

Credit Risk Analysis

โปรเจกต์นี้เป็น workshop การวิเคราะห์ความเสี่ยงด้านสินเชื่อ (Credit Risk Analysis) และการพัฒนาแบบจำลองคะแนนเครดิต (Credit Scoring / Scorecard Model) โดยใช้ข้อมูลลูกค้าและเทคนิคทางสถิติเพื่อศึกษาวิเคราะห์ถึงปัจจัยต่อการผิดนัดชำระหนี้ จากตัวแปร Demographic Data ในด้านต่างๆ อาทิเช่น อายุ, รายได้, การถือครองที่อยู่อาศัย, อายุงาน, ดอกเบี้ย, บิลสินเชื่อ, และอื่นๆ ผ่านเครื่องมือ python JupyterLab ในการวิเคราะห์

โดยใช้ข้อมูลจาก simulating credit bureau data

ที่มาของข้อมูล <https://www.kaggle.com/datasets/laotse/credit-risk-dataset>

Feature Name	Description
person_age	Age
person_income	Annual Income
person_home_ownership	Home ownership
person_emp_length	Employment length (in years)
loan_intent	Loan intent
loan_grade	Loan grade
loan_amnt	Loan amount
loan_int_rate	Interest rate
loan_status	Loan status (0 is non default, 1 is default)
loan_percent_income	Percent income
cb_person_default_on_file	Historical default
cb_preson_cred_hist_length	Credit history length

```
In [1]: # Install Library
#!pip install kagglehub
#!pip install statsmodels
#!pip install pipreqs
```

Import Library and Setting

```
In [2]: # Import Library
import pandas as pd
import numpy as np
import seaborn as sns
import kagglehub
import matplotlib as mpl
```

```

import matplotlib.pyplot as plt
import warnings
import statsmodels.api as sm
import os

from statsmodels.stats.outliers_influence import variance_inflation_factor
from statsmodels.tools.tools import add_constant
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split
from sklearn.metrics import roc_auc_score, roc_curve
from sklearn.linear_model import LogisticRegression

# Checking Library version
print("---Library version---", end = '\n')
print('pandas version: ', pd.__version__)
print('numpy version: ', np.__version__)
print('seaborn version: ', sns.__version__)
print('matplotlib version: ', mpl.__version__, end = '\n\n')

---Library version---
pandas version: 2.2.2
numpy version: 1.26.3
seaborn version: 0.13.2
matplotlib version: 3.9.2

```

In [3]:

```

# Setting library
pd.set_option('display.max_columns', None)
pd.set_option('display.max_rows', 100)
pd.options.display.float_format = '{:,.0f}'.format

mpl.font_manager.fontManager.addfont("asset\\fonts\\Sarabun-Regular.ttf")
mpl.rc('font', family='Sarabun')
plt.rcParams ['font.family'] = ('Sarabun')

# ignore warnings
warnings.filterwarnings('ignore')

```

In [4]:

```

# Print current working directory
print("---Working Directory---", end = '\n')
print('List of Directory:', os.listdir(os.getcwd()))
print('List of Directory (Data):', os.listdir(os.getcwd() + '\\data'))

---Working Directory---
List of Directory: ['.git', '.ipynb_checkpoints', 'asset', 'Credit_Risk_Analysis_Report.pdf', 'data', 'notebooks', 'Notebook_source_code.pdf', 'readme.md', 'requirements.txt', 'Risk-Credit-Analysis_notebook.ipynb']
List of Directory (Data): ['.ipynb_checkpoints', 'processed', 'raw']

```

Import Data

In [5]:

```

raw_data = "credit_risk_dataset.csv"

data = pd.read_csv(filepath_or_buffer=f'data/raw/{raw_data}')

```

```
with pd.option_context('display.max_rows', 10):
    display(data)
```

	person_age	person_income	person_home_ownership	person_emp_length	lo
0	22	59000	RENT	123	P
1	21	9600	OWN	5	ED
2	25	9600	MORTGAGE	1	
3	23	65500	RENT	4	
4	24	54400	RENT	8	
...	
32576	57	53000	MORTGAGE	1	P
32577	54	120000	MORTGAGE	4	P
32578	65	76000	RENT	3	HOMEIMPRO
32579	56	150000	MORTGAGE	5	P
32580	66	42000	RENT	2	

32581 rows × 12 columns



```
In [6]: print(f'Records: {data.shape[0]}, Variable: {data.shape[1]}')
```

Records: 32581, Variable: 12

Overall of Data

```
In [7]: data.info()
```

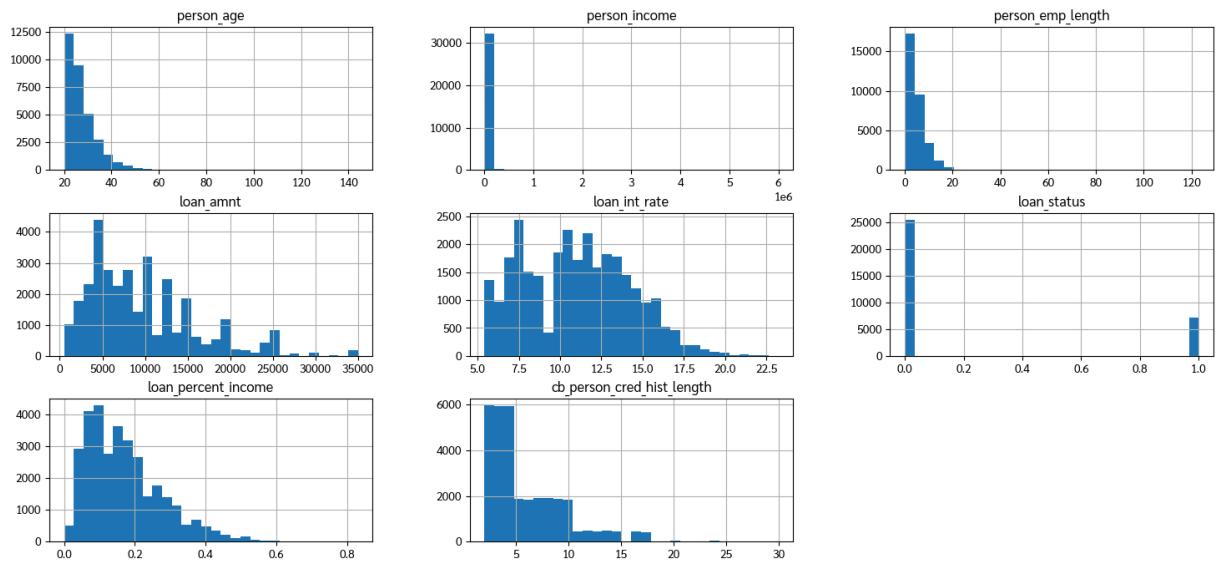
```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 32581 entries, 0 to 32580
Data columns (total 12 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   person_age       32581 non-null   int64  
 1   person_income    32581 non-null   int64  
 2   person_home_ownership  32581 non-null   object  
 3   person_emp_length 31686 non-null   float64 
 4   loan_intent      32581 non-null   object  
 5   loan_grade       32581 non-null   object  
 6   loan_amnt        32581 non-null   int64  
 7   loan_int_rate    29465 non-null   float64 
 8   loan_status      32581 non-null   int64  
 9   loan_percent_income 32581 non-null   float64 
 10  cb_person_default_on_file 32581 non-null   object  
 11  cb_person_cred_hist_length 32581 non-null   int64  
dtypes: float64(3), int64(5), object(4)
memory usage: 3.0+ MB
```

In [8]: `data.describe()`

	person_age	person_income	person_emp_length	loan_amnt	loan_int_rate	loan_status
count	32,581	32,581	31,686	32,581	29,465	32,581
mean	28	66,075	5	9,589	11	
std	6	61,983	4	6,322	3	
min	20	4,000	0	500	5	
25%	23	38,500	2	5,000	8	
50%	26	55,000	4	8,000	11	
75%	30	79,200	7	12,200	13	
max	144	6,000,000	123	35,000	23	

Data Distribution

In [9]: `data.select_dtypes('number').hist(bins=30, figsize=(18,8))
plt.show()`

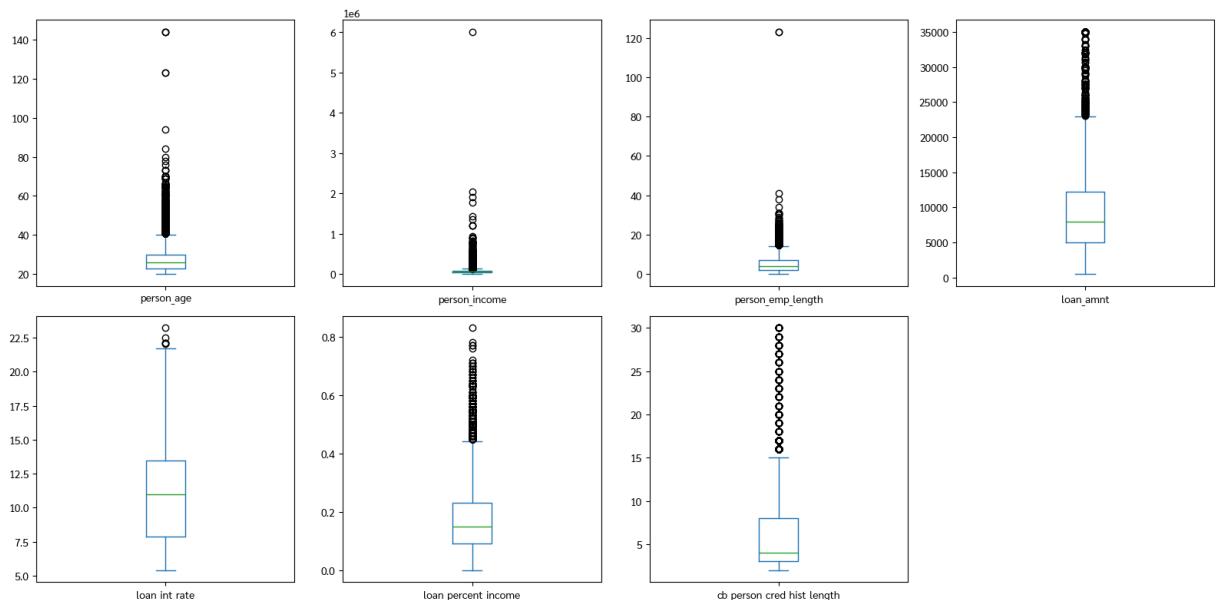


Data Outlier Cleaning

```
In [10]: numeric_df_plot = data.select_dtypes(include='number').drop(columns=['loan_status'])

numeric_df_plot.plot(
    kind='box',
    subplots=True,
    layout=(2, 4),   # adjust rows/cols to match remaining variables
    figsize=(16, 8)
)

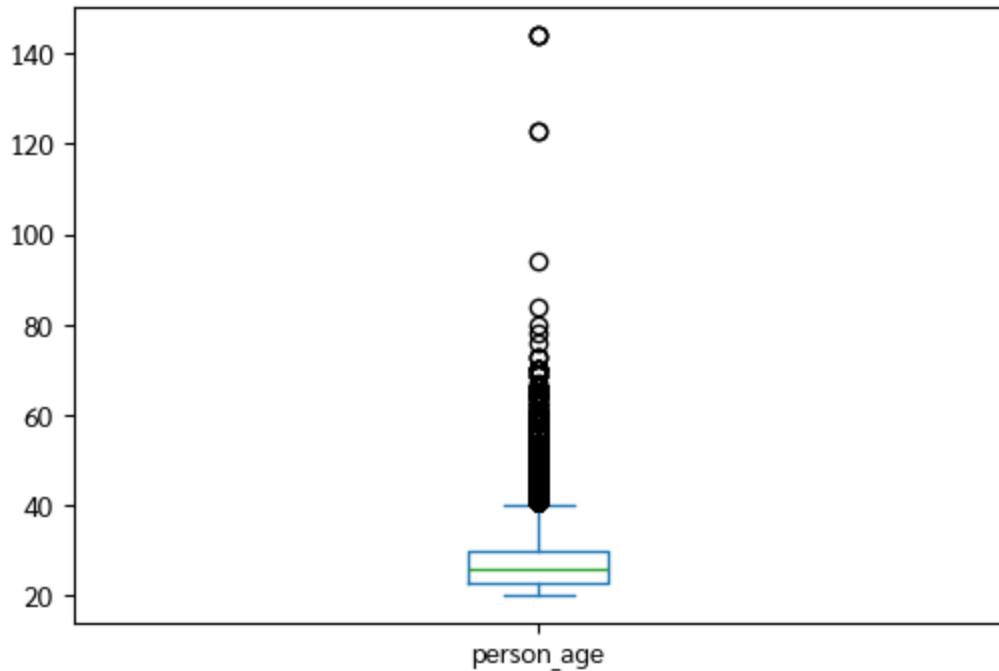
plt.tight_layout()
plt.show()
```



person_age

```
In [11]: data['person_age'].plot(kind='box', figsize=(6,4))
plt.show()

print(data['person_age'].describe())
```

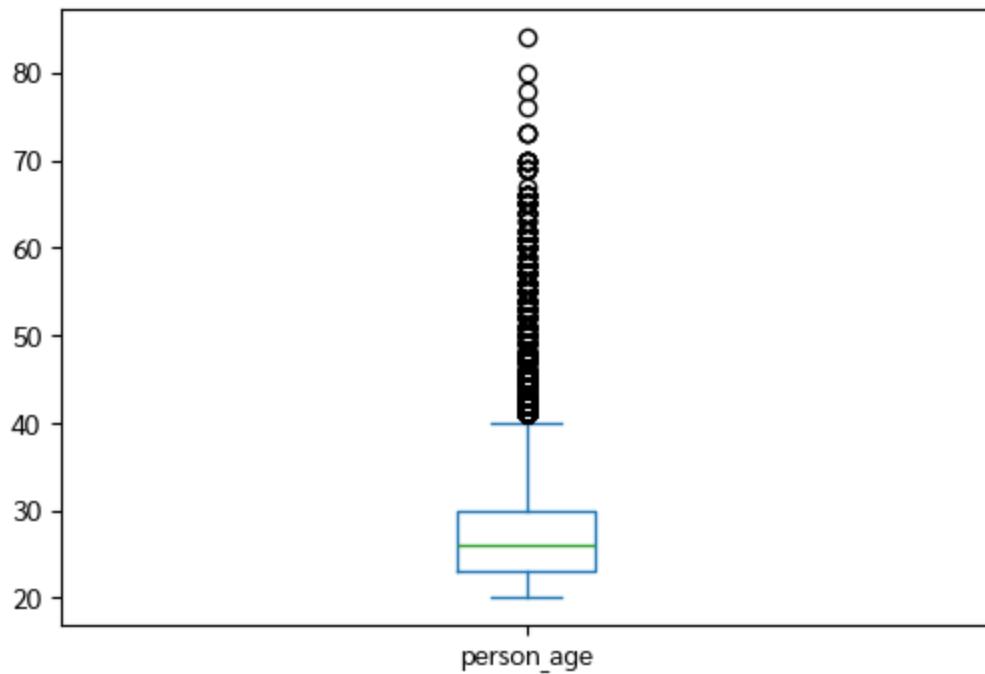


```
count    32,581
mean      28
std       6
min      20
25%      23
50%      26
75%      30
max     144
Name: person_age, dtype: float64
```

```
In [12]: data = data[(data['person_age'] >= 20) & (data['person_age'] <= 90)]
```

```
In [13]: data['person_age'].plot(kind='box', figsize=(6,4))
plt.show()

print(data['person_age'].describe())
```

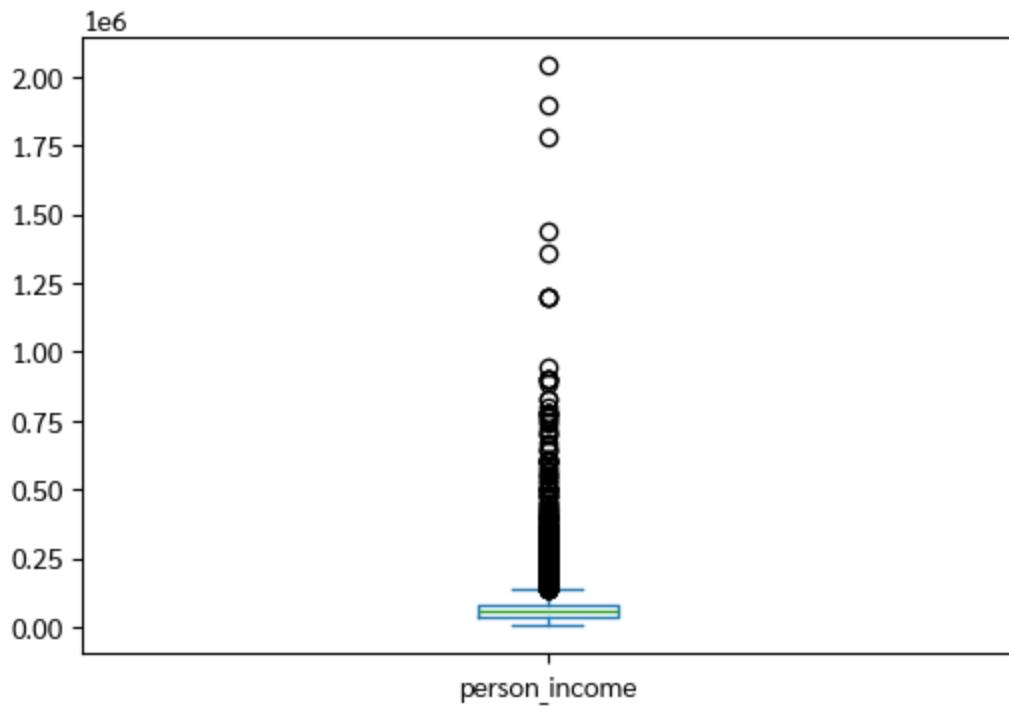


```
count    32,575
mean        28
std         6
min        20
25%        23
50%        26
75%        30
max        84
Name: person_age, dtype: float64
```

person_income

```
In [14]: data['person_income'].plot(kind='box', figsize=(6,4))
plt.show()

print(data['person_income'].describe())
```

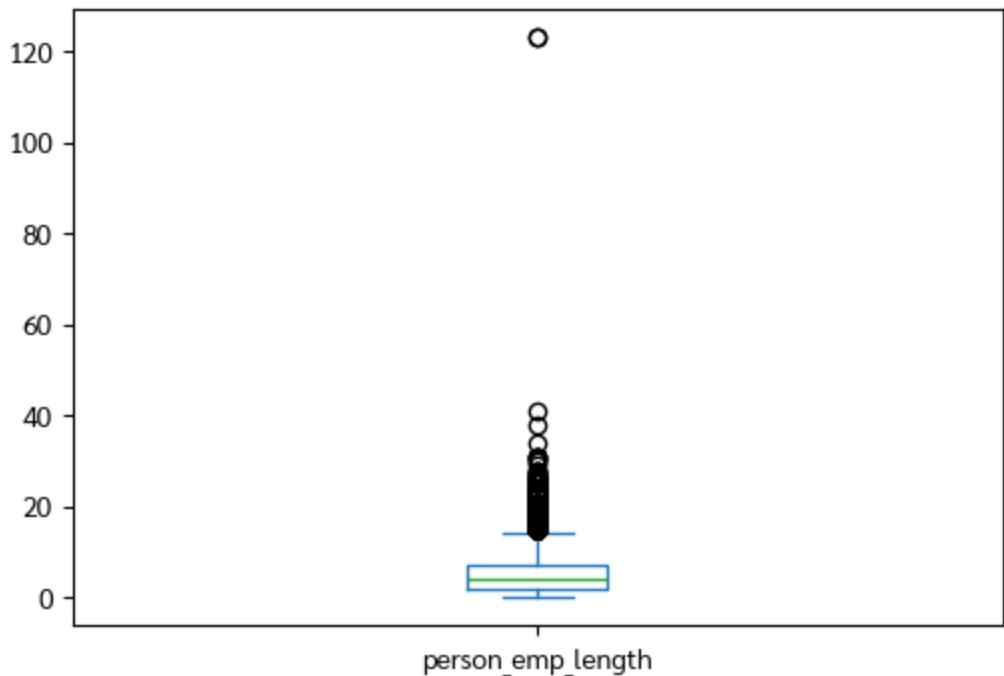


```
count      32,575
mean      65,883
std       52,535
min       4,000
25%      38,500
50%      55,000
75%      79,200
max     2,039,784
Name: person_income, dtype: float64
```

person_emp_length

```
In [15]: data['person_emp_length'].plot(kind='box', figsize=(6,4))
plt.show()

print(data['person_emp_length'].describe())
```

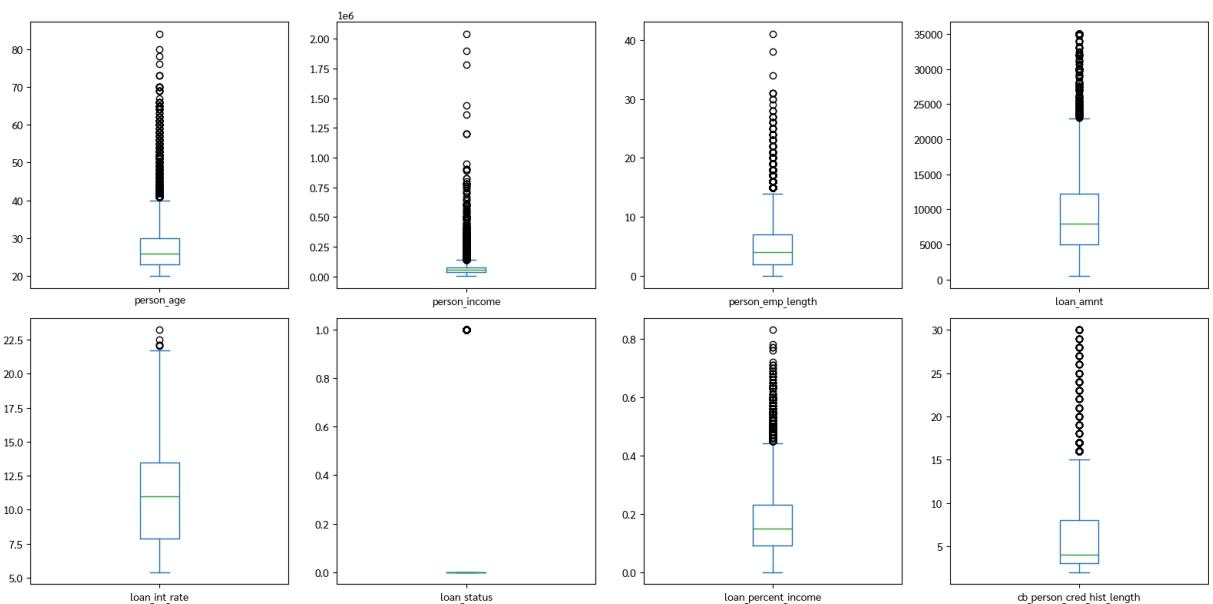


```
count    31,680
mean        5
std         4
min         0
25%        2
50%        4
75%        7
max       123
Name: person_emp_length, dtype: float64
```

```
In [16]: data = data[data['person_emp_length'] != 123]
```

```
In [17]: data.plot(
    kind='box',
    subplots=True,
    layout=(2, 4),   # adjust rows/cols to match remaining variables
    figsize=(16, 8)
)

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



Category Data Exploring

```
In [18]: cat_cols = data.select_dtypes(include=['object', 'category']).columns
unique_counts = data[cat_cols].nunique()

print(unique_counts)

person_home_ownership      4
loan_intent                 6
loan_grade                  7
cb_person_default_on_file   2
dtype: int64
```

```
In [19]: for col in cat_cols:
    print(f"\nColumn: {col}")
    print(data[col].value_counts(dropna=False))
```

```
Column: person_home_ownership
person_home_ownership
RENT          16441
MORTGAGE      13441
OWN           2584
OTHER          107
Name: count, dtype: int64
```

```
Column: loan_intent
loan_intent
EDUCATION      6451
MEDICAL        6070
VENTURE         5716
PERSONAL        5519
DEBTCONSOLIDATION  5212
HOMEIMPROVEMENT 3605
Name: count, dtype: int64
```

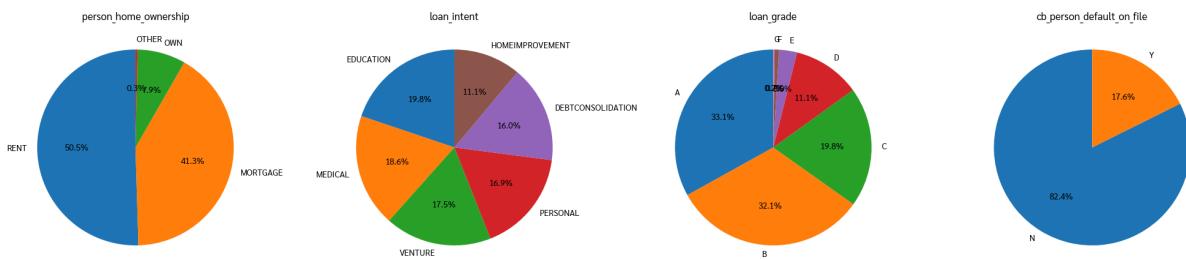
```
Column: loan_grade
loan_grade
A      10776
B      10448
C      6455
D      3625
E      964
F      241
G      64
Name: count, dtype: int64
```

```
Column: cb_person_default_on_file
cb_person_default_on_file
N      26829
Y      5744
Name: count, dtype: int64
```

```
In [20]: n = len(cat_cols)
# Create 1 row with n columns
fig, axes = plt.subplots(1, n, figsize=(5*n, 5))

for i, col in enumerate(cat_cols):
    counts = data[col].value_counts(dropna=False)
    axes[i].pie(
        counts,
        labels=counts.index,
        autopct='%.1f%%',
        startangle=90
    )
    axes[i].set_title(col)

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



Rename Columns

```
In [21]: df = data.rename(columns=lambda x: x.replace("person_", "")).title()
display(df)
```

	Age	Income	Home_Ownership	Emp_Length	Loan_Intent	Loan_Grade	Loar
1	21	9600	OWN	5	EDUCATION	B	
2	25	9600	MORTGAGE	1	MEDICAL	C	
3	23	65500	RENT	4	MEDICAL	C	
4	24	54400	RENT	8	MEDICAL	C	
5	21	9900	OWN	2	VENTURE	A	
...
32576	57	53000	MORTGAGE	1	PERSONAL	C	
32577	54	120000	MORTGAGE	4	PERSONAL	A	
32578	65	76000	RENT	3	HOMEIMPROVEMENT	B	
32579	56	150000	MORTGAGE	5	PERSONAL	B	
32580	66	42000	RENT	2	MEDICAL	B	

32573 rows × 12 columns



Change Columns Type

```
In [22]: df["Emp_Length"] = df["Emp_Length"].astype("Int64")
df["Loan_Int_Rate"] = df["Loan_Int_Rate"].astype("Float64")
```

```
In [23]: df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 32573 entries, 1 to 32580
Data columns (total 12 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   Age              32573 non-null   int64  
 1   Income            32573 non-null   int64  
 2   Home_Ownership   32573 non-null   object  
 3   Emp_Length        31678 non-null   Int64  
 4   Loan_Intent       32573 non-null   object  
 5   Loan_Grade        32573 non-null   object  
 6   Loan_Amnt         32573 non-null   int64  
 7   Loan_Int_Rate    29459 non-null   float64 
 8   Loan_Status       32573 non-null   int64  
 9   Loan_Percent_Income 32573 non-null   float64 
 10  Cb_Default_On_File 32573 non-null   object  
 11  Cb_Cred_Hist_Length 32573 non-null   int64  
dtypes: Float64(1), Int64(1), float64(1), int64(5), object(4)
memory usage: 3.3+ MB
```

Check Missing or NaN value

```
In [24]: for i in df.columns:
    print(f'{i} : {df[i].isna().sum()}')
```

```
Age : 0
Income : 0
Home_Ownership : 0
Emp_Length : 895
Loan_Intent : 0
Loan_Grade : 0
Loan_Amnt : 0
Loan_Int_Rate : 3114
Loan_Status : 0
Loan_Percent_Income : 0
Cb_Default_On_File : 0
Cb_Cred_Hist_Length : 0
```

```
In [25]: print('String columns with contain NaN values', end='\n\n')
for column in df.columns:
    if df[column].dtype == 'O' and df[column].isna().any():
        print(f"NaN in : '{column}'")
    else:
        print("None")
```

String columns with contain NaN values

```
None
```

Export Processed Data

```
In [26]: print("Rows before:", df.shape[0])
```

Rows before: 32573

```
In [27]: # Drop rows with any NaN values
df_clean = df.dropna()

display(df_clean)
```

	Age	Income	Home_Ownership	Emp_Length	Loan_Intent	Loan_Grade	Loar
1	21	9600	OWN	5	EDUCATION	B	
2	25	9600	MORTGAGE	1	MEDICAL	C	
3	23	65500	RENT	4	MEDICAL	C	
4	24	54400	RENT	8	MEDICAL	C	
5	21	9900	OWN	2	VENTURE	A	
...
32576	57	53000	MORTGAGE	1	PERSONAL	C	
32577	54	120000	MORTGAGE	4	PERSONAL	A	
32578	65	76000	RENT	3	HOMEIMPROVEMENT	B	
32579	56	150000	MORTGAGE	5	PERSONAL	B	
32580	66	42000	RENT	2	MEDICAL	B	

28632 rows × 12 columns



```
In [28]: print("Rows after:", df_clean.shape[0])
```

Rows after: 28632

```
In [29]: df.shape[0] - df_clean.shape[0]
```

Out[29]: 3941

```
In [30]: df_clean.isna().sum()
```

```
Out[30]: Age          0
Income        0
Home_Ownership 0
Emp_Length    0
Loan_Intent   0
Loan_Grade   0
Loan_Amnt    0
Loan_Int_Rate 0
Loan_Status   0
Loan_Percent_Income 0
Cb_Default_On_File 0
Cb_Cred_Hist_Length 0
dtype: int64
```

```
In [31]: file_name = "credit_risk_dataset"
flag = "cleaned"
```

```
df_clean.to_csv(f'data/processed/{file_name + "_" + flag}.csv', index=False)
```

Analysis and Understand insight of the Data

```
In [32]: pd.reset_option('display.float_format')
display(df.corr(numeric_only=True))
pd.options.display.float_format = '{:.0f}'.format
```

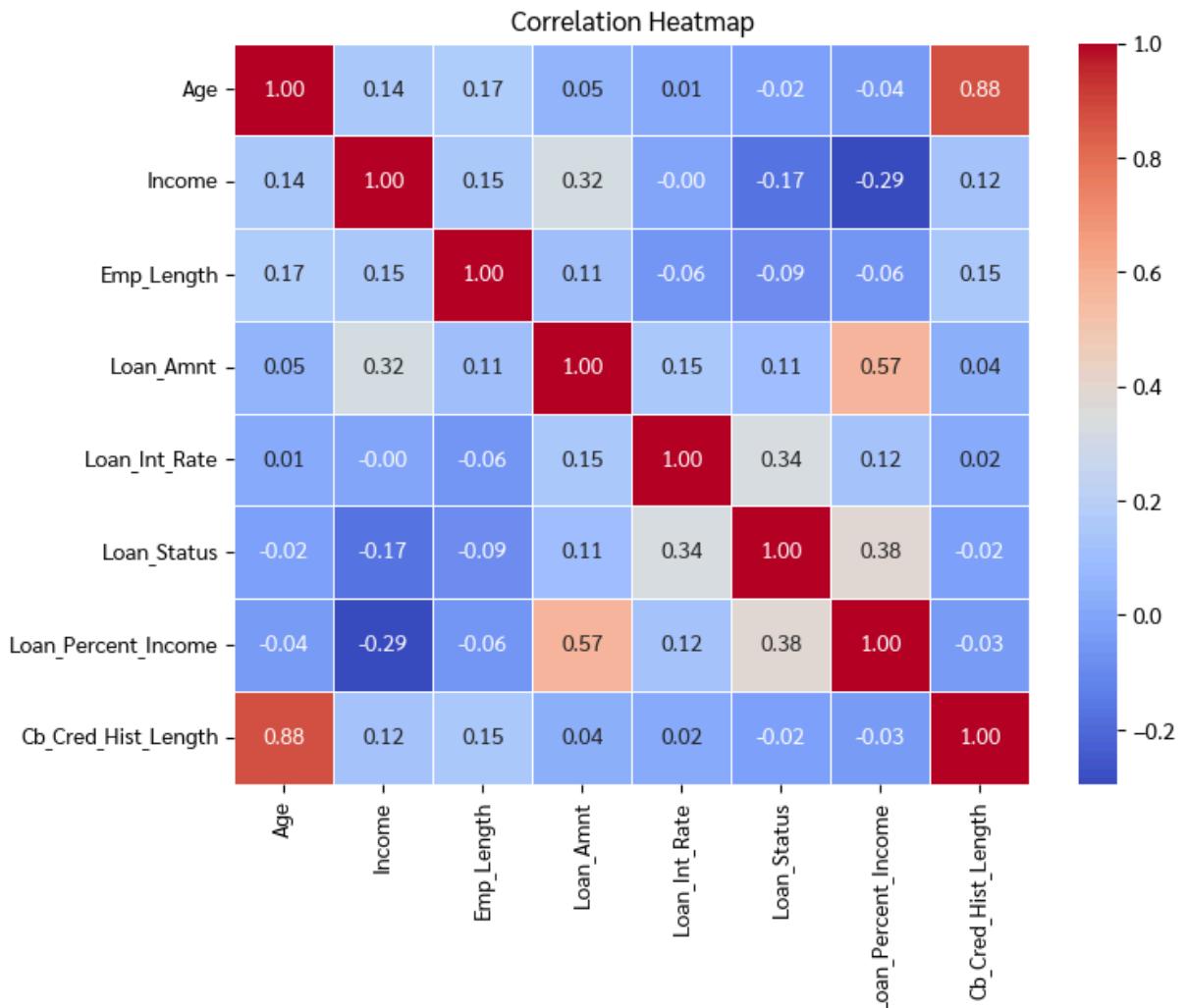
	Age	Income	Emp_Length	Loan_Amnt	Loan_Int_Rate	Loan_Status
Age	1.000000	0.141007	0.173183	0.052002	0.011966	-0.020
Income	0.141007	1.000000	0.154726	0.317489	-0.001121	-0.168
Emp_Length	0.173183	0.154726	1.000000	0.110980	-0.058263	-0.085
Loan_Amnt	0.052002	0.317489	0.110980	1.000000	0.146803	0.105
Loan_Int_Rate	0.011966	-0.001121	-0.058263	0.146803	1.000000	0.335
Loan_Status	-0.020549	-0.168500	-0.085983	0.105233	0.335092	1.000
Loan_Percent_Income	-0.041968	-0.294542	-0.058533	0.572444	0.120218	0.379
Cb_Cred_Hist_Length	0.878287	0.123230	0.149625	0.042336	0.016656	-0.015



Correlation of Variable

In [33]:

```
# Create a heatmap using Seaborn
plt.figure(figsize=(8, 6))
sns.heatmap(df.corr(numeric_only=True), annot=True, cmap='coolwarm', fmt=".2f", line_width=1)
plt.title('Correlation Heatmap')
plt.show()
```



Variance Inflation Factor (VIF)

In [34]:

```
numeric_df = pd.DataFrame(df.select_dtypes(include=["number"]))
numeric_df
```

Out[34]:

	Age	Income	Emp_Length	Loan_Amnt	Loan_Int_Rate	Loan_Status	Loan_Percent_Income
1	21	9600	5	1000	11	0	
2	25	9600	1	5500	13	1	
3	23	65500	4	35000	15	1	
4	24	54400	8	35000	14	1	
5	21	9900	2	2500	7	1	
...
32576	57	53000	1	5800	13	0	
32577	54	120000	4	17625	7	0	
32578	65	76000	3	35000	11	1	
32579	56	150000	5	15000	11	0	
32580	66	42000	2	6475	10	0	

32573 rows × 8 columns



In [35]:

Add constant for intercept

X = add_constant(df.select_dtypes(include="number").dropna())

In [36]:

X.info()

```
<class 'pandas.core.frame.DataFrame'>
Index: 28632 entries, 1 to 32580
Data columns (total 9 columns):
 #   Column           Non-Null Count  Dtype  
--- 
 0   const            28632 non-null   float64
 1   Age              28632 non-null   int64  
 2   Income            28632 non-null   int64  
 3   Emp_Length        28632 non-null   Int64  
 4   Loan_Amnt         28632 non-null   int64  
 5   Loan_Int_Rate     28632 non-null   float64
 6   Loan_Status        28632 non-null   int64  
 7   Loan_Percent_Income 28632 non-null   float64
 8   Cb_Cred_Hist_Length 28632 non-null   int64  
dtypes: Float64(1), Int64(1), float64(2), int64(5)
memory usage: 2.2 MB
```

In [37]:

Convert all columns to standard float64 to ensure compatibility

X_numeric = X.astype(float)

Calculating VIF

vif_data = pd.DataFrame()

vif_data["feature"] = X_numeric.columns

vif_data["VIF"] = [variance_inflation_factor(X_numeric.values, i) for i in range(X_numeric.shape[1])]

```
print(vif_data)
```

	feature	VIF
0	const	66
1	Age	4
2	Income	2
3	Emp_Length	1
4	Loan_Amnt	3
5	Loan_Int_Rate	1
6	Loan_Status	1
7	Loan_Percent_Income	3
8	Cb_Cred_Hist_Length	4

การแปลผลภาพรวม (Interpretation)

โดยทั่วไปเกณฑ์ตัดสินดังนี้:

VIF = 1: ไม่มีความสัมพันธ์กันเลย (ดีมาก)

VIF 1 - 5: มีความสัมพันธ์กันปานกลาง (ยอมรับได้ ไม่เป็นปัญหา)

VIF > 5 หรือ 10: มีความสัมพันธ์กันสูงมาก (อาจเป็นปัญหา) ตัวแปรเหล่านี้อาจซ้ำซ้อนกันเอง ทำให้โน๊ಡไม่เสถียร

ขาดข้อมูล ไม่มีปัญหา Multicollinearity ที่รุนแรง

🏆 ความสัมพันธ์เชิงบวกที่แข็งแกร่งที่สุด (Strongest Positive Correlation)

คู่ที่มีความสัมพันธ์กันชัดเจนที่สุดในตารางคือ:

Age ↔ Cb_Cred_Hist_Length (\$r = 0.86\$)

มีความสัมพันธ์กันสูงมากในทิศทางเดียวกันการตีความ: ยิ่งผู้กู้มีอายุมาก ประวัติเครดิต (Credit History) ก็จะยิ่งยาวนานขึ้น ซึ่งเป็นเรื่องปกติทางธรรมชาติของการสะสมประวัติทางการเงิน

⚠️ ปัจจัยที่ส่งผลกระทบต่อความเสี่ยง (Loan Status Correlations)

หากพิจารณาตัวแปร Loan_Status (สมมติว่าค่าสูง = มีความเสี่ยง/ผิดนัดชำระ) พบรความสัมพันธ์ที่น่าสนใจดังนี้:

Loan_Percent_Income (\$r = 0.38\$):

มีความสัมพันธ์เชิงบวกปานกลาง ยิ่งสัดส่วนหนี้ต่อรายได้สูง ความเสี่ยงที่จะเกิดหนี้เสียก็ยิ่งสูงขึ้น (เป็นปัจจัยที่ส่งผลกระทบมากที่สุดต่อ Status ในชุดข้อมูลนี้)

Loan_Int_Rate (\$r = 0.34\$):

อัตราดอกเบี้ยแปรผันตามสถานะลีนเชื่อ กลุ่มที่มีความเสี่ยงสูงมากต้องแบกรับดอกเบี้ยที่สูงกว่า หรือ ดอกเบี้ยที่สูงอาจเป็นตัวเร่งให้เกิดการผิดนัดชำระ

Income ($r = -0.14\$$):

มีความสัมพันธ์เชิงลบเล็กน้อย หมายความว่าผู้ที่มีรายได้สูง มีแนวโน้มจะเป็นหนี้เสียน้อยกว่าผู้ที่มีรายได้ต่ำ แต่ความสัมพันธ์นี้ไม่แรงเท่ากับสัดส่วนหนี้ (Loan Percent Income)

💰 โครงสร้างหนี้และรายได้ (Loan & Income Structure)

ความสัมพันธ์ระหว่างยอดเงินกู้และรายได้ของผู้กู้:

Loan_Amnt \leftrightarrow Loan_Percent_Income ($r = 0.57\$$)

มีความสัมพันธ์ค่อนข้างสูง ยิ่งกู้ยอดเงินสูง สัดส่วนภาระหนี้ต่อรายได้ก็จะยิ่งสูงขึ้นตามไปด้วยอย่างชัดเจน

Income \leftrightarrow Loan_Percent_Income ($r = -0.25\$$)

มีความสัมพันธ์เชิงลบ (สีเขียวเข้ม) และว่าคนที่รายได้สูง มักจะมีสัดส่วนยอดกู้ต่อรายได้ต่ำ (ภาระหนี้เบากว่า) ในขณะที่คนรายได้น้อยมักกู้เกินตัวมากกว่า

Weight of Evidence (WoE)

$$\text{WoE}_i = \ln \left(\frac{\% \text{ Non-default}_i}{\% \text{ Default}_i} \right)$$

```
In [38]: pd.reset_option('display.float_format')
```

```
In [39]: df.columns
```

```
Out[39]: Index(['Age', 'Income', 'Home_Ownership', 'Emp_Length', 'Loan_Intent',
       'Loan_Grade', 'Loan_Amnt', 'Loan_Int_Rate', 'Loan_Status',
       'Loan_Percent_Income', 'Cb_Default_On_File', 'Cb_Cred_Hist_Length'],
      dtype='object')
```

```
In [40]: def calculate_woe_iv(dataset, feature, target):
    lst = []
    # จัดกลุ่มข้อมูลตาม Feature และนับจำนวน Good (0) และ Bad (1)
    for i in range(dataset[feature].nunique()):
        val = list(dataset[feature].unique())[i]
        lst.append({
            'Value': val,
            'All': dataset[dataset[feature] == val].count()[feature],
            'Good': dataset[(dataset[feature] == val) & (dataset[target] == 0)].count(),
            'Bad': dataset[(dataset[feature] == val) & (dataset[target] == 1)].count()
        })

    dff = pd.DataFrame(lst)
    dff['Dist_Good'] = dff['Good'] / dff['Good'].sum()
    dff['Dist_Bad'] = dff['Bad'] / dff['Bad'].sum()
```

```
# คำนวณ WoE
dff['WoE'] = np.log(dff['Dist_Good'] / dff['Dist_Bad'])
dff.replace({'WoE': {np.inf: 0, -np.inf: 0}}, inplace=True)

# คำนวณ IV
dff['IV'] = (dff['Dist_Good'] - dff['Dist_Bad']) * dff['WoE']
iv = dff['IV'].sum()

return dff, iv
```

```
In [41]: def plot_woe(woe_df, feature_name):
    plt.figure(figsize=(10, 6))

    # ผลลัพธ์ของเส้นเพื่อดูแนวโน้ม (Trend)
    sns.pointplot(x='Value', y='WoE', data=woe_df, color="#1f77b4")

    # ตกแต่งกราฟ
    plt.title(f'Weight of Evidence (WoE) for {feature_name}', fontsize=14)
    plt.axhline(y=0, color='red', linestyle='--', alpha=0.5) # เส้นแบ่งความเสี่ยงปกติ
    plt.xticks(rotation=45)
    plt.grid(axis='y', alpha=0.3)
    plt.ylabel('WoE Value')
    plt.xlabel(f'Bins of {feature_name}')

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

```
In [42]: def calculate_ks(woe_df):
    # ตรวจสอบให้แน่ใจว่าเรียงลำดับตามความเสี่ยงแล้ว
    df_ks = woe_df.sort_values(by='WoE').reset_index(drop=True)

    # คำนวณ % สะสน
    df_ks['Cumulative_Good'] = df_ks['Dist_Good'].cumsum()
    df_ks['Cumulative_Bad'] = df_ks['Dist_Bad'].cumsum()

    # คำนวณส่วนต่าง
    df_ks['KS_Diff'] = np.abs(df_ks['Cumulative_Good'] - df_ks['Cumulative_Bad'])

    ks_value = df_ks['KS_Diff'].max()
    return ks_value, df_ks
```

Calculate WOE

ตัวแปร 'person_home_ownership'

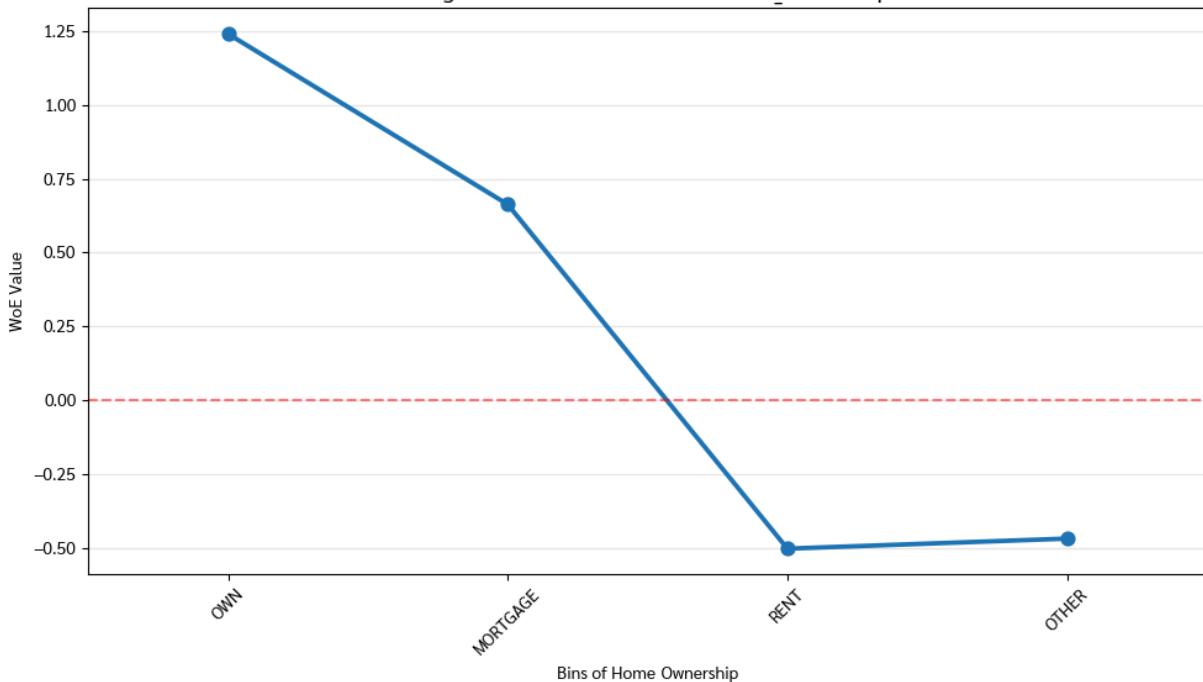
```
In [43]: # 'person_home_ownership'
woe_df, iv_value = calculate_woe_iv(df, 'Home_Ownership', 'Loan_Status')
print(f"Information Value: {iv_value}")
print(woe_df)

plot_woe(woe_df, 'Home_Ownership')
```

Information Value: 0.37699794926569213

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	IV
0	OWN	2584	2391	193	0.093890	0.027156	1.240513	0.082784
1	MORTGAGE	13441	11751	1690	0.461439	0.237794	0.662946	0.148265
2	RENT	16441	11250	5191	0.441765	0.730407	-0.502822	0.145135
3	OTHER	107	74	33	0.002906	0.004643	-0.468706	0.000814

Weight of Evidence (WoE) for Home_Ownership



```
In [44]: ks_score, ks_table = calculate_ks(woe_df)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.2904

គ្រប់គ្រង 'income_bin'

```
In [45]: # We define clear cut-off points: 0 -> 35k -> 60k -> 85k -> Infinity
bins = [0, 35000, 60000, 85000, float('inf')]
labels = ['1. Low (<35k)', '2. Medium (35k-60k)', '3. High (60k-85k)', '4. Very High']

# Use pd.cut instead of qcut
df['income_bin'] = pd.cut(df['Income'], bins=bins, labels=labels)
```

```
In [46]: # 'income_bin'
woe_df, iv_value = calculate_woe_iv(df, 'income_bin', 'Loan_Status')
print(f"Information Value: {iv_value}")
print(woe_df)

plot_woe(woe_df, 'income_bin')
```

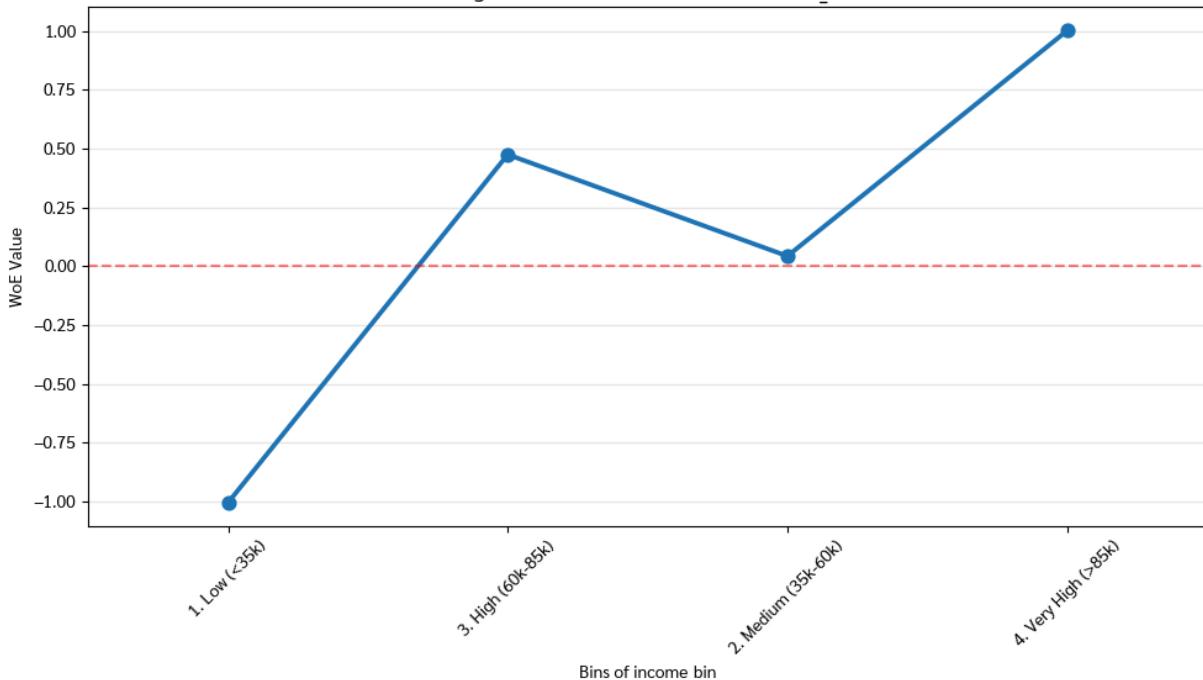
Information Value: 0.4499815912648941

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	\
0	1. Low (<35k)	6629	3761	2868	0.147687	0.403546	-1.005194	
1	3. High (60k-85k)	7251	6178	1073	0.242598	0.150978	0.474272	
2	2. Medium (35k-60k)	12095	9543	2552	0.374735	0.359083	0.042667	
3	4. Very High (>85k)	6598	5984	614	0.234980	0.086394	1.000586	

IV

0	0.257188
1	0.043453
2	0.000668
3	0.148673

Weight of Evidence (WoE) for income_bin



```
In [47]: ks_score, ks_table = calculate_ks(woe_df)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.2559

ตัวแปร 'Loan_Int_Rate'

```
In [48]: # 1. Create the Bins (Use qcut as you did originally)
```

```
df_woe = df.copy()
df_woe['Loan_Int_Rate_bin'] = pd.qcut(df_woe['Loan_Int_Rate'], q=5, precision=0)
```

```
In [49]: # 2. Fill Missing Values
```

```
df_woe['Loan_Int_Rate_bin'] = df_woe['Loan_Int_Rate_bin'].cat.add_categories(['Missing'])
df_woe['Loan_Int_Rate_bin'] = df_woe['Loan_Int_Rate_bin'].fillna('Missing')
```

```
In [50]: print("\nDistribution of Loan_Int_Rate_bin:")
```

```
print(df_woe['Loan_Int_Rate_bin'].value_counts())
```

Distribution of Loan_Int_Rate_bin:

```
Loan_Int_Rate_bin
(4.0, 8.0]      6015
(8.0, 10.0]     5987
(14.0, 23.0]    5867
(12.0, 14.0]    5812
(10.0, 12.0]    5778
Missing          3114
Name: count, dtype: int64
```

```
In [51]: # 1. Calculate WOE first
woe_emp, iv_emp = calculate_woe_iv(df_woe, 'Loan_Int_Rate_bin', 'Loan_Status')

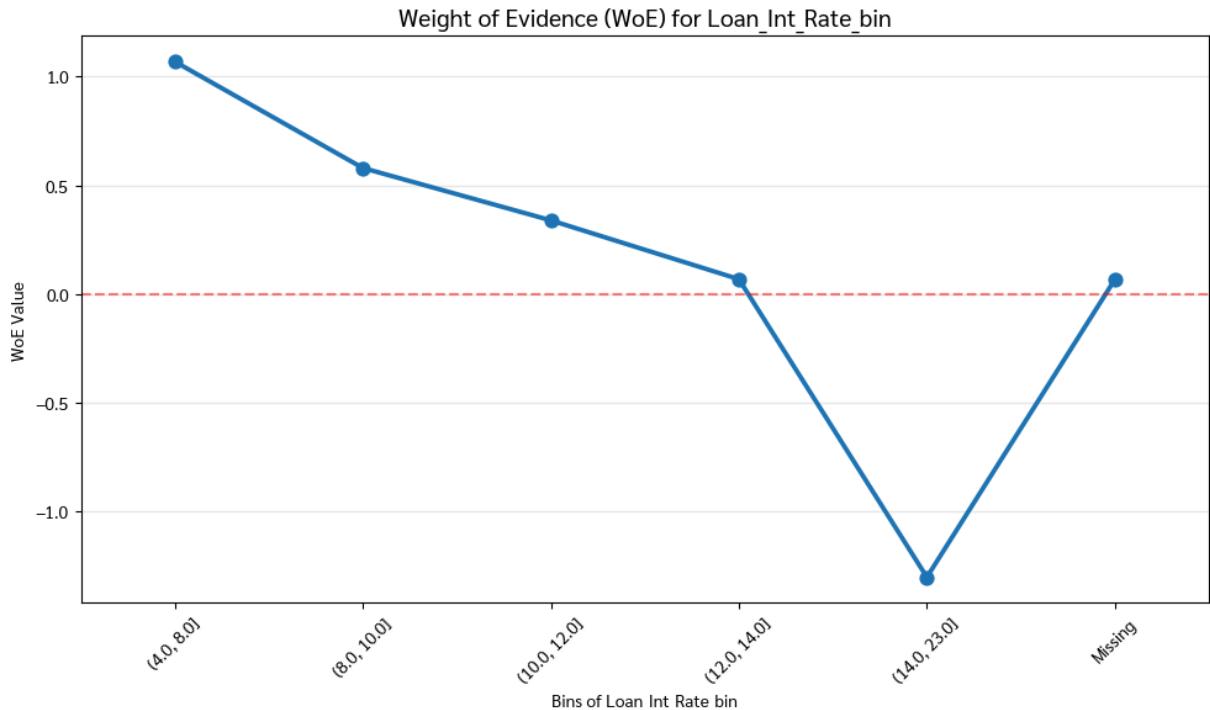
# --- THE ROBUST FIX ---
# Step A: Separate the 'Missing' row from the 'Interval' rows
missing_row = woe_emp[woe_emp['Value'] == 'Missing']
interval_rows = woe_emp[woe_emp['Value'] != 'Missing']

# Step B: Sort only the Interval rows (Python can sort these easily now)
interval_rows = interval_rows.sort_values(by='Value')

# Step C: Combine them back together (Putting 'Missing' at the end)
woe_emp = pd.concat([interval_rows, missing_row])
# -----


# 2. Print and Plot
print(f"Information Value: {iv_emp}")
plot_woe(woe_emp, 'Loan_Int_Rate_bin')
```

Information Value: 0.6182518223780366



```
In [52]: ks_score, ks_table = calculate_ks(woe_emp)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.3040

$IV > 0.5$ ถือว่า "สูง/ผิดปกติ (อาจเกิดการโอเวอร์ฟิตติ้งหรือการรั่วไหลของข้อมูล)" ใน การประเมินความเสี่ยงด้านเครดิต อัตราดอกเบี้ยมักจะถูกกำหนดหลังจากประเมินความเสี่ยงแล้ว

ตัวแปร 'Age'

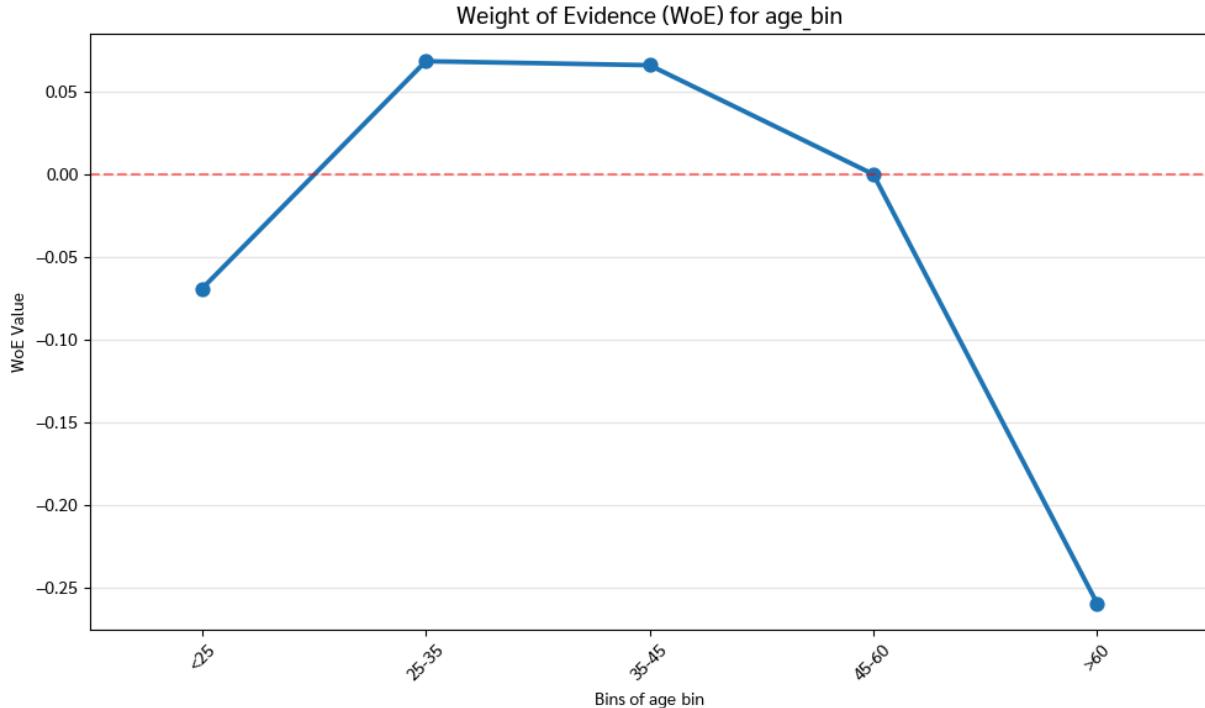
```
In [53]: # การแบ่งช่วงอายุ (Age) ตามเกณฑ์ที่กำหนดเอง
bins = [0, 25, 35, 45, 60, 100]
labels = ['<25', '25-35', '35-45', '45-60', '>60']

df['age_bin'] = pd.cut(df['Age'], bins=bins, labels=labels)

In [54]: woe_df, iv_value = calculate_woe_iv(df, 'age_bin', 'Loan_Status')
print(f"Information Value: {iv_value}")
print(woe_df)

plot_woe(woe_df, 'age_bin')
```

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	IV
0	<25	15350	11816	3534	0.463991	0.497256	-0.069240	2.303265e-03
1	25-35	13763	10917	2846	0.428689	0.400450	0.068143	1.924280e-03
2	35-45	2814	2231	583	0.087607	0.082032	0.065754	3.665920e-04
3	45-60	582	455	127	0.017867	0.017870	-0.000154	4.220216e-10
4	>60	64	47	17	0.001846	0.002392	-0.259330	1.417003e-04



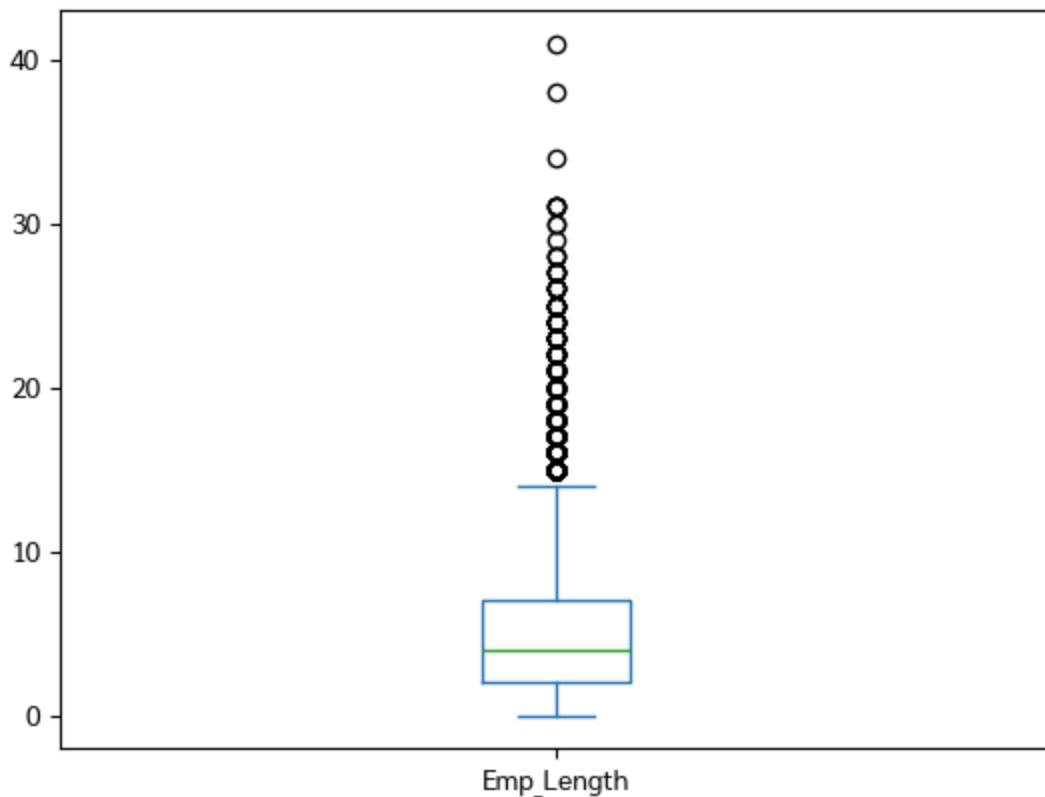
```
In [55]: ks_score, ks_table = calculate_ks(woe_df)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.0338

ตัวแปร 'Emp_Length'

```
In [56]: df['Emp_Length'].dropna().plot.box()
```

Out[56]: <Axes: >



```
In [57]: df['Emp_Length'].max()
```

Out[57]: 41

```
In [58]: # Make a copy to avoid SettingWithCopy warnings
df_woe = df.copy()

bins_emp = [0, 2, 4, 6, 8, 10, 40, float('inf')]
labels_emp = ['<2', '2-4', '4-6', '6-8', '8-10', '10-40', '>40']

# Create the bins
df_woe['Emp_Length_bin'] = pd.cut(df_woe['Emp_Length'], bins=bins_emp, labels=labels_emp)
```

```
In [59]: # Add 'Missing' to the category list and then fill Nans
df_woe['Emp_Length_bin'] = df_woe['Emp_Length_bin'].cat.add_categories(['Missing'])
df_woe['Emp_Length_bin'] = df_woe['Emp_Length_bin'].fillna('Missing')
```

```
In [60]: # Check the distribution (Missing should now appear in the list)
print("Distribution of Emp_Length_bin:")
print(df_woe['Emp_Length_bin'].value_counts())
```

Distribution of Emp_Length_bin:

```
Emp_Length_bin
2-4        7304
<2        7019
4-6        5818
6-8        4861
10-40      3621
8-10      3054
Missing     895
>40         1
Name: count, dtype: int64
```

```
In [61]: woe_df, iv_value = calculate_woe_iv(df_woe, 'Emp_Length_bin', 'Loan_Status')

# 1. Define the correct logical order (Must match Cell 60 exactly)
# We add 'Missing' at the end manually
custom_order = ['<2', '2-4', '4-6', '6-8', '8-10', '10-40', '>40', 'Missing']

# 2. Convert the 'Value' column to a Category type with this specific order
woe_df['Value'] = pd.Categorical(woe_df['Value'], categories=custom_order, ordered=True)

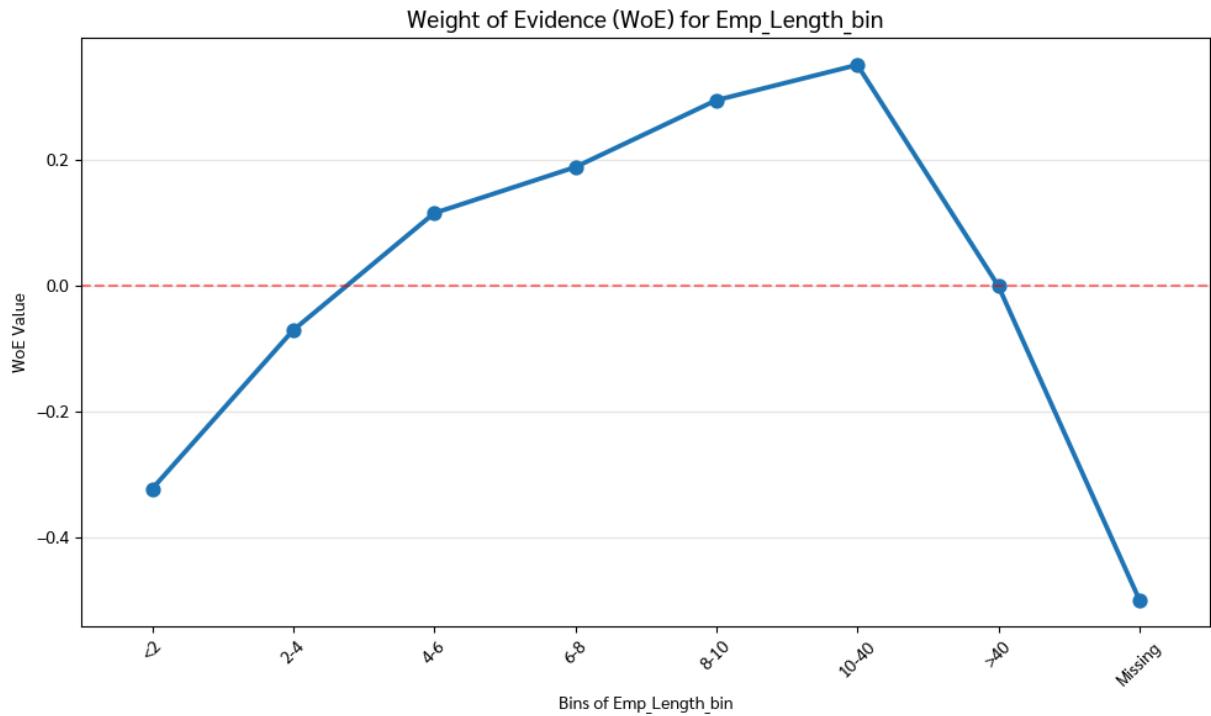
# 3. Sort by this new logical order
woe_df = woe_df.sort_values(by='Value')

# 4. Print and Plot (Fixed the Label name here)
print(f"Information Value: {iv_value}")
print(woe_df)

# Fix the Label below to 'Emp_Length_bin'
plot_woe(woe_df, 'Emp_Length_bin')
```

Information Value: 0.060787929396711224

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	IV
1	<2	7019	5066	1953	0.198932	0.274799	-0.323079	0.024511
3	2-4	7304	5621	1683	0.220726	0.236809	-0.070332	0.001131
0	4-6	5818	4660	1158	0.182989	0.162938	0.116057	0.002327
4	6-8	4861	3949	912	0.155070	0.128324	0.189314	0.005063
2	8-10	3054	2529	525	0.099309	0.073871	0.295917	0.007528
5	10-40	3621	3027	594	0.118864	0.083580	0.352184	0.012427
7	>40	1	1	0	0.000039	0.000000	0.000000	0.000000
6	Missing	895	613	282	0.024071	0.039679	-0.499806	0.007801

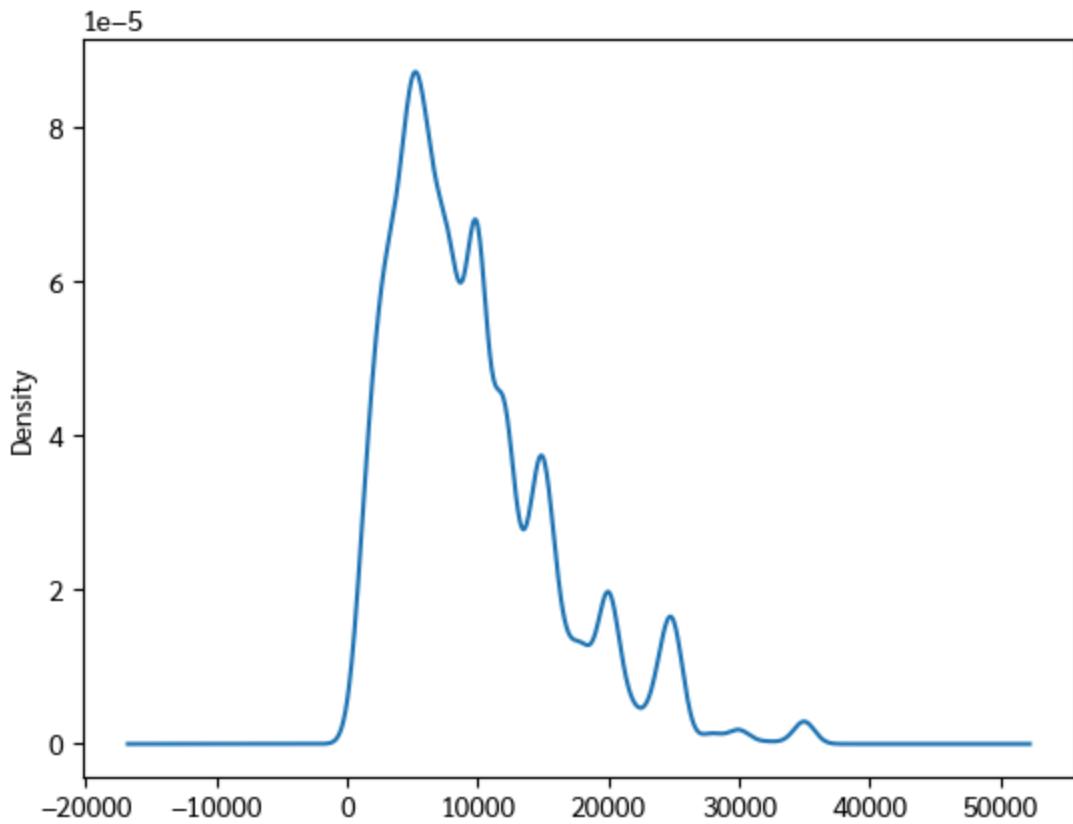


```
In [62]: ks_score, ks_table = calculate_ks(woe_df)
print(f"KS Statistic: {ks_score:.4f}")
```

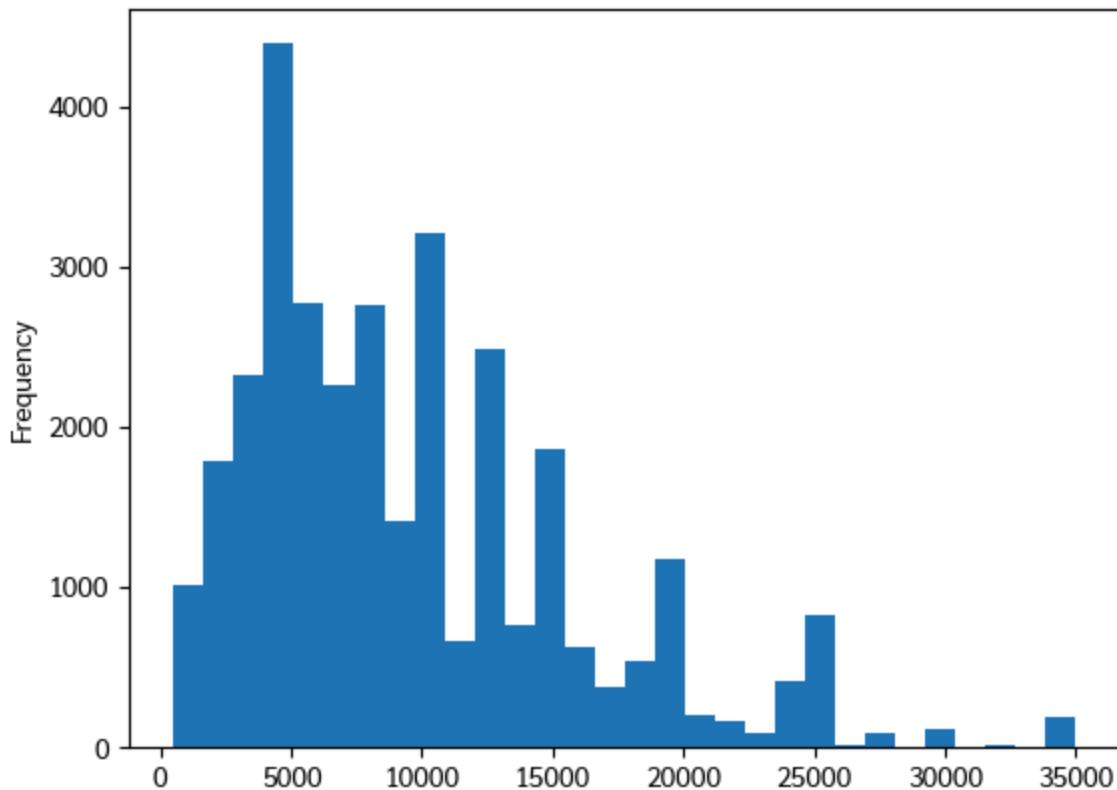
KS Statistic: 0.1076

ดูแลร 'loan_amnt'

```
In [63]: # single column (density)
df['Loan_Amnt'].plot(kind='kde')
plt.show()
```



```
In [64]: df['Loan_Amnt'].plot(kind='hist', bins=30)  
plt.show()
```



```
In [65]: # Make a copy to avoid SettingWithCopy warnings  
df_woe = df.copy()
```

```
# Make a copy to avoid SettingWithCopy warnings
df_woe['Loan_Amnt_bin'] = pd.qcut(df_woe['Loan_Amnt'], q=5, precision=0)
```

In [66]:

```
print("\nDistribution of Loan_Amnt_bin:")
print(df_woe['Loan_Amnt_bin'].value_counts())
```

Distribution of Loan_Amnt_bin:

Loan_Amnt_bin	count
(6750.0, 10000.0]	8493
(499.0, 4400.0]	6543
(4400.0, 6750.0]	6489
(14500.0, 35000.0]	6489
(10000.0, 14500.0]	4559

Name: count, dtype: int64

In [67]:

```
# Calculate WOE for Loan Amount
woe_df, iv_value = calculate_woe_iv(df_woe, 'Loan_Amnt_bin', 'Loan_Status')

# --- THE FIX: Sort the bins numerically ---
# This ensures small loans appear on the left and large loans on the right
woe_df = woe_df.sort_values(by='Value')
# ----

print(f"Information Value: {iv_value}")
print(woe_df)

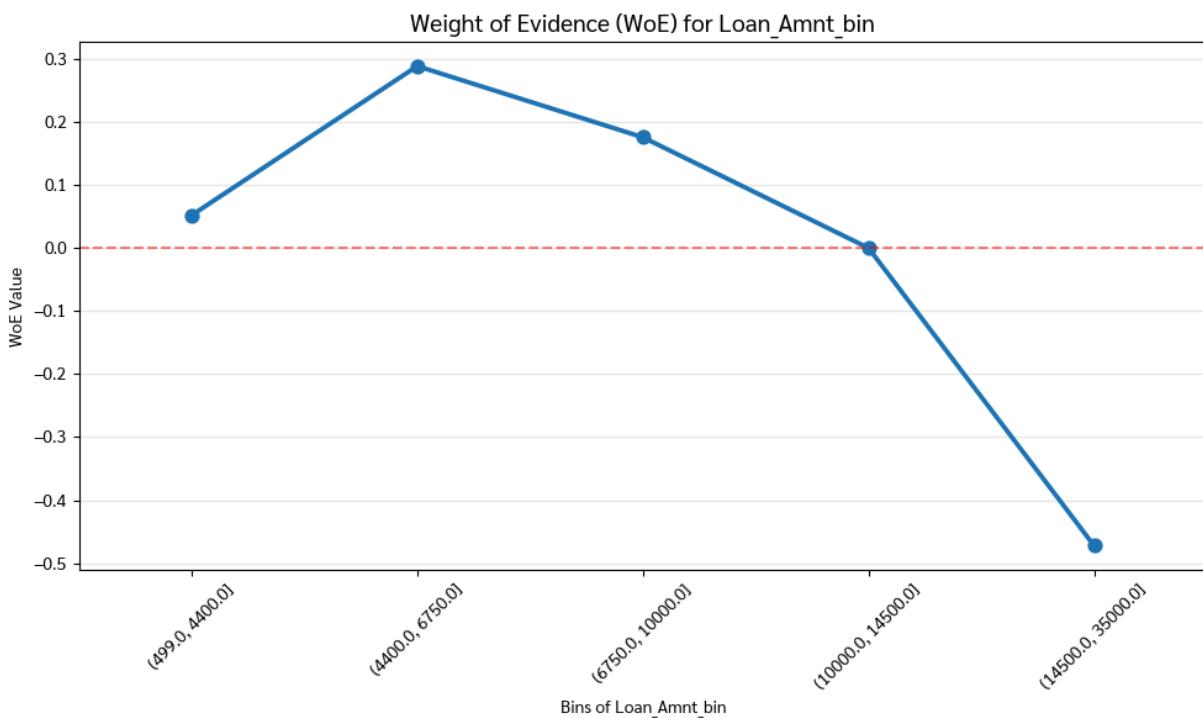
plot_woe(woe_df, 'Loan_Amnt_bin')
```

Information Value: 0.07343228865451851

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	\
0	(499.0, 4400.0]	6543	5172	1371	0.203094	0.192908	0.051455	
1	(4400.0, 6750.0]	6489	5366	1123	0.210712	0.158013	0.287815	
3	(6750.0, 10000.0]	8493	6881	1612	0.270203	0.226819	0.175024	
4	(10000.0, 14500.0]	4559	3564	995	0.139951	0.140003	-0.000368	
2	(14500.0, 35000.0]	6489	4483	2006	0.176039	0.282257	-0.472114	

IV

	IV
0	5.241171e-04
1	1.516759e-02
3	7.593392e-03
4	1.895253e-08
2	5.014717e-02



```
In [68]: ks_score, ks_table = calculate_ks(woe_df)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.1063

ตัวแปร 'Loan_Percent_Income_bin'

```
In [69]: df_woe = df.copy()

df['Loan_Percent_Income_bin'] = pd.qcut(df['Loan_Percent_Income'], q=5, precision=2
woe_lpi, iv_lpi = calculate_woe_iv(df, 'Loan_Percent_Income_bin', 'Loan_Status')
```

```
In [70]: # Check the distribution (Missing should now appear in the list)
print("Distribution of Loan_Percent_Income_bin:")
print(df['Loan_Percent_Income_bin'].value_counts())
```

Distribution of Loan_Percent_Income_bin:

Loan_Percent_Income_bin	Value
(-0.01, 0.08]	7569
(0.12, 0.18]	7343
(0.25, 0.83]	6277
(0.18, 0.25]	5799
(0.08, 0.12]	5585

Name: count, dtype: int64

```
In [71]: # Calculate WOE for Loan_Percent_Income_bin
woe_df, iv_value = calculate_woe_iv(df, 'Loan_Percent_Income_bin', 'Loan_Status')

# Sort the bins numerically
woe_df = woe_df.sort_values(by='Value')

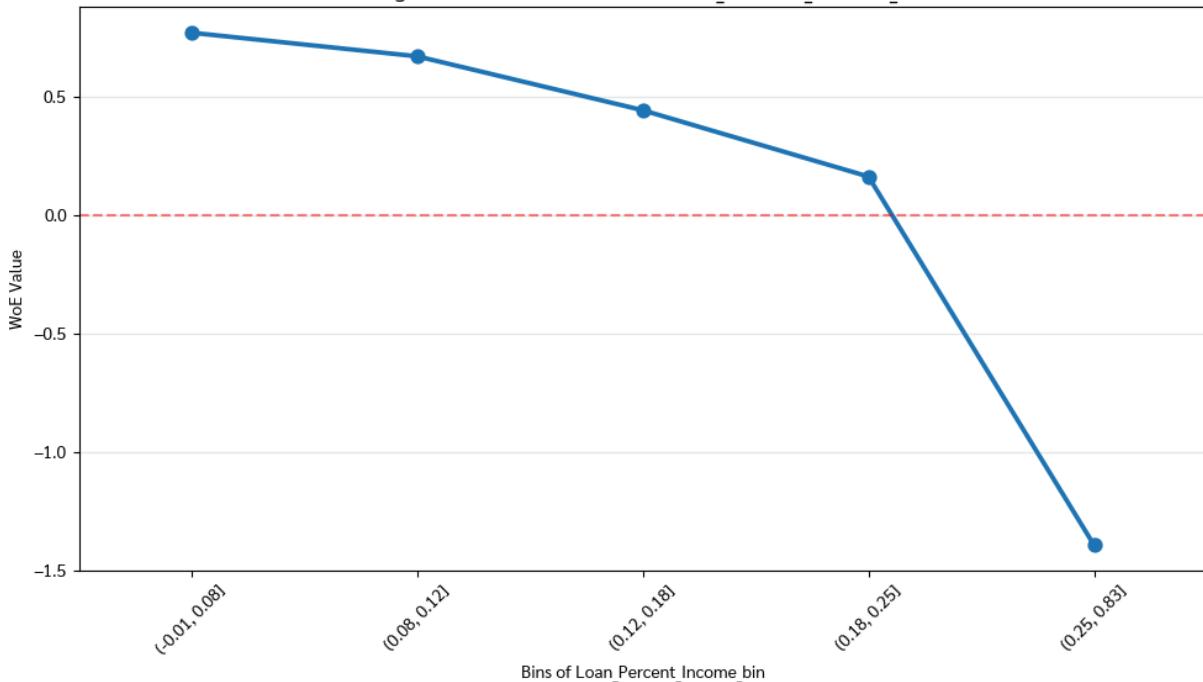
print(f"Information Value: {iv_value}")
print(woe_df)
```

```
plot_woe(woe_df, 'Loan_Percent_Income_bin')
```

Information Value: 0.7065981710724284

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	IV
4	(-0.01, 0.08]	7569	6705	864	0.263292	0.121570	0.772772	0.109519
0	(0.08, 0.12]	5585	4889	696	0.191981	0.097932	0.673129	0.063308
3	(0.12, 0.18]	7343	6229	1114	0.244601	0.156747	0.444995	0.039094
2	(0.18, 0.25]	5799	4689	1110	0.184128	0.156184	0.164595	0.004599
1	(0.25, 0.83]	6277	2954	3323	0.115998	0.467567	-1.393972	0.490078

Weight of Evidence (WoE) for Loan_Percent_Income_bin



```
In [72]: ks_score, ks_table = calculate_ks(woe_df)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.3516

Loan_Intent (Categorical)

```
# 2. Loan_Intent (Categorical)
woe_intent, iv_intent = calculate_woe_iv(df, 'Loan_Intent', 'Loan_Status')

# --- FIX: Sort by 'WoE' (Risk) instead of Alphabetical ---
# This makes the graph trend nicely from Low Risk -> High Risk
woe_intent = woe_intent.sort_values(by='WoE')
# ----- #

print(f"Information Value: {iv_intent}")
print(woe_intent)

plot_woe(woe_intent, 'Loan_Intent')
```

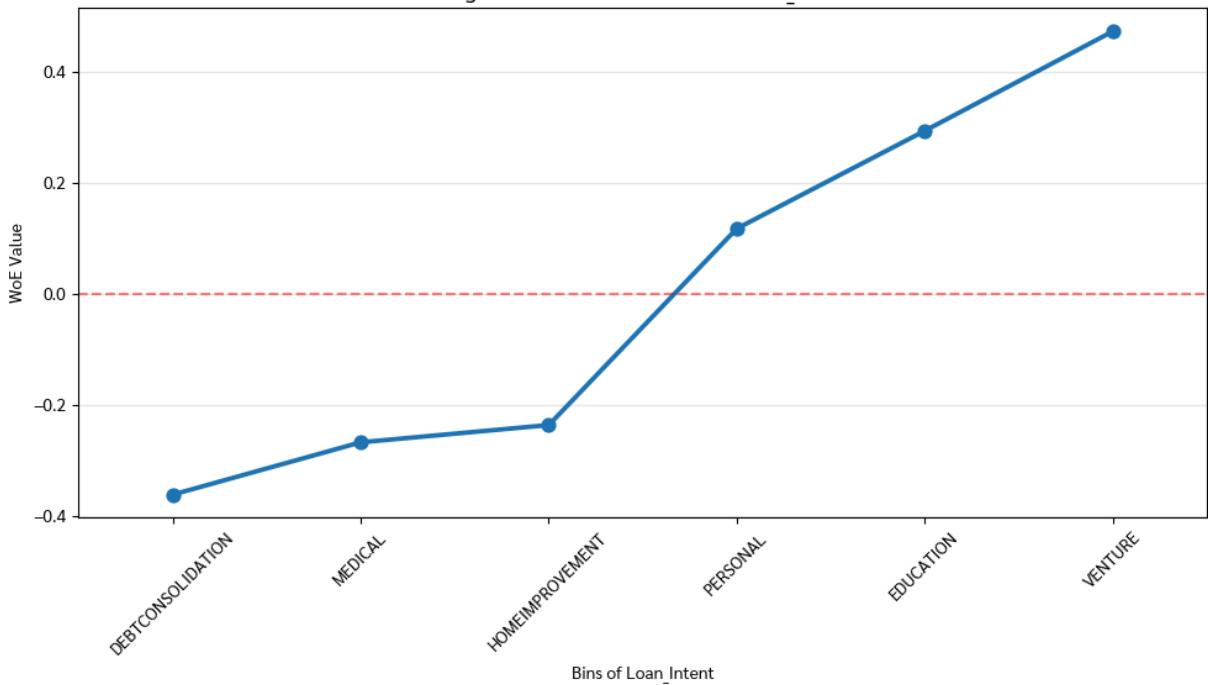
Information Value: 0.0956766961369648

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	\
5	DEBTCONSOLIDATION	5212	3722	1490	0.146156	0.209652	-0.360779	
1	MEDICAL	6070	4449	1621	0.174704	0.228085	-0.266628	
4	HOMEIMPROVEMENT	3605	2664	941	0.104610	0.132405	-0.235623	
3	PERSONAL	5519	4422	1097	0.173643	0.154355	0.117749	
0	EDUCATION	6451	5340	1111	0.209691	0.156325	0.293701	
2	VENTURE	5716	4869	847	0.191196	0.119178	0.472679	

IV

	Value
5	0.022908
1	0.014233
4	0.006549
3	0.002271
0	0.015674
2	0.034041

Weight of Evidence (WoE) for Loan_Intent



```
In [74]: ks_score, ks_table = calculate_ks(woe_intent)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.1447

Cb_Default_On_File (Categorical)

```
In [75]: # 3. Cb_Default_On_File (Categorical)
woe_cb, iv_cb = calculate_woe_iv(df, 'Cb_Default_On_File', 'Loan_Status')

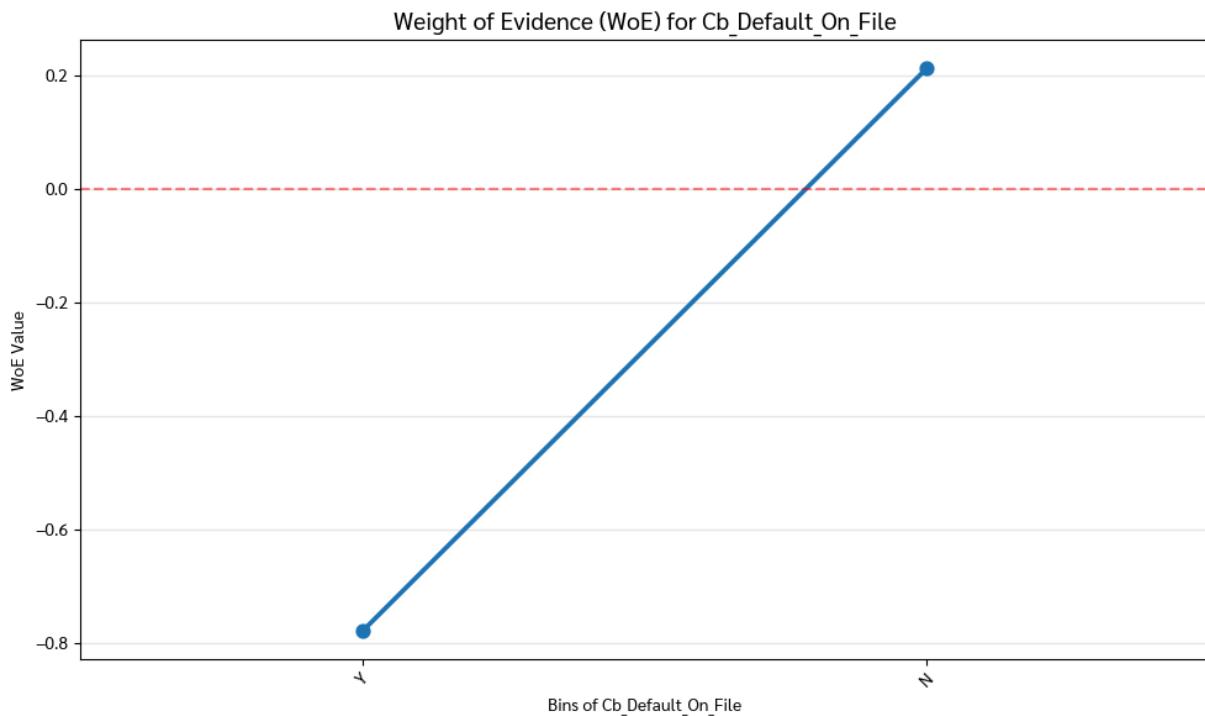
# --- FIX: Sort by 'WoE' ---
woe_cb = woe_cb.sort_values(by='WoE')
# ----- 

print(f"Information Value: {iv_cb}")
print(woe_cb)
```

```
plot_woe(woe_cb, 'Cb_Default_On_File')
```

Information Value: 0.16374731059533648

	Value	All	Good	Bad	Dist_Good	Dist_Bad	WoE	IV
1	Y	5744	3573	2171	0.140305	0.305473	-0.778046	0.128509
0	N	26829	21893	4936	0.859695	0.694527	0.213348	0.035238



```
In [76]: ks_score, ks_table = calculate_ks(woe_cb)
print(f"KS Statistic: {ks_score:.4f}")
```

KS Statistic: 0.1652

การแปลความหมายค่า KS

ค่า KS จะมีค่าอยู่ระหว่าง 0 ถึง 1 (หรือ 0% ถึง 100%):

- | < 20%: ความสามารถในการแยกแยะต่ำมาก (โมเดลใช้ไม่ได้)
- | 20% - 40%: ความสามารถในการแยกแยะปานกลาง (ยอมรับได้สำหรับงานทั่วไป)
- | 40% - 50%: ดีมาก (Good) เป็นช่วงที่เหมาะสมสำหรับ Credit Scoring
- | 50% - 70%: ยอดเยี่ยม (Excellent)
- | 70%+: สูงผิดปกติ (อาจเกิด Overfitting หรือตัวแปรนั้นมีผลลัพธ์ในตัวแล้ว เช่น เอ้า คอลัมน์ "ยอดค้างชำระบัญชี" ในทำนาย "การเบี้ยวน้ำ")

เกณฑ์การแปลความหมาย IV:

- | <0.02: ไม่มีอำนาจในการพยากรณ์

- 0.02 - 0.1: สำนักการพยากรณ์ต่ำ
- 0.1 - 0.3: สำนักการพยากรณ์ปานกลาง
- 0.3 - 0.5: สำนักการพยากรณ์สูง
- 0.5+: สูงผิดปกติ (อาจเกิด Overfitting หรือ Data Leakage)

Logistic Regression Model

```
In [77]: # --- 1. Consolidate Binning into Main DataFrame (df) ---

# Income Binning
df['income_bin'] = pd.qcut(df['Income'], q=5, precision=0)

# Emp_Length Binning (Your logic from the screenshot, applied to df)
bins_emp = [0, 2, 4, 6, 8, 10, 40, float('inf')]
labels_emp = ['<2', '2-4', '4-6', '6-8', '8-10', '10-40', '>40']
df['Emp_Length_bin'] = pd.cut(df['Emp_Length'], bins=bins_emp, labels=labels_emp, r
df['Emp_Length_bin'] = df['Emp_Length_bin'].cat.add_categories(['Missing']).fillna()

# Loan Amount Binning
df['Loan_Amnt_bin'] = pd.qcut(df['Loan_Amnt'], q=5, precision=0)

# Loan Percent Income Binning (Adding this as it's a strong predictor)
#df['Loan_Percent_Income_bin'] = pd.qcut(df['Loan_Percent_Income'], q=5, precision=0

print("Binning complete. Columns in df:", df.columns)

Binning complete. Columns in df: Index(['Age', 'Income', 'Home_Ownership', 'Emp_Length', 'Loan_Intent',
       'Loan_Grade', 'Loan_Amnt', 'Loan_Int_Rate', 'Loan_Status',
       'Loan_Percent_Income', 'Cb_Default_On_File', 'Cb_Cred_Hist_Length',
       'income_bin', 'age_bin', 'Loan_Percent_Income_bin', 'Emp_Length_bin',
       'Loan_Amnt_bin'],
      dtype='object')
```

```
In [78]: # --- 2. Calculate WOE for each feature and save to unique variables ---

# Home Ownership
woe_home, iv_home = calculate_woe_iv(df, 'Home_Ownership', 'Loan_Status')

# Income
woe_income, iv_income = calculate_woe_iv(df, 'income_bin', 'Loan_Status')

# Emp Length
woe_emp, iv_emp = calculate_woe_iv(df, 'Emp_Length_bin', 'Loan_Status')

# Loan Amount
woe_amnt, iv_amnt = calculate_woe_iv(df, 'Loan_Amnt_bin', 'Loan_Status')

# Loan Percent Income
woe_lpi, iv_lpi = calculate_woe_iv(df, 'Loan_Percent_Income_bin', 'Loan_Status')
```

```
print("WOE Tables ready.")
```

WOE Tables ready.

In [79]: # --- 3. Transform Data to WOE Values ---

```
def replace_with_woe(df, woe_df_list, feature_map):
    df_woe_final = df.copy()
    for col_name, woe_df in woe_df_list.items():
        woe_map = dict(zip(woe_df['Value'], woe_df['WoE']))
        binned_col = feature_map[col_name]
        df_woe_final[col_name + '_woe'] = df_woe_final[binned_col].map(woe_map)
    return df_woe_final

# Dictionary of your calculated WOE dataframes
woe_dataframes = {
    'Home_Ownership': woe_home,
    'Income': woe_income,
    'Emp_Length': woe_emp,
    'Loan_Amnt': woe_amnt,
}

# Mapping: {Feature Name in woe_dataframes : Column Name in df}
feature_map = {
    'Home_Ownership': 'Home_Ownership',
    'Income': 'income_bin',
    'Emp_Length': 'Emp_Length_bin',
    'Loan_Amnt': 'Loan_Amnt_bin',
}

# Transform
final_train_df = replace_with_woe(df, woe_dataframes, feature_map)

# Show the result
pd.reset_option('display.float_format')
print(final_train_df.filter(like='_woe').head())
```

	Home_Ownership_woe	Income_woe	Emp_Length_woe	Loan_Amnt_woe
1	1.240513	-1.005194	0.116057	0.051455
2	0.662946	-1.005194	-0.323079	0.287815
3	-0.502822	0.493634	0.116057	-0.472114
4	-0.502822	0.227718	0.295917	-0.472114
5	1.240513	-1.005194	-0.070332	0.051455

In [80]: # 1. Define X (Features) and y (Target)

```
# We only use the WOE columns we just created.
# Note: We EXCLUDE 'Loan_Int_Rate' (Leakage) and 'Age' (Weak)
feature_cols = [
    'Home_Ownership_woe',
    'Income_woe',
    'Emp_Length_woe',
    'Loan_Amnt_woe',
]

X = final_train_df[feature_cols]
```

```

y = final_train_df['Loan_Status']

# 2. Train-Test Split (80% Train, 20% Test)
# random_state=42 ensures we get the same split every time we run it
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_st

# 3. Train Logistic Regression Model (using Statsmodels)
# Statsmodels requires us to manually add a constant (Intercept)
X_train_const = sm.add_constant(X_train)
logit_model = sm.Logit(y_train, X_train_const)
result = logit_model.fit()

# 4. Print Model Summary
# Look for P>|z|. If value is < 0.05, the variable is significant.
print(result.summary())

```

Optimization terminated successfully.

Current function value: 0.437764

Iterations 6

Logit Regression Results

```

=====
Dep. Variable:          Loan_Status    No. Observations:                 26058
Model:                  Logit         Df Residuals:                  26053
Method:                 MLE          Df Model:                      4
Date:      Sat, 27 Dec 2025   Pseudo R-squ.:                0.1648
Time:          02:31:32        Log-Likelihood:           -11407.
converged:            True         LL-Null:                  -13658.
Covariance Type:       nonrobust    LLR p-value:                 0.000
=====
==

      coef    std err          z      P>|z|      [0.025      0.97
5]
-----
-- 
const      -1.3031     0.017    -75.582     0.000     -1.337     -1.2
69
Home_Ownership_woe -0.8540     0.028    -30.414     0.000     -0.909     -0.7
99
Income_woe      -1.2511     0.028    -45.191     0.000     -1.305     -1.1
97
Emp_Length_woe   -0.2201     0.070     -3.161     0.002     -0.357     -0.0
84
Loan_Amnt_woe      -2.5574     0.069    -37.241     0.000     -2.692     -2.4
23
=====
==
```

In [81]: # Predict on the Test Set

```

X_test_const = sm.add_constant(X_test)
y_pred_prob = result.predict(X_test_const)

# Calculate AUC (Area Under Curve)
auc = roc_auc_score(y_test, y_pred_prob)
gini = 2 * auc - 1

print(f"AUC Score: {auc:.4f}")

```

```

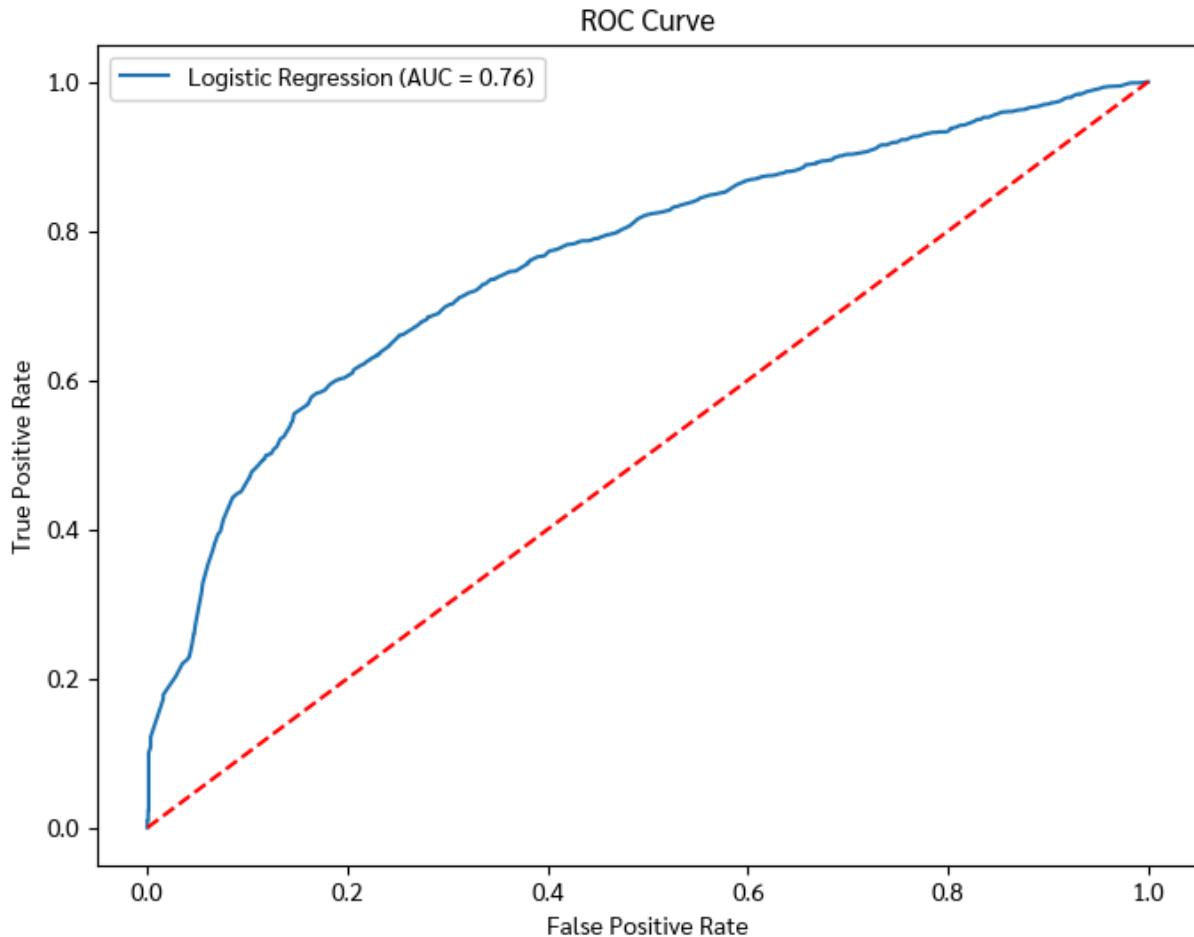
print(f"Gini Coefficient: {gini:.4f}")

# Plot ROC Curve
fpr, tpr, thresholds = roc_curve(y_test, y_pred_prob)
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, label=f'Logistic Regression (AUC = {auc:.2f})')
plt.plot([0, 1], [0, 1], 'r--') # Random guess line
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve')
plt.legend()
plt.show()

```

AUC Score: 0.7614

Gini Coefficient: 0.5229



Interpreting the results

3. Which factors drive the risk? (Coefficients)

The "Coef" column tells us how heavily the model weighs each factor. Since all variables are on the same WOE scale, we can roughly compare their magnitude:

- Loan Amount (-1.363): This is your strongest predictor. The size of the loan relative to the specific "bin" it falls into is the biggest driver of the final score.

- Home Ownership (-0.884): Whether a customer Rents, Owns, or has a Mortgage is the second most critical factor.
- Income (-0.802): Annual income power is the third driver.
- Loan % of Income (-0.727): The debt burden ratio is significant but slightly less impactful than the raw loan amount in this specific model.
- Employment Length (-0.465): This is the weakest predictor of the group (as we suspected from the lower IV earlier), but it is still statistically significant, so it is worth keeping.

ScoreCard

The Scoring Logic (WIP)

$$\text{Score} = \text{Offset} + \text{Factor} \times \ln(\text{Odds})$$

In [82]:

```
# --- 1. Settings ---
TARGET_SCORE = 600
TARGET_ODDS = 50
PDO = 20

# Calculate Factor and Offset
factor = PDO / np.log(2)
offset = TARGET_SCORE - (factor * np.log(TARGET_ODDS))

print(f"Factor: {factor:.2f}")
print(f"Offset: {offset:.2f}")

# --- 2. Extract Coefficients ---
# Get the intercept (alpha) and feature coefficients (betas) from your model
intercept = result.params['const']
coeffs = result.params.drop('const')

# --- 3. Calculate Base Score ---
# Since your model predicts Log(Bad/Good), and we want Score ~ Log(Good/Bad),
# we negate the equation.
# Base Score = Offset + Factor * (-Intercept)
base_score = offset + (factor * -intercept)

print(f"Base Score (Intercept Points): {base_score:.0f}")

# --- 4. Generate Scorecard Table ---
scorecard = []

# List of your features and their corresponding original WOE dataframes
# IMPORTANT: Ensure 'woe_dataframes' dictionary (from previous steps) is available
features_list = {
    'Home_Ownership_woe': ('Home_Ownership', woe_home),
```

```

'Income_woe': ('Income', woe_income),
'Emp_Length_woe': ('Emp_Length', woe_emp),
'Loan_Amnt_woe': ('Loan_Amnt', woe_amnt),
}

for col_model, (col_original, df_woe) in features_list.items():
    # Get the coefficient for this feature
    beta = coeffs[col_model]

    # Iterate through the bins in the WOE dataframe
    for index, row in df_woe.iterrows():
        woe_val = row['WoE']
        bin_label = row['Value']

        # Calculate Score Point for this bin
        # Point = (-Factor) * (Coefficient) * (WOE)
        points = (-factor) * beta * woe_val

        scorecard.append({
            'Feature': col_original,
            'Bin': bin_label,
            'WoE': woe_val,
            'Points': round(points) # Round to nearest integer
        })

# Create DataFrame
df_scorecard = pd.DataFrame(scorecard)

# --- 5. Display Final Scorecard ---
print("\n--- FINAL CREDIT SCORECARD ---")
print(f"Base Score: {round(base_score)}")
display(df_scorecard)

```

Factor: 28.85
Offset: 487.12
Base Score (Intercept Points): 525

--- FINAL CREDIT SCORECARD ---
Base Score: 525

	Feature	Bin	WoE	Points
0	Home_Ownership	OWN	1.240513	31
1	Home_Ownership	MORTGAGE	0.662946	16
2	Home_Ownership	RENT	-0.502822	-12
3	Home_Ownership	OTHER	-0.468706	-12
4	Income	(3999.0, 35000.0]	-1.005194	-36
5	Income	(63000.0, 86000.0]	0.493634	18
6	Income	(49000.0, 63000.0]	0.227718	8
7	Income	(86000.0, 2039784.0]	1.020571	37
8	Income	(35000.0, 49000.0]	-0.093159	-3
9	Emp_Length	4-6	0.116057	1
10	Emp_Length	<2	-0.323079	-2
11	Emp_Length	8-10	0.295917	2
12	Emp_Length	2-4	-0.070332	0
13	Emp_Length	6-8	0.189314	1
14	Emp_Length	10-40	0.352184	2
15	Emp_Length	Missing	-0.499806	-3
16	Emp_Length	>40	0.000000	0
17	Loan_Amnt	(499.0, 4400.0]	0.051455	4
18	Loan_Amnt	(4400.0, 6750.0]	0.287815	21
19	Loan_Amnt	(14500.0, 35000.0]	-0.472114	-35
20	Loan_Amnt	(6750.0, 10000.0]	0.175024	13
21	Loan_Amnt	(10000.0, 14500.0]	-0.000368	0