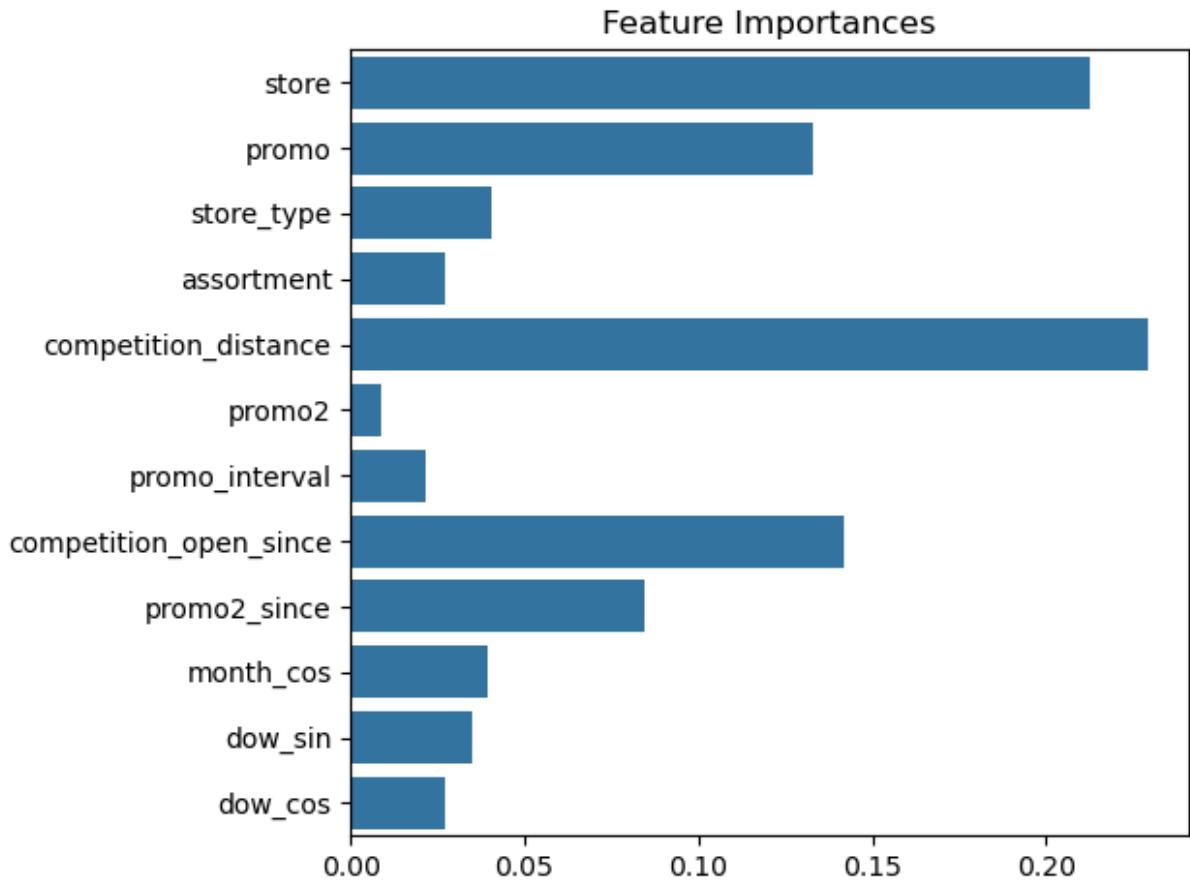


In [278...]

```
#Feature importance Check of best_model_rf_8
```

```
importances = best_model_rf_8.feature_importances_
features = selected_features_rf

sns.barplot(x = importances, y = features)
plt.title("Feature Importances")
plt.tight_layout()
plt.show()
```



Best r2 score we have got using random forest model is 0.8185, let's use XGBoost model to see if there's an improvement in r2

XGBOOST

Training the data on XGBoost model

```
In [237]: #Training the check_X_train on XGBoost and hyperparameter tuning - random_se

param_grid = { 'n_estimators': [200, 300, 500],
               'max_depth': [6, 8, 10],
               'learning_rate': [0.01, 0.05, 0.1],
               'subsample': [0.7, 0.9, 1.0],
               'colsample_bytree': [0.7, 0.9, 1.0],
               'gamma': [0, 1, 5],
               'min_child_weight': [1, 5, 10]
             }
```

```
tscv = TimeSeriesSplit(n_splits = 3)

xgb = XGBRegressor(objective = 'reg:squarederror', random_state = 42, n_jobs = -1)

#RandomizedSearchCV for hyperparameter tuning

random_search_xgb_2 = RandomizedSearchCV(estimator = xgb, param_distributions = {
    'n_estimators': np.arange(100, 500, 50),
    'max_depth': np.arange(3, 10),
    'learning_rate': np.logspace(-3, -1, 5),
    'gamma': np.arange(0, 10, 2),
    'min_child_weight': np.arange(1, 6, 1),
    'subsample': np.arange(0.5, 1.0, 0.1),
    'colsample_bytree': np.arange(0.5, 1.0, 0.1)
}, scoring = 'neg_mean_squared_error', cv = tscv, n_iter = 20, verbose = 1, random_state = 42, n_jobs = -1)

#Fit the model
random_search_xgb_2.fit(check_X_train, check_y_train)

print("Best parameters: ", random_search_xgb_2.best_params_)
print("Best RMSE: ", (-random_search_xgb_2.best_score_) ** 0.5)
```

Fitting 3 folds for each of 20 candidates, totalling 60 fits
 Best parameters: {'subsample': 0.9, 'n_estimators': 500, 'min_child_weight': 5, 'max_depth': 10, 'learning_rate': 0.05, 'gamma': 1, 'colsample_bytree': 0.7}
 Best RMSE: 1621.6175005560387

```
In [280...]: best_model_xgb_2 = random_search_xgb_2.best_estimator_

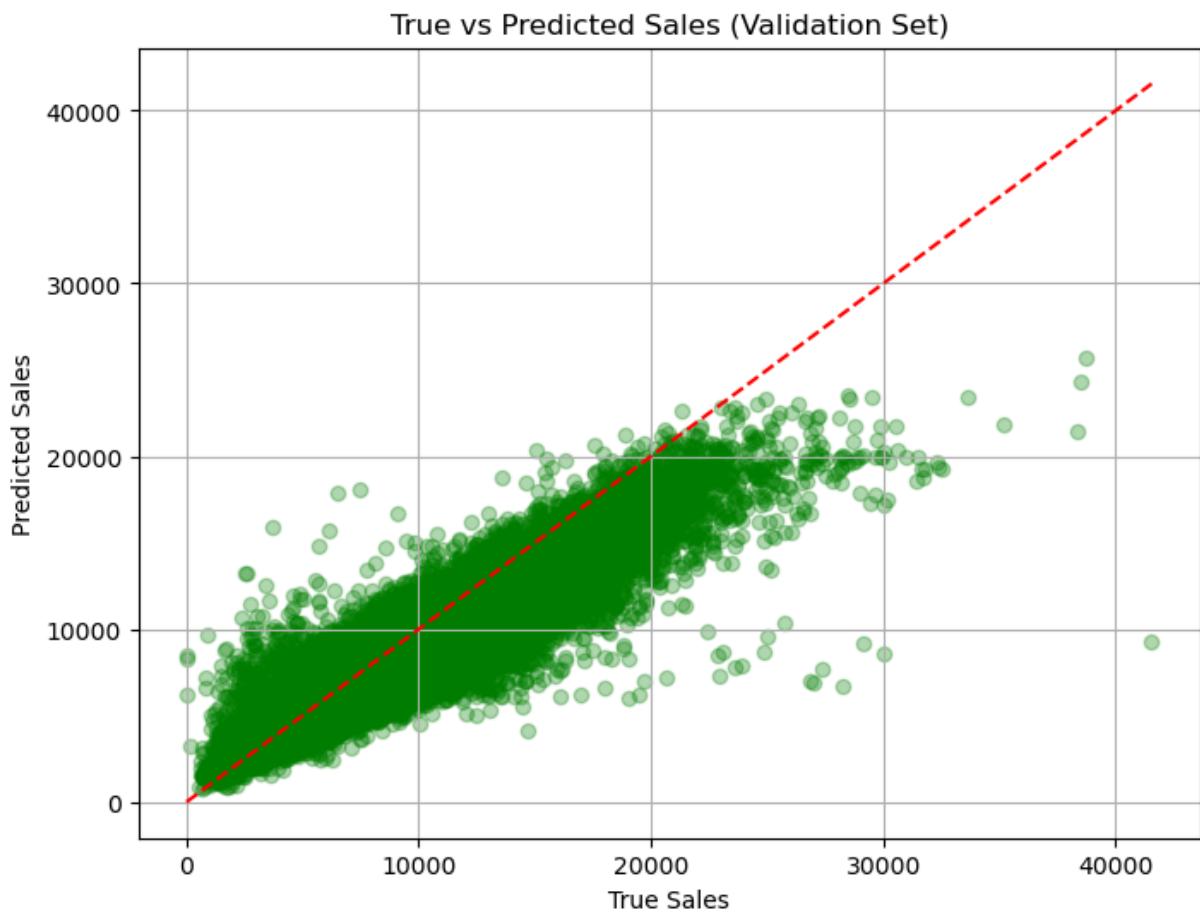
#Prediction of Validation Set:
check_y_val_pred = best_model_xgb_2.predict(check_X_val)

#Calculate performance metrics
mae = mean_absolute_error(check_y_val, check_y_val_pred)
rmse = mean_squared_error(check_y_val, check_y_val_pred, squared = False)
r2 = r2_score(check_y_val, check_y_val_pred)
rmspe = rmspe(check_y_val, check_y_val_pred)

print(f"MAE: {mae:.2f}")
print(f"RMSE: {rmse:.2f}")
print(f"R2 Score: {r2: .4f}")
print(f"RMSPE: {rmspe: .4f}")
```

MAE: 861.42
 RMSE: 1256.37
 R2 Score: 0.8318
 RMSPE: 0.1929

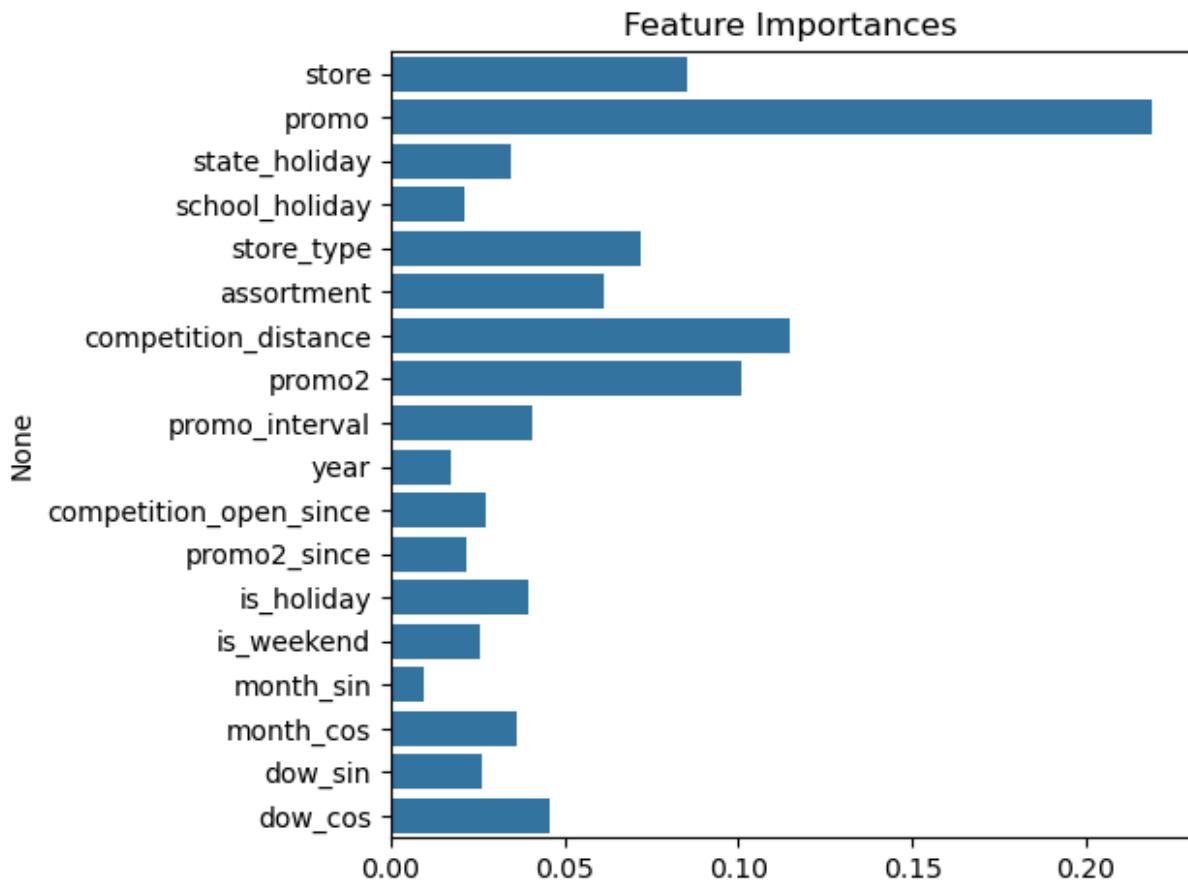
```
In [643...]: #Scatter Plot: True vs Predicted
plt.figure(figsize=(8,6))
plt.scatter(check_y_val, check_y_val_pred, alpha=0.3, color='green')
plt.xlabel("True Sales")
plt.ylabel("Predicted Sales")
plt.title("True vs Predicted Sales (Validation Set)")
plt.plot([check_y_val.min(), check_y_val.max()], [check_y_val.min(), check_y_val.max()])
plt.grid()
plt.show()
```



In [645...]: #Feature importance Check of best_model_xgb_2

```
importances = best_model_xgb_2.feature_importances_
features = check_X_train.columns

sns.barplot(x = importances, y = features)
plt.title("Feature Importances")
plt.tight_layout()
plt.show()
```



Removing 'competiton_opne_since' and 'promo2_since' columns and training the data on XGBoost model

```
In [209]: #Training the check_X_train on XGBoost and hyperparameter tuning - random_se
param_grid = { 'n_estimators': [200, 300, 500],
               'max_depth': [6, 8, 10],
               'learning_rate': [0.01, 0.05, 0.1],
               'subsample': [0.7, 0.9, 1.0],
               'colsample_bytree': [0.7, 0.9, 1.0],
               'gamma': [0, 1, 5],
               'min_child_weight': [1, 5, 10]
             }

tscv = TimeSeriesSplit(n_splits = 3)

features_no_timedelta = [col for col in check_X_train.columns if col not in
xgb = XGBRegressor(objective = 'reg:squarederror', random_state = 42, n_jobs = -1)

#RandomizedSearchCV for hyperparameter tuning

random_search_xgb_2_1 = RandomizedSearchCV(estimator = xgb, param_distributi
                           scoring = 'neg_mean_squared_error', n_iter = 10, cv = tscv)

#Fit the model
random_search_xgb_2_1.fit(check_X_train[features_no_timedelta], check_y_train)
```

```
print("Best parameters: ", random_search_xgb_2_1.best_params_)
print("Best RMSE: ", (-random_search_xgb_2_1.best_score_) ** 0.5)
```

Fitting 3 folds for each of 20 candidates, totalling 60 fits
 Best parameters: {'subsample': 0.9, 'n_estimators': 500, 'min_child_weight': 10, 'max_depth': 10, 'learning_rate': 0.05, 'gamma': 1, 'colsample_bytree': 0.7}
 Best RMSE: 1403.4615392911223

```
In [267...]: best_model_xgb_2_1 = random_search_xgb_2_1.best_estimator_

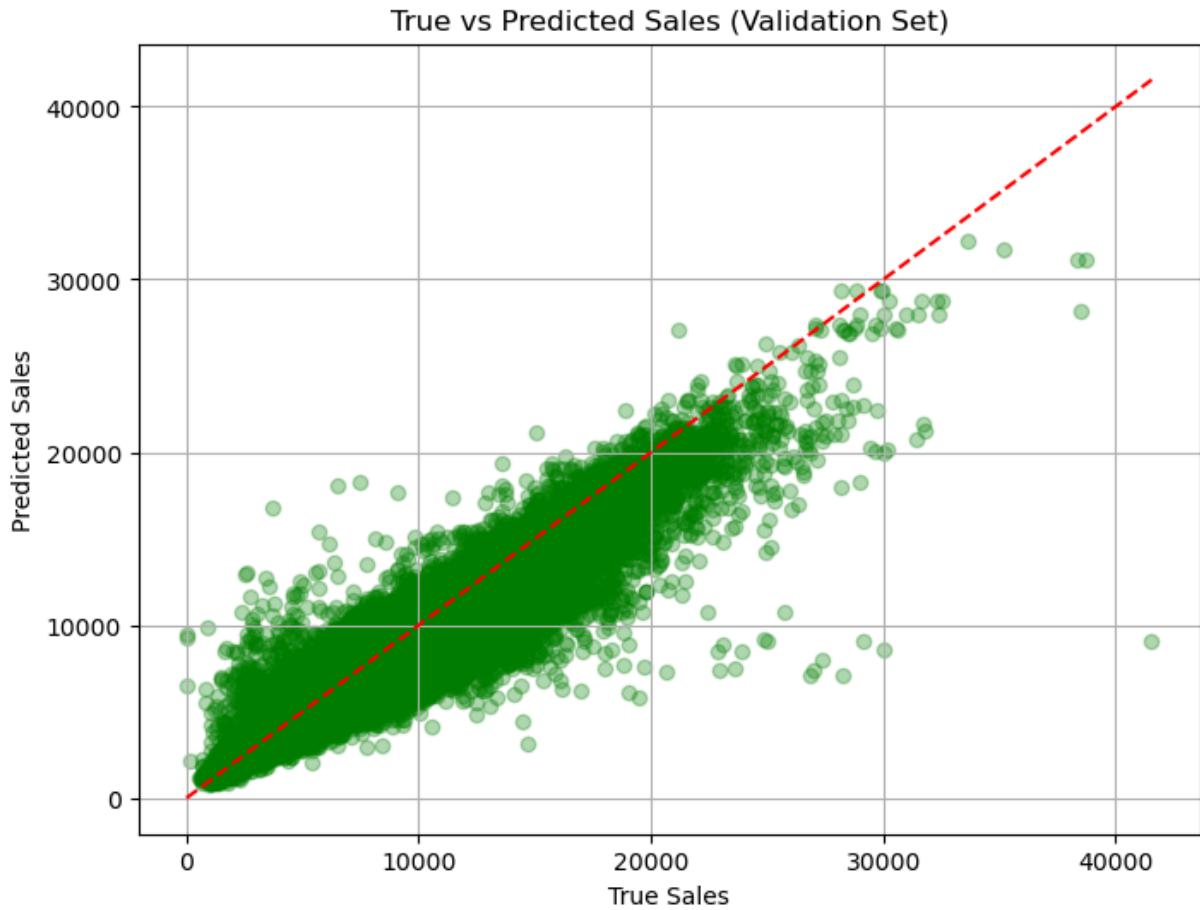
#Prediction of Validation Set:
check_y_val_pred = best_model_xgb_2_1.predict(check_X_val[features_no_timedependent])

#Calculate performance metrics
mae = mean_absolute_error(check_y_val, check_y_val_pred)
rmse = mean_squared_error(check_y_val, check_y_val_pred, squared = False)
r2 = r2_score(check_y_val, check_y_val_pred)
rmspe_score = rmspe(check_y_val, check_y_val_pred)

print(f"MAE: {mae:.2f}")
print(f"RMSE: {rmse:.2f}")
print(f"R2 Score: {r2: .4f}")
print(f"RMSPE: {rmspe_score: .4f}")
```

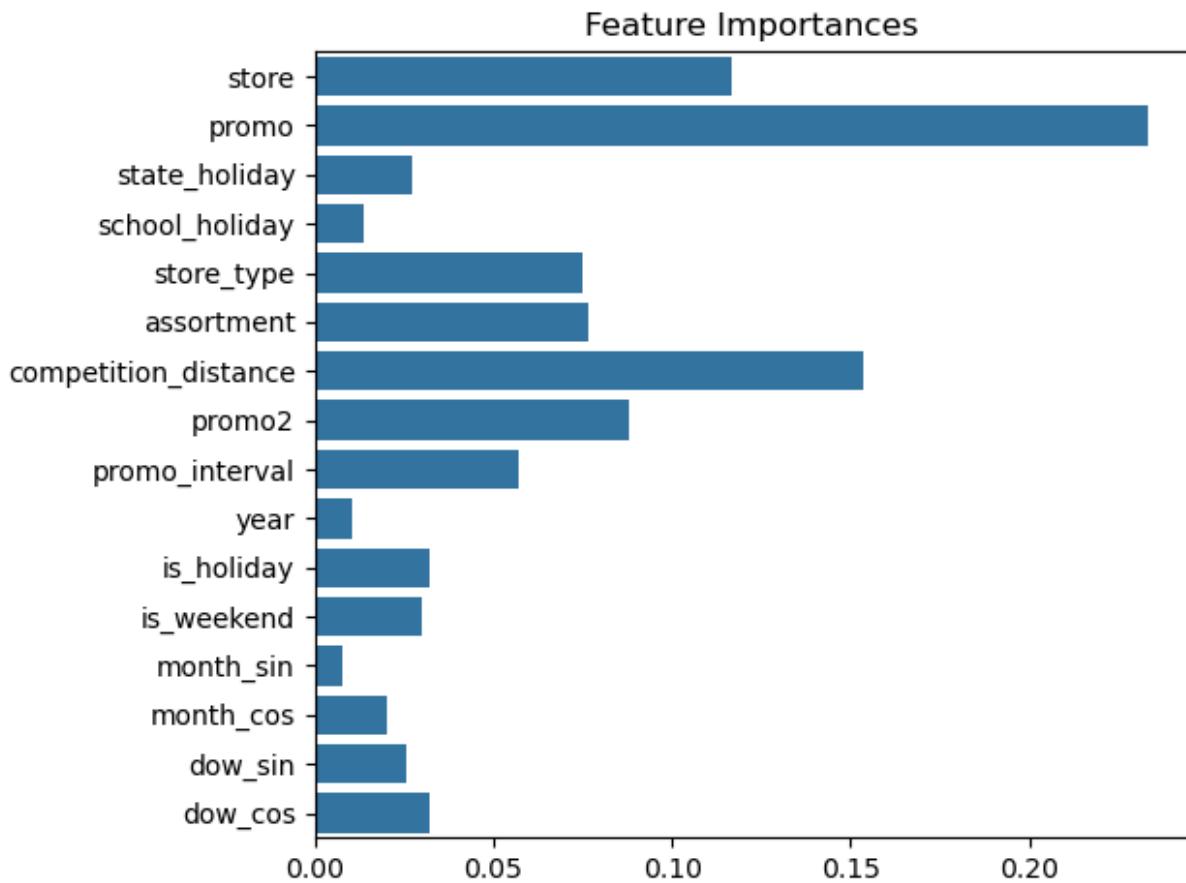
MAE: 743.56
 RMSE: 1094.49
 R2 Score: 0.8724
 RMSPE: 0.1597

```
In [219...]: #Scatter Plot: True vs Predicted
plt.figure(figsize=(8,6))
plt.scatter(check_y_val, check_y_val_pred, alpha=0.3, color='green')
plt.xlabel("True Sales")
plt.ylabel("Predicted Sales")
plt.title("True vs Predicted Sales (Validation Set)")
plt.plot([check_y_val.min(), check_y_val.max()], [check_y_val.min(), check_y_val.max()])
plt.grid()
plt.show()
```



In [221]: #Feature importance Check of best_model_xgb_2_1

```
importances = best_model_xgb_2_1.feature_importances_
features = features_no_timedelta
sns.barplot(x = importances, y = features)
plt.title("Feature Importances")
plt.tight_layout()
plt.show()
```



We have got the best R2 Score of 0.8724 using the XGBoost model (`best_model_xgb_2_1`) we will use that for the prediction of sales in the test set

```
In [285...]: #Predicting the value of Sales in the test set using best_model_xgb_2_1 mode
test_set_pred = best_model_xgb_2_1.predict(test_set[features_no_timedelta])
test_set_pred
```

```
Out[285...]: array([5358.851 , 4891.519 , 5778.1074, ..., 9820.62 , 4788.348 ,
       4740.5786], dtype=float32)
```

Conclusion:

In this project, I tackled the Rossmann Store Sales Forecasting problem using machine learning models, with a focus on time-aware feature engineering and validation. The goal was to predict daily sales across 1,115 stores based on historical data, promotions, holidays, and store attributes.

Feature Engineering:

Performed label encoding on categorical variables such as `StoreType`, `Assortment`, and `StateHoliday` to make them machine-readable.

Created time-aware features like:

CompetitionOpenSince — number of months since a competing store opened.

Promo2Since — number of months since a store started participating in Promo2.

Extracted date-based features like year, month from the Date column to capture temporal patterns.

Modeling:

Evaluated a range of regression models including Random Forest, and XGBoost.

Among these XGBoost emerged as the best-performing model with:

R² Score: 0.8724 — explaining ~87% of the variance in sales.

RMSPE: 0.1597 — indicating only ~16% average percentage deviation from true sales values (after excluding days with zero sales).

Validation Strategy: Used time-based train-validation split to mimic a realistic forecasting scenario, ensuring the model only had access to past data while validating on unseen future periods.

Interpretation of Results:

An R² > 0.85 on real-world sales data is a strong indicator that the model has successfully captured major patterns — such as weekly seasonality, promotional effects, and store-specific behaviors.

An RMSPE of ~16% suggests good predictive accuracy, especially considering the dataset's diversity (many stores, regions, and external factors).

In []: