Install dependencies

```
!pip -q install pandas numpy scikit-learn matplotlib xgboost shap
```

Connect to Drive and set Directory Paths

```
from google.colab import drive
drive.mount("/content/drive")
```

```
Mounted at /content/drive
```

```
from pathlib import Path

PROJECT = "churn_prediction_business_pipeline"
BASE = Path("/content/drive/MyDrive") / PROJECT
DATA_DIR = BASE / "data"
PLOTS_DIR = BASE / "plots"
MODELS_DIR = BASE / "models"

for d in [DATA_DIR, PLOTS_DIR, MODELS_DIR]:
    d.mkdir(parents=True, exist_ok=True)

print("BASE:", BASE)
```

```
BASE: /content/drive/MyDrive/churn_prediction_business_pipeline
```

Load-clean-split Dataset

```
# The dataset is available on the github link below
# https://github.com/IBM/telco-customer-churn-on-icp4d.git
# Download the csv file and add it to drive

import pandas as pd
from pathlib import Path

DATA_PATH = Path("/content/drive/MyDrive/churn_prediction_business_pipeline/data/Telco-Customer-Churn.csv")

df = pd.read_csv(DATA_PATH)
df.head()
```

	customerID	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService	MultipleLines	InternetService	OnlineSecurity
0	7590-VHVEG	Female	0	Yes	No	1	No	No phone service	DSL	No
1	5575-GNVDE	Male	0	No	No	34	Yes	No	DSL	Yes
2	3668-QPYBK	Male	0	No	No	2	Yes	No	DSL	Yes
3	7795-CFOCW	Male	0	No	No	45	No	No phone service	DSL	Yes
4	9237-HQITU	Female	0	No	No	2	Yes	No	Fiber optic	No

5 rows × 21 columns

```
# Quick confirmation
df.shape
df.columns
df["Churn"].value_counts()
```

	count
Churn	
No	5174
Yes	1869

dtype: int64

```
# target: "Churn" -> 1/0
df["Churn"] = (df["Churn"].astype(str).str.strip().str.lower() == "yes").astype(int)

# TotalCharges has blanks; coerce to numeric
df["TotalCharges"] = pd.to_numeric(df["TotalCharges"], errors="coerce")

# Drop ID column
if "customerID" in df.columns:
    df = df.drop(columns=["customerID"])

# Drop rows with missing TotalCharges
df = df.dropna(subset=["TotalCharges"]).reset_index(drop=True)

df.shape, df["Churn"].mean()
```

```
((7032, 20), np.float64(0.26578498293515357))
```

```
# Train/Validation/Test Split
from sklearn.model_selection import train_test_split

X = df.drop(columns=["Churn"])
y = df["Churn"]

X_train, X_temp, y_train, y_temp = train_test_split(
    X, y, test_size=0.30, random_state=42, stratify=y
)
X_val, X_test, y_val, y_test = train_test_split(
    X_temp, y_temp, test_size=0.50, random_state=42, stratify=y_temp
)

print(X_train.shape, X_val.shape, X_test.shape)
print("Churn rate:", y_train.mean(), y_val.mean(), y_test.mean())
```

```
(4922, 19) (1055, 19) (1055, 19)
Churn rate: 0.2657456318569687 0.2663507109004739 0.26540284360189575
```

```
# Preprocess: one-hot encode categoricals + scale numerics

from sklearn.compose import ColumnTransformer
from sklearn.preprocessing import OneHotEncoder, StandardScaler
from sklearn.pipeline import Pipeline

num_cols = X_train.select_dtypes(include=["int64","float64"]).columns.tolist()
cat_cols = [c for c in X_train.columns if c not in num_cols]

preprocess = ColumnTransformer(
    transformers=[
        ("num", StandardScaler(), num_cols),
        ("cat", OneHotEncoder(handle_unknown="ignore"), cat_cols),
    ]
)

num_cols, cat_cols[:5], len(cat_cols)
```

```
(['SeniorCitizen', 'tenure', 'MonthlyCharges', 'TotalCharges'],
 ['gender', 'Partner', 'Dependents', 'PhoneService', 'MultipleLines'],
 15)
```

Models

```
# Model 1 - Logistic Regression Baseline

from sklearn.linear_model import LogisticRegression
from sklearn.metrics import roc_auc_score, average_precision_score

lr_model = Pipeline(steps=[
    ("preprocess", preprocess),
    ("clf", LogisticRegression(max_iter=2000, class_weight="balanced"))
])

lr_model.fit(X_train, y_train)

val_proba_lr = lr_model.predict_proba(X_val)[:, 1]
print("LR Val ROC-AUC:", roc_auc_score(y_val, val_proba_lr))
print("LR Val PR-AUC :", average_precision_score(y_val, val_proba_lr))
```

```
LR Val ROC-AUC: 0.8531292817273121
LR Val PR-AUC : 0.6536612309798182
```

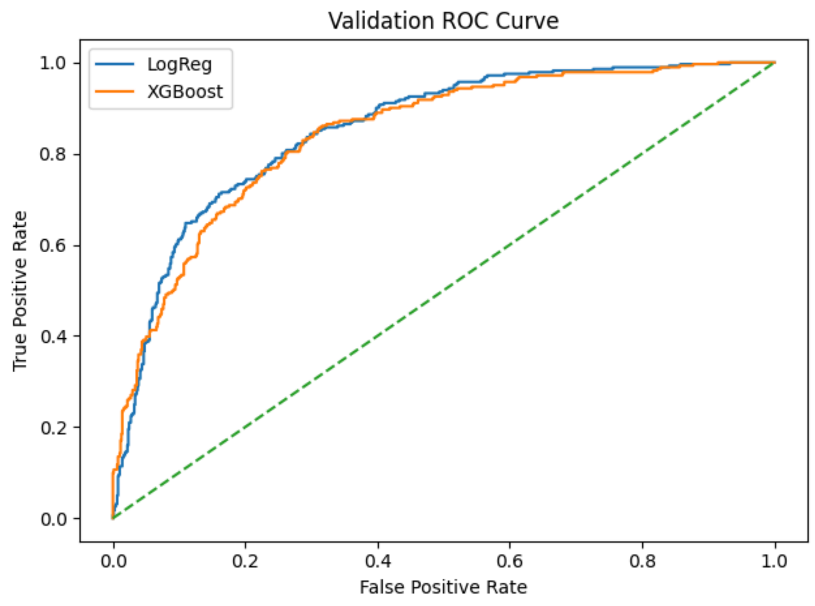
```
# Model 2 - XGBoost
```

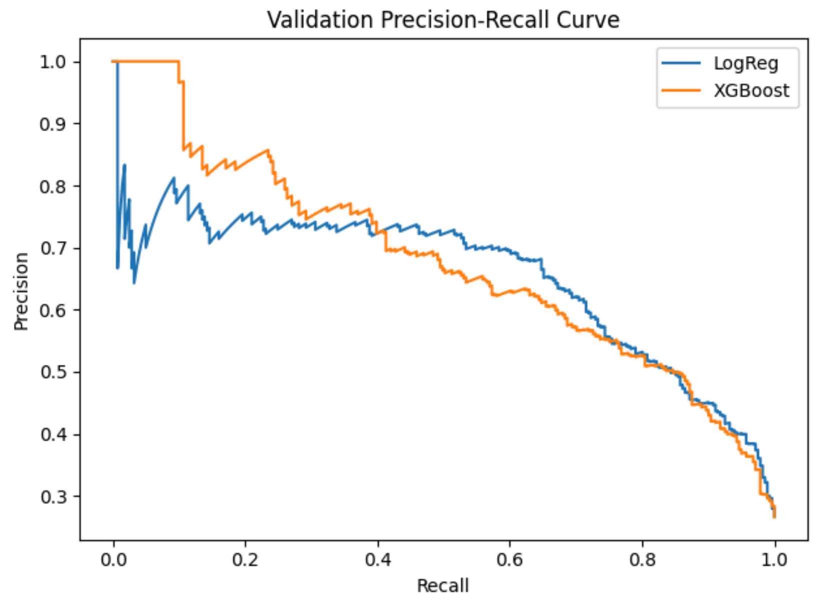
```
from xgboost import XGBClassifier

xgb_model = Pipeline(steps=[
    ("preprocess", preprocess),
    ("clf", XGBClassifier(
        n_estimators=500,
        max_depth=4,
        learning_rate=0.05,
        subsample=0.9,
        colsample_bytree=0.9,
        reg_lambda=1.0,
        random_state=42,
        eval_metric="logloss",
        n_jobs=-1
    ))
])

xgb_model.fit(X_train, y_train)

val_proba_xgb = xgb_model.predict_proba(X_val)[:, 1]
print("XGB Val ROC-AUC:", roc_auc_score(y_val, val_proba_xgb))
print("XGB Val PR-AUC :", average_precision_score(y_val, val_proba_xgb))
```

```
XGB Val ROC-AUC: 0.8432577450412426
XGB Val PR-AUC : 0.6776818476179516
```

Plot ROC and PR curves

```
import matplotlib.pyplot as plt
from sklearn.metrics import roc_curve, precision_recall_curve

def save_plot(path):
    plt.tight_layout()
    plt.savefig(path, dpi=200)
    plt.show()

# ROC
fpr_lr, tpr_lr, _ = roc_curve(y_val, val_proba_lr)
fpr_x, tpr_x, _ = roc_curve(y_val, val_proba_xgb)

plt.figure()
plt.plot(fpr_lr, tpr_lr, label="LogReg")
plt.plot(fpr_x, tpr_x, label="XGBoost")
plt.plot([0,1],[0,1], linestyle="--")
plt.title("Validation ROC Curve")
plt.xlabel("False Positive Rate")
plt.ylabel("True Positive Rate")
plt.legend()
save_plot(PLOTS_DIR / "val_roc.png")

# PR
p_lr, r_lr, _ = precision_recall_curve(y_val, val_proba_lr)
p_x, r_x, _ = precision_recall_curve(y_val, val_proba_xgb)

plt.figure()
plt.plot(r_lr, p_lr, label="LogReg")
plt.plot(r_x, p_x, label="XGBoost")
plt.title("Validation Precision-Recall Curve")
plt.xlabel("Recall")
plt.ylabel("Precision")
plt.legend()
save_plot(PLOTS_DIR / "val_pr.png")
```





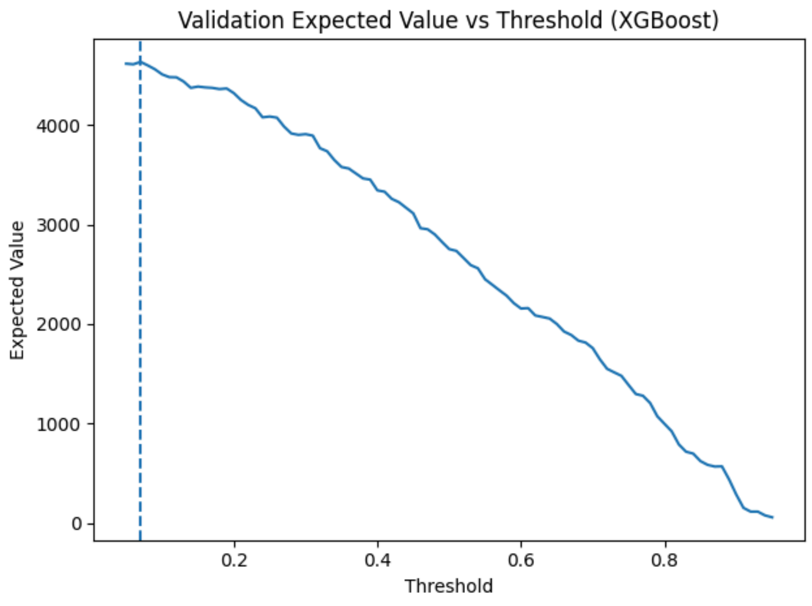
Threshold Optimization (Business style)

```
import numpy as np
from pathlib import Path

COST_CONTACT = 1.0
VALUE_SAVE = 20.0

def expected_value(y_true, y_proba, threshold):
    pred = (y_proba >= threshold).astype(int)
    # contact = pred==1
    contacted = pred.sum()
    # true positives = churners correctly contacted
    tp = ((pred == 1) & (y_true == 1)).sum()
    # value - cost
    return tp * VALUE_SAVE - contacted * COST_CONTACT

thresholds = np.linspace(0.05, 0.95, 91)
values = [expected_value(y_val.values, val_proba_xgb, t) for t in thresholds]
best_idx = int(np.argmax(values))
best_t = float(thresholds[best_idx])

best_t, values[best_idx]


MODELS_DIR = Path("/content/drive/MyDrive/churn_prediction_business_pipeline/models")
MODELS_DIR.mkdir(parents=True, exist_ok=True)

threshold_path = MODELS_DIR / "best_threshold.txt"
```

```
with open(threshold_path, "w") as f:
    f.write(str(best_t))

print("Saved best threshold to:", threshold_path)
```

```
Saved best threshold to: /content/drive/MyDrive/churn_prediction_business_pipeline/models/best_threshold.txt
```

```
# Plot

plt.figure()
plt.plot(thresholds, values)
plt.title("Validation Expected Value vs Threshold (XGBoost)")
plt.xlabel("Threshold")
plt.ylabel("Expected Value")
plt.axvline(best_t, linestyle="--")
save_plot(PLOTS_DIR / "val_threshold_value.png")
print("Best threshold:", best_t)
```



```
Best threshold: 0.07
```

Final Test evaluation (Using best threshold)

```
from sklearn.metrics import confusion_matrix, classification_report

test_proba = xgb_model.predict_proba(X_test)[:, 1]
test_pred = (test_proba >= best_t).astype(int)

print("TEST ROC-AUC:", roc_auc_score(y_test, test_proba))
print("TEST PR-AUC :", average_precision_score(y_test, test_proba))

print("\nConfusion matrix:\n", confusion_matrix(y_test, test_pred))
print("\nReport:\n", classification_report(y_test, test_pred, target_names=["no-churn","churn"]))
```

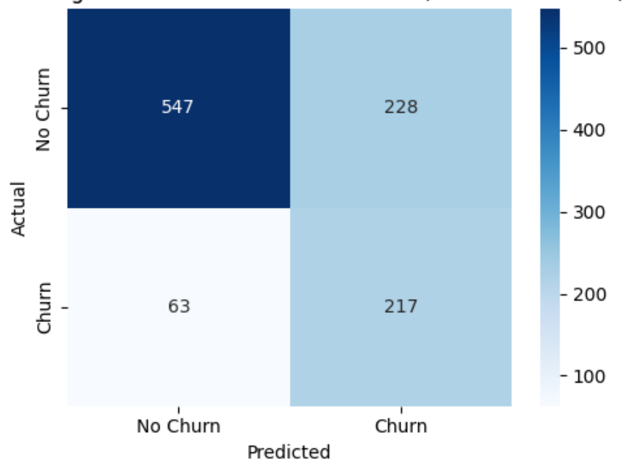
```
TEST ROC-AUC: 0.8147096774193548
TEST PR-AUC : 0.5903343652823299

Confusion matrix:
 [[363 412]
 [ 19 261]]

Report:
               precision    recall  f1-score   support

    no-churn       0.95      0.47      0.63       775
       churn       0.39      0.93      0.55       280

    accuracy                           0.59      1055
   macro avg       0.67      0.70      0.59      1055
weighted avg       0.80      0.59      0.61      1055
```

```
from sklearn.metrics import confusion_matrix, classification_report

test_proba = lr_model.predict_proba(X_test)[:, 1]
test_pred = (test_proba >= best_t).astype(int)
```

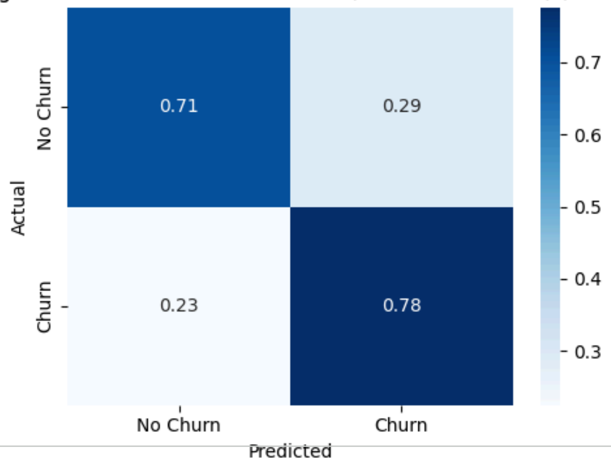
```
print("TEST ROC-AUC:", roc_auc_score(y_test, test_proba))
print("TEST PR-AUC :", average_precision_score(y_test, test_proba))

print("\nConfusion matrix:\n", confusion_matrix(y_test, test_pred))
print("\nReport:\n", classification_report(y_test, test_pred, target_names=["no-churn","churn"]))
```

```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix

def plot_and_save_cm(y_true, y_pred, title, out_path, normalize=False):
    cm = confusion_matrix(y_true, y_pred)

    if normalize:
        cm_plot = cm.astype(float) / cm.sum(axis=1, keepdims=True)
        fmt = ".2f"
        suffix = " (Normalized)"
    else:
        cm_plot = cm
        fmt = "d"
        suffix = ""

    plt.figure(figsize=(5,4))
    sns.heatmap(
        cm_plot,
        annot=True,
        fmt=fmt,
        cmap="Blues",
        xticklabels=["No Churn", "Churn"],
        yticklabels=["No Churn", "Churn"],
    )
    plt.xlabel("Predicted")
    plt.ylabel("Actual")
    plt.title(title + suffix)
    plt.tight_layout()
    plt.savefig(out_path, dpi=200)
    plt.show()

# Logistic Regression @ 0.5
lr_test_proba = lr_model.predict_proba(X_test)[:, 1]
lr_test_pred_05 = (lr_test_proba >= 0.5).astype(int)

plot_and_save_cm(
    y_test, lr_test_pred_05,
    title="Logistic Regression - Test Confusion Matrix (Threshold = 0.50)",
    out_path=PLOTS_DIR / "cm_lr_thresh_0p50.png",
    normalize=False
)
plot_and_save_cm(
    y_test, lr_test_pred_05,
    title="Logistic Regression - Test Confusion Matrix (Threshold = 0.50)",
    out_path=PLOTS_DIR / "cm_lr_thresh_0p50_normalized.png",
    normalize=True
)

# XGBoost @ 0.5
xgb_test_proba = xgb_model.predict_proba(X_test)[:, 1]
xgb_test_pred_05 = (xgb_test_proba >= 0.5).astype(int)

plot_and_save_cm(
    y_test, xgb_test_pred_05,
    title="XGBoost - Test Confusion Matrix (Threshold = 0.50)",
    out_path=PLOTS_DIR / "cm_xgb_thresh_0p50.png",
    normalize=False
)
plot_and_save_cm(
    y_test, xgb_test_pred_05,
    title="XGBoost - Test Confusion Matrix (Threshold = 0.50)",
    out_path=PLOTS_DIR / "cm_xgb_thresh_0p50_normalized.png",
    normalize=True
)

# XGBoost @ optimized threshold (business-aware)
xgb_test_pred_opt = (xgb_test_proba >= best_t).astype(int)

plot_and_save_cm(
    y_test, xgb_test_pred_opt,
    title=f"XGBoost - Test Confusion Matrix (Optimized Threshold = {best_t:.2f})",
    out_path=PLOTS_DIR / "cm_xgb_thresh_opt.png",
    normalize=False
)
plot_and_save_cm(
    y_test, xgb_test_pred_opt,
    title=f"XGBoost - Test Confusion Matrix (Optimized Threshold = {best_t:.2f})",
    out_path=PLOTS_DIR / "cm_xgb_thresh_opt_normalized.png",
    normalize=True
)

print("Saved confusion matrices to:", PLOTS_DIR)
```

Logistic Regression - Test Confusion Matrix (Threshold = 0.50)



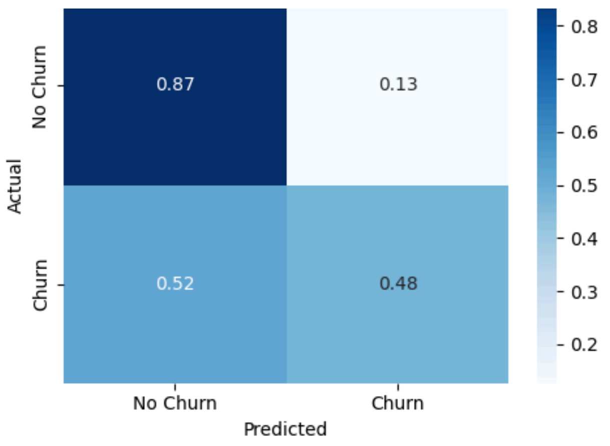
Logistic Regression - Test Confusion Matrix (Threshold = 0.50) (Normalized)



SHAP explainability (XGBoost)

XGBoost - Test Confusion Matrix (Threshold = 0.50)

```
import shap

# Processed feature matrix + feature names from the pipeline
ohe = xgb_model.named_steps["preprocess"].named_transformers_["cat"]
cat_feature_names = ohe.get_feature_names_out(cat_cols).tolist()
feature_names = num_cols + cat_feature_names

X_val_processed = xgb_model.named_steps["preprocess"].transform(X_val)

booster = xgb_model.named_steps["clf"]
explainer = shap.TreeExplainer(booster)
shap_values = explainer.shap_values(X_val_processed)

plt.figure()
shap.summary_plot(shap_values, X_val_processed, feature_names=feature_names, show=False)
plt.tight_layout()
plt.savefig(PLOTS_DIR / "shap_summary.png", dpi=200)
plt.show()
```



XGBoost - Test Confusion Matrix (Optimized Threshold = 0.07)