

Flipkart Project – Ready notebook

This notebook includes EDA, feature engineering, modeling pipeline and saves final outputs to /Users/shivalimuthukumar/Desktop/. Run top-to-bottom.

In [21]: `conda install -c conda-forge "numpy<2.0" --yes`

```
zsh:1: no such file or directory: 2.0
```

Note: you may need to restart the kernel to use updated packages.

In [22]: `!pip install -U scikit-learn imbalanced-learn --quiet`

In [23]: `import pandas as pd
import numpy as np
import matplotlib.pyplot as plt, seaborn as sns
sns.set(style='whitegrid')
from datetime import datetime
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.preprocessing import StandardScaler, OneHotEncoder, OrdinalEncoder
from sklearn.impute import SimpleImputer
from sklearn.pipeline import Pipeline
from sklearn.compose import ColumnTransformer
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import classification_report, confusion_matrix
import joblib
import warnings
warnings.filterwarnings('ignore')
print('Imports ready.')`

Imports ready.

In [24]: `# 1. Load dataset`

```
df = pd.read_csv("/Users/shivalimuthukumar/Desktop/Customer_support.csv")
print("Rows, Columns:", df.shape)
display(df.head(3))
display(df.info())
```

Rows, Columns: (85907, 20)

	Unique id	channel_name	category	Sub-category	Customer Remarks	Order_id	order
0	7e9ae164-6a8b-4521-a2d4-	Outcall	Product Queries	Life Insurance	NaN	c27c9bb4-fa36-4140-9f1f-	

	58f7c9fff13f						21009254ffdb
1	b07ec1b0-f376-43b6-86df-ec03da3b2e16	Outcall	Product Queries	Product Specific Information	NaN	d406b0c7-ce17-4654-b9de-f08d421254bd	
2	200814dd-27c7-4149-ba2b-bd3af3092880	Inbound	Order Related	Installation/demo	NaN	c273368d-b961-44cb-beaf-62d6fd6c00d5	

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 85907 entries, 0 to 85906
```

```
Data columns (total 20 columns):
```

#	Column	Non-Null Count	Dtype
0	Unique id	85907	non-null
1	channel_name	85907	non-null
2	category	85907	non-null
3	Sub-category	85907	non-null
4	Customer Remarks	28742	non-null
5	Order_id	67675	non-null
6	order_date_time	17214	non-null
7	Issue_reported_at	85907	non-null
8	issue_responded	85907	non-null
9	Survey_response_Date	85907	non-null
10	Customer_City	17079	non-null
11	Product_category	17196	non-null
12	Item_price	17206	non-null
13	connected_handling_time	242	non-null
14	Agent_name	85907	non-null
15	Supervisor	85907	non-null
16	Manager	85907	non-null
17	Tenure Bucket	85907	non-null
18	Agent Shift	85907	non-null
19	CSAT Score	85907	non-null

```
dtypes: float64(2), int64(1), object(17)
```

```
memory usage: 13.1+ MB
```

None

```
In [25]: # 2. Quick cleaning & type conversions
# Trim column names
df.columns = df.columns.str.strip()

# Show columns for quick reference
print("Columns:", list(df.columns))

# Common conversions
possible_date_cols = [c for c in df.columns if any(k in c.lower() for k in ['date', 'time', 'datetime'])]
print("Possible datetime columns:", possible_date_cols)

# Convert recognized date/time columns to datetime
for c in possible_date_cols:
    try:
        df[c] = pd.to_datetime(df[c], errors='coerce')
    except Exception as e:
        print(f"Could not convert {c} to datetime:", e)

# Basic missing counts
missing = df.isna().sum().sort_values(ascending=False)
display(missing[missing > 0].head(40))
```

Columns: ['Unique_id', 'channel_name', 'category', 'Sub-category', 'Customer Remarks', 'Order_id', 'order_date_time', 'Issue_reported_at', 'issue_responded', 'Survey_response_Date', 'Customer_City', 'Product_category', 'Item_price', 'connected_handling_time', 'Agent_name', 'Supervisor', 'Manager', 'Tenure_Bucket', 'Agent_Shift', 'CSAT_Score']
 Possible datetime columns: ['order_date_time', 'Survey_response_Date', 'connected_handling_time']

connected_handling_time	85665
Customer_City	68828
Product_category	68711
Item_price	68701
order_date_time	68693
Customer Remarks	57165
Order_id	18232
dtype:	int64

```
In [26]: # 3. EDA - distribution of target and important features
# 3.1 CSAT distribution (to find target column)
target_col = None
for candidate in ['CSAT Score', 'CSAT', 'CSAT_Score', 'CSATScore']:
    if candidate in df.columns:
        target_col = candidate
        break

if target_col is None:
    # fallback: search numeric column that looks like CSAT
    for c in df.columns:
        if df[c].nunique() <= 6 and df[c].dtype in [np.int64, np.float64]:
            target_col = c
```

```
        print("Candidate for target:", c, df[c].unique())
    raise ValueError("No obvious CSAT column found. Please ensure '"

print("Target column:", target_col)
display(df[target_col].value_counts(dropna=False).sort_index())

# 3.2 Basic distributions for numeric columns
num_cols = df.select_dtypes(include=[np.number]).columns.tolist()
print("Numeric columns:", num_cols)
df[num_cols].hist(bins=15, figsize=(12,8))
plt.tight_layout()
plt.show()

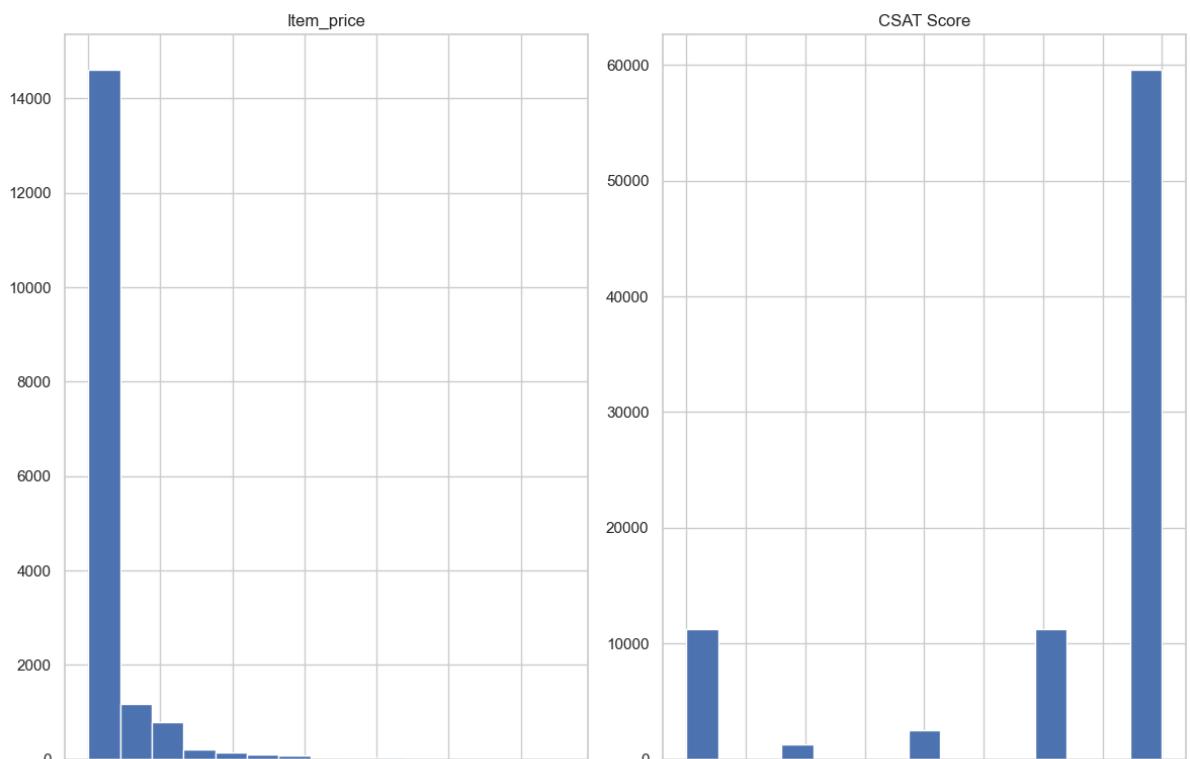
# 3.3 Top categorical value counts
cat_cols = df.select_dtypes(include=['object']).columns.tolist()
print("Categorical columns example counts:")
for c in cat_cols[:8]:
    print(f"--- {c} ---")
    print(df[c].value_counts(dropna=False).head(10))
    print()
```

Target column: CSAT Score

CSAT Score
1 11230
2 1283
3 2558
4 11219
5 59617

Name: count, dtype: int64

Numeric columns: ['Item_price', 'CSAT Score']



Categorical columns example counts:

--- Unique id ---

Unique id	
7e9ae164-6a8b-4521-a2d4-58f7c9fff13f	1
4a7fec30-68f5-4891-b934-6a666e00930e	1
67792991-fd16-465f-bbdc-3189a0f16395	1
c629cb55-3c2b-448c-8598-96eeb0f30f13	1
67f2636b-055f-4ae5-a360-c3f35c09205c	1
c382055a-079b-4fbc-9390-c0e8310219d9	1
9e7bb01a-df3b-401d-8d25-197ed437e5cb	1
465b0fb0-99c0-4bbc-87d0-4bb73c281337	1
b7957c1f-6f86-41da-bda6-845b7f1cf611	1
e78186b5-b3fe-440d-86ca-b2da6d3773d1	1

Name: count, dtype: int64

--- channel_name ---

channel_name	
Inbound	68142
Outcall	14742
Email	3023

Name: count, dtype: int64

--- category ---

category	
Returns	44097
Order Related	23215
Refund Related	4550
Product Queries	3692
Shopzilla Related	2792
Payments related	2327
Feedback	2294
Cancellation	2212
Offers & Cashback	480
Others	99

Name: count, dtype: int64

--- Sub-category ---

Sub-category	
Reverse Pickup Enquiry	22389
Return request	8523
Delayed	7388
Order status enquiry	6922
Installation/demo	4116
Fraudulent User	4108
Product Specific Information	3589
Refund Enquiry	2665
Wrong	2597
Missing	2556

Name: count, dtype: int64

--- Customer Remarks ---

Customer Remarks	
------------------	--

```
-----  
NaN      57165  
Good     1390  
Good     1158  
Very good 569  
Nice     316  
Thanks    276  
Ok       259  
No       258  
Thank you 244  
Nice     239  
Name: count, dtype: int64
```

--- Order_id ---

```
Order_id  
NaN                      18232  
b13cbde9-ffe7-41de-8b1c-a5547a1769b6   1  
d7ae97cf-a6e9-4cd1-80d3-ae401b0e9302   1  
22a084d7-c496-4d54-acdf-e444b43ed32d   1  
e55d5ede-b2a4-4e84-91b7-e83f131922c2   1  
c57533a2-6ac9-4fbe-aae2-6bcefa6f29e6   1  
897c08b3-df15-4760-ac9b-58564a671bc3   1  
6332073d-aa96-4861-8a90-ad1aa347f208   1  
5af19aea-ae61-46f9-88c8-b8712fc3f478   1  
9db75247-1d17-4f0a-ac8b-419ed604872a   1  
Name: count, dtype: int64
```

--- Issue_reported at ---

```
Issue_reported at  
15/08/2023 10:59    13  
13/08/2023 10:40    13  
06/08/2023 18:22    12  
14/08/2023 12:08    12  
28/08/2023 12:35    11  
27/08/2023 10:08    11  
24/08/2023 19:44    11  
11/08/2023 19:04    11  
16/08/2023 11:29    11  
15/08/2023 10:42    11  
Name: count, dtype: int64
```

--- issue_responded ---

```
issue_responded  
28/08/2023 00:00    3378  
27/08/2023 00:00     21  
08/08/2023 17:51     13  
17/08/2023 11:34     12  
16/08/2023 11:35     12  
14/08/2023 10:59     12  
09/08/2023 11:17     12  
16/08/2023 13:24     12  
17/08/2023 12:01     11  
18/08/2023 10:52     11  
Name: count, dtype: int64
```

```
In [27]: # Robust parsing + feature engineering (paste and run)
import re
from dateutil import parser
import numpy as np
import pandas as pd

# 1) Detect likely column names (safe, case-insensitive)
reported_col = None
responded_col = None
handling_col = None
for c in df.columns:
    lc = c.lower()
    if ('report' in lc or 'reported' in lc) and ('issue' in lc or 'resolved' in lc):
        reported_col = reported_col or c
    if 'respond' in lc or 'responded' in lc:
        responded_col = responded_col or c
    if 'handling' in lc or 'connected_handling' in lc or 'connected_resolved' in lc:
        handling_col = handling_col or c

print("Detected columns:", "reported:", reported_col, "responded:", responded_col, "handling:", handling_col)

# 2) Convert a Series to datetime robustly
def safe_to_datetime(series):
    s = pd.to_datetime(series, errors='coerce', infer_datetime_form='%Y-%m-%d %H:%M:%S')
    if s.isna().mean() > 0.10:
        # try cleaning some common artifacts then re-parse
        cleaned = series.astype(str).str.strip().replace({'': None, 'N/A': None})
        cleaned = cleaned.str.replace(r'\.\0$', '', regex=True)
        s2 = pd.to_datetime(cleaned, errors='coerce', infer_datetime_form='%Y-%m-%d %H:%M:%S')
        s = s.fillna(s2)
    # final fallback to python-dateutil row-wise (slower)
    if s.isna().any():
        def try_parse(x):
            if pd.isna(x):
                return pd.NaT
            try:
                return parser.parse(str(x))
            except Exception:
                return pd.NaT
        mask = s.isna()
        if mask.any():
            s.loc[mask] = series[mask].apply(try_parse)
    return s

# 3) Parse reported/responded if present
if reported_col:
    df[reported_col + "_parsed"] = safe_to_datetime(df[reported_col])
    print(f"{reported_col} parsed: {df[reported_col + '_parsed'].notnull().sum()}")
if responded_col:
    df[responded_col + "_parsed"] = safe_to_datetime(df[responded_col])
    print(f"{responded_col} parsed: {df[responded_col + '_parsed'].notnull().sum()}"
```

```
# 4) Compute response time in minutes when both parsed columns exist
rep_par = reported_col + "_parsed" if reported_col else None
resp_par = responded_col + "_parsed" if responded_col else None
if rep_par in df.columns and resp_par in df.columns:
    df['response_time_mins'] = (df[resp_par] - df[rep_par]).dt.total_seconds() / 60.0
    print("response_time_mins non-null:", df['response_time_mins'].count())
else:
    df['response_time_mins'] = np.nan
    print("response_time_mins set to NaN (missing parsed columns).")

# 5) Parse handling duration to minutes (accepts HH:MM:SS, MM:SS, n)
def parse_duration_minutes(x):
    if pd.isna(x):
        return np.nan
    if isinstance(x, (int, float, np.integer, np.floating)) and not isinstance(x, str):
        return float(x) / 60.0
    s = str(x).strip()
    # keep digits and colons only
    s_clean = re.sub(r'^\d+(:\d+(:\d+)?|:\d+)?$', '', s)
    if ':' in s_clean:
        parts = [p for p in s_clean.split(':') if p != '']
        try:
            parts = [float(p) for p in parts]
        except:
            return np.nan
    if len(parts) == 3:
        secs = parts[0]*3600 + parts[1]*60 + parts[2]
        return secs / 60.0
    if len(parts) == 2:
        secs = parts[0]*60 + parts[1]
        return secs / 60.0
    return np.nan
    if re.fullmatch(r'^-?\d+(\.\d+)?$', s_clean):
        try:
            secs = float(s_clean)
            return secs / 60.0
        except:
            return np.nan
    # fallback: extract first number and treat it as seconds
    nums = re.findall(r'\d+(\.\d+)?', s)
    if nums:
        try:
            return float(nums[0]) / 60.0
        except:
            return np.nan
    return np.nan

if handling_col:
    df['handling_time_mins'] = df[handling_col].apply(parse_duration_minutes)
    print("handling_time_mins non-null:", df['handling_time_mins'].count())
else:
    df['handling_time_mins'] = np.nan
```

```
print("handling_time_mins set to NaN (no handling column found)

# 6) Text features from remarks/feedback (simple and fast)
text_col = None
for c in df.columns:
    lc = c.lower()
    if 'remark' in lc or 'feedback' in lc or 'comment' in lc:
        text_col = c
        break
print("Detected text column:", text_col)

if text_col:
    df['remark_len'] = df[text_col].fillna("").astype(str).str.len()
    df['remark_word_count'] = df[text_col].fillna("").astype(str).str.split().apply(len)
    keywords = ['refund', 'return', 'late', 'delayed', 'broken', 'wrong']
    for kw in keywords:
        df[f'kw_{kw.replace(" ", "_")}] = df[text_col].fillna("").str.contains(kw).sum()
else:
    df['remark_len'] = np.nan
    df['remark_word_count'] = np.nan

# 7) Price and tenure parsing (coerce numbers)
price_col = None
for c in df.columns:
    if 'price' in c.lower() or 'item price' in c.lower() or 'item_p':
        price_col = price_col or c
if price_col:
    df['item_price'] = pd.to_numeric(df[price_col].astype(str).str.replace('$', '').str.replace(',', ''))

    print("item_price non-null:", df['item_price'].notna().sum())
else:
    df['item_price'] = np.nan

tenure_col = None
for c in df.columns:
    if 'tenure' in c.lower():
        tenure_col = tenure_col or c
if tenure_col:
    def parse_tenure(x):
        try:
            s = str(x)
            if '-' in s:
                a,b = re.findall(r'\d+(\.\d+)?', s)[:2]
                return (float(a) + float(b)) / 2.0
            nums = re.findall(r'\d+(\.\d+)?', s)
            if nums:
                return float(nums[0])
            return np.nan
        except:
            return np.nan
    df['tenure_months'] = df[tenure_col].apply(parse_tenure)
    print("tenure_months non-null:", df['tenure_months'].notna().sum())
else:
    df['tenure_months'] = np.nan
```

```
# 8) Show sample of engineered features for quick sanity check
show_cols = []
if rep_par in df.columns: show_cols.append(rep_par)
if resp_par in df.columns: show_cols.append(resp_par)
show_cols += ['response_time_mins', 'handling_time_mins', 'remark_len']
show_cols = [c for c in show_cols if c in df.columns]
print("\nSample of engineered features (first 8 rows):")
display(df[show_cols].head(8))
```

Detected columns: reported: Issue_reported at responded: issue_responded handling: connected_handling_time
Issue_reported at parsed: 85907 non-null out of 85907
issue_responded parsed: 85907 non-null out of 85907
response_time_mins non-null: 85907
handling_time_mins non-null: 0
Detected text column: Customer Remarks
item_price non-null: 17206
tenure_months non-null: 0

Sample of engineered features (first 8 rows):

	Issue_reported at_parsed	issue_responded_parsed	response_time_mins	handling_time_mins	rema
0	2023-01-08 11:13:00	2023-01-08 11:47:00	34.0		NaN
1	2023-01-08 12:52:00	2023-01-08 12:54:00	2.0		NaN
2	2023-01-08 20:16:00	2023-01-08 20:38:00	22.0		NaN
3	2023-01-08 20:56:00	2023-01-08 21:16:00	20.0		NaN
4	2023-01-08 10:30:00	2023-01-08 10:32:00	2.0		NaN
5	2023-01-08 15:13:00	2023-01-08 18:39:00	206.0		NaN
6	2023-01-08 15:31:00	2023-01-08 23:52:00	501.0		NaN
7	2023-01-08 16:17:00	2023-01-08 16:23:00	6.0		NaN

In [28]: # Sanity check after feature engineering
print("Target column check:")
possible_targets = [c for c in df.columns if 'csat' in c.lower() or
if possible_targets:
 print("Detected potential CSAT columns:", possible_targets)
else:
 print("No obvious CSAT column found. Check dataset header manua

```

# Inspect target distribution if column found
target_col = possible_targets[0] if possible_targets else None
if target_col:
    print("\nCSAT value counts:")
    print(df[target_col].value_counts(dropna=False).sort_index())

# Check parsing results
print("\nDatetime & duration feature checks:")
for col in ['response_time_mins', 'handling_time_mins']:
    if col in df.columns:
        print(f"{col}: non-null = {df[col].notna().sum()}, mean = {df[col].mean()}")
    else:
        print(f"{col} not found in df.")

# Check sample remarks
text_col = None
for c in df.columns:
    if 'remark' in c.lower() or 'feedback' in c.lower() or 'comment' in c.lower():
        text_col = c
        break

if text_col:
    print(f"\nSample customer remarks (non-empty from {text_col}):")
    display(df.loc[df[text_col].notna() & (df[text_col] != '')], [text_col])
else:
    print("\nNo customer remarks column detected.")

```

Target column check:

Detected potential CSAT columns: ['CSAT Score']

CSAT value counts:
CSAT Score
1 11230
2 1283
3 2558
4 11219
5 59617
Name: count, dtype: int64

Datetime & duration feature checks:

response_time_mins: non-null = 85907, mean = 332.62, median = 5.00
handling_time_mins: non-null = 0, mean = nan, median = nan

Sample customer remarks (non-empty from Customer Remarks):

Customer Remarks

7	Very good
8	Shopzilla app and it's all coustomer care serv...
11	Very bad

17	Something
19	All good

```
In [29]: # Define binary target
# try common CSAT column names
target_candidates = ['CSAT Score', 'CSAT_Score', 'CSATScore', 'CSAT', 'target_col = None
for c in target_candidates:
    if c in df.columns:
        target_col = c
        break
# fallback: pick numeric column with small unique values (1-5 typical)
if target_col is None:
    for c in df.select_dtypes(include=[np.number]).columns:
        if df[c].nunique() <= 6:
            target_col = c
            break

if target_col is None:
    raise ValueError("No CSAT-like column found. Please tell me the

print("Using CSAT column:", target_col)
# Map to binary: satisfied if >=4 when numeric
if pd.api.types.is_numeric_dtype(df[target_col]):
    df['target'] = (df[target_col] >= 4).astype(int)
else:
    df['target'] = df[target_col].astype(str).str.lower().map(
        lambda x: 1 if x in ['satisfied', 'yes', 'positive', '1', '4', '']
    ).fillna(0).astype(int)

print("Target distribution:")
display(df['target'].value_counts())
```

Using CSAT column: CSAT Score
Target distribution:

```
target
1    70836
0    15071
Name: count, dtype: int64
```

```
In [30]: # Missing summary and drop very-sparse columns
missing_frac = df.isna().mean().sort_values(ascending=False)
print("Columns with >50% missing (will be dropped):")
drop_cols = missing_frac[missing_frac > 0.5].index.tolist()
display(missing_frac[missing_frac > 0.5])
df = df.drop(columns=drop_cols)
print("Dropped columns:", drop_cols)

# update feature lists
numeric_cols = df.select_dtypes(include=[np.number]).columns.tolist()
if 'target' in numeric_cols: numeric_cols.remove('target')
cat_cols = df.select_dtypes(include=['object']).columns.tolist()
print("Numeric features left:", numeric_cols)
print("Categorical features left (sample):", cat_cols[:10])
```

Columns with >50% missing (will be dropped):

handling_time_mins	1.000000
tenure_months	1.000000
connected_handling_time	0.997183
Customer_City	0.801192
Product_category	0.799830
Item_price	0.799714
item_price	0.799714
order_date_time	0.799621
Customer Remarks	0.665429

dtype: float64

Dropped columns: ['handling_time_mins', 'tenure_months', 'connecte
d_handling_time', 'Customer_City', 'Product_category', 'Item_pric
e', 'item_price', 'order_date_time', 'Customer Remarks']

Numeric features left: ['CSAT Score', 'response_time_mins', 'rema
rk_len', 'remark_word_count', 'kw_refund', 'kw_return', 'kw_late',
'kw_delayed', 'kw_broken', 'kw_wrong', 'kw_cancel', 'kw_replacemen
t', 'kw_unsatisfied', 'kw_not_delivered', 'kw_delay']

Categorical features left (sample): ['Unique id', 'channel_name',
'category', 'Sub-category', 'Order_id', 'Issue_reported at', 'issu
e_responded', 'Agent_name', 'Supervisor', 'Manager']

In [32]:

```

# Split data and run two baseline models

# Prepare X,y
feature_columns = numeric_features + ohe_features + ord_features
X = df[feature_columns].copy()
y = df['target'].copy()
# drop any rows where y is null
mask = y.notna()
X = X[mask]; y = y[mask]

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)
print("Train/test shapes:", X_train.shape, X_test.shape)
from sklearn.pipeline import Pipeline

def eval_pipeline(clf, name):
    pipeline = Pipeline(steps=[('pre', preprocessor), ('clf', clf)])
    pipeline.fit(X_train, y_train)
    y_pred = pipeline.predict(X_test)
    proba = pipeline.predict_proba(X_test)[:,1] if hasattr(pipeline, 'predict_proba') else None
    print(f"\n{name} results:")
    print(classification_report(y_test, y_pred, digits=4))
    if proba is not None:
        print("ROC AUC:", roc_auc_score(y_test, proba))
        cm = confusion_matrix(y_test, y_pred)
        sns.heatmap(cm, annot=True, fmt='d')
        plt.title(f"Confusion matrix - {name}")
        plt.show()
    return pipeline

lr = LogisticRegression(max_iter=1000, class_weight='balanced', random_state=42)
rf = RandomForestClassifier(n_estimators=200, class_weight='balanced', random_state=42)

pipe_lr = eval_pipeline(lr, "Logistic Regression")
pipe_rf = eval_pipeline(rf, "Random Forest")

```

Train/test shapes: (68725, 7) (17182, 7)

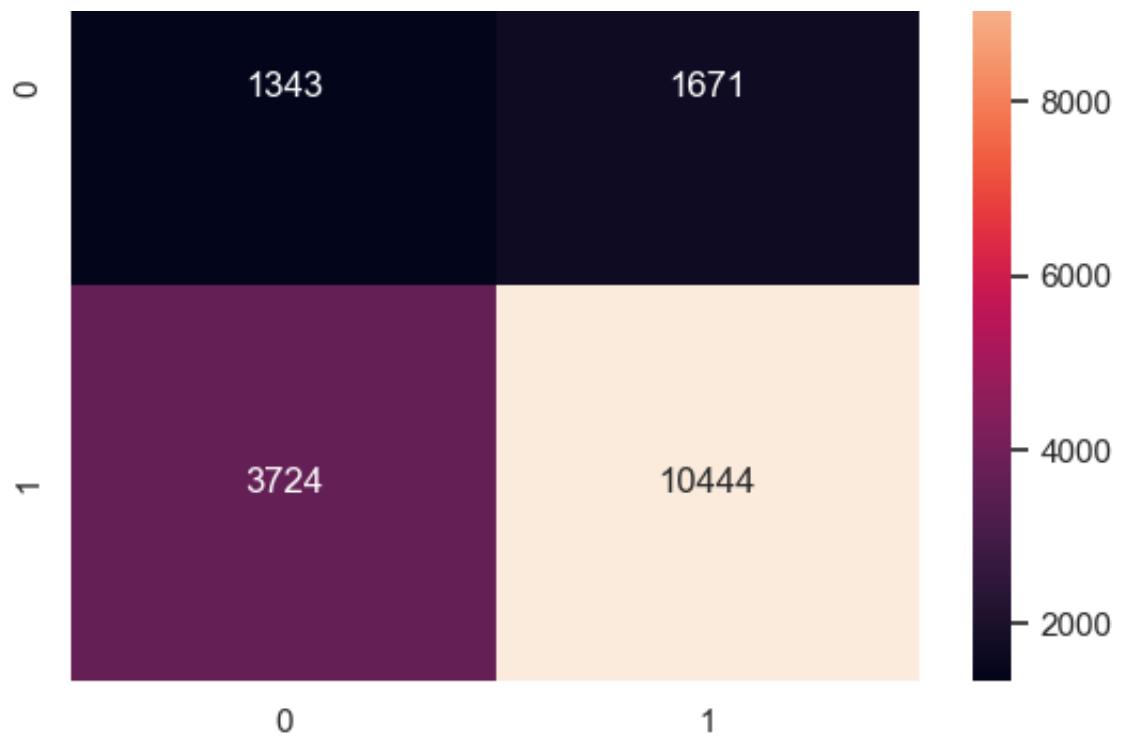
Logistic Regression results:

	precision	recall	f1-score	support
0	0.2650	0.4456	0.3324	3014
1	0.8621	0.7372	0.7947	14168
accuracy			0.6860	17182
macro avg	0.5636	0.5914	0.5636	17182
weighted avg	0.7573	0.6860	0.7136	17182

ROC AUC: 0.6266357764087561

Confusion matrix - Logistic Regression



**Random Forest results:**

	precision	recall	f1-score	support
0	0.3403	0.1997	0.2517	3014
1	0.8435	0.9176	0.8790	14168
accuracy			0.7917	17182
macro avg	0.5919	0.5587	0.5654	17182
weighted avg	0.7552	0.7917	0.7690	17182

ROC AUC: 0.6483454236900112

Confusion matrix - Random Forest





```
In [35]: # Handle class imbalance (simple and clean)
from sklearn.ensemble import RandomForestClassifier
from imblearn.over_sampling import SMOTE
from sklearn.metrics import classification_report

# Convert data to processed arrays for SMOTE
X_train_trans = preprocessor.fit_transform(X_train)
X_test_trans = preprocessor.transform(X_test)

sm = SMOTE(random_state=42)
X_res, y_res = sm.fit_resample(X_train_trans, y_train)
print('Resampled training data shape:', X_res.shape)

# Retrain Random Forest on balanced data
rf_bal = RandomForestClassifier(n_estimators=200, class_weight='balanced')
rf_bal.fit(X_res, y_res)

# Evaluate on test set
y_pred_bal = rf_bal.predict(X_test_trans)
print('\nBalanced RF model results:')
print(classification_report(y_test, y_pred_bal, digits=4))
```

Resampled training data shape: (113336, 16)

Balanced RF model results:

	precision	recall	f1-score	support
0	0.3402	0.3540	0.3470	3014
1	0.8614	0.8540	0.8577	14168
accuracy			0.7663	17182
macro avg	0.6008	0.6040	0.6023	17182
weighted avg	0.7700	0.7663	0.7681	17182

```
In [36]: # Store baseline predictions for later comparison
y_pred = pipe_rf.predict(X_test) # or pipe_lr if you want logistic
print("Stored baseline model predictions for comparison.")
```

Stored baseline model predictions for comparison.

```
In [37]: # Compare baseline vs balanced model performance
from sklearn.metrics import classification_report
import pandas as pd

def get_metrics_dict(y_true, y_pred, label):
    rep = classification_report(y_true, y_pred, output_dict=True)
    return {
        "Model": label,
        "Accuracy": rep["accuracy"],
        "Precision_0": rep["0"]["precision"],
        "Recall_0": rep["0"]["recall"],
        "Precision_1": rep["1"]["precision"],
        "Recall_1": rep["1"]["recall"],
        "F1_macro": rep["macro avg"]["f1-score"]
    }

try:
    baseline_metrics = get_metrics_dict(y_test, y_pred, "Baseline")
    balanced_metrics = get_metrics_dict(y_test, y_pred_bal, "Balanced")
    df_compare = pd.DataFrame([baseline_metrics, balanced_metrics])
    display(df_compare)
except Exception as e:
    print("Could not compare models:", e)
```

	Model	Accuracy	Precision_0	Recall_0	Precision_1	Recall_1	F1_macro
0	Baseline	0.791701	0.340305	0.199735	0.843509	0.917631	0.565368
1	Balanced_SMOTE	0.766267	0.340242	0.354015	0.861384	0.853967	0.602326

```
In [38]: # Small GridSearch for RandomForest
from sklearn.model_selection import GridSearchCV
rf_for_grid = RandomForestClassifier(random_state=42, class_weight='balanced')
pipe_grid = Pipeline([('pre', preprocessor), ('clf', rf_for_grid)])
param_grid = {'clf__n_estimators': [100, 200], 'clf__max_depth': [None]}
grid = GridSearchCV(pipe_grid, param_grid, cv=3, scoring='f1', n_jobs=-1)
grid.fit(X_train, y_train)
print('Best params:', grid.best_params_)
best_model = grid.best_estimator_
y_pred = best_model.predict(X_test)
print('\nBest model report:'); print(classification_report(y_test, y_pred))
```

Fitting 3 folds for each of 8 candidates, totalling 24 fits

```
/Users/shivalimuthukumar/anaconda3/lib/python3.11/site-packages/pandas/core/arrays/masked.py:61: UserWarning: Pandas requires version '1.3.6' or newer of 'bottleneck' (version '1.3.5' currently installed).
    from pandas.core import (
/Users/shivalimuthukumar/anaconda3/lib/python3.11/site-packages/pandas/core/arrays/masked.py:61: UserWarning: Pandas requires version
```

```
n '1.3.6' or newer of 'bottleneck' (version '1.3.5' currently installed).
    from pandas.core import (
/Users/shivalimuthukumar/anaconda3/lib/python3.11/site-packages/pandas/core/arrays/masked.py:61: UserWarning: Pandas requires version '1.3.6' or newer of 'bottleneck' (version '1.3.5' currently installed).
    from pandas.core import (
/Users/shivalimuthukumar/anaconda3/lib/python3.11/site-packages/pandas/core/arrays/masked.py:61: UserWarning: Pandas requires version '1.3.6' or newer of 'bottleneck' (version '1.3.5' currently installed).
    from pandas.core import (
/Users/shivalimuthukumar/anaconda3/lib/python3.11/site-packages/pandas/core/arrays/masked.py:61: UserWarning: Pandas requires version '1.3.6' or newer of 'bottleneck' (version '1.3.5' currently installed).
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/Users/shivalimuthukumar/anaconda3/lib/python3.11/site-packages/pandas/core/arrays/masked.py:61: UserWarning: Pandas requires version '1.3.6' or newer of 'bottleneck' (version '1.3.5' currently installed).
    from pandas.core import (
/Users/shivalimuthukumar/anaconda3/lib/python3.11/site-packages/pandas/core/arrays/masked.py:61: UserWarning: Pandas requires version '1.3.6' or newer of 'bottleneck' (version '1.3.5' currently installed).
    from pandas.core import (
Best params: {'clf__max_depth': None, 'clf__min_samples_split': 2,
'clf__n_estimators': 200}
```

Best model report:

	precision	recall	f1-score	support
0	0.3403	0.1997	0.2517	3014
1	0.8435	0.9176	0.8790	14168
accuracy			0.7917	17182
macro avg	0.5919	0.5587	0.5654	17182
weighted avg	0.7552	0.7917	0.7690	17182

In [39]: # Save the final model

```
final_model = best_model if 'best_model' in globals() else pipe_rf
model_path = '/Users/shivalimuthukumar/Desktop/flipkart_final_model'
joblib.dump(final_model, model_path)
print('Saved model to', model_path)
test_out = X_test.copy(); test_out['y_true']=y_test; test_out['y_pr
if hasattr(final_model.named_steps['clf'], 'predict_proba'): test_ou
test_out.to_csv("/Users/shivalimuthukumar/Desktop/test_predictions.
print("Saved test predictions to /Users/shivalimuthukumar/Desktop/t
```

Saved model to /Users/shivalimuthukumar/Desktop/flipkart_final_mod
el.joblib

Saved test predictions to /Users/shivalimuthukumar/Desktop/test_pr
edictions.csv

In []: