1. Import liberaries

In [52]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

2. Loading CSV into IDE.

In [53]:
```
census_data = pd.read_csv('E:/projects/pakistan-census-analysis/data/pakistan_distr
census_data.head()
```

Out[53]:

	Province	District	Population	Area_km²	Density	Literacy_Rate (%)	Internet_Penetratio (%
0	Punjab	Lahore	3885/650	380.03	10224.59	50.93	22.2
1	Punjab	Rawalpindi	18449464	578.20	31908.45	57.83	11.6
2	Punjab	Faisalabad	17106909	2226.46	7683+46	64.38	49.3
3	Punjab	Multan	14226749	1005.41	14150.2	65.70	54.5
4	Punjab	Gujranwala	5507277	2534.05	2173.31	53.99	18.5

2. Check for Missing or Null Values

In [54]:
```
census_data.isnull().sum()
```

Out[54]:
```
Province                  0
District                  0
Population                0
Area_km²                  0
Density                   0
Literacy_Rate (%)         0
Internet_Penetration (%)  0
Urbanization (%)          0
dtype: int64
```

3. Clean Columns

In [55]:
```
print(census_data.columns.tolist())
```

```
['Province', 'District', 'Population', 'Area_km²', 'Density', 'Literacy_Rate (%)',
'Internet_Penetration (%)', 'Urbanization (%) ']
```

In [56]:
```
census_data.rename(columns=lambda x:x.strip(), inplace=True)

int_errors = r"[/,/./ /-/+]"
```

```
int_columns = census_data[['Population','Area_km²','Density']]
for i_col in int_columns:
    census_data[i_col] = census_data[i_col].astype(str).str.replace(int_errors,'',
    census_data[i_col] = pd.to_numeric(census_data[i_col], errors='coerce').astype(

# for % values
f_errors = r"[,\%/ /-]"
f_columns = census_data[['Literacy_Rate (%)','Internet_Penetration (%)','Urbanizati
for f_col in f_columns:
    census_data[f_col] = census_data[f_col].astype(str).str.replace(f_errors,'', re
    census_data[f_col] = pd.to_numeric(census_data[f_col], errors='coerce')
```

In [57]:
```
census_data.head()
```

Out[57]:

	Province	District	Population	Area_km²	Density	Literacy_Rate (%)	Internet_Penetration (%
0	Punjab	Lahore	3885650	38003	1022459	50.93	22.28
1	Punjab	Rawalpindi	18449464	5782	3190845	57.83	11.64
2	Punjab	Faisalabad	17106909	222646	768346	64.38	49.38
3	Punjab	Multan	14226749	100541	141502	65.70	54.52
4	Punjab	Gujranwala	5507277	253405	217331	53.99	18.55

In [58]:
```
census_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 45 entries, 0 to 44
Data columns (total 8 columns):
 #   Column                   Non-Null Count  Dtype
---  ------                   --------------  -----
 0   Province                 45 non-null     object
 1   District                 45 non-null     object
 2   Population               45 non-null     Int64
 3   Area_km²                 45 non-null     Int64
 4   Density                  44 non-null     Int64
 5   Literacy_Rate (%)        45 non-null     float64
 6   Internet_Penetration (%)  45 non-null     float64
 7   Urbanization (%)         45 non-null     float64
dtypes: Int64(3), float64(3), object(2)
memory usage: 3.1+ KB
```

In [59]:
```
# 5. Add a Unique ID Column

census_data.insert(0, "District_ID", range(1, 1 + len(census_data)))
```

In [60]:
```
# 6. Save the Cleaned Dataset

census_data.to_csv("cleaned_pakistan_census_data.csv", index=False)
print("Cleaned dataset saved as 'cleaned_pakistan_census_data.csv'")
```

```
Cleaned dataset saved as 'cleaned_pakistan_census_data.csv'
```

Cleaned Data

In [61]:
```
cleaned_census_data = pd.read_csv('cleaned_pakistan_census_data.csv')
```

3. Exploratory Data Analysis

In [62]:
```
# check  rows and columns
cleaned_census_data.shape
```

Out[62]:
```
(45, 9)
```

In [63]:
```
cleaned_census_data.describe()
```

Out[63]:

	District_ID	Population	Area_km²	Density	Literacy_Rate (%)	Internet_Pene
count	45.000000	4.500000e+01	45.000000	4.400000e+01	45.000000	45.
mean	23.000000	1.041212e+07	182303.866667	6.465170e+05	59.764222	62.
std	13.133926	5.594445e+06	115078.006828	6.875951e+05	13.209609	181.
min	1.000000	1.204043e+06	5782.000000	2.482100e+04	38.100000	10.
25%	12.000000	5.518105e+06	75719.000000	2.125025e+05	49.320000	22.
50%	23.000000	9.860248e+06	202555.000000	3.736970e+05	57.840000	37.
75%	34.000000	1.541755e+07	287615.000000	7.751280e+05	71.110000	50.
max	45.000000	1.989477e+07	348448.000000	3.190845e+06	84.970000	1252.

In [64]:
```
# unique values
census_data['Province'].unique()
census_data['District'].unique()
```

Out[64]:
```
array(['Lahore', 'Rawalpindi', 'Faisalabad', 'Multan', 'Gujranwala',
       'Bahawalpur', 'Sialkot', 'Sargodha', 'Karachi East',
       'Karachi West', 'Hyderabad', 'Sukkur', 'Larkana', 'Mirpurkhas',
       'Nawabshah', 'Thatta', 'Peshawar', 'Abbottabad', 'Mardan', 'Swat',
       'Kohat', 'Dera Ismail Khan', 'Mansehra', 'Charsadda', 'Quetta',
       'Khuzdar', 'Gwadar', 'Turbat', 'Sibi', 'Zhob', 'Panjgur',
       'Lasbela', 'Gilgit', 'Skardu', 'Diamer', 'Hunza', 'Ghanche',
       'Ghizer', 'Muzaffarabad', 'Mirpur', 'Kotli', 'Bagh', 'Rawalakot',
       'Hattian Bala', 'Islamabad'], dtype=object)
```

In [65]:
```
# number of districts per province
no_of_districts = census_data['Province'].value_counts()
no_of_districts
```

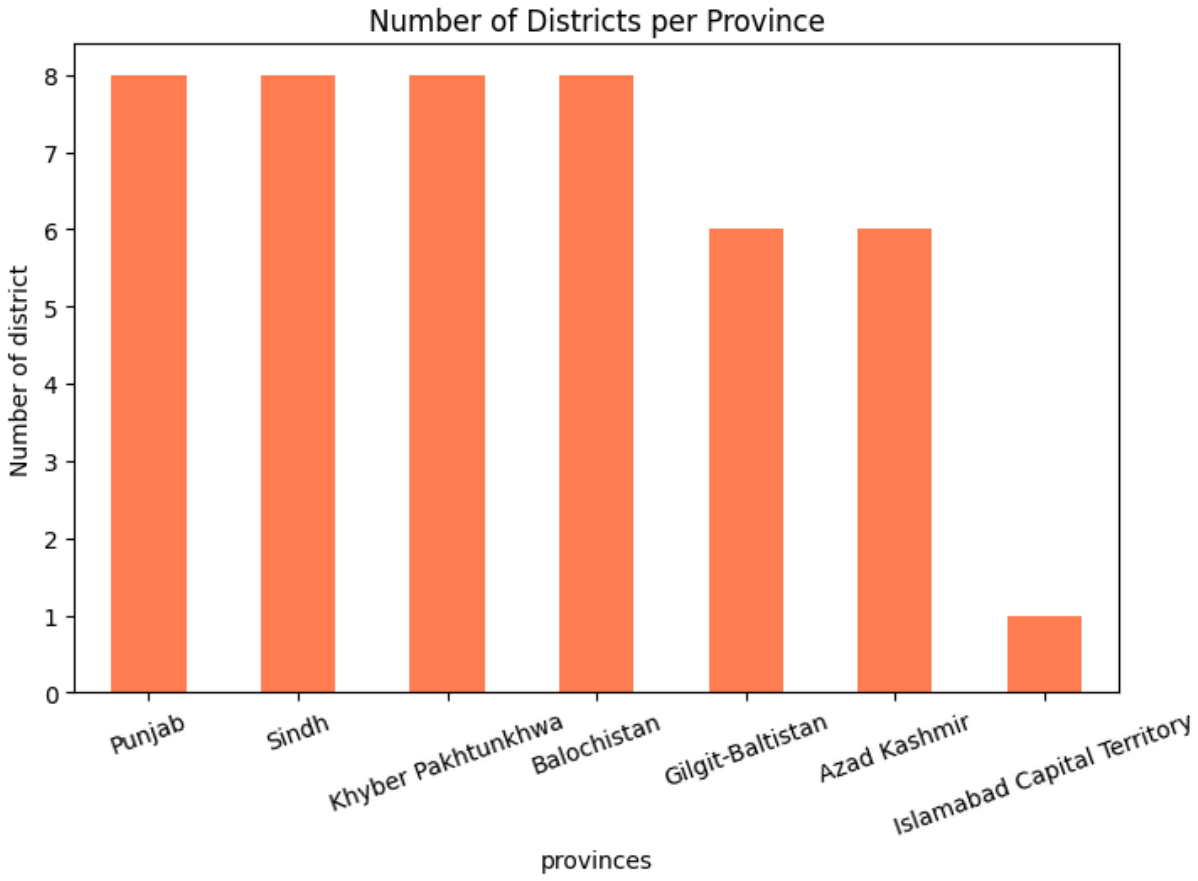
Out[65]:
```
Province
Punjab                          8
Sindh                           8
Khyber Pakhtunkhwa              8
Balochistan                     8
Gilgit-Baltistan                6
Azad Kashmir                    6
Islamabad Capital Territory     1
Name: count, dtype: int64
```

In [66]:
```
# mean provinces
data_avg = census_data['Province'].value_counts().sum()
data_avg.mean()
```

Out[66]:
```
np.float64(45.0)
```

In [67]:
```
# province chart
no_of_districts.plot(kind='bar', figsize=(8,5), color = 'coral')
plt.title("Number of Districts per Province")
plt.xlabel('provinces')
plt.ylabel('Number of district')
plt.xticks(rotation=20)
plt.tight_layout
```

Out[67]:
```
<function matplotlib.pyplot.tight_layout(*, pad: 'float' = 1.08, h_pad: 'float | None' = None, w_pad: 'float | None' = None, rect: 'tuple[float, float, float, float] | None' = None) -> 'None'>
```

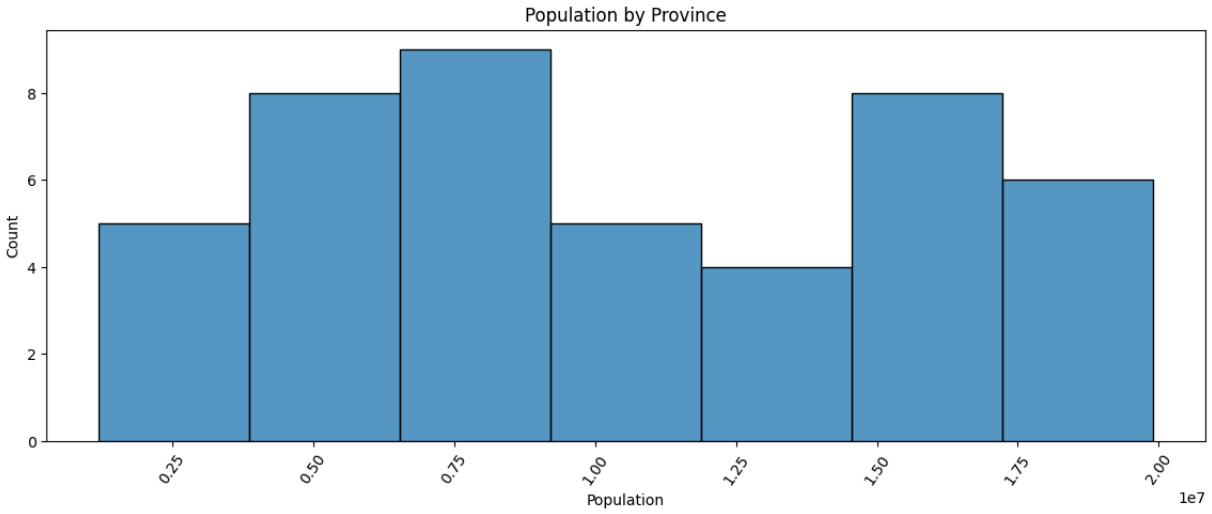


4. Analyze Individual Features

A. Population

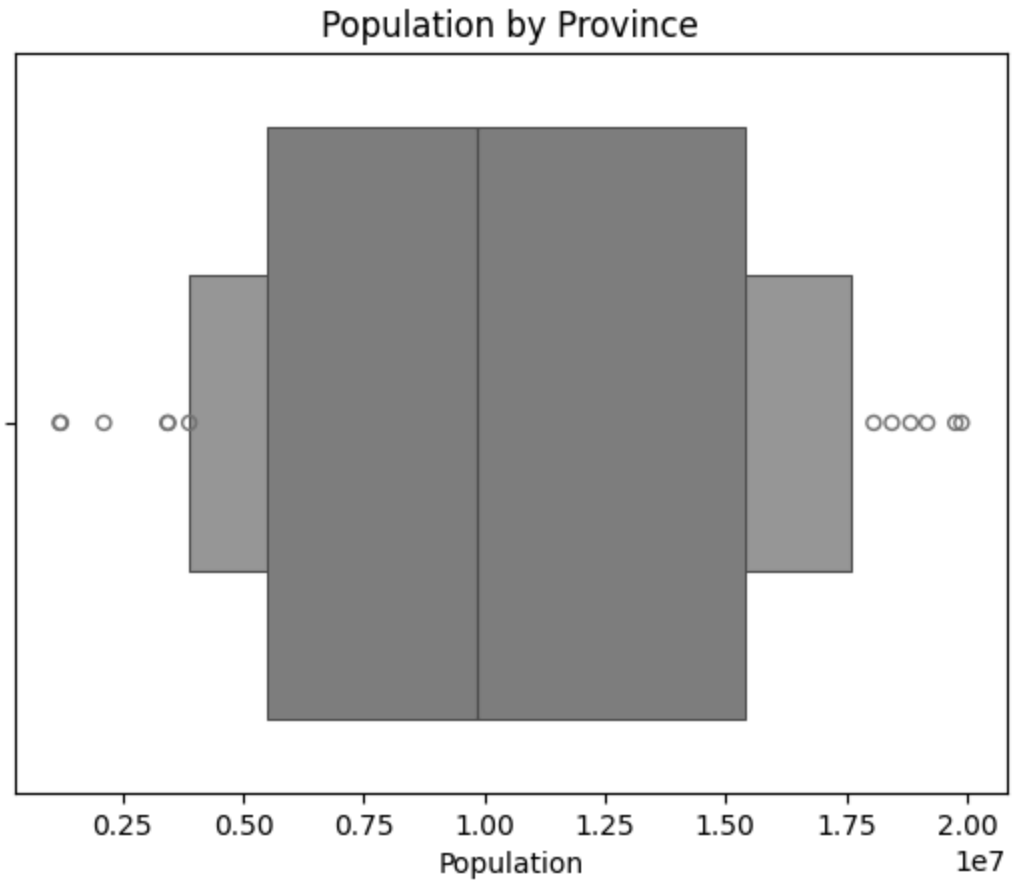
In [68]:
```
# population
figure = plt.figure(figsize=(14,5))
sns.histplot(data=census_data, x=census_data['Population'])
plt.title('Population by Province')
plt.xticks(rotation=55)
plt.tight_layout
```

Out[68]:
```
<function matplotlib.pyplot.tight_layout(*, pad: 'float' = 1.08, h_pad: 'float | None' = None, w_pad: 'float | None' = None, rect: 'tuple[float, float, float, float] | None' = None) -> 'None'>
```



In [69]:
```
# population outliers
sns.boxenplot(data=cleaned_census_data, x='Population', color='grey')
plt.title('Population by Province')
```

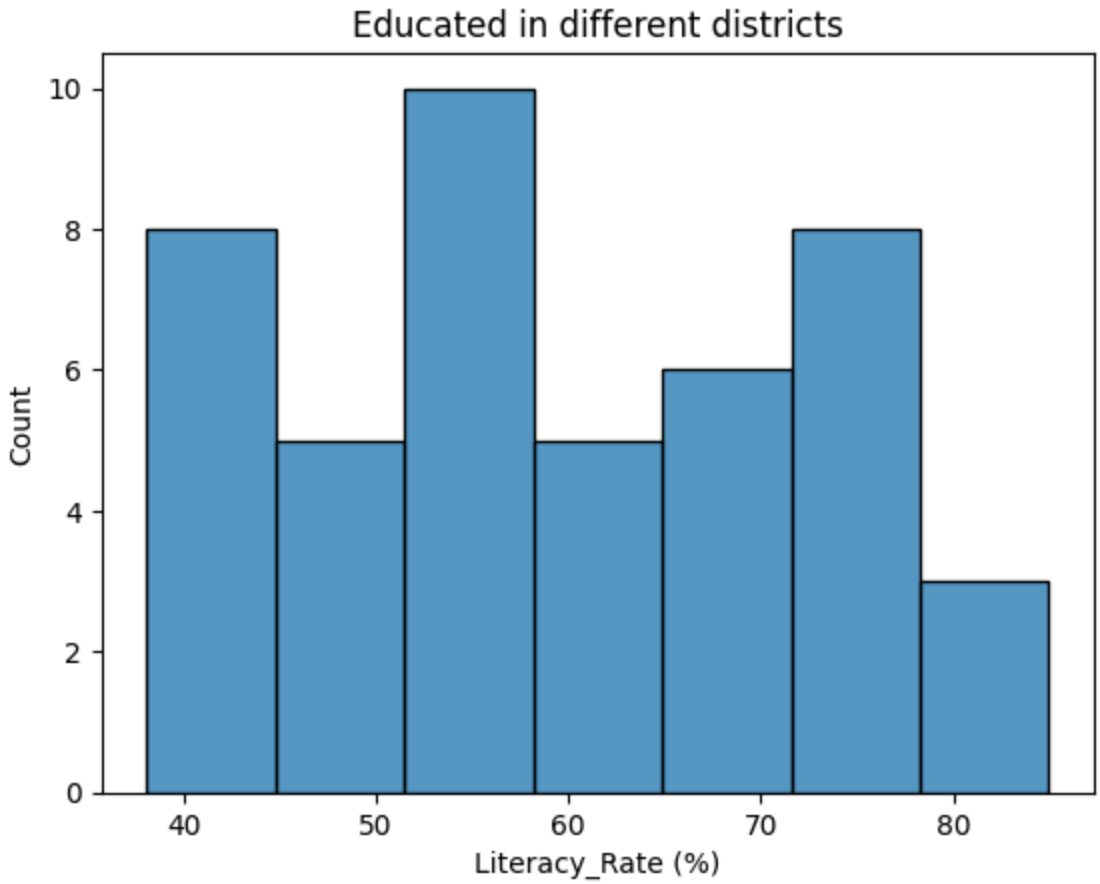
Out[69]:
```
Text(0.5, 1.0, 'Population by Province')
```



B. Literacy Rate (%)

In [70]:
```
sns.histplot(data=cleaned_census_data, x='Literacy_Rate (%)')
plt.title('Educated in different districts')
```

Out[70]:
```
Text(0.5, 1.0, 'Educated in different districts')
```



Districts with Min/Max Literacy

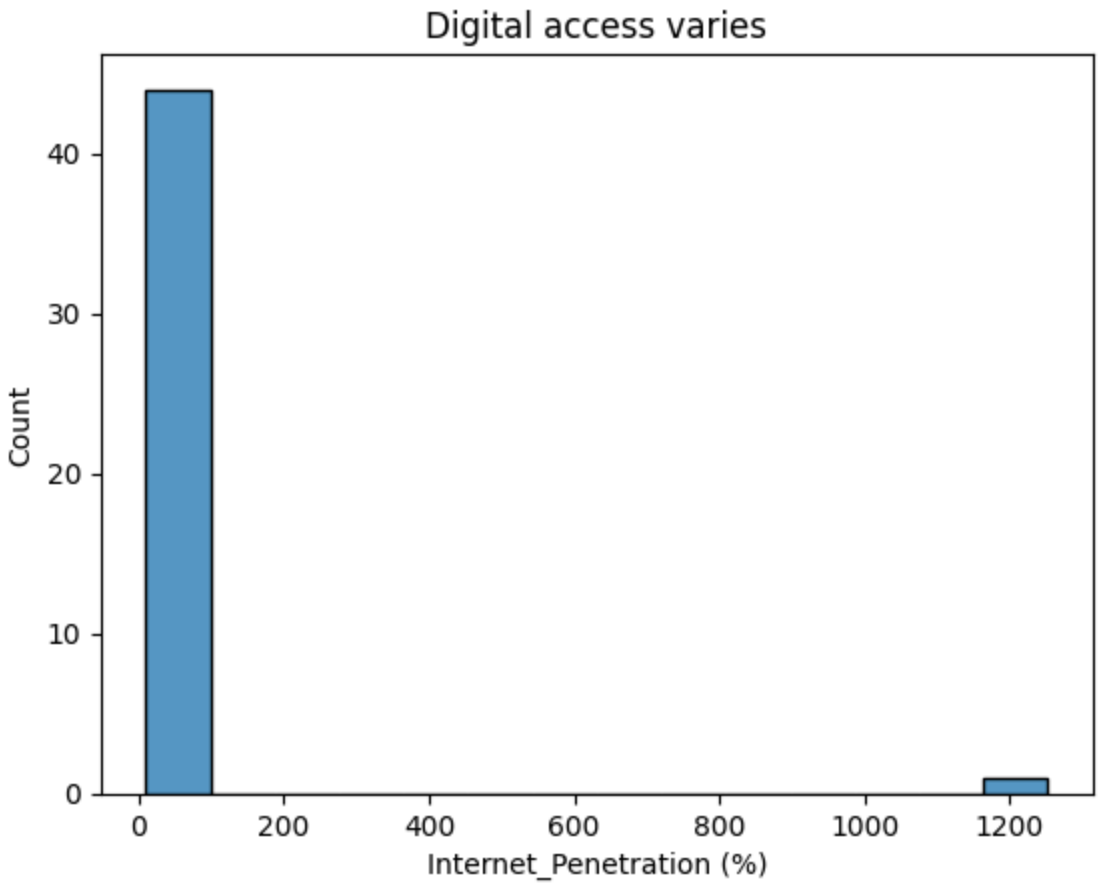
In [71]:
```
cleaned_census_data['Literacy_Rate (%)'] = pd.to_numeric(cleaned_census_data['Liter

lowest = cleaned_census_data.loc[cleaned_census_data['Literacy_Rate (%)'].idxmin()]
highest = cleaned_census_data.loc[cleaned_census_data['Literacy_Rate (%)'].idxmax()

print("Lowest Literacy District:")
print(lowest[['District', 'Province', 'Literacy_Rate (%)']])

print("\nHighest Literacy District:")
print(highest[['District', 'Province', 'Literacy_Rate (%)']])
```

```
Lowest Literacy District:
District             Hattian Bala
Province             Azad Kashmir
Literacy_Rate (%)            38.1
Name: 43, dtype: object

Highest Literacy District:
District                     Bagh
Province             Azad Kashmir
Literacy_Rate (%)           84.97
Name: 41, dtype: object
```

C. Internet Penetration (%)

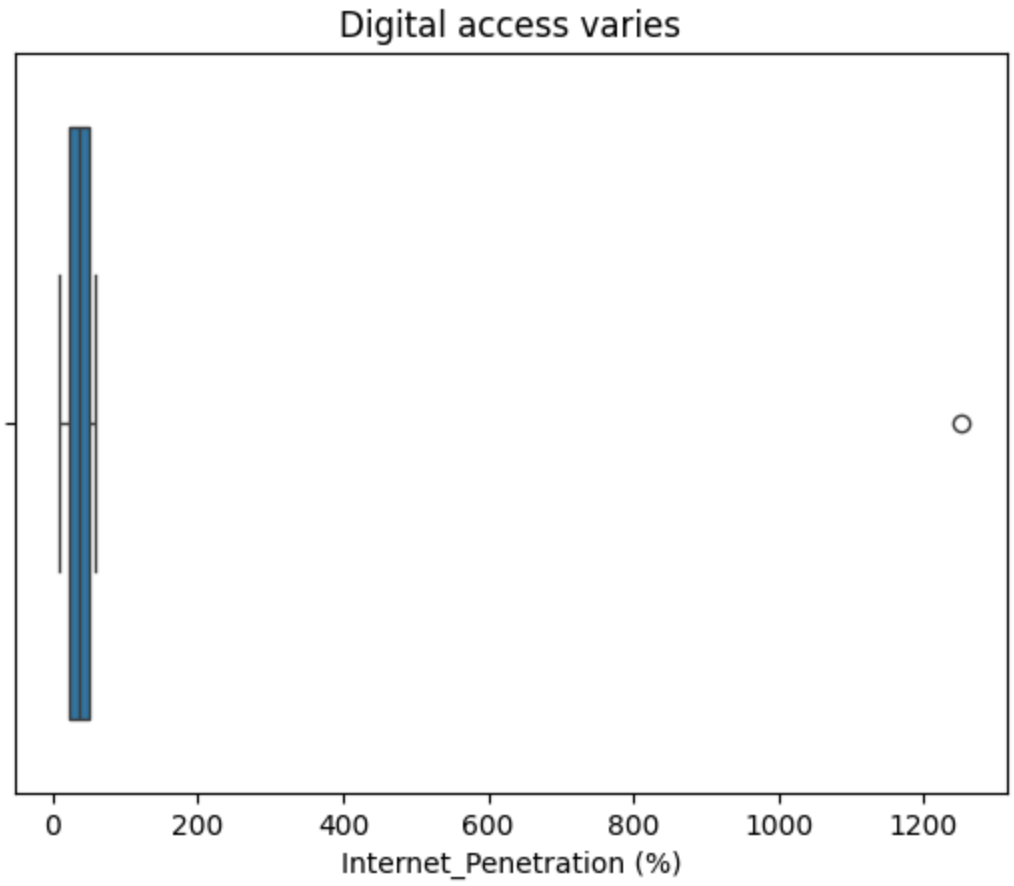
In [72]:
```
# Histogram
sns.histplot(data=cleaned_census_data, x='Internet_Penetration (%)')
plt.title('Digital access varies')
```

Out[72]: Text(0.5, 1.0, 'Digital access varies')



In [73]:
```
# boxplot for outliers
sns.boxplot(data=cleaned_census_data, x='Internet_Penetration (%)')
plt.title('Digital access varies')
```

Out[73]: Text(0.5, 1.0, 'Digital access varies')



Low-penetration districts

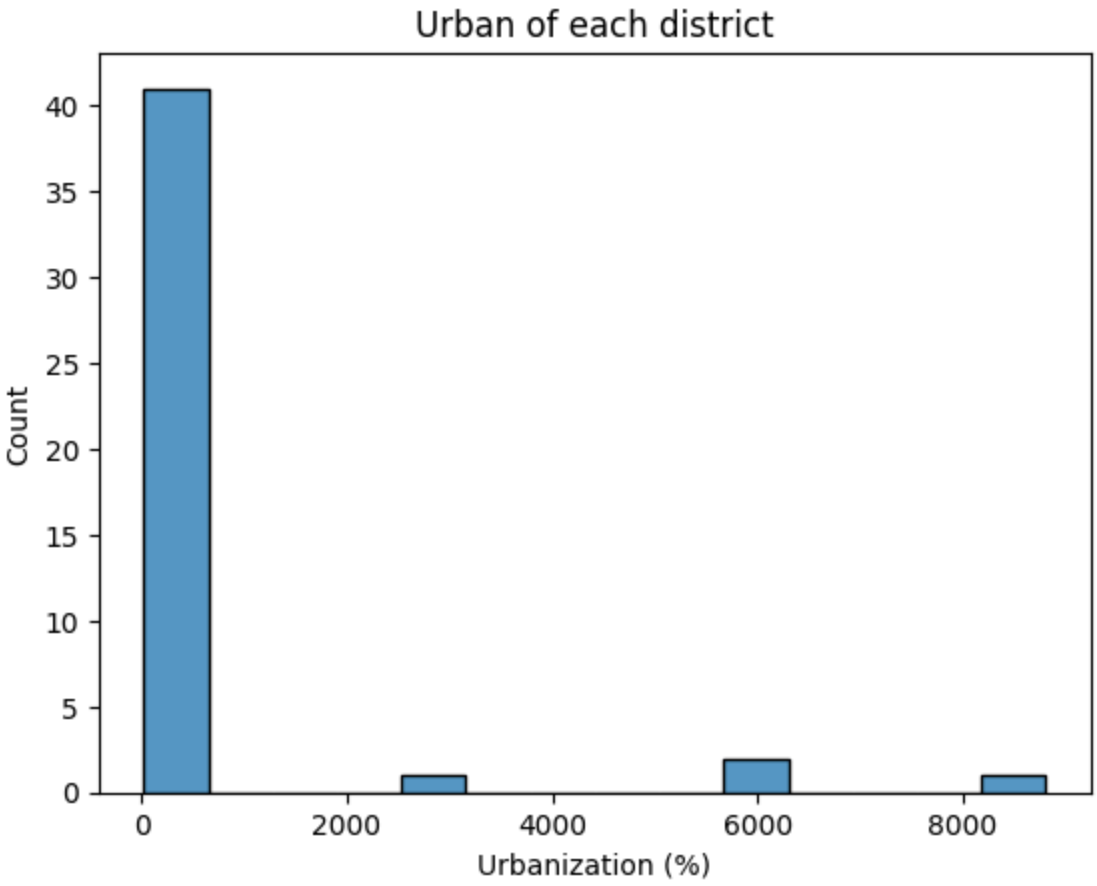
In [74]:
```
cleaned_census_data['Internet_Penetration (%)'] = pd.to_numeric(cleaned_census_data
low_penetration = cleaned_census_data.sort_values(by='Internet_Penetration (%)').he
print(low_penetration[['District', 'Province', 'Internet_Penetration (%)']])
```

	District	Province	Internet_Penetration (%)
22	Mansehra	Khyber Pakhtunkhwa	10.18
32	Gilgit	Gilgit-Baltistan	11.16
1	Rawalpindi	Punjab	11.64
18	Mardan	Khyber Pakhtunkhwa	12.59
19	Swat	Khyber Pakhtunkhwa	13.49
14	Nawabshah	Sindh	13.64
11	Sukkur	Sindh	13.93
4	Gujranwala	Punjab	18.55
36	Ghanche	Gilgit-Baltistan	20.47
24	Quetta	Balochistan	20.94

D. Urbanization (%)

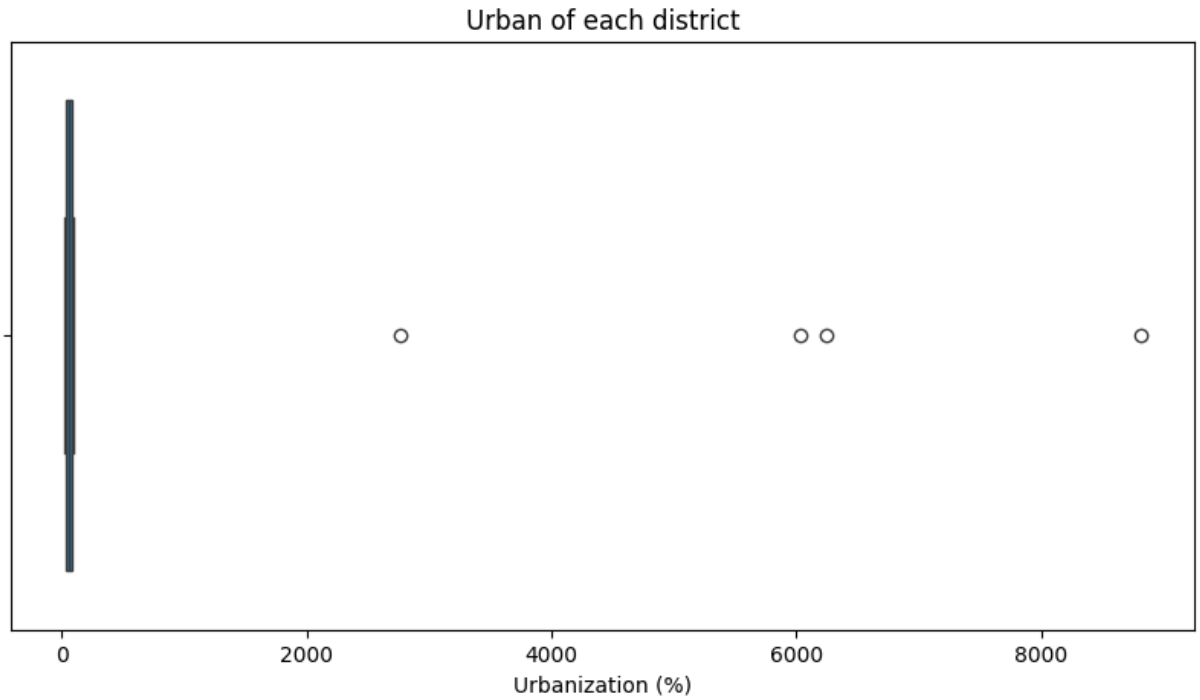
In [75]:
```
sns.histplot(data=cleaned_census_data, x='Urbanization (%)')
plt.title('Urban of each district')
```

Out[75]:
```
Text(0.5, 1.0, 'Urban of each district')
```



In [76]:
```
figure = plt.figure(figsize=(10,5))
sns.boxplot(data=cleaned_census_data,x='Urbanization (%)')
plt.title('Urban of each district')
```

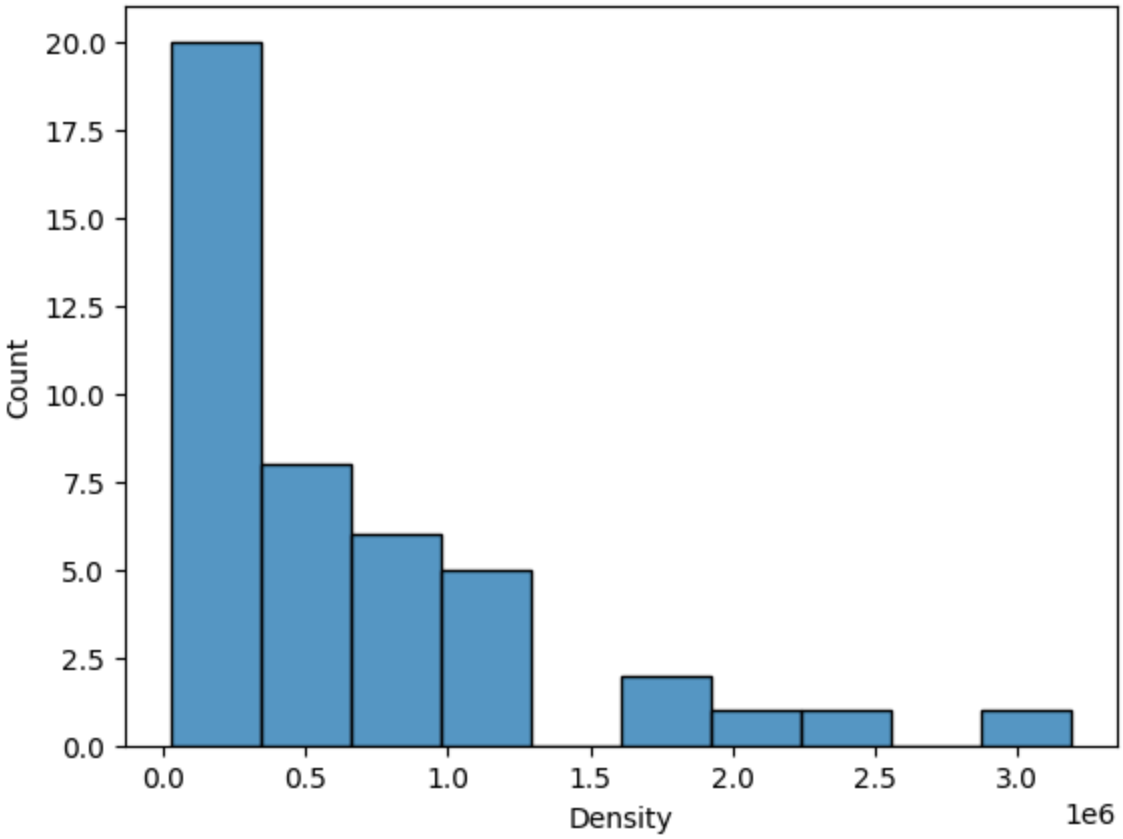
Out[76]: Text(0.5, 1.0, 'Urban of each district')



E. Density

In [77]:
```
sns.histplot(data=cleaned_census_data, x='Density')
plt.title('')
```

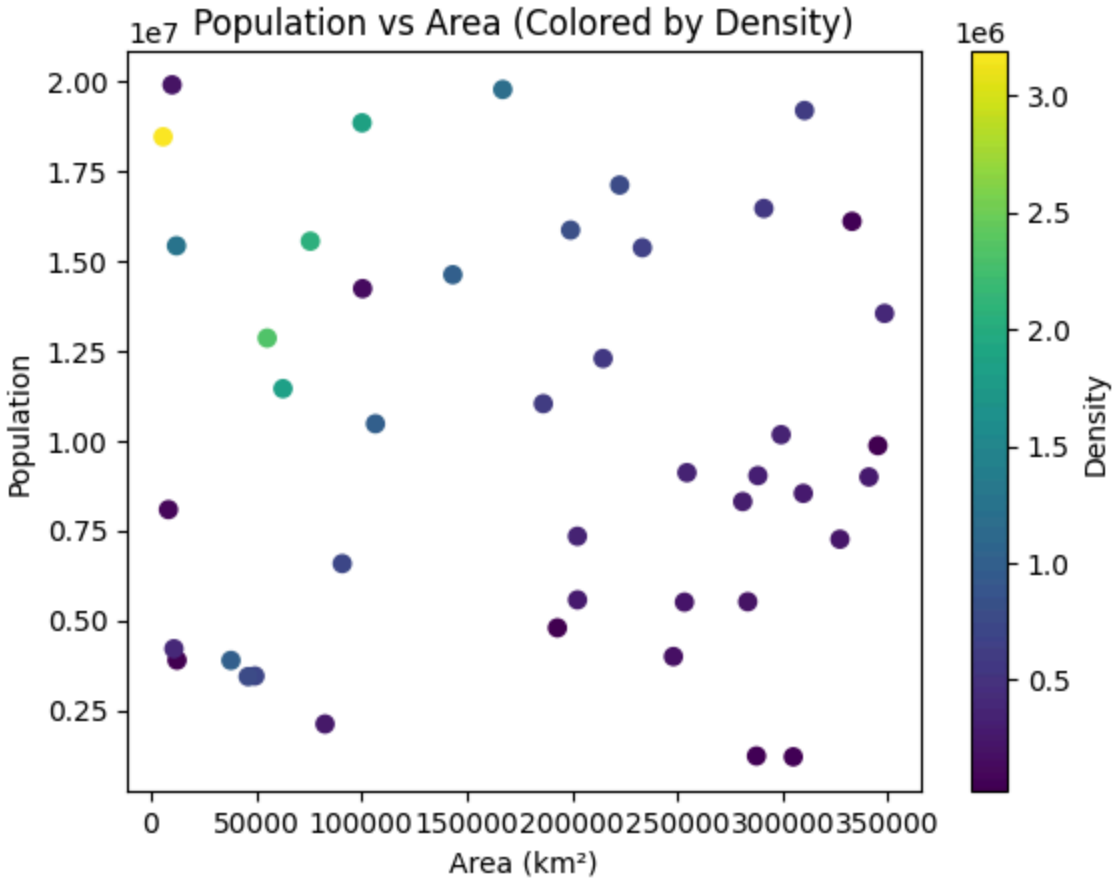
Out[77]:
```
Text(0.5, 1.0, '')
```



Compare with population and area

In [78]:
```
plt.scatter(cleaned_census_data['Area_km²'], cleaned_census_data['Population'], c=c
plt.xlabel('Area (km²)')
plt.ylabel('Population')
plt.title('Population vs Area (Colored by Density)')
plt.colorbar(label='Density')
```

Out[78]:
```
<matplotlib.colorbar.Colorbar at 0x162282b5e50>
```



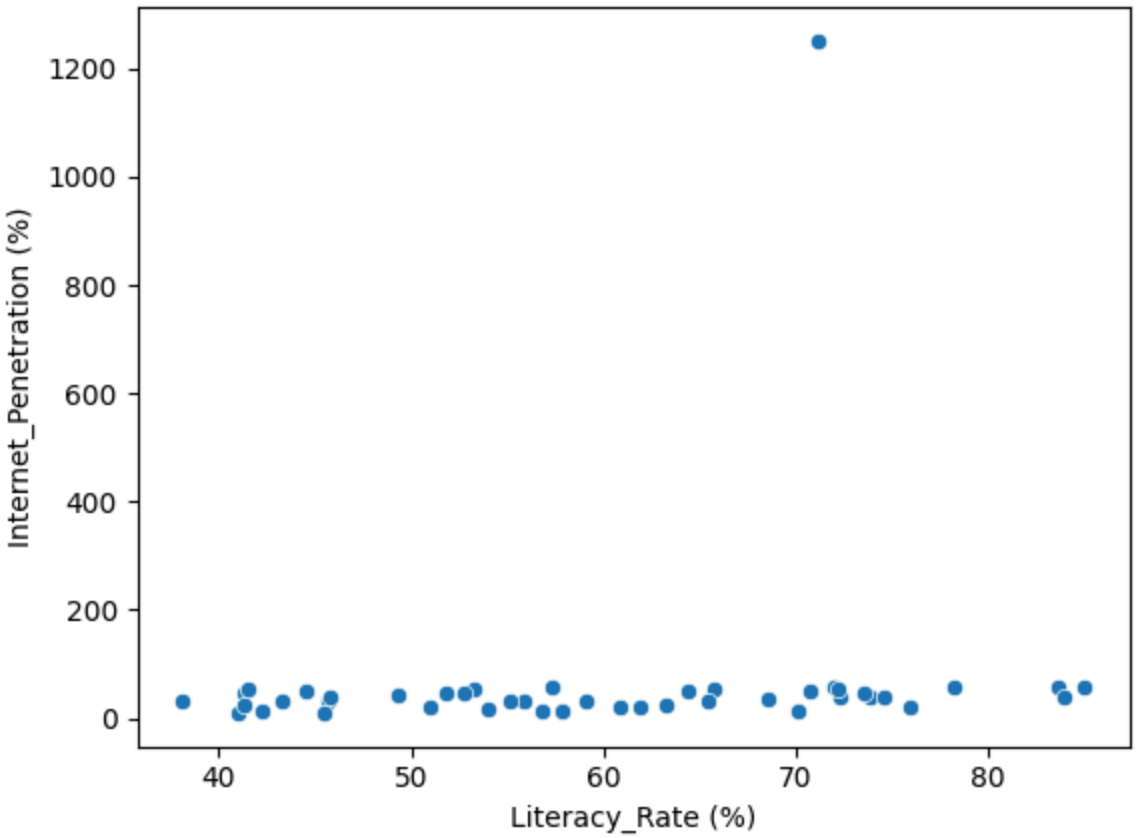
5. Explore Relationships

A. Literacy vs Internet Access

In [79]:
```
sns.scatterplot(data=cleaned_census_data, x='Literacy_Rate (%)', y='Internet_Penetr
```

```
C:\Users\shanz\AppData\Local\Temp\ipykernel_13032\1352337142.py:1: UserWarning: Igno
ring `palette` because no `hue` variable has been assigned.
  sns.scatterplot(data=cleaned_census_data, x='Literacy_Rate (%)', y='Internet_Penet
ration (%)', palette=('red'))
```

Out[79]:
```
<Axes: xlabel='Literacy_Rate (%)', ylabel='Internet_Penetration (%)'>
```

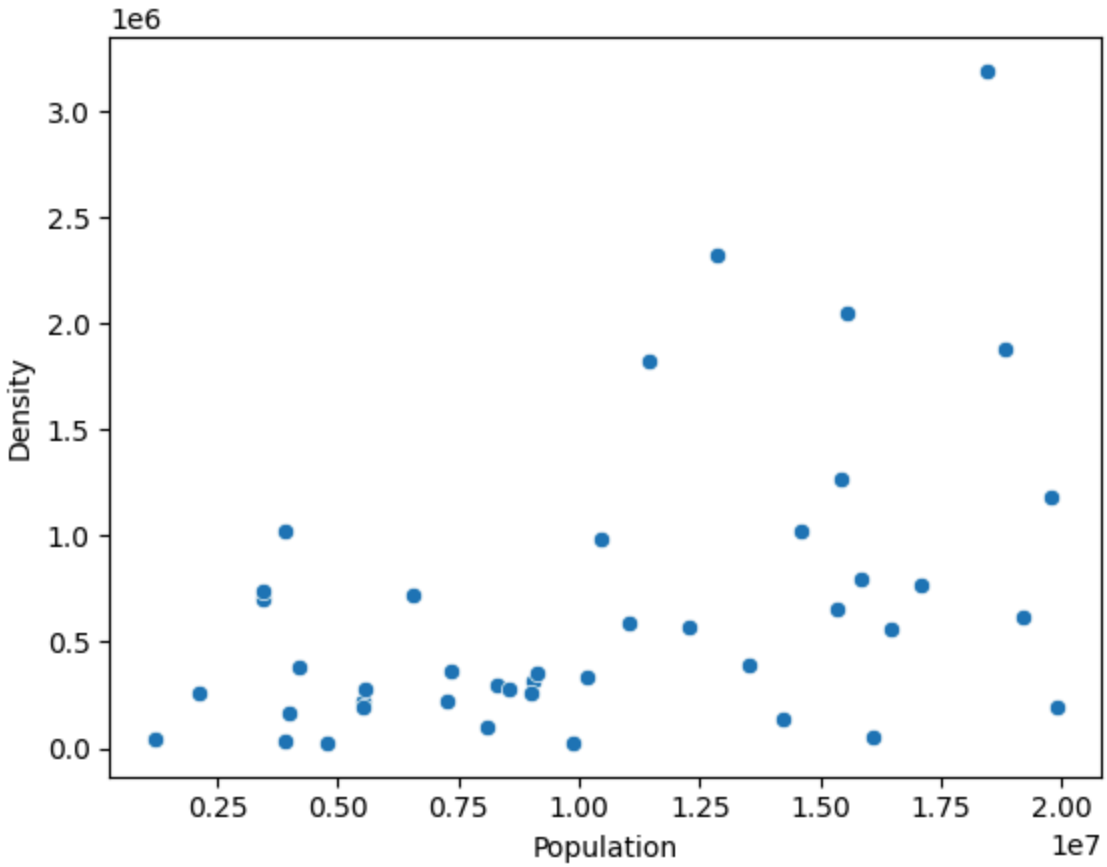


B. Population vs Density

In [80]:
```
sns.scatterplot(data=cleaned_census_data, x='Population', y='Density', palette='red
```

```
C:\Users\shanz\AppData\Local\Temp\ipykernel_13032\1298121632.py:1: UserWarning: Igno
ring `palette` because no `hue` variable has been assigned.
  sns.scatterplot(data=cleaned_census_data, x='Population', y='Density', palette='re
d')
```

Out[80]:
```
<Axes: xlabel='Population', ylabel='Density'>
```

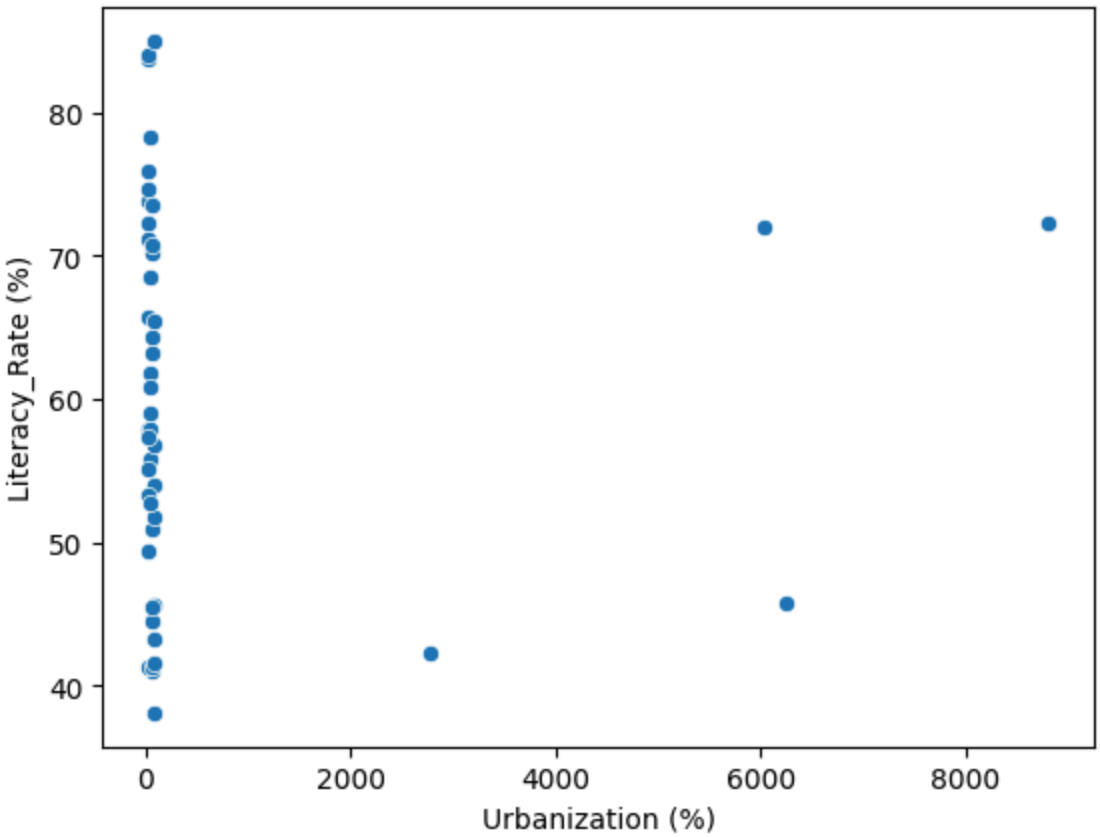


C. Urbanization vs Literacy

In [81]:
```
sns.scatterplot(data=cleaned_census_data, x='Urbanization (%)', y='Literacy_Rate (%
```

```
C:\Users\shanz\AppData\Local\Temp\ipykernel_13032\2764827018.py:1: UserWarning: Igno
ring `palette` because no `hue` variable has been assigned.
  sns.scatterplot(data=cleaned_census_data, x='Urbanization (%)', y='Literacy_Rate
(%)', palette='red')
```

Out[81]:
```
<Axes: xlabel='Urbanization (%)', ylabel='Literacy_Rate (%)'>
```



D. Correlation Matrix + Heatmap

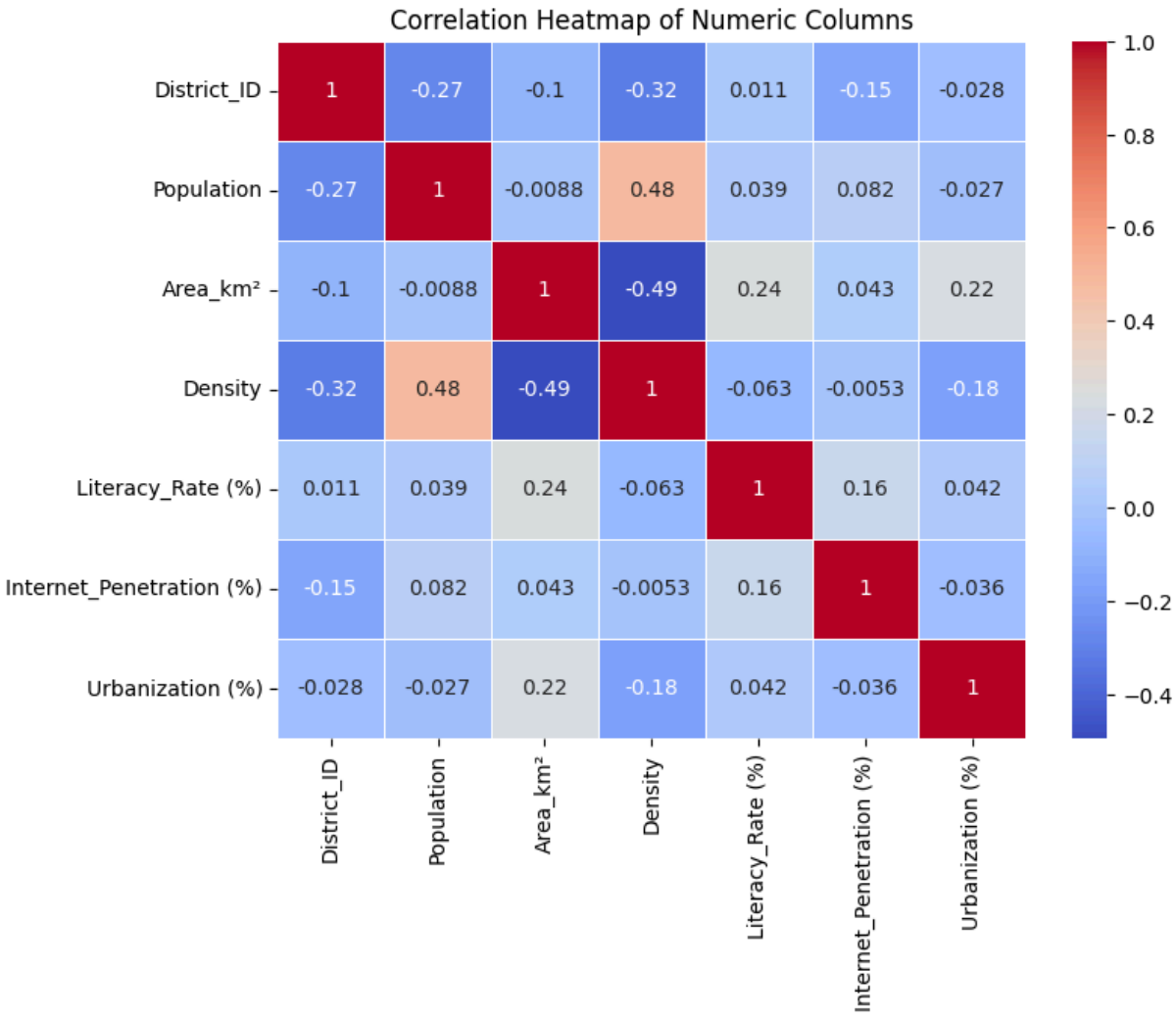
In [82]:
```
numeric_data = cleaned_census_data.select_dtypes(include=['number'])
corr_matrix = numeric_data.corr()
corr_matrix
```

Out[82]:

	District_ID	Population	Area_km²	Density	Literacy_Rate (%)	Internet_P
District_ID	1.000000	-0.274542	-0.102811	-0.319845	0.011268	
Population	-0.274542	1.000000	-0.008755	0.483720	0.039294	
Area_km²	-0.102811	-0.008755	1.000000	-0.494412	0.243879	
Density	-0.319845	0.483720	-0.494412	1.000000	-0.063292	
Literacy_Rate (%)	0.011268	0.039294	0.243879	-0.063292	1.000000	
Internet_Penetration (%)	-0.146464	0.081765	0.043447	-0.005317	0.159264	
Urbanization (%)	-0.028429	-0.026616	0.218480	-0.184871	0.042083	

In [83]:
```
# heat map
figure = plt.figure(figsize=(8,6))
sns.heatmap(corr_matrix, annot=True, cmap='coolwarm', linewidths=0.5)
plt.title("Correlation Heatmap of Numeric Columns")
```

Out[83]: Text(0.5, 1.0, 'Correlation Heatmap of Numeric Columns')



6. Grouped Analysis

A. Average values per province

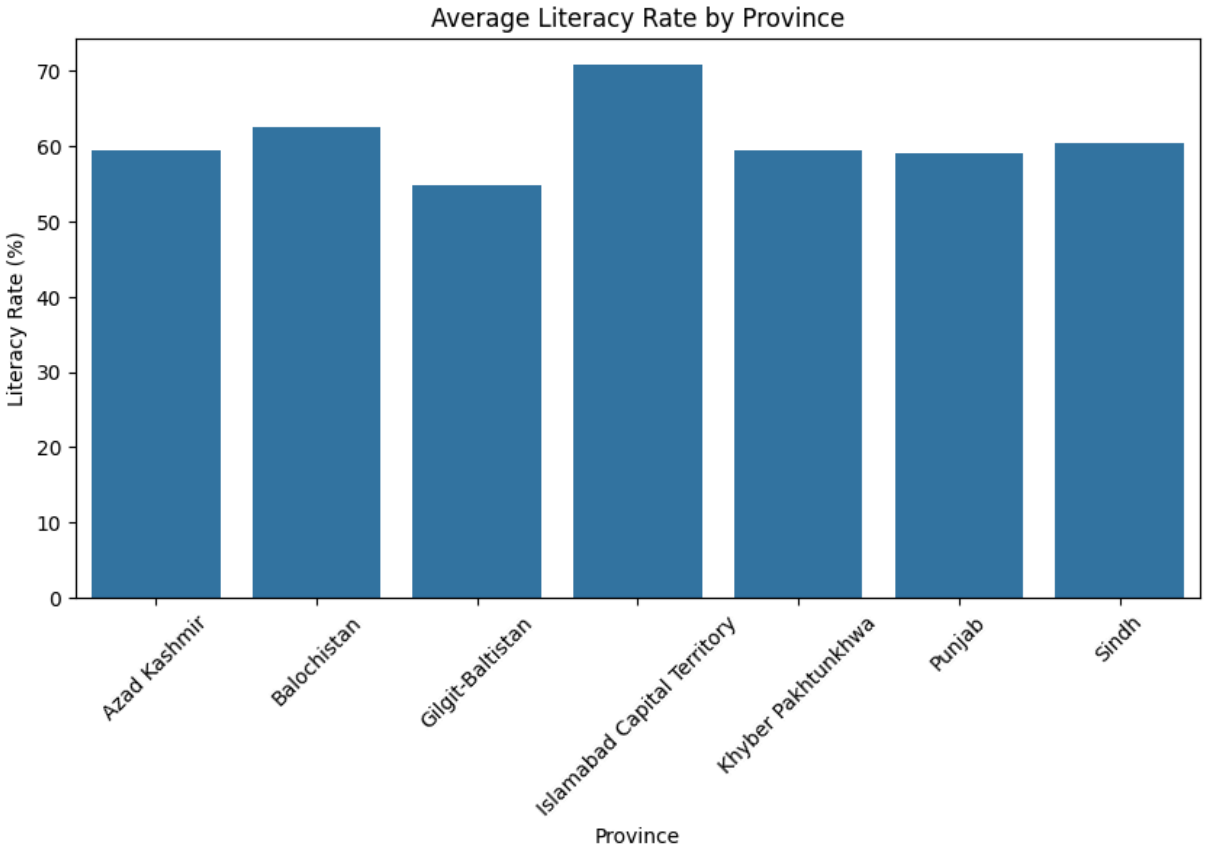
In [84]:
```
# agg_province_avg = cleaned_census_data.groupby('Province').mean()

avg_values = cleaned_census_data.groupby('Province')[['Literacy_Rate (%)','Internet
avg_values
```

Out[84]:

Province	Literacy_Rate (%)	Internet_Penetration (%)	Urbanization (%)	Population
Azad Kashmir	59.458333	41.813333	61.305000	5.366248e+06
Balochistan	62.601250	36.453750	822.703750	1.132248e+07
Gilgit-Baltistan	54.825000	35.911667	1040.868333	9.260825e+06
Islamabad Capital Territory	70.740000	50.180000	74.840000	1.541755e+07
Khyber Pakhtunkhwa	59.527500	29.635000	393.240000	9.793939e+06
Punjab	59.096250	33.772500	1152.681250	1.156220e+07
Sindh	60.393750	187.096250	53.310000	1.299204e+07

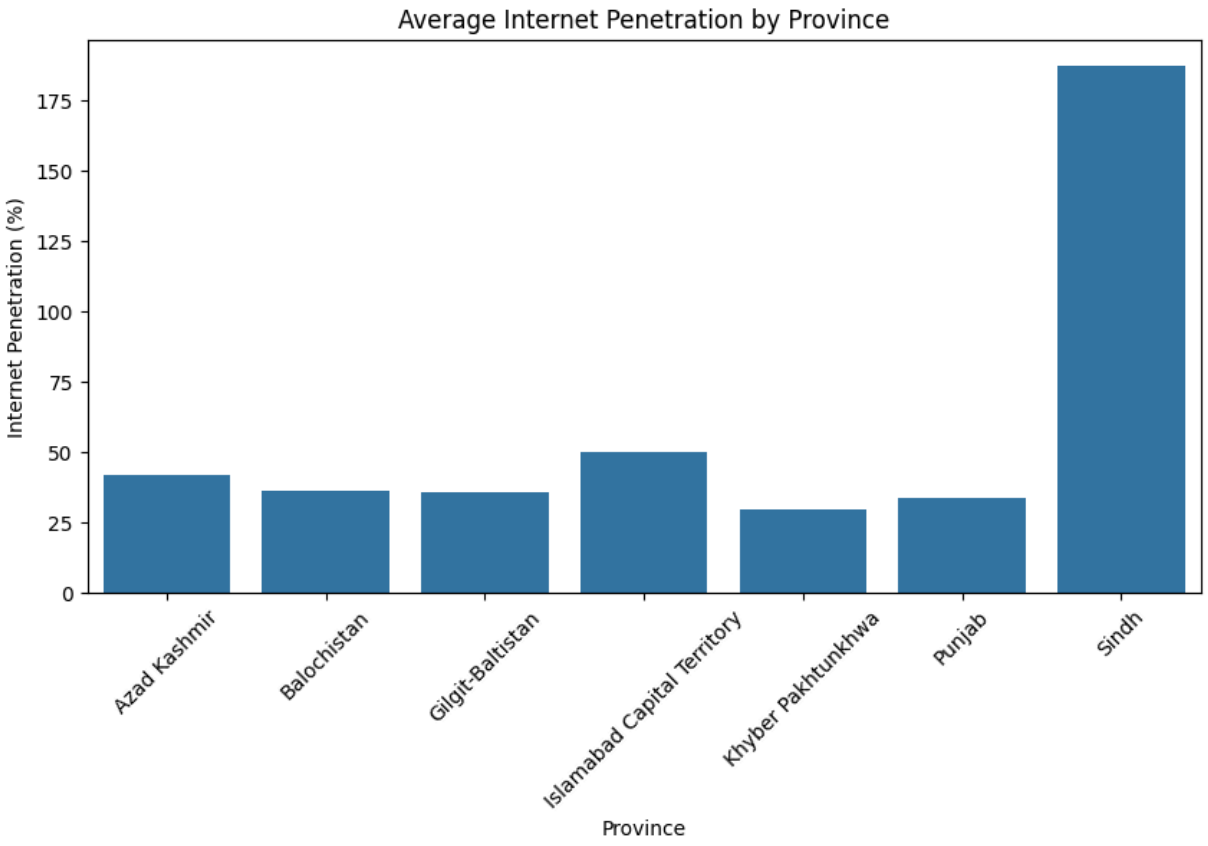
Literacy Rate

In [85]:
```
plt.figure(figsize=(10, 5))
sns.barplot(x=avg_values.index, y=avg_values['Literacy_Rate (%)'])
plt.title('Average Literacy Rate by Province')
plt.ylabel('Literacy Rate (%)')
plt.xticks(rotation=45)
plt.show()
```



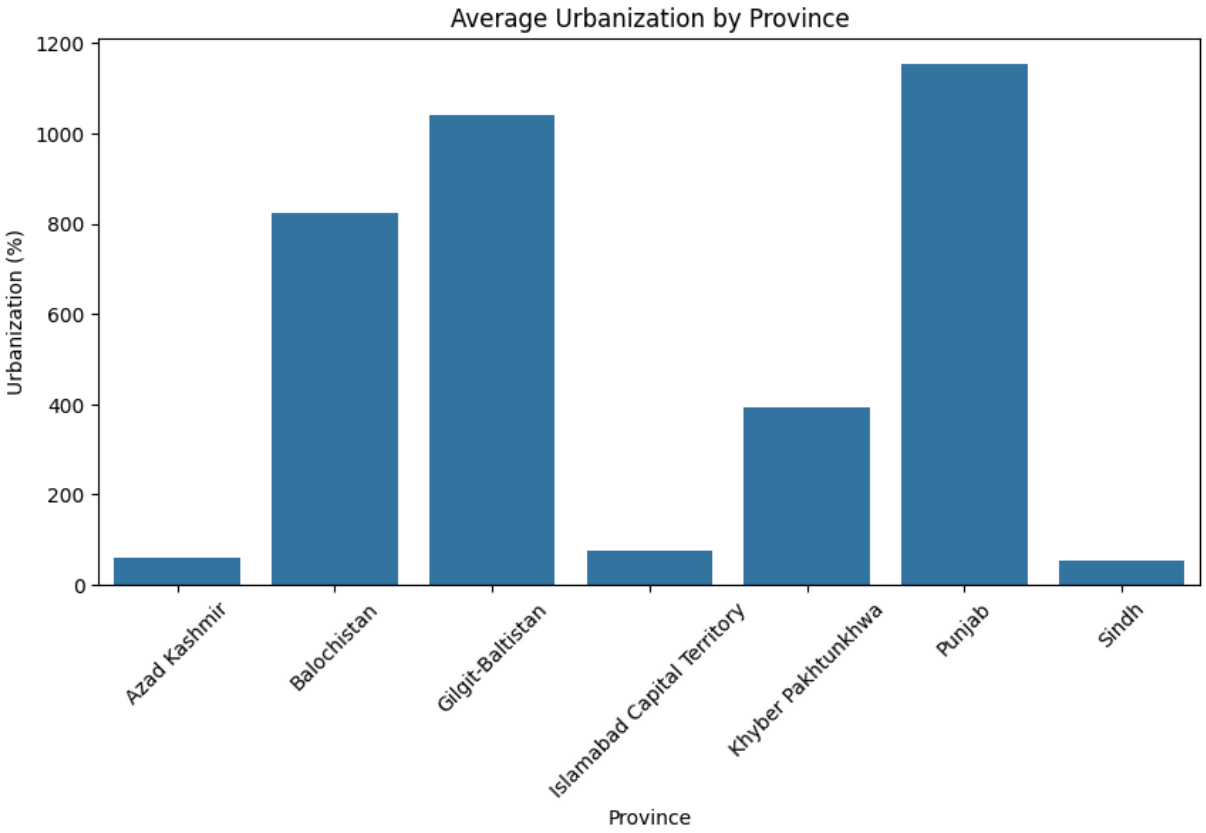
Internet Penetration

In [86]:
```
plt.figure(figsize=(10, 5))
sns.barplot(x=avg_values.index, y=avg_values['Internet_Penetration (%)'])
plt.title('Average Internet Penetration by Province')
plt.ylabel('Internet Penetration (%)')
plt.xticks(rotation=45)
plt.show()
```



Urbanization

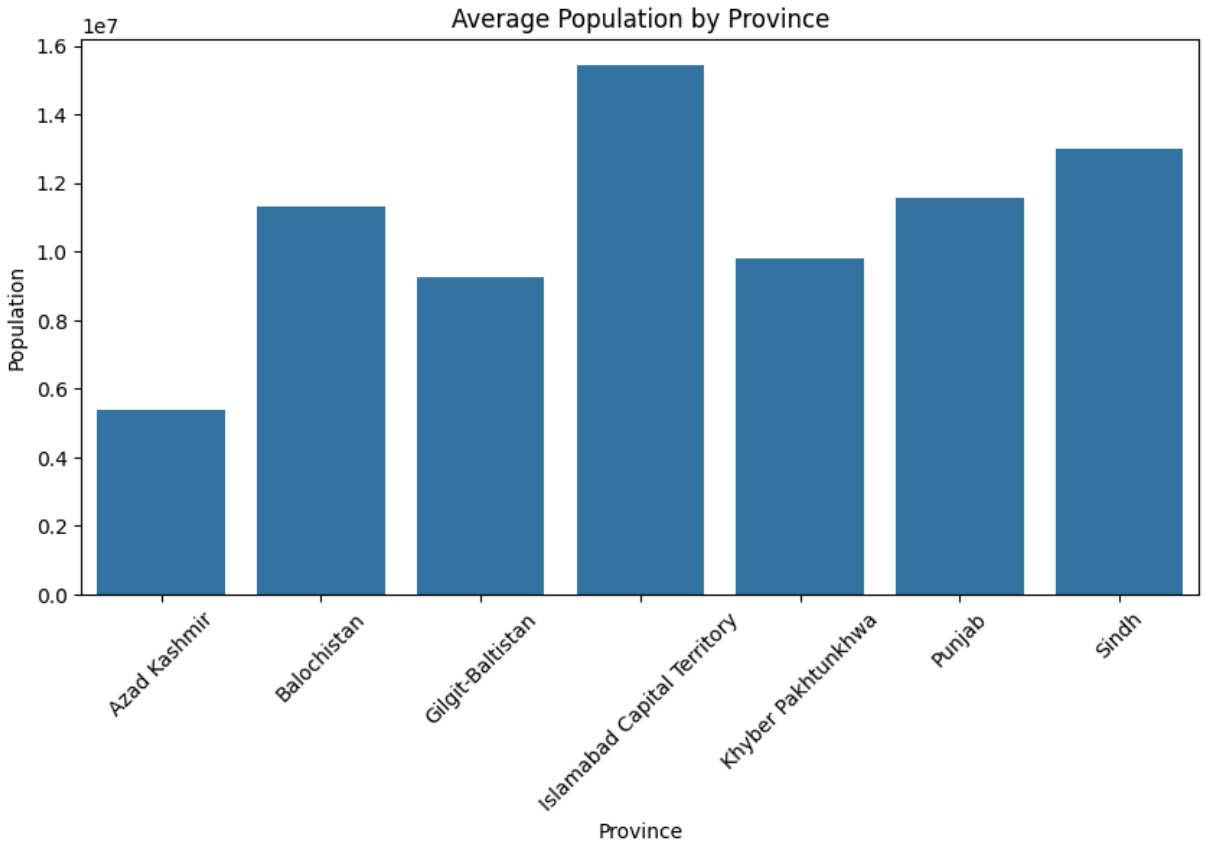
In [87]:
```
plt.figure(figsize=(10, 5))
sns.barplot(x=avg_values.index, y=avg_values['Urbanization (%)'])
plt.title('Average Urbanization by Province')
plt.ylabel('Urbanization (%)')
plt.xticks(rotation=45)
plt.show()
```



Population

In [88]:
```
plt.figure(figsize=(10, 5))
sns.barplot(x=avg_values.index, y=avg_values['Population'])
plt.title('Average Population by Province')
plt.ylabel('Population')
plt.xticks(rotation=45)
```

Out[88]:
```
([0, 1, 2, 3, 4, 5, 6],
 [Text(0, 0, 'Azad Kashmir'),
  Text(1, 0, 'Balochistan'),
  Text(2, 0, 'Gilgit-Baltistan'),
  Text(3, 0, 'Islamabad Capital Territory'),
  Text(4, 0, 'Khyber Pakhtunkhwa'),
  Text(5, 0, 'Punjab'),
  Text(6, 0, 'Sindh')])
```



7. Identify Key Insights

Most literate district

In [89]:
```
most_literate_district_idx = cleaned_census_data['Literacy_Rate (%)'].idxmax()
most_literate = cleaned_census_data.loc[most_literate_district_idx]
most_literate_value = most_literate['Literacy_Rate (%)']
most_literate_value
```

Out[89]: np.float64(84.97)

Most urbanized district

In [90]:
```
most_urbanize_district_idx = cleaned_census_data['Urbanization (%)'].idxmax()
most_urbanize = cleaned_census_data.loc[most_urbanize_district_idx]
most_urbanize_value = most_urbanize['Urbanization (%)']
most_urbanize_value
```

Out[90]: np.float64(8812.0)

Least internet-penetrated province

In [91]:
```
least_Internet_idx = cleaned_census_data['Internet_Penetration (%)'].idxmin()
least_Internet = cleaned_census_data.loc[least_Internet_idx]
least_Internet_value = least_Internet['Internet_Penetration (%)']
least_Internet_value
```

Out[91]: np.float64(10.18)

Top 5 literate districts to CSV for report

In [92]:
```
top_literate_district = cleaned_census_data.sort_values('Literacy_Rate (%)').head()
top_literate_district[['Province', 'District', 'Literacy_Rate (%)']]
```

Out[92]:

	Province	District	Literacy_Rate (%)
43	Azad Kashmir	Hattian Bala	38.10
32	Gilgit-Baltistan	Gilgit	41.01
34	Gilgit-Baltistan	Diamer	41.33
33	Gilgit-Baltistan	Skardu	41.34
40	Azad Kashmir	Kotli	41.54

Q: Which province has the highest number of districts?

In [93]:
```
district_counts = cleaned_census_data['Province'].value_counts()
print(district_counts)
```

```
Province
Punjab                          8
Sindh                           8
Khyber Pakhtunkhwa              8
Balochistan                     8
Gilgit-Baltistan                6
Azad Kashmir                    6
Islamabad Capital Territory     1
Name: count, dtype: int64
```

Q: Which district has the highest literacy rate?

In [94]:
```
max_lit = cleaned_census_data.loc[cleaned_census_data['Literacy_Rate (%)'].idxmax()
print(max_lit[['Province', 'District', 'Literacy_Rate (%)']])
```

```
Province             Azad Kashmir
District                    Bagh
Literacy_Rate (%)          84.97
Name: 41, dtype: object
```

Q: Which province has the lowest internet penetration on average?

In [95]:
```
internet_by_province = cleaned_census_data.groupby("Province")["Internet_Penetratio
print(internet_by_province)
```

```
Province
Khyber Pakhtunkhwa              29.635000
Punjab                          33.772500
Gilgit-Baltistan                35.911667
Balochistan                     36.453750
Azad Kashmir                    41.813333
Islamabad Capital Territory     50.180000
Sindh                          187.096250
Name: Internet_Penetration (%), dtype: float64
```

Q: Which district has the highest population density?

In [96]:
```
high_density = cleaned_census_data.sort_values("Density", ascending=False).head()
print(high_density[['District', 'Density']])
```

```
     District    Density
1   Rawalpindi  3190845.0
7     Sargodha  2327497.0
16    Peshawar  2053185.0
13  Mirpurkhas  1878609.0
5   Bahawalpur  1825034.0
```

Q: Which districts have a high urban population but low internet penetration?

In [97]:
```
suspicious = cleaned_census_data[
    (cleaned_census_data['Urbanization (%)'] > 50) & (cleaned_census_data['Internet
]
print(suspicious[['District', 'Urbanization (%)', 'Internet_Penetration (%)']])
```

```
     District  Urbanization (%)  Internet_Penetration (%)
4   Gujranwala             87.00                     18.55
11      Sukkur             64.45                     13.93
14   Nawabshah             83.92                     13.64
18      Mardan           2768.00                     12.59
22    Mansehra             70.55                     10.18
32      Gilgit             58.77                     11.16
```

Q: Which regions show both high literacy and high urbanization?

In [98]:
```
filtered = cleaned_census_data[(cleaned_census_data['Province'].isin(['Sindh', 'Pun
                      (cleaned_census_data['Urbanization (%)'] > 60) &
                      (cleaned_census_data['Literacy_Rate (%)'] > 60)]
print(filtered[['Province', 'District', 'Urbanization (%)', 'Literacy_Rate (%)']])
```

```
   Province    District  Urbanization (%)  Literacy_Rate (%)
2    Punjab  Faisalabad             69.09              64.38
6    Punjab     Sialkot           8812.00              72.30
11    Sindh      Sukkur             64.45              70.13
```

Q: What is the distribution of population across provinces?

In [99]:
```
print(cleaned_census_data[['District', 'Population']].sort_values('Population', asc
print(cleaned_census_data[['District', 'Population']].sort_values('Population').hea
```

```
      District  Population
33      Skardu    19894773
17  Abbottabad    19765450
15      Thatta    19181404
13  Mirpurkhas    18838132
1   Rawalpindi    18449464
        District  Population
34        Diamer     1204043
14     Nawabshah     1227105
43  Hattian Bala     2117477
41          Bagh     3435271
38  Muzaffarabad     3452355
```

Q: Which small districts (area < 1000) have high literacy (above 80%)?

In [100…

```
small_area = cleaned_census_data[cleaned_census_data['Area_km²'] < 15000]
high_lit = small_area[small_area['Literacy_Rate (%)'] > 70]
print(high_lit[['District', 'Area_km²', 'Literacy_Rate (%)']])
```

```
     District  Area_km²  Literacy_Rate (%)
44  Islamabad     12128              70.74
```