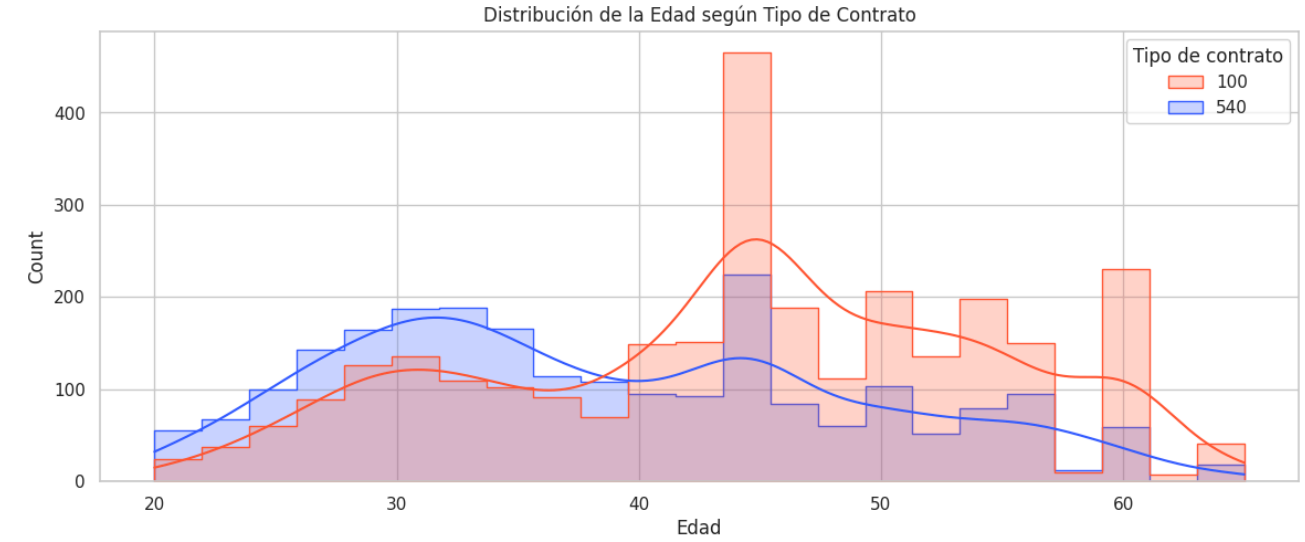
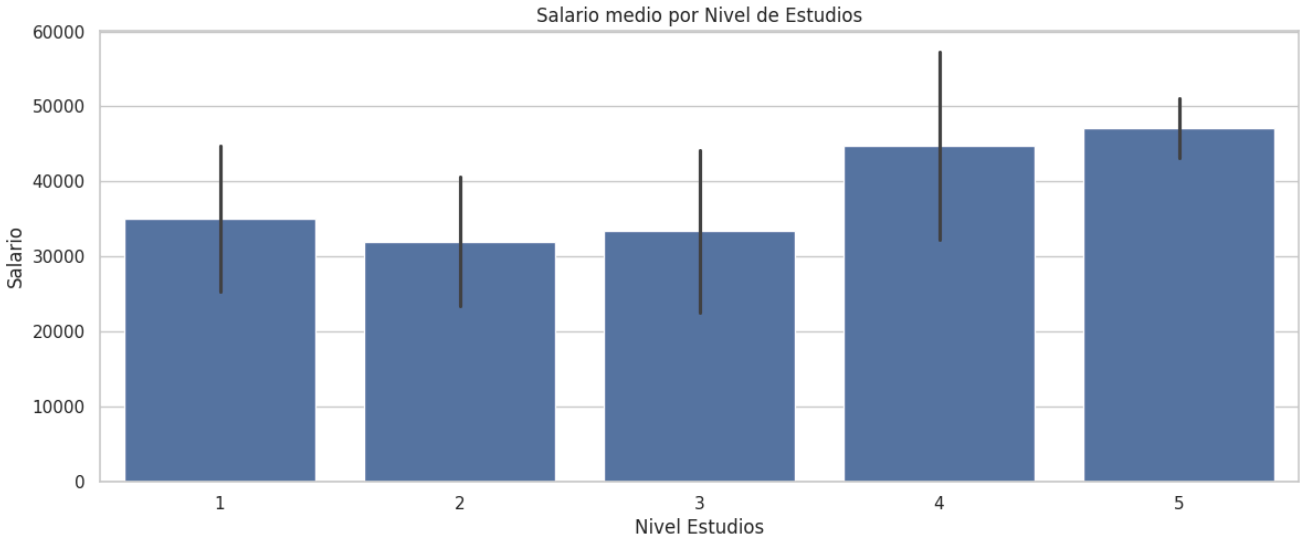
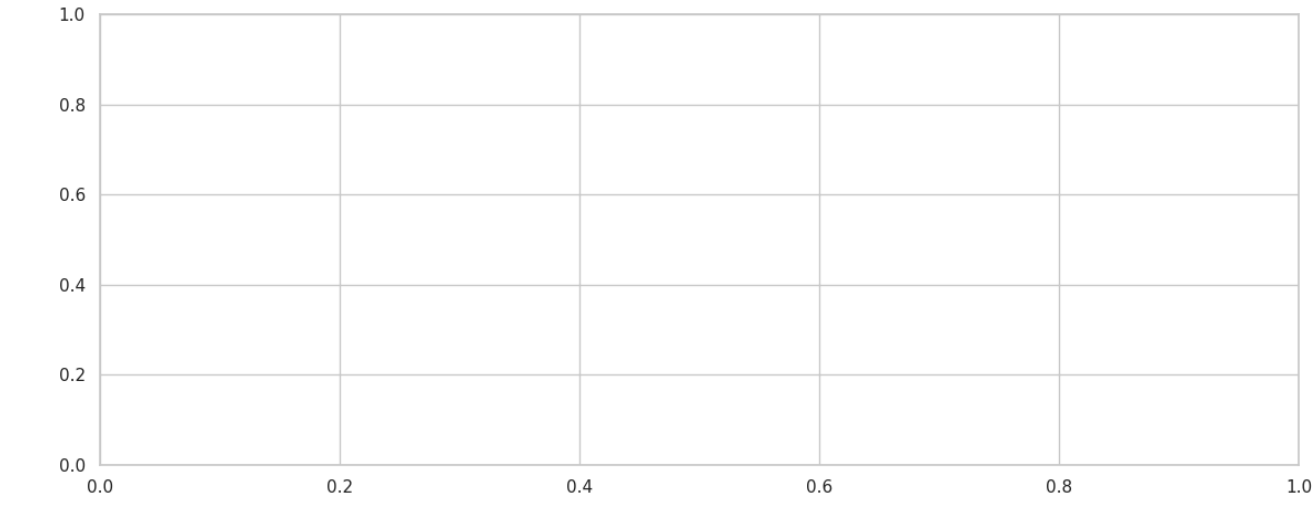
```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

file_path = "/content/DatasetFinalNC.xlsx"
df = pd.read_excel(file_path)
```

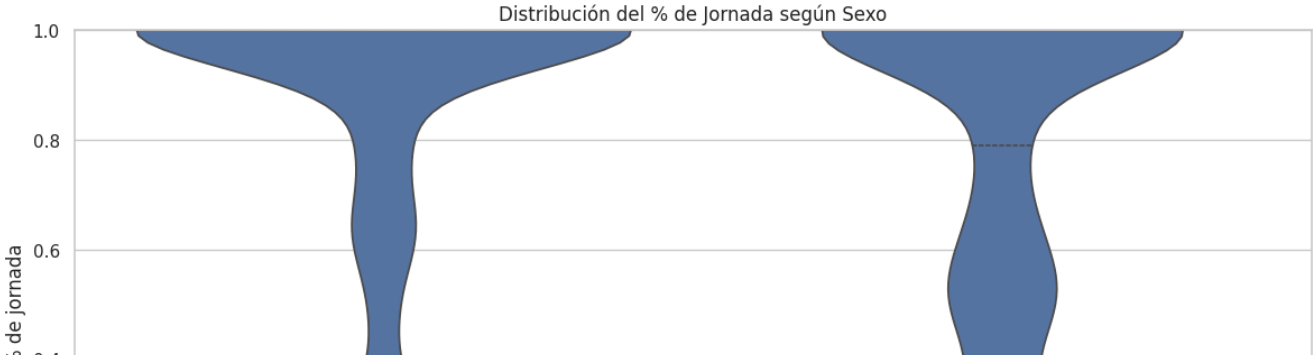
```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from scipy.stats import pearsonr


file_path = "/content/DatasetFinalNC.xlsx"
df = pd.read_excel(file_path)


sns.set(style="whitegrid")


corr_edad_contrato = pearsonr(df['Edad'], df['Tipo de contrato'])[0]
corr_salario_estudios = pearsonr(df['Salario'], df['Nivel Estudios'])[0]
corr_jornada_sexo = pearsonr(df['% de jornada'], df['Sexo'])[0]


fig, axes = plt.subplots(3, 1, figsize=(14, 18))


palette_contratos = {100: "#FF5733", 540: "#335CFF"}
sns.histplot(
    data=df,
    x='Edad',
    hue='Tipo de contrato',
    kde=True,
    element='step',
    common_norm=False,
    ax=axes[0],
    palette=palette_contratos
)
axes[0].set_title(f'Distribución de la Edad según Tipo de Contrato')


sns.barplot(data=df, x='Nivel Estudios', y='Salario', ci='sd', ax=axes[1])
axes[1].set_title(f'Salario medio por Nivel de Estudios')


plt.figure(figsize=(12, 6))
sns.violinplot(data=df, x='Sexo', y='% de jornada', inner='quartile')
plt.title(f'Distribución del % de Jornada según Sexo')
plt.xlabel('Sexo')
plt.ylabel('% de jornada')
plt.xticks([0, 1], ['Mujer (0)', 'Hombre (1)'])
plt.ylim(0, 1)
plt.grid(True)
plt.tight_layout()
plt.show()
```

```
<ipython-input-1-dfffbdcbf418>:37: FutureWarning:

The `ci` parameter is deprecated. Use `errorbar='sd'` for the same effect.

  sns.barplot(data=df, x='Nivel Estudios', y='Salario', ci='sd', ax=axes[1])
```



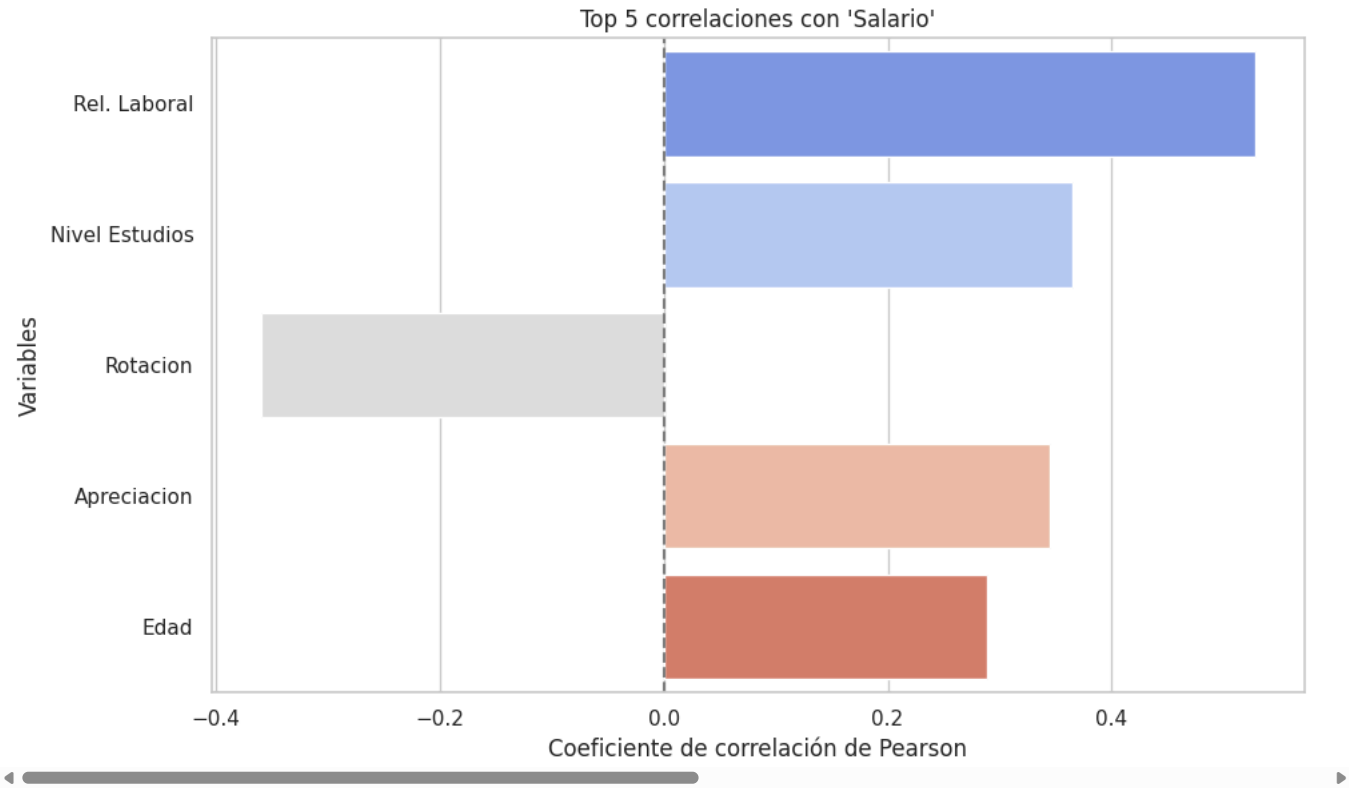






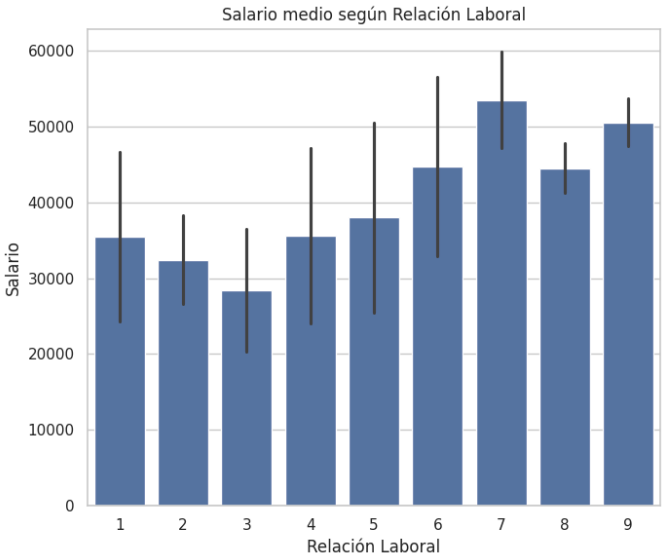

```
import matplotlib.pyplot as plt
import seaborn as sns

correlation_matrix = df.corr(numeric_only=True)

salario_corr = correlation_matrix["Salario"].drop("Salario").sort_values(key=abs, ascending=False).head(5)


plt.figure(figsize=(10, 6))
sns.barplot(x=salario_corr.values, y=salario_corr.index, palette="coolwarm", orient='h')
plt.title("Top 5 correlaciones con 'Salario'")
plt.xlabel("Coeficiente de correlación de Pearson")
plt.ylabel("Variables")
plt.axvline(0, color='gray', linestyle='--')
plt.tight_layout()
plt.show()
```

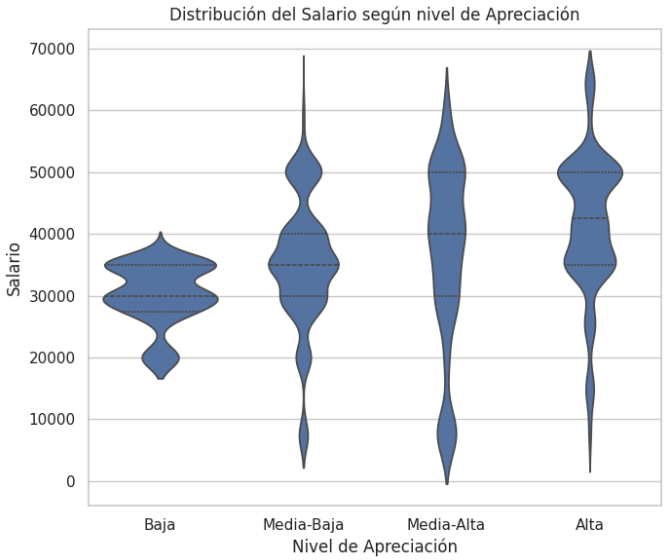
```
<ipython-input-3-5b0a4cef57e7>:12: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v0.14.0. Assign the `y` variable to `hue` and set `le

  sns.barplot(x=salario_corr.values, y=salario_corr.index, palette="coolwarm", orient='h')
```



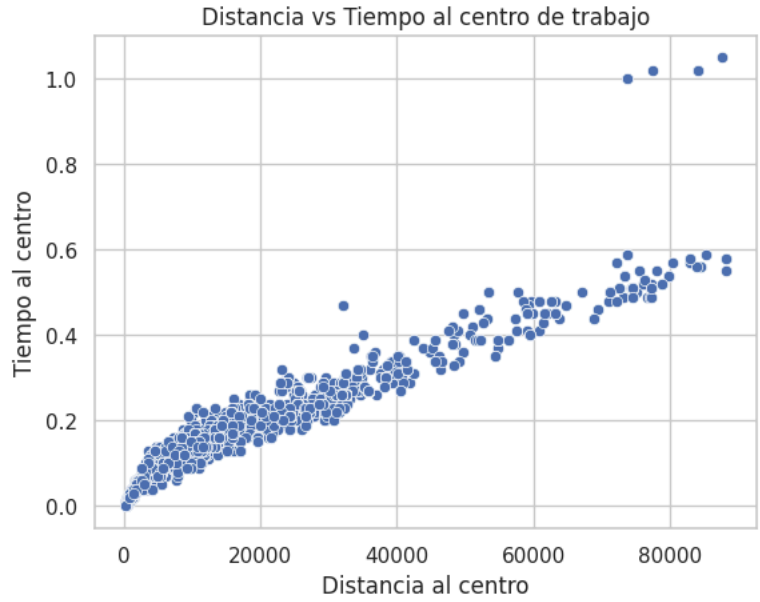

```
df['Apreciacion_bin'] = pd.cut(df['Apreciacion'], bins=[0, 3, 5, 7, 10], labels=['Baja', 'Media-Baja', 'Media-Alta', 'Alta'])

plt.figure(figsize=(14, 6))

plt.subplot(1, 2, 1)
sns.barplot(data=df, x='Rel. Laboral', y='Salario', ci='sd')
plt.title('Salario medio según Relación Laboral')
plt.xlabel('Relación Laboral')
plt.ylabel('Salario')

plt.subplot(1, 2, 2)
sns.violinplot(data=df, x='Apreciacion_bin', y='Salario', inner='quartile')
plt.title('Distribución del Salario según nivel de Apreciación')
plt.xlabel('Nivel de Apreciación')
plt.ylabel('Salario')

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

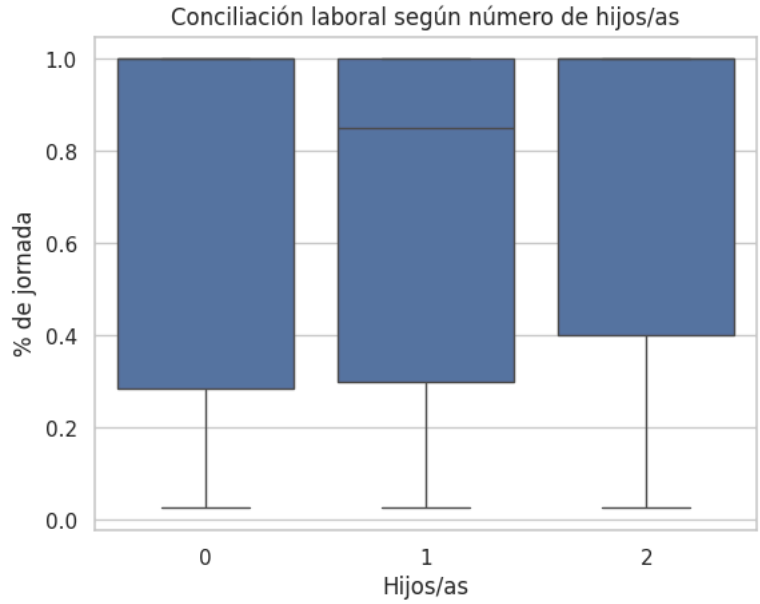
```
<ipython-input-19-5d1f602db407>:12: FutureWarning:

The `ci` parameter is deprecated. Use `errorbar='sd'` for the same effect.

  sns.barplot(data=df, x='Rel. Laboral', y='Salario', ci='sd')
```



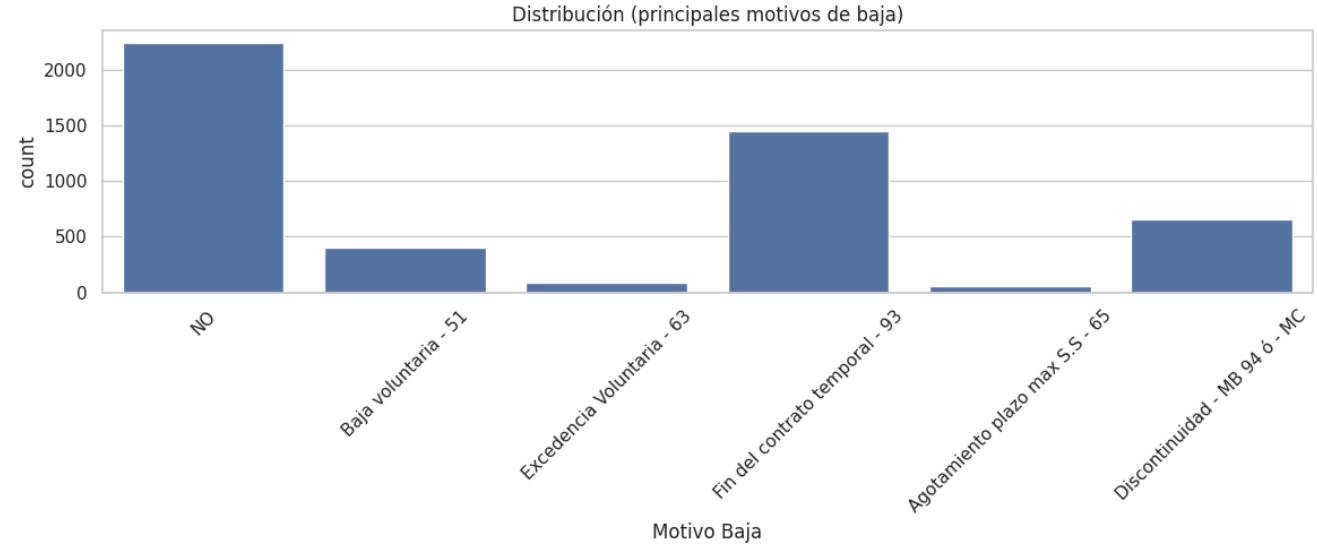


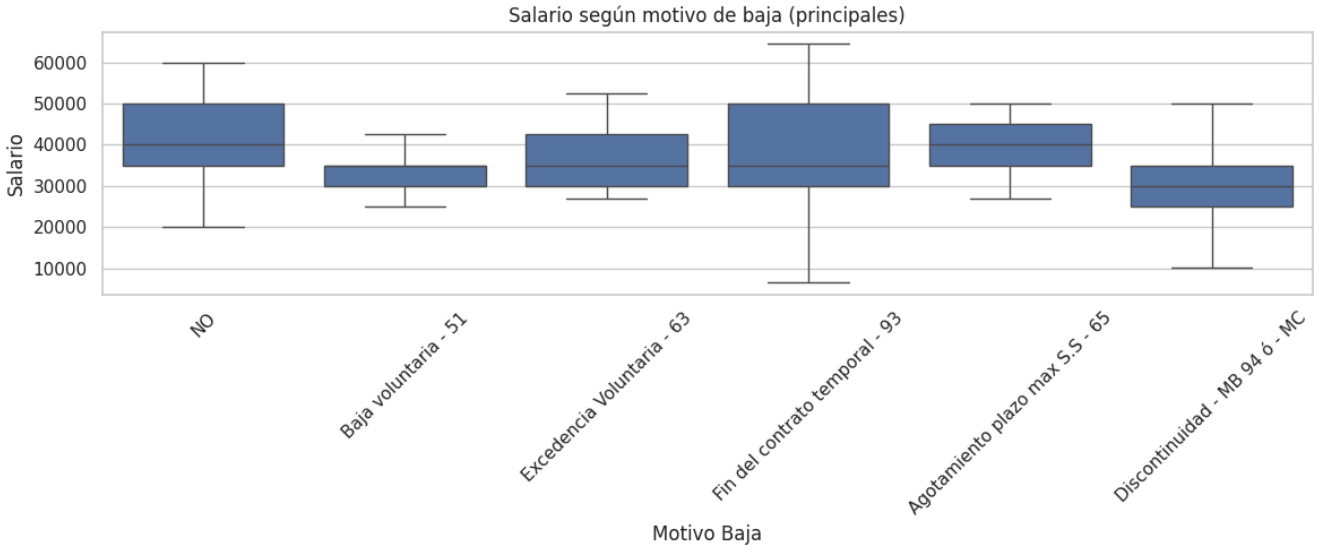

```
sns.scatterplot(data=df, x='Distancia al centro', y='Tiempo al centro')
plt.title('Distancia vs Tiempo al centro de trabajo')
plt.show()

sns.boxplot(x='Hijos/as', y='% de jornada', data=df)
plt.title('Conciliación laboral según número de hijos/as')
plt.show()
```

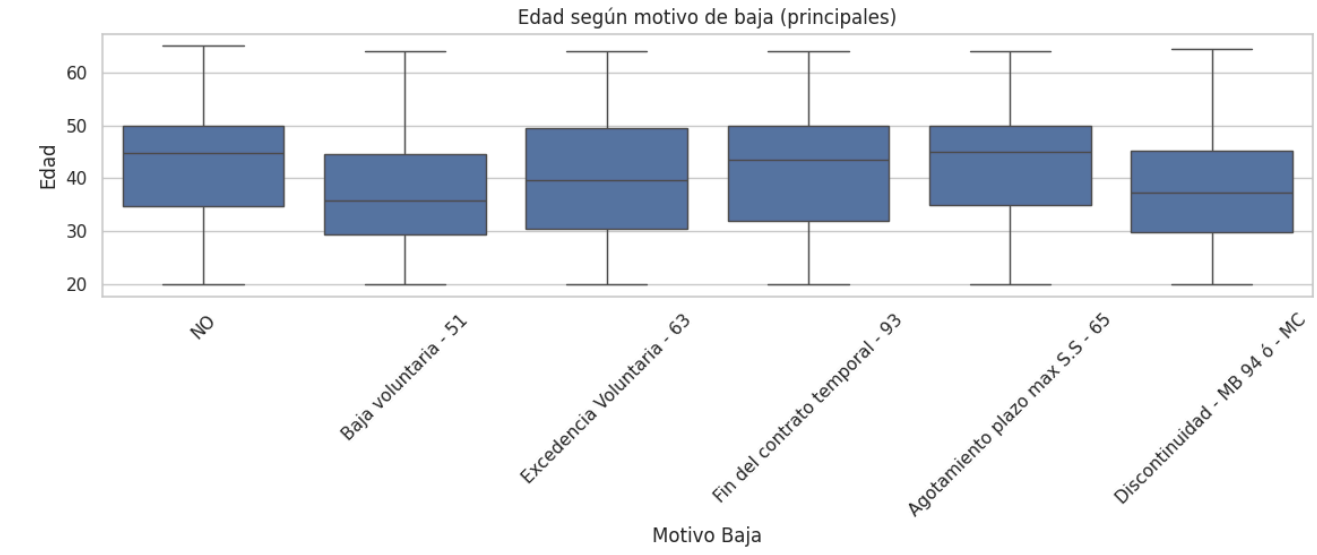





```
top_motivos = df[df['Motivo Baja'] != 'NO']['Motivo Baja'].value_counts().head(5).index.tolist()

motivos_seleccionados = ['NO'] + top_motivos
df_filtrado = df[df['Motivo Baja'].isin(motivos_seleccionados)]

fig, axes = plt.subplots(3, 1, figsize=(12, 15))

sns.countplot(ax=axes[0], data=df_filtrado, x='Motivo Baja')
axes[0].set_title('Distribución (principales motivos de baja)')
axes[0].tick_params(axis='x', rotation=45)

sns.boxplot(ax=axes[1], data=df_filtrado, x='Motivo Baja', y='Salario', showfliers=False)
axes[1].set_title('Salario según motivo de baja (principales)')
axes[1].tick_params(axis='x', rotation=45)

sns.boxplot(ax=axes[2], data=df_filtrado, x='Motivo Baja', y='Edad')
axes[2].set_title('Edad según motivo de baja (principales)')
axes[2].tick_params(axis='x', rotation=45)

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

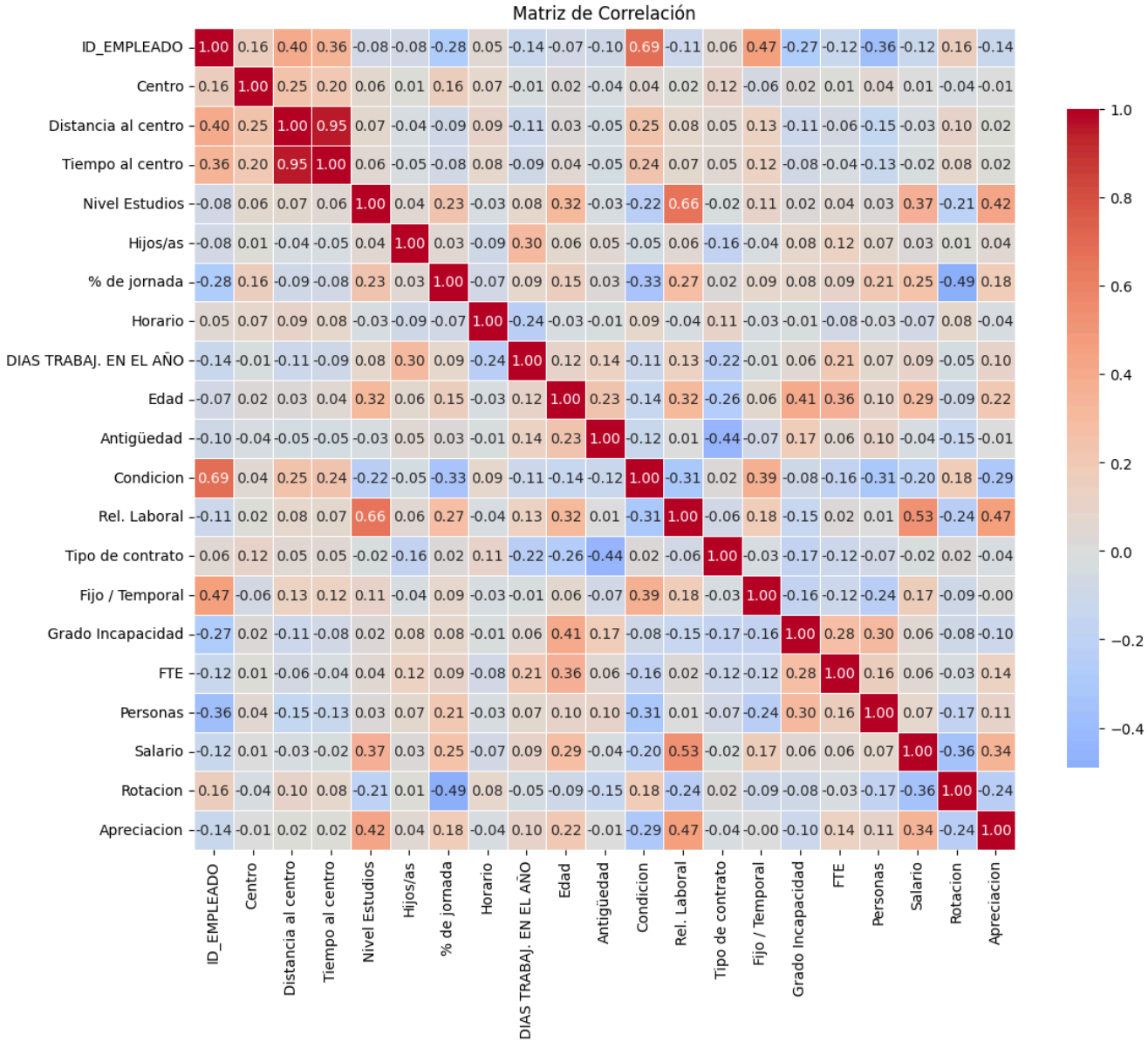






Análisis de negocio

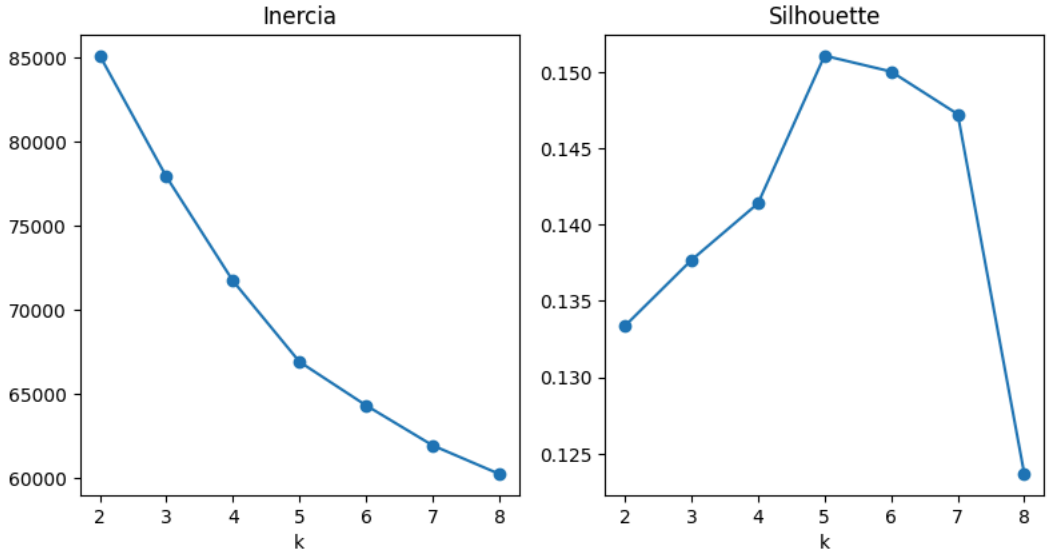
```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

file_path = "/content/DatasetFinalNC.xlsx"
df = pd.read_excel(file_path)

corr_matrix = df.corr(numeric_only=True)

abs_corr = corr_matrix.abs()
mask = (abs_corr > 0.2).sum(axis=1) > 1
filtered_corr = corr_matrix.loc[mask, mask]

plt.figure(figsize=(12, 10))
sns.heatmap(filtered_corr, annot=True, fmt=".2f", cmap="coolwarm", center=0,
            square=True, linewidths=0.5, cbar_kws={"shrink": 0.8})
plt.title("Matriz de Correlación")
plt.tight_layout()
plt.show()
```




```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

from sklearn.preprocessing import StandardScaler
```

```
from sklearn.cluster import KMeans
from sklearn.metrics import (silhouette_score,
                             calinski_harabasz_score,
                             davies_bouldin_score,
                             adjusted_rand_score)

FILE_IN  = "/content/DatasetFinalNC.xlsx"
FILE_OUT = "MasterDataset_k5.xlsx"

df = pd.read_excel(FILE_IN)

feat_cols = [
    "Centro","Sexo","Condicion","Rel. Laboral","Tipo de contrato",
    "Fijo / Temporal","Nivel Estudios","Antigüedad","Edad",
    "Salario","Apreciacion","Distancia al centro",
    "Tiempo al centro","Hijos/as","% de jornada","Horario",
    "Grado Incapacidad","FTE","Personas"
]
X = df[feat_cols].fillna(df[feat_cols].mean())
X_scaled = StandardScaler().fit_transform(X)

ks = range(2, 9)

def dunn_index(X, labels):
    """Devuelve el índice de Dunn (max → mejor)"""
    from scipy.spatial.distance import cdist, pdist
    clusters = [X[labels == k] for k in np.unique(labels)]
    intra_dists = [pdist(c, metric='euclidean').max() if len(c) > 1 else 0
                   for c in clusters]
    max_intra = max(intra_dists)
    inter = np.inf
    for i in range(len(clusters)):
        for j in range(i + 1, len(clusters)):
            dist_ij = cdist(clusters[i], clusters[j], metric='euclidean').min()
            inter = min(inter, dist_ij)
    return inter / max_intra if max_intra > 0 else 0

def gap_statistic(X, refs=10, k_max=10):
    """Calcula Gap Statistic (Tibshirani, 2001) para k = 1 … k_max"""
    from sklearn.cluster import KMeans
    from numpy.random import default_rng
    rng = default_rng(42)
    shape = X.shape
    tops = X.max(axis=0); lows = X.min(axis=0)
    gaps = np.zeros(k_max)
    s_k  = np.zeros(k_max)
    for k in range(1, k_max + 1):
        km = KMeans(n_clusters=k, n_init=10, random_state=42).fit(X)
        orig_disp = np.log(km.inertia_)
        ref_disps = np.zeros(refs)
        for i in range(refs):
            random_ref = rng.uniform(lows, tops, size=shape)
            ref_km = KMeans(n_clusters=k, n_init=3, random_state=42).fit(random_ref)
            ref_disps[i] = np.log(ref_km.inertia_)
        gaps[k-1] = ref_disps.mean() - orig_disp
        s_k[k-1]  = np.sqrt(((ref_disps - ref_disps.mean())**2).sum() / refs) * np.sqrt(1 + 1/refs)
    return gaps, s_k

inertia, silh, ch, dunn, db = [], [], [], [], []
gap, gap_err = gap_statistic(X_scaled, refs=20, k_max=max(ks))

for k in ks:
    km = KMeans(n_clusters=k, n_init=10, random_state=42)
    labels = km.fit_predict(X_scaled)

    inertia.append(km.inertia_)
    silh.append(silhouette_score(X_scaled, labels))
    ch.append(calinski_harabasz_score(X_scaled, labels))
    dunn.append(dunn_index(X_scaled, labels))
    db.append(davies_bouldin_score(X_scaled, labels))

def bootstrap_stability(X, k, n_iter=30, sample_frac=0.8):
    n = X.shape[0]
    labels_master = KMeans(n_clusters=k, n_init=10,
                           random_state=42).fit_predict(X)
    scores = []
    rng = np.random.default_rng(123)
    for _ in range(n_iter):
        idx = rng.choice(n, int(n*sample_frac), replace=False)
        labels_sub = KMeans(n_clusters=k, n_init=10,
                            random_state=42).fit_predict(X[idx])
        scores.append(adjusted_rand_score(labels_master[idx], labels_sub))
```

```
    return np.mean(scores)

stab = [bootstrap_stability(X_scaled, k) for k in ks]

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

plt.subplot(231); plt.plot(ks, inertia, 'o-'); plt.title("Inercia"); plt.xlabel("k")
plt.subplot(232); plt.plot(ks, silh, 'o-');    plt.title("Silhouette"); plt.xlabel("k")

plt.tight_layout(); plt.show()

k_final = 5
km5 = KMeans(n_clusters=k_final, n_init=10, random_state=42)
df["cluster_5"] = km5.fit_predict(X_scaled)

print("\n=== Métricas para k = 5 ===")
print("Silhouette:",       silh[ks.index(5)])
print("Calinski-Harabasz:", ch[ks.index(5)])
print("Dunn:",              dunn[ks.index(5)])
print("Gap:",               gap[4])
print("Estabilidad ARI:",   stab[ks.index(5)])

df.to_excel(FILE_OUT, index=False)
print(f"\nArchivo guardado en: {FILE_OUT}")
```




```
=== Métricas para k = 5 ===
Silhouette: 0.1510636470193829
Calinski-Harabasz: 601.8014978817861
Dunn: 0.03332887161603404
Gap: 0.46081460906701643
Estabilidad ARI: 0.9885181649709127

Archivo guardado en: MasterDataset_k5.xlsx
```

```
import pandas as pd

FILE   = "/content/DatasetFinal.xlsx"
CL_COL = "cluster_5"

df = pd.read_excel(FILE)

counts = df[CL_COL].value_counts().sort_index()
print("\nNº de empleados por cluster:")
print(counts)
```

```
Nº de empleados por cluster:
cluster_5
0    1259
1    1430
2     763
3     652
4    1061
Name: count, dtype: int64
```

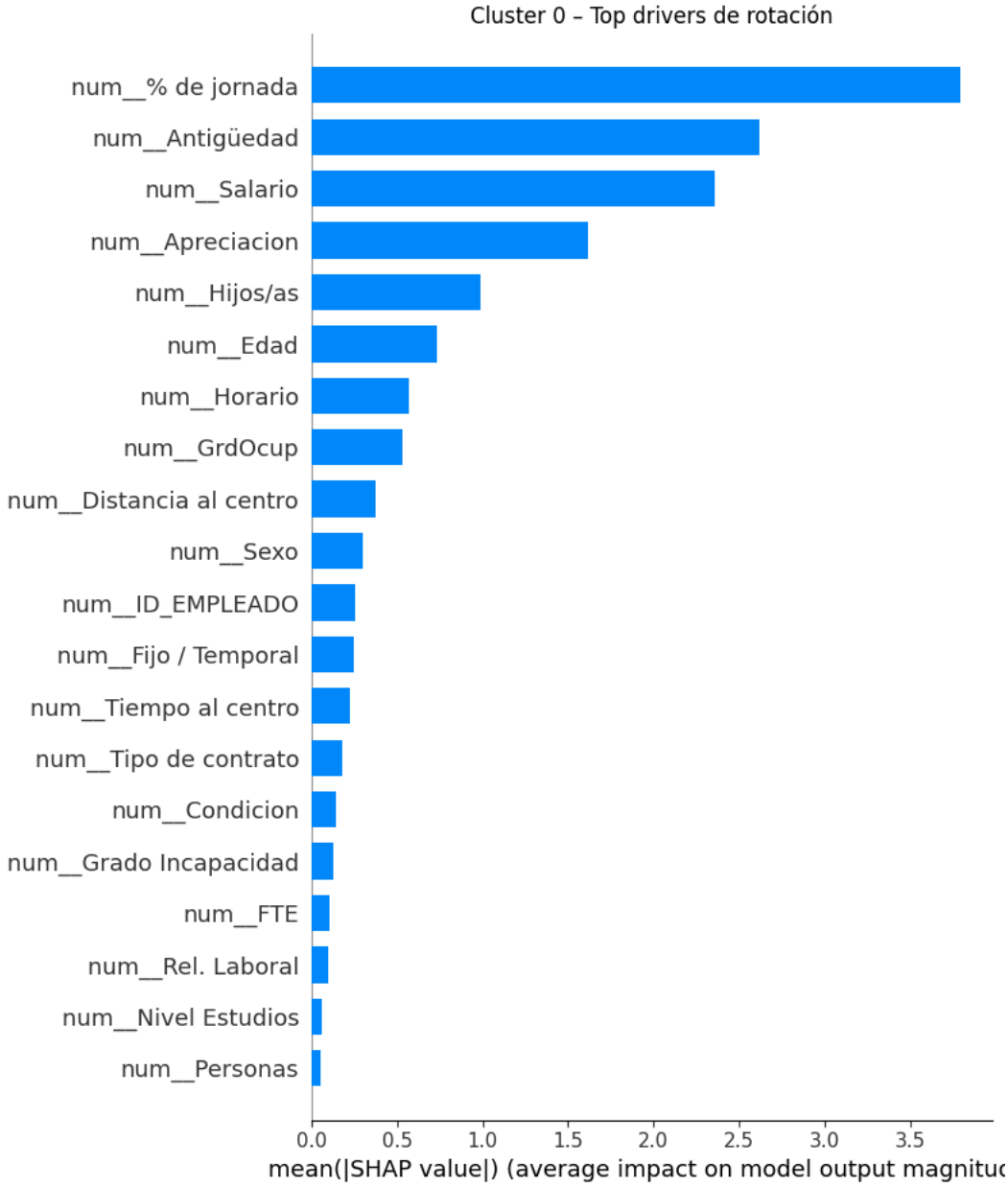
```
# PREGUNTA 1: Perfil detallado de cada cluster
import pandas as pd
```

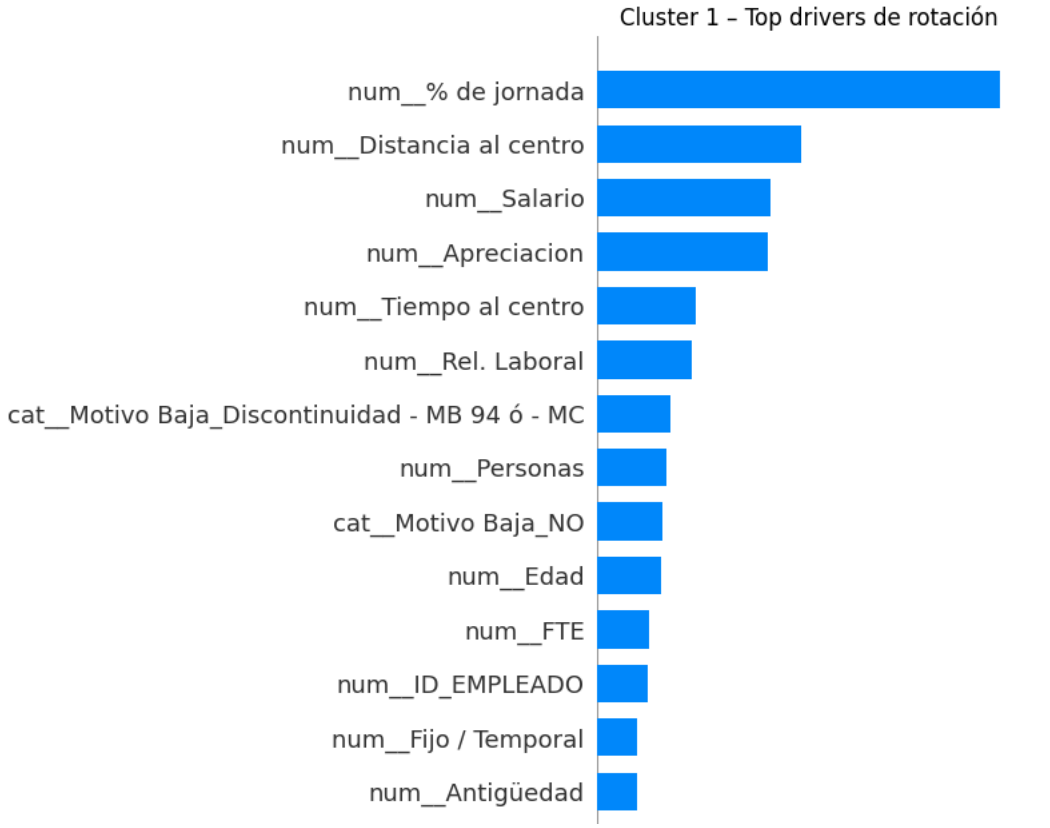
```
FILE_IN  = "/content/DatasetFinal.xlsx"
FILE_OUT = "Cluster_Profile.xlsx"

df = pd.read_excel(FILE_IN)

cont_cols = ["Salario", "Antigüedad", "Edad", "Apreciacion", "Distancia al centro",
             "Nivel Estudios", "Rel. Laboral", "FTE"]
cat_cols  = ["Fijo / Temporal", "Rotacion"]


cont_stats = (
    df.groupby("cluster_5")[cont_cols]
      .agg(["mean", "median"])
      .round(2)
)


cont_stats.columns = ['_'.join(col) for col in cont_stats.columns]

agg = (
    df.groupby("cluster_5")
      .agg(
         Temporal_rate=("Fijo / Temporal", "mean"),
         Rotacion_rate=("Rotacion", "mean"),
         Num_empleados=("cluster_5", "size")
      )
      .round(3)
)

profile = pd.concat([agg, cont_stats], axis=1).reset_index()

cols_order = ["cluster_5", "Num_empleados",
              "Salario_mean", "Antigüedad_mean", "Edad_mean", "Apreciacion_mean",
              "Distancia al centro_mean", "Nivel Estudios_mean", "Rel. Laboral_mean", "FTE_mean",
              "Temporal_rate", "Rotacion_rate"]

profile = profile[[col for col in cols_order if col in profile.columns]]

print("\n=== Perfil resumido por cluster ===")
print(profile)

profile.to_excel(FILE_OUT, index=False)
print(f"\nTabla exportada a: {FILE_OUT}")
```

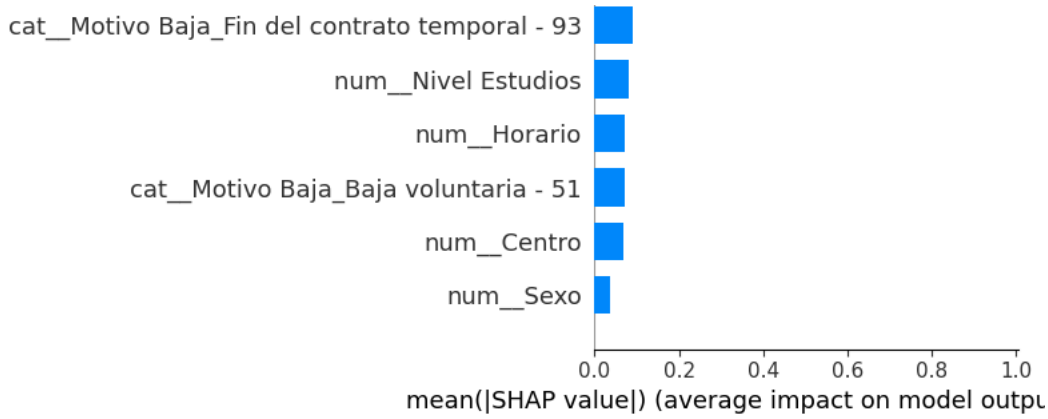
```
=== Perfil resumido por cluster ===
   cluster_5  Num_empleados  Salario_mean  Antigüedad_mean  Edad_mean  \
0          0           1259      38719.39             5.64      49.78
1          1           1430      32606.60             1.24      32.98
2          2            763      45180.21             5.42      42.83
3          3            652      53531.44             4.70      50.46
4          4           1061      26312.44             7.72      37.46

   Apreciacion_mean  Distancia al centro_mean  Nivel Estudios_mean  \
0              5.38                  19426.96                 3.20
1              5.17                  23938.67                 2.82
2              7.82                  20222.55                 3.87
3              7.10                  28683.25                 4.28
4              4.51                  23295.84                 2.34

   Rel. Laboral_mean  FTE_mean  Temporal_rate  Rotacion_rate
0               4.03      0.72          0.192          0.109
1               3.56      0.56          0.302          0.281
2               6.80      0.68          0.020          0.038
3               7.68      0.57          0.890          0.025
4               2.90      0.56          0.287          0.323

Tabla exportada a: Cluster_Profile.xlsx
```

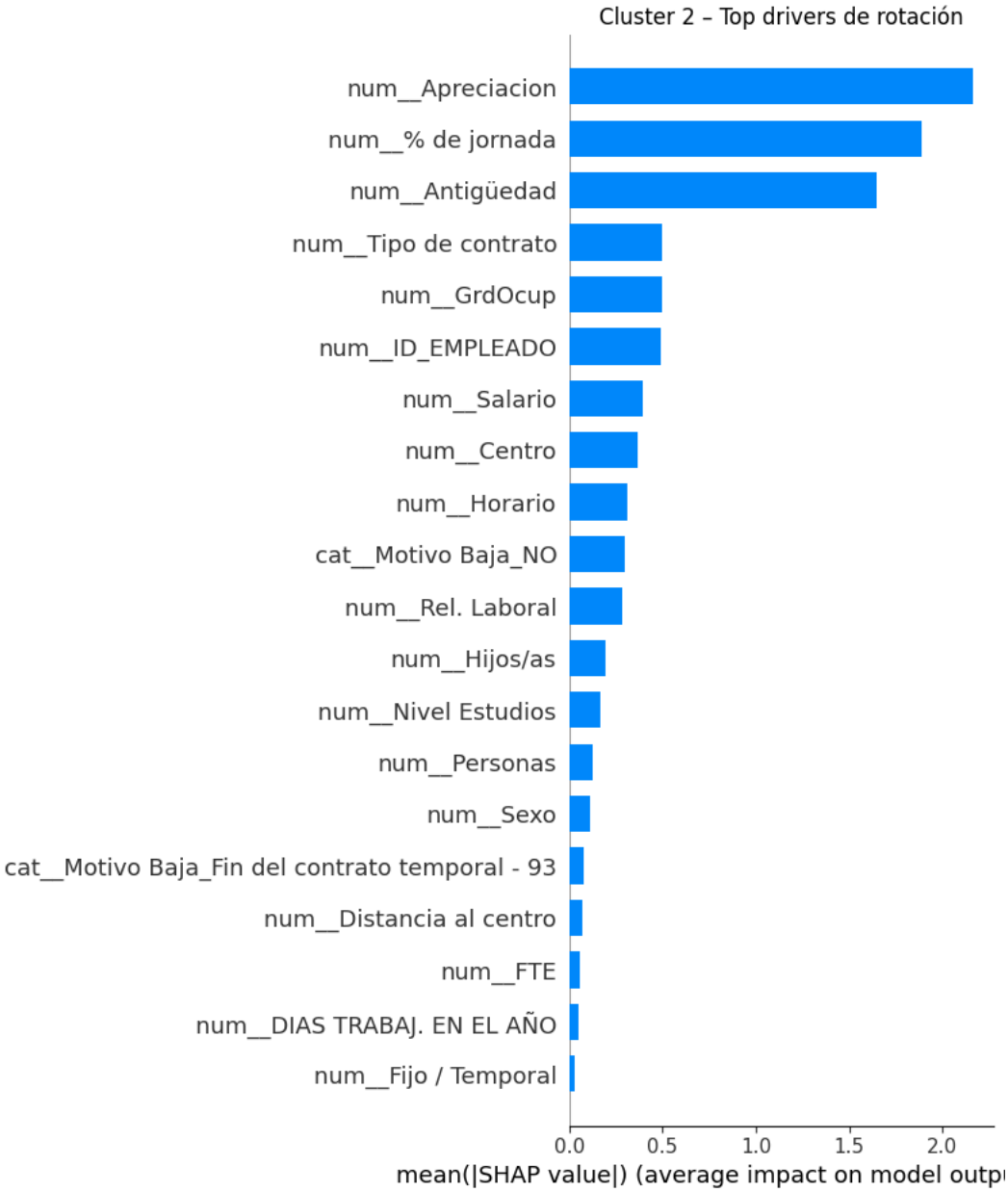
```
# PREGUNTA 2: ¿Qué variables disparan la rotación dentro de cada cluster?

import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline
from sklearn.linear_model import LogisticRegression
import shap, matplotlib.pyplot as plt

FILE = "/content/MasterDataset_k5_noOut_modificado_final2.xlsx"
df = pd.read_excel(FILE)
```

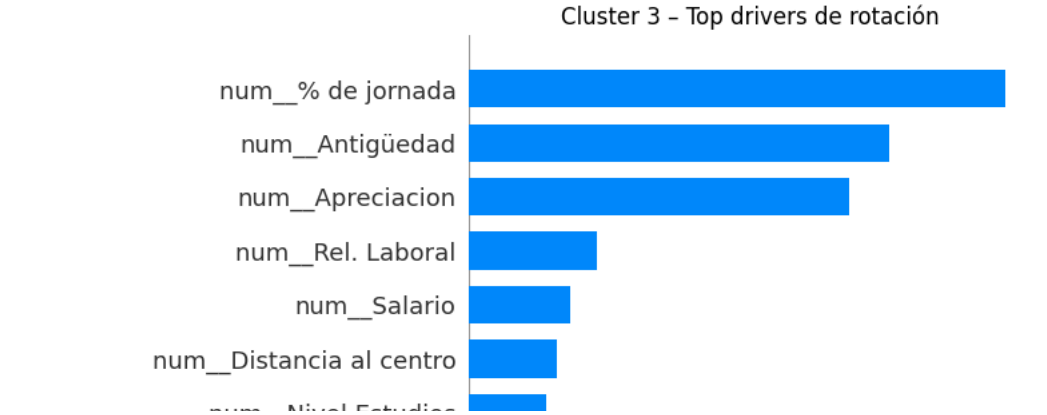
```
target = "Rotacion"
num_cols = df.select_dtypes(include="number").columns.tolist()
cat_cols = df.select_dtypes(include="object").columns.tolist()
num_cols.remove(target)

results = []

for cl in sorted(df["cluster_5"].unique()):
    dfi = df[df["cluster_5"] == cl].copy()

    X = dfi[num_cols + cat_cols]
    y = dfi[target]

    numeric_transformer = Pipeline([("scaler", StandardScaler())])
    categorical_transform = OneHotEncoder(handle_unknown="ignore")

    preproc = ColumnTransformer(
        [("num", numeric_transformer, num_cols),
         ("cat", categorical_transform, cat_cols)]
    )

    model = LogisticRegression(max_iter=1000, class_weight="balanced")

    pipe = Pipeline([("prep", preproc),
                     ("clf", model)])

    X_train, X_test, y_train, y_test = train_test_split(
        X, y, test_size=0.25, random_state=42, stratify=y)

    pipe.fit(X_train, y_train)
    auc = pipe.score(X_test, y_test)
    results.append((cl, auc))

    # --- SHAP: dentro del bucle ---
    explainer = shap.Explainer(pipe["clf"], pipe["prep"].transform(X_train))
    shap_values = explainer(pipe["prep"].transform(X_test))

    feature_names = pipe["prep"].get_feature_names_out()
    X_test_transformed = pipe["prep"].transform(X_test)
    X_test_df = pd.DataFrame(X_test_transformed, columns=feature_names)

    shap.summary_plot(shap_values, features=X_test_df, feature_names=feature_names,
                      show=False, plot_type="bar")
    plt.title(f"Cluster {cl} – Top drivers de rotación")
    plt.tight_layout()
    plt.show()

print("\nAUC/Acc por cluster:", results)
```

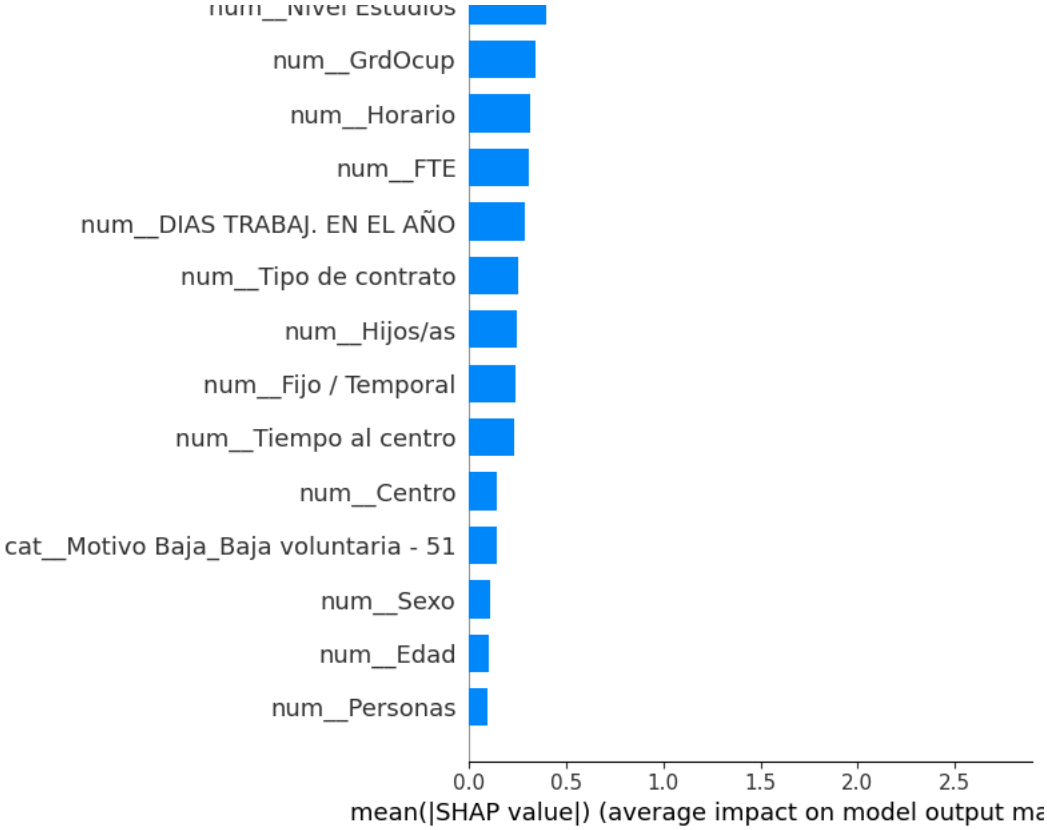

Cluster 0 – Top drivers de rotación
num__% de jornada
num__Antigüedad
num__Salario
num__Apreciacion
num__Hijos/as
num__Edad
num__Horario
num__GrdOcup
num__Distancia al centro
num__Sexo
num__ID_EMPLEADO
num__Fijo / Temporal
num__Tiempo al centro
num__Tipo de contrato
num__Condicion
num__Grado Incapacidad
num__FTE
num__Rel. Laboral
num__Nivel Estudios
num__Personas
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
mean(|SHAP value|) (average impact on model output magnitud

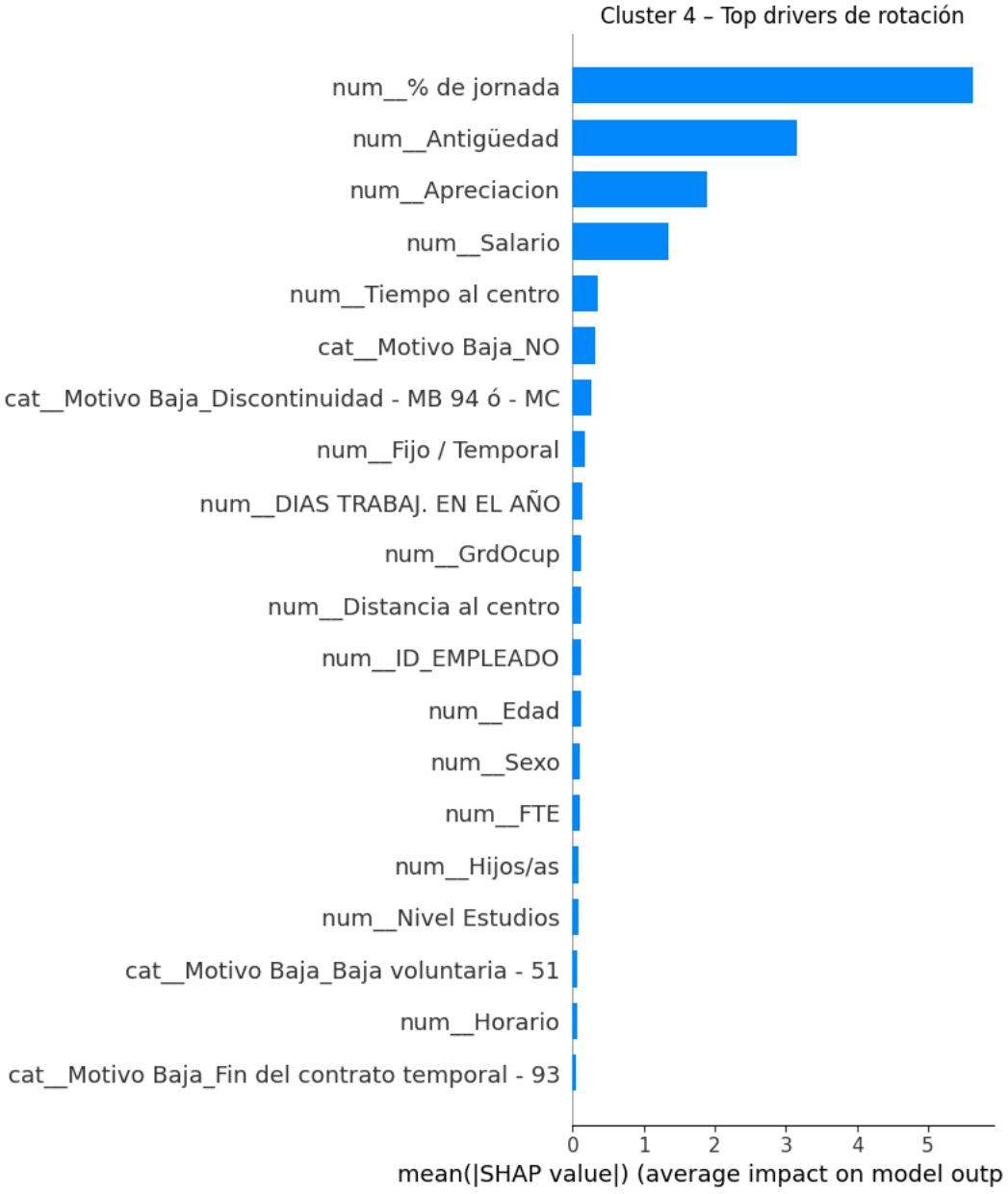

Cluster 1 – Top drivers de rotación
num__% de jornada
num__Distancia al centro
num__Salario
num__Apreciacion
num__Tiempo al centro
num__Rel. Laboral
cat__Motivo Baja_Discontinuidad - MB 94 ó - MC
num__Personas
cat__Motivo Baja_NO
num__Edad
num__FTE
num__ID_EMPLEADO
num__Fijo / Temporal
num__Antigüedad


cat__Motivo Baja_Fin del contrato temporal - 93
num__Nivel Estudios
num__Horario
cat__Motivo Baja_Baja voluntaria - 51
num__Centro
num__Sexo
0.0
0.2
0.4
0.6
0.8
1.0
mean(|SHAP value|) (average impact on model outpu


Cluster 2 – Top drivers de rotación
num__Apreciacion
num__% de jornada
num__Antigüedad
num__Tipo de contrato
num__GrdOcup
num__ID_EMPLEADO
num__Salario
num__Centro
num__Horario
cat__Motivo Baja_NO
num__Rel. Laboral
num__Hijos/as
num__Nivel Estudios
num__Personas
num__Sexo
cat__Motivo Baja_Fin del contrato temporal - 93
num__Distancia al centro
num__FTE
num__DIAS TRABAJ. EN EL AÑO
num__Fijo / Temporal
0.0
0.5
1.0
1.5
2.0
mean(|SHAP value|) (average impact on model outp


Cluster 3 – Top drivers de rotación
num__% de jornada
num__Antigüedad
num__Apreciacion
num__Rel. Laboral
num__Salario
num__Distancia al centro


num__Nivel Estudios
num__GrdOcup
num__Horario
num__FTE
num__DIAS TRABAJ. EN EL AÑO
num__Tipo de contrato
num__Hijos/as
num__Fijo / Temporal
num__Tiempo al centro
num__Centro
cat__Motivo Baja_Baja voluntaria - 51
num__Sexo
num__Edad
num__Personas
0.0
0.5
1.0
1.5
2.0
2.5
mean(|SHAP value|) (average impact on model output ma

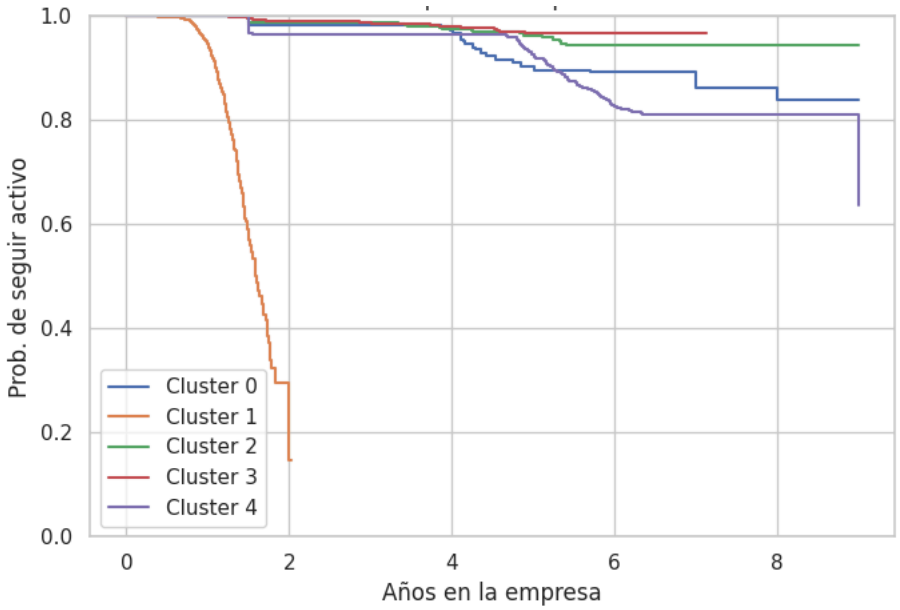

Cluster 4 – Top drivers de rotación
num__% de jornada
num__Antigüedad
num__Apreciacion
num__Salario
num__Tiempo al centro
cat__Motivo Baja_NO
cat__Motivo Baja_Discontinuidad - MB 94 ó - MC
num__Fijo / Temporal
num__DIAS TRABAJ. EN EL AÑO
num__GrdOcup
num__Distancia al centro
num__ID_EMPLEADO
num__Edad
num__Sexo
num__FTE
num__Hijos/as
num__Nivel Estudios
cat__Motivo Baja_Baja voluntaria - 51
num__Horario
cat__Motivo Baja_Fin del contrato temporal - 93
0
1
2
3
4
5
mean(|SHAP value|) (average impact on model outp

```
AUC/Acc por cluster: [(np.int64(0), 0.9873015873015873), (np.int64(1), 0.7150837988826816), (np.int64(2), 0.9842931937172775), (np
```

```
!pip install lifelines --quiet
```

```
  Preparing metadata (setup.py) ... done
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 349.3/349.3 kB 18.1 MB/s eta 0:00:00
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 115.7/115.7 kB 8.8 MB/s eta 0:00:00
  Building wheel for autograd-gamma (setup.py) ... done
```

```
# PREGUNTA 4: ¿Cómo evoluciona la probabilidad de permanecer en la empresa a lo largo del tiempo y cómo difiere por cluster?

import pandas as pd
import matplotlib.pyplot as plt
from lifelines import KaplanMeierFitter, CoxPHFitter

FILE = "/content/DatasetFinal.xlsx"
df   = pd.read_excel(FILE)

surv_df = df[["Antigüedad", "Rotacion", "cluster_5"]].copy()
surv_df.rename(columns={"Antigüedad": "tenure", "Rotacion": "event"}, inplace=True)

km = KaplanMeierFitter()

plt.figure(figsize=(7,5))
for cl in sorted(surv_df["cluster_5"].unique()):
    mask = surv_df["cluster_5"] == cl
    km.fit(durations=surv_df.loc[mask, "tenure"],
           event_observed=surv_df.loc[mask, "event"],
           label=f"Cluster {cl}")
    km.plot(ci_show=False)

plt.title("Curvas Kaplan–Meier por cluster")
plt.xlabel("Años en la empresa")
plt.ylabel("Prob. de seguir activo")
plt.ylim(0,1); plt.grid(True); plt.tight_layout()
plt.show()

cox_df = pd.get_dummies(surv_df, columns=["cluster_5"], drop_first=True)

cox = CoxPHFitter()
cox.fit(cox_df, duration_col="tenure", event_col="event")
cox.print_summary()
```



model	lifelines.CoxPHFitter
duration col	'tenure'
event col	'event'
baseline estimation	breslow
number of observations	5165
number of events observed	927
partial log-likelihood	-6606.80
time fit was run	2025-05-11 21:00:40 UTC

	coef	exp(coef)	se(coef)	coef lower 95%	coef upper 95%	exp(coef) lower 95%	exp(coef) upper 95%	cmp to	z	p	-log2(p)
cluster_5_1	3.78	43.82	0.15	3.48	4.08	32.54	59.01	0.00	24.90	<0.005	452.15
cluster_5_2	-1.20	0.30	0.21	-1.61	-0.80	0.20	0.45	0.00	-5.84	<0.005	27.52
cluster_5_3	-1.19	0.31	0.26	-1.71	-0.67	0.18	0.51	0.00	-4.49	<0.005	17.09
cluster_5_4	0.26	1.30	0.11	0.05	0.48	1.05	1.61	0.00	2.42	0.02	6.03

Concordance	0.79
Partial AIC	13221.61
log-likelihood ratio test	1418.15 on 4 df
-log2(p) of ll-ratio test	1013.51

```
pip install lifelines
```

```
Requirement already satisfied: lifelines in /usr/local/lib/python3.11/dist-packages (0.30.0)
Requirement already satisfied: numpy>=1.14.0 in /usr/local/lib/python3.11/dist-packages (from lifelines) (2.0.2)
Requirement already satisfied: scipy>=1.7.0 in /usr/local/lib/python3.11/dist-packages (from lifelines) (1.15.2)
Requirement already satisfied: pandas>=2.1 in /usr/local/lib/python3.11/dist-packages (from lifelines) (2.2.2)
Requirement already satisfied: matplotlib>=3.0 in /usr/local/lib/python3.11/dist-packages (from lifelines) (3.10.0)
Requirement already satisfied: autograd>=1.5 in /usr/local/lib/python3.11/dist-packages (from lifelines) (1.7.0)
Requirement already satisfied: autograd-gamma>=0.3 in /usr/local/lib/python3.11/dist-packages (from lifelines) (0.5.0)
Requirement already satisfied: formulaic>=0.2.2 in /usr/local/lib/python3.11/dist-packages (from lifelines) (1.1.1)
Requirement already satisfied: interface-meta>=1.2.0 in /usr/local/lib/python3.11/dist-packages (from formulaic>=0.2.2->lifelines)
Requirement already satisfied: typing-extensions>=4.2.0 in /usr/local/lib/python3.11/dist-packages (from formulaic>=0.2.2->lifelines
Requirement already satisfied: wrapt>=1.0 in /usr/local/lib/python3.11/dist-packages (from formulaic>=0.2.2->lifelines) (1.17.2)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (1.3.2
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (4.57
Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (1.4.8
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (24.2)
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (11.2.1)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (3.2.3
Requirement already satisfied: python-dateutil>=2.7 in /usr/local/lib/python3.11/dist-packages (from matplotlib>=3.0->lifelines) (2
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-packages (from pandas>=2.1->lifelines) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-packages (from pandas>=2.1->lifelines) (2025.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-packages (from python-dateutil>=2.7->matplotlib>=3.0->life
```

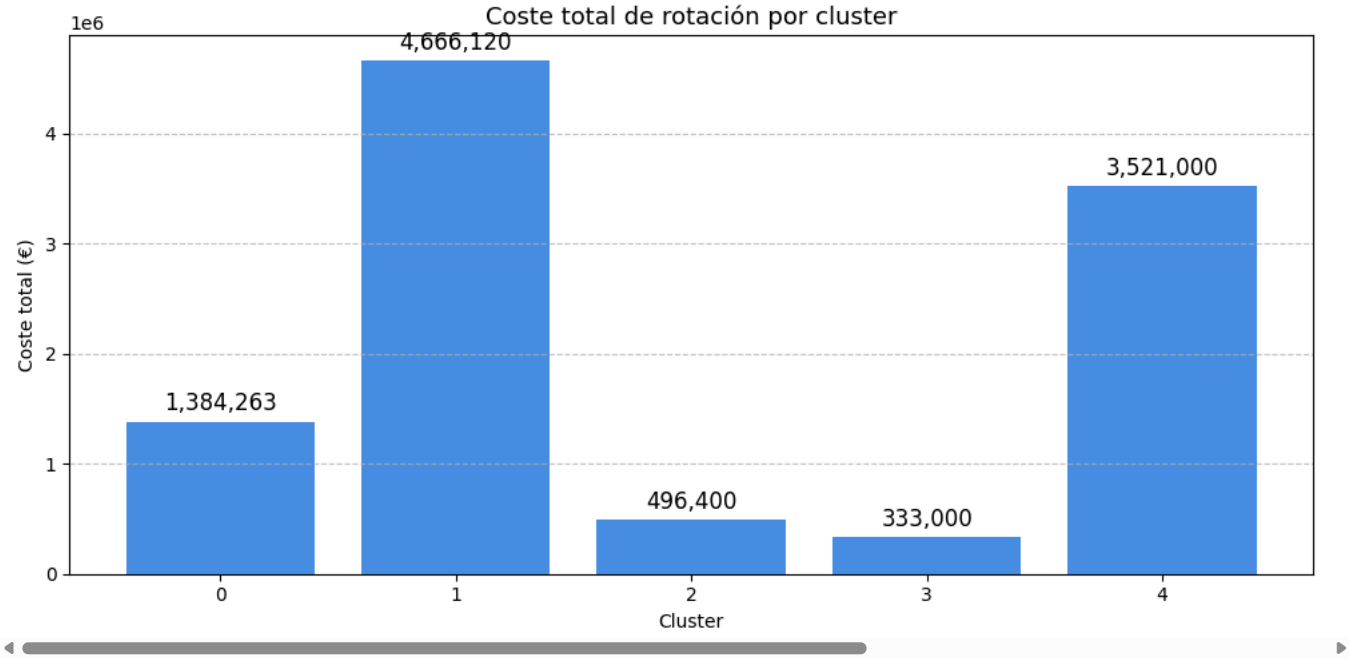
```
import pandas as pd
from lifelines import CoxPHFitter

df = pd.read_excel("/content/DatasetFinal.xlsx")

surv_df = df[["Antigüedad", "Rotacion", "cluster_5"]].copy()
surv_df.rename(columns={"Antigüedad": "tenure", "Rotacion": "event"}, inplace=True)

cox_df_full = pd.get_dummies(surv_df, columns=["cluster_5"], drop_first=True)
cox_full = CoxPHFitter()
cox_full.fit(cox_df_full, duration_col="tenure", event_col="event")
print("AIC parcial del modelo completo:", cox_full.AIC_partial_)

cox_null = CoxPHFitter()
cox_null.fit(surv_df[["tenure", "event"]], duration_col="tenure", event_col="event")
print("AIC parcial del modelo nulo:", cox_null.AIC_partial_)
```

```
AIC parcial del modelo completo: 13221.606254868553
AIC parcial del modelo nulo: 14631.756976704877
```

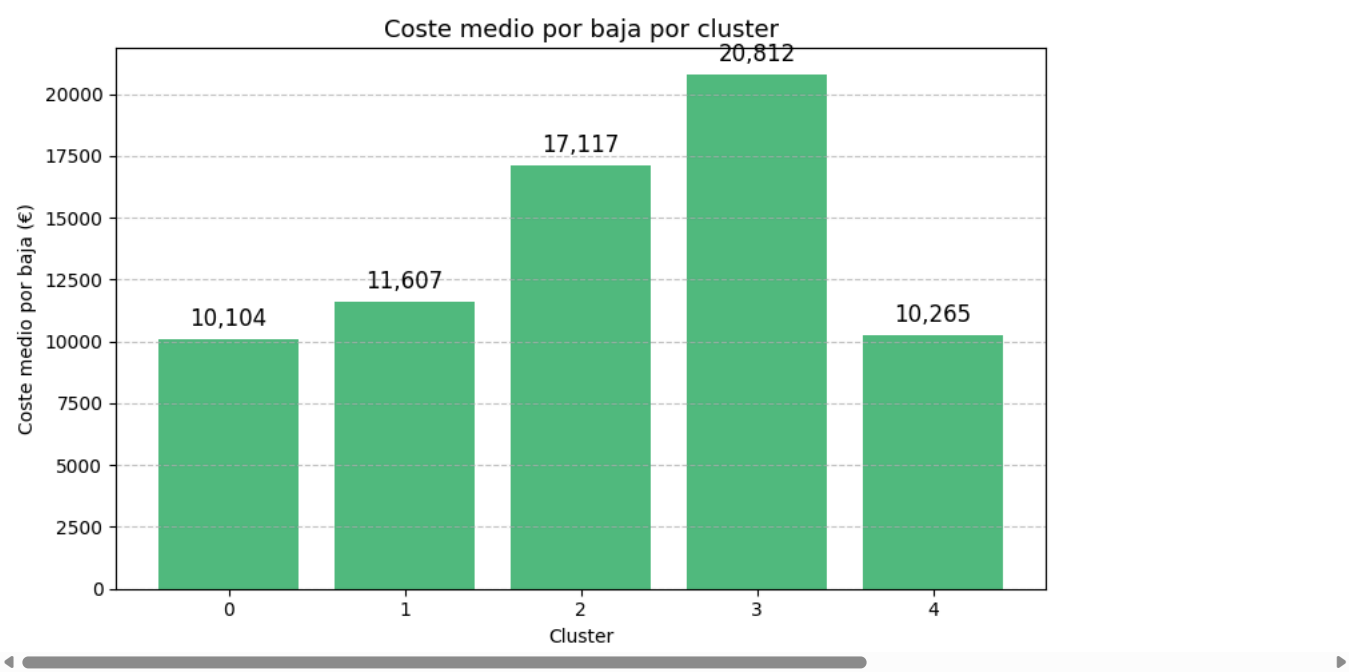
```
# PREGUNTA 5: ¿Cuánto cuesta la rotación en cada cluster y dónde conviene invertir primero?
import pandas as pd

FILE = "/content/DatasetFinal.xlsx"
df = pd.read_excel(FILE)

rotados = df[df["Rotacion"] == 1].copy()

rotados["Coste_baja"] = rotados["Salario"] * 0.4

coste_cluster = rotados.groupby("cluster_5").agg(
    Bajas=("Coste_baja", "size"),
    Coste_total=("Coste_baja", "sum"),
    Coste_medio_por_baja=("Coste_baja", "mean")
).round(0)

coste_cluster = coste_cluster.sort_values("Coste_total", ascending=False)
print(coste_cluster)

coste_cluster.to_excel("Coste_Rotacion_por_Cluster.xlsx")
```

cluster_5	Bajas	Coste_total	Coste_medio_por_baja
1	402	4666120.0	11607.0
4	343	3521000.0	10265.0
0	137	1384263.0	10104.0
2	29	496400.0	17117.0
3	16	333000.0	20812.0

```
import matplotlib.pyplot as plt

clusters = ["0", "1", "2", "3", "4"]
costes = [1384263, 4666120, 496400, 333000, 3521000]

plt.figure(figsize=(10, 5))
bars = plt.bar(clusters, costes, color="#4A90E2")

for bar in bars:
    yval = bar.get_height()
    plt.text(bar.get_x() + bar.get_width()/2, yval + 50000, f"{int(yval):,}",
             ha='center', va='bottom', fontsize=12)

plt.title("Coste total de rotación por cluster", fontsize=13)
plt.xlabel("Cluster")
plt.ylabel("Coste total (€)")
plt.grid(axis="y", linestyle="--", alpha=0.7)
plt.tight_layout()
plt.show()
```



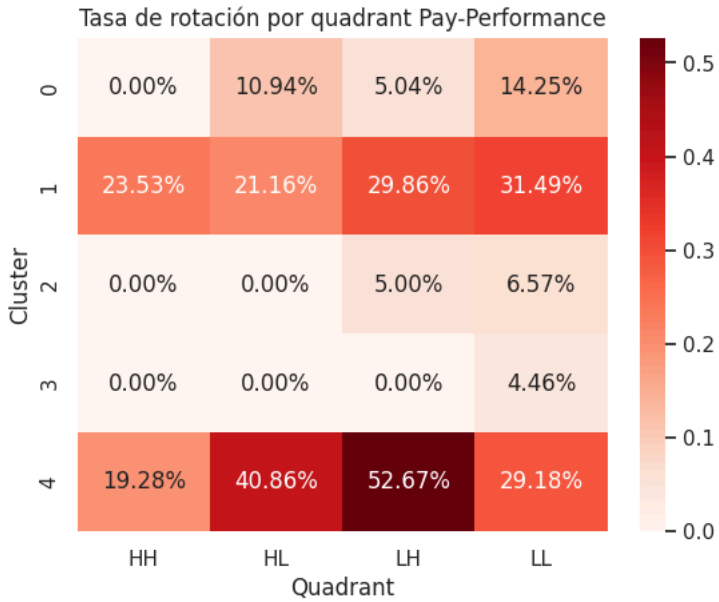

```
import matplotlib.pyplot as plt

clusters = ["0", "1", "2", "3", "4"]
coste_medio = [10104.0, 11607.0, 17117.0, 20812.0, 10265.0]

plt.figure(figsize=(8, 5))
bars = plt.bar(clusters, coste_medio, color="#50B97D")

for bar in bars:
    yval = bar.get_height()
    plt.text(bar.get_x() + bar.get_width()/2, yval + 300, f"{int(yval):,}",
             ha='center', va='bottom', fontsize=12)

plt.title("Coste medio por baja por cluster", fontsize=13)
plt.xlabel("Cluster")
plt.ylabel("Coste medio por baja (€)")
plt.grid(axis="y", linestyle="--", alpha=0.7)
plt.tight_layout()
plt.show()
```




```
# PREGUNTA 6: ¿Los empleados con alto desempeño pero salario bajo se marchan más?

import pandas as pd
import numpy as np
from scipy import stats
import seaborn as sns
```

```
import matplotlib.pyplot as plt

FILE = "/content/DatasetFinal.xlsx"
df   = pd.read_excel(FILE)

def label_quadrant(sub):
    q_salary_lo = sub["Salario"].quantile(0.25)
    q_salary_hi = sub["Salario"].quantile(0.75)
    q_perf_hi   = sub["Apreciacion"].quantile(0.75)
    q_perf_lo   = sub["Apreciacion"].quantile(0.25)

    cond_perf_hi = sub["Apreciacion"] >= q_perf_hi
    cond_perf_lo = sub["Apreciacion"] <= q_perf_lo
    cond_sal_hi  = sub["Salario"] >= q_salary_hi
    cond_sal_lo  = sub["Salario"] <= q_salary_lo

    quadrant = np.where( cond_perf_hi & cond_sal_lo, "HL",
               np.where( cond_perf_hi & cond_sal_hi, "HH",
               np.where( cond_perf_lo & cond_sal_hi, "LH","LL")))


    return pd.Series(quadrant, index=sub.index)

df["Quadrant"] = (
    df.groupby("cluster_5", group_keys=False)
      .apply(label_quadrant)
)

tab = (pd.crosstab(index=[df["cluster_5"], df["Quadrant"]],
                   columns=df["Rotacion"],
                   normalize="index")
         .rename(columns={0: "Activo", 1: "Baja"})
         .reset_index())

print(tab.head())

pivot = tab.pivot(index="cluster_5", columns="Quadrant", values="Baja")
sns.heatmap(pivot, annot=True, fmt=".2%", cmap="Reds")
plt.title("Tasa de rotación por quadrant Pay-Performance")
plt.ylabel("Cluster")
plt.show()

chi2, p, dof, exp = stats.chi2_contingency(
        pd.crosstab(df["Quadrant"], df["Rotacion"]))
print(f"χ² global quadrant vs rotación: p = {p:.4f}")
```

```
<ipython-input-35-0120fb899932>:34: DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns. This behavior is de
  .apply(label_quadrant)          # ahora es una Serie
Rotacion  cluster_5 Quadrant    Activo      Baja
0                 0       HH  1.000000  0.000000
1                 0       HL  0.890566  0.109434
2                 0       LH  0.949640  0.050360
3                 0       LL  0.857546  0.142454
4                 1       HH  0.764706  0.235294
```




```
χ² global quadrant vs rotación: p = 0.0000
```

```
# PREGUNTA 7: ¿Qué ahorro obtendríamos si aplicamos una intervención de RR. HH. y reducimos la rotación?

import pandas as pd
import numpy as np

FILE = "/content/DatasetFinal.xlsx"

COSTE_BAJA = {0: 10104, 1: 11607, 2: 17117, 3: 20812, 4: 10265}

PARAMS = {

    1: dict(
        filtro       = lambda t: (t["Quadrant"] == "HL"),
        convert_pct  = 1.0,
        salary_uplift= 2000,
        bonus        = 0,
        delta_rot    = 0.40
    ),
    4: dict(
        filtro       = lambda t: (t["Quadrant"] == "HL"),
        convert_pct  = 1.0,
        salary_uplift= 2000,
        bonus        = 0,
        delta_rot    = 0.35
    ),
    3: dict(
        filtro       = lambda t: (t["Apreciacion"] >= t["Apreciacion"].quantile(0.70)),
        convert_pct  = 0.0,
        salary_uplift= 0,
        bonus        = 1000,
        delta_rot    = 0.25
    ),
    0: dict(
        filtro       = lambda t: (t["Rotacion"] == 0),
        convert_pct  = 0.0,
        salary_uplift= 0,
        bonus        = 300,
        delta_rot    = 0.30
    ),
    2: dict(
        filtro       = lambda t: (t["Rotacion"] == 0),
        convert_pct  = 0.0,
        salary_uplift= 0,
        bonus        = 0,
        delta_rot    = 0.15
    )
}

df = pd.read_excel(FILE)

if "Quadrant" not in df.columns:
    def label_quadrant(sub):
        q_sal_lo = sub["Salario"].quantile(0.25)
        q_sal_hi = sub["Salario"].quantile(0.75)
        q_perf_hi= sub["Apreciacion"].quantile(0.75)
        q_perf_lo= sub["Apreciacion"].quantile(0.25)
        hi_perf  = sub["Apreciacion"] >= q_perf_hi
        lo_perf  = sub["Apreciacion"] <= q_perf_lo
        hi_sal   = sub["Salario"] >= q_sal_hi
        lo_sal   = sub["Salario"] <= q_sal_lo
        return np.where( hi_perf & lo_sal, "HL",
               np.where( hi_perf & hi_sal, "HH",
               np.where( lo_perf & hi_sal, "LH", "LL")))
    df["Quadrant"] = df.groupby("cluster_5", group_keys=False).apply(label_quadrant)

def simulate(df, cluster, p):
    sub        = df[(df["cluster_5"] == cluster) & (df["Fijo / Temporal"] == 1)]
    eligibles  = sub[p["filtro"](sub)]

    n_conv     = int(len(eligibles) * p["convert_pct"])

    n_bonus    = len(eligibles) if p["bonus"] else 0


    bajas_elig = eligibles["Rotacion"].sum()
    evitadas   = int(bajas_elig * p["delta_rot"])

    ahorro     = evitadas * COSTE_BAJA[cluster]
    coste_conv = n_conv  * p["salary_uplift"]
    coste_bonus= n_bonus * p["bonus"]
    coste_tot  = coste_conv + coste_bonus
    roi        = ahorro / coste_tot if coste_tot else np.nan
```

```
        return {
            "Cluster": cluster,
            "Temporales": len(sub),
            "Eligibles": len(eligibles),
            "Convertidos": n_conv,
            "Ahorro €": round(ahorro),
            "Coste €": round(coste_tot),
            "ROI": round(roi, 2)
        }

    resumen = [ simulate(df, cl, PARAMS[cl]) for cl in PARAMS.keys() ]
    tabla = pd.DataFrame(resumen)
    print(tabla)
    tabla.to_excel("ROI_escenarios_segmentados.xlsx", index=False)
```

```
   Cluster  Temporales  Eligibles  Convertidos  Ahorro €  Coste €  ROI
0        1         432          0            0         0        0  NaN
1        4         304          0            0         0        0  NaN
2        3         580        242            0         0   242000  0.0
3        0         242        234            0         0    70200  0.0
4        2          15         15            0         0        0  NaN
<ipython-input-36-c76d71f55c5b>:70: DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns. This behavior is de
  df["Quadrant"] = df.groupby("cluster_5", group_keys=False).apply(label_quadrant)
```

```
    import pandas as pd
    import numpy as np

    FILE = "/content/MasterDataset_k5_noOut_modificado_final2.xlsx"

    COSTE_BAJA = {0: 10104, 1: 11607, 2: 17117, 3: 20812, 4: 10265}


    PARAMS = {

        1: dict(
            filtro=lambda t: (t["Quadrant"] == "HL") |
                             ((t["Quadrant"] == "HH") &
                              (t["Salario"] < t["Salario"].quantile(0.40))),
            convert_pct=1.0, salary_uplift=1000, bonus=0, delta_rot=0.35
        ),
        4: dict(
            filtro=lambda t: (t["Quadrant"] == "HL") |
                             ((t["Quadrant"] == "HH") &
                              (t["Salario"] < t["Salario"].quantile(0.40))),
            convert_pct=1.0, salary_uplift=1000, bonus=0, delta_rot=0.30
        ),
        3: dict(
            filtro=lambda t: t["Apreciacion"] >= t["Apreciacion"].quantile(0.85),
            convert_pct=0.0, salary_uplift=0, bonus=500, delta_rot=0.25
        ),
        0: dict(
            filtro=lambda t: t["Antigüedad"] < 1,
            convert_pct=0.0, salary_uplift=0, bonus=300, delta_rot=0.40
        ),
        2: dict(
            filtro=lambda t: t["Rotacion"] == 0,
            convert_pct=0.0, salary_uplift=0, bonus=0, delta_rot=0.00
        )
    }


    df = pd.read_excel(FILE)

    if "Quadrant" not in df.columns:
        def quadrant(sub):
            q_sal_lo = sub["Salario"].quantile(0.25)
            q_sal_hi = sub["Salario"].quantile(0.75)
            q_perf_hi= sub["Apreciacion"].quantile(0.75)
            q_perf_lo= sub["Apreciacion"].quantile(0.25)
            hi_perf  = sub["Apreciacion"] >= q_perf_hi
            lo_perf  = sub["Apreciacion"] <= q_perf_lo
            hi_sal   = sub["Salario"] >= q_sal_hi
            lo_sal   = sub["Salario"] <= q_sal_lo
            return np.where( hi_perf & lo_sal, "HL",
                   np.where( hi_perf & hi_sal, "HH",
                   np.where( lo_perf & hi_sal, "LH", "LL")))
        df["Quadrant"] = df.groupby("cluster_5", group_keys=False).apply(quadrant)

    def simulate(df, cluster, p):
```

```
    sub  = df[(df["cluster_5"] == cluster) & (df["Fijo / Temporal"] == 1)].copy()
    elig = sub[p["filtro"](sub)]

    n_conv    = int(len(elig) * p["convert_pct"])
    n_bonus   = len(elig) if p["bonus"] else 0
    bajas_elig= elig["Rotacion"].sum()
    evitadas  = int(bajas_elig * p["delta_rot"])

    ahorro    = evitadas * COSTE_BAJA[cluster]
    coste     = n_conv * p["salary_uplift"] + n_bonus * p["bonus"]
    roi       = round(ahorro / coste, 2) if coste else np.nan

    return dict(Cluster=cluster, Temporales=len(sub), Eligibles=len(elig),
                Convertidos=n_conv, Ahorro=round(ahorro),
                Coste=round(coste), ROI=roi)

tabla = pd.DataFrame([simulate(df, cl, PARAMS[cl]) for cl in PARAMS])
print(tabla)
tabla.to_excel("ROI_escenarios_segmentados_v2.xlsx", index=False)
```

```
   Cluster  Temporales  Eligibles  Convertidos  Ahorro   Coste  ROI
0        1         432          0            0       0       0  NaN
1        4         304          0            0       0       0  NaN
2        3         580        242            0       0  121000  0.0
3        0         242          0            0       0       0  NaN
4        2          15         15            0       0       0  NaN
<ipython-input-37-31f6a014d126>:58: DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns. This behavior is de
  df["Quadrant"] = df.groupby("cluster_5", group_keys=False).apply(quadrant)
```

```
import pandas as pd
import numpy as np

FILE = "/content/DatasetFinal.xlsx"

COSTE_BAJA = {0: 10104, 1: 11607, 2: 17117, 3: 20812, 4: 10265}


PARAMS = {
    1: dict(
        filtro=lambda t: (t["Apreciacion"] >= t["Apreciacion"].quantile(0.70)) &
                         (t["Salario"] <= t["Salario"].quantile(0.40)),
        convert_pct=0.50, salary_uplift=500, bonus=0, delta_rot=0.35
    ),
    4: dict(
        filtro=lambda t: (t["Apreciacion"] >= t["Apreciacion"].quantile(0.70)) &
                         (t["Salario"] <= t["Salario"].quantile(0.40)),
        convert_pct=0.50, salary_uplift=500, bonus=0, delta_rot=0.30
    ),
    3: dict(
        filtro=lambda t: t["Apreciacion"] >= t["Apreciacion"].quantile(0.85),
        convert_pct=0.0, salary_uplift=0, bonus=0, delta_rot=0.00
    ),
    0: dict(
        filtro=lambda t: t["Antigüedad"] < 1,
        convert_pct=0.0, salary_uplift=0, bonus=0, delta_rot=0.00
    ),
    2: dict(
        filtro=lambda t: t["Rotacion"] == 0,
        convert_pct=0.0, salary_uplift=0, bonus=0, delta_rot=0.00
    )
}


df = pd.read_excel(FILE)

if "Quadrant" not in df.columns:
    def quadrant(sub):
        q_sal_lo = sub["Salario"].quantile(0.25)
        q_sal_hi = sub["Salario"].quantile(0.75)
        q_perf_hi = sub["Apreciacion"].quantile(0.75)
        q_perf_lo = sub["Apreciacion"].quantile(0.25)
        hi_perf = sub["Apreciacion"] >= q_perf_hi
        lo_perf = sub["Apreciacion"] <= q_perf_lo
        hi_sal = sub["Salario"] >= q_sal_hi
        lo_sal = sub["Salario"] <= q_sal_lo
        return np.where(hi_perf & lo_sal, "HL",
                        np.where(hi_perf & hi_sal, "HH",
                                 np.where(lo_perf & hi_sal, "LH", "LL")))
    df["Quadrant"] = df.groupby("cluster_5", group_keys=False).apply(quadrant)

def simulate(df, cluster, p):
    sub = df[(df["cluster_5"] == cluster) & (df["Fijo / Temporal"] == 1)].copy()
```

```
        elig = sub[p["filtro"](sub)]

        n_conv = int(len(elig) * p["convert_pct"])
        n_bonus = len(elig) if p["bonus"] else 0
        bajas_elig = elig["Rotacion"].sum()
        evitadas = int(bajas_elig * p["delta_rot"])

        ahorro = evitadas * COSTE_BAJA[cluster]
        coste = n_conv * p["salary_uplift"] + n_bonus * p["bonus"]
        roi = round(ahorro / coste, 2) if coste else np.nan

        return dict(Cluster=cluster, Temporales=len(sub), Eligibles=len(elig),
                    Convertidos=n_conv, Ahorro=round(ahorro),
                    Coste=round(coste), ROI=roi)


    tabla = pd.DataFrame([simulate(df, cl, PARAMS[cl]) for cl in PARAMS])

    print(tabla)
    tabla.to_excel("ROI_escenarios_segmentados_FINAL.xlsx", index=False)
```

```
    Cluster  Temporales  Eligibles  Convertidos  Ahorro  Coste   ROI
0        1         432        127           63  104463  31500  3.32
1        4         304         91           45   51325  22500  2.28
2        3         580        242            0       0      0   NaN
3        0         242          0            0       0      0   NaN
4        2          15         15            0       0      0   NaN
<ipython-input-50-cf86f69df437>:56: DeprecationWarning: DataFrameGroupBy.apply operated on the grouping columns. This behavior is de
  df["Quadrant"] = df.groupby("cluster_5", group_keys=False).apply(quadrant)
```

```
    import pandas as pd
    import numpy as np

    FILE = "/content/DatasetFinal.xlsx"
    df = pd.read_excel(FILE)

    COSTE_BAJA = {0: 10104, 1: 11607, 2: 17117, 3: 20812, 4: 10265}

    if "Quadrant" not in df.columns:
        def quadrant(sub):
            q_sal_lo = sub["Salario"].quantile(0.25)
            q_sal_hi = sub["Salario"].quantile(0.75)
            q_perf_hi = sub["Apreciacion"].quantile(0.75)
            q_perf_lo = sub["Apreciacion"].quantile(0.25)
            hi_perf = sub["Apreciacion"] >= q_perf_hi
            lo_perf = sub["Apreciacion"] <= q_perf_lo
            hi_sal = sub["Salario"] >= q_sal_hi
            lo_sal = sub["Salario"] <= q_sal_lo
            return np.where(hi_perf & lo_sal, "HL",
                            np.where(hi_perf & hi_sal, "HH",
                                     np.where(lo_perf & hi_sal, "LH", "LL")))
        df["Quadrant"] = df.groupby("cluster_5", group_keys=False).apply(quadrant)

    def simulate_grid(df, cluster, filtro_func, convert_pct_list, uplift_list, delta_rot_list, bonus=0):
        results = []
        sub = df[(df["cluster_5"] == cluster) & (df["Fijo / Temporal"] == 1)].copy()
        elig_total = filtro_func(sub)
        for convert_pct in convert_pct_list:
            for uplift in uplift_list:
                for delta_rot in delta_rot_list:
                    elig = sub[elig_total]
                    n_conv = int(len(elig) * convert_pct)
                    n_bonus = len(elig) if bonus else 0
                    bajas_elig = elig["Rotacion"].sum()
                    evitadas = int(bajas_elig * delta_rot)
                    ahorro = evitadas * COSTE_BAJA[cluster]
                    coste = n_conv * uplift + n_bonus * bonus
                    roi = round(ahorro / coste, 2) if coste else np.nan
                    results.append({
                        "Cluster": cluster,
                        "Convert_pct": convert_pct,
                        "Uplift": uplift,
                        "Delta_rot": delta_rot,
                        "Bonus": bonus,
                        "Eligibles": len(elig),
                        "Convertidos": n_conv,
                        "Ahorro": round(ahorro),
                        "Coste": round(coste),
                        "ROI": roi
                    })
        return pd.DataFrame(results)
```