DnB Loan Default Prediction Assignment

August 10, 2022

1 Importing the Data Wrangling and Visualization libaries

[57]:

```
import numpy as np
import pandas as pd

import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
sns.set_theme(style = "darkgrid")
```

2 Importing the dataset

[3]:

```
df = pd.read_csv('/content/Borrower_Payment_History.csv')
df.head()
```

[3]:

```
            subject_id        account_id DATE_REPORTED currency_code  \
0  110113010000498773  2201160002396407     02-JAN-18           TZS
1  110115010001596750  2201170002990772     08-JAN-18           TZS
2  110114010000832340  2201140001177207     02-JAN-18           TZS
3  110114010000740514  2201160002371670     02-JAN-18           TZS
4  110114010000811717  2201140001161294     08-JAN-18           TZS

         REPAYMENT_FREQUENCY  NUMBER_OF_INSTALLMENTS  SANCTION_AMT  \
0  MonthlyInstalments30Days                      6.0      400000.0
1  MonthlyInstalments30Days                     61.0     3500000.0
2  MonthlyInstalments30Days                     57.0     4200000.0
3  MonthlyInstalments30Days                     24.0    60000000.0
4  MonthlyInstalments30Days                     69.0     3400000.0

   TOT_OUTSTD_BAL  OVER_DUE_AMT  AMOUNT_OF_INSTALLMENT  … LAST_AMOUNT_PAID  \
0            0.00      205609.4                   0.00  …              NaN
1      3272849.49           0.0              100243.11  …              NaN
2       870462.93           0.0              106652.40  …              NaN
3     15740676.93           0.0             2987342.81  …              NaN
4       828981.51           0.0               99164.00  …              NaN
```

```
  DATE_ACC_OPEN DATE_ACC_CLOSE      INSTALMENT_LOAN_TYPE loan_status  \
0     29-JUN-16      29-DEC-16  OtherInstalmentOperation    Existing
1     29-JUN-17      05-JUL-22              ConsumerLoan    Existing
2     27-DEC-13            NaN              ConsumerLoan    Existing
3     11-MAY-16            NaN              BusinessLoan    Existing
4     20-FEB-13      16-NOV-18              ConsumerLoan    Existing

  ASSET_CLASSIFICATION  REASON_FOR_CLOSURE  NO_OF_DAYS_PAST_DUE  LOAN_TENURE  \
0                  NaN                 NaN                399.0          NaN
1                  NaN                 NaN                  0.0          NaN
2                  NaN                 NaN                  0.0          NaN
3                  NaN                 NaN                 18.0          NaN
4                  NaN                 NaN                  0.0          NaN

  EXPECTED_END_DATE_OF_LOAN
0                 29-DEC-16
1                 05-JUL-22
2                 27-SEP-18
3                 11-MAY-18
4                 16-NOV-18

[5 rows x 21 columns]
```

3 Explore the basics of the Dataset

[4]:

```
# Check the size of the dataframe

rows, cols = df.shape
print('Rows: ', rows, '| Columns: ', cols)
```

```
Rows:  6000 | Columns:  21
```

[5]:

```
# Understand the fields in the dataframe

df.columns
```

[5]:

```
Index(['subject_id', 'account_id', 'DATE_REPORTED', 'currency_code',
       'REPAYMENT_FREQUENCY', 'NUMBER_OF_INSTALLMENTS', 'SANCTION_AMT',
       'TOT_OUTSTD_BAL', 'OVER_DUE_AMT', 'AMOUNT_OF_INSTALLMENT',
       'DATE_LATEST_PAY_RECEIVED', 'LAST_AMOUNT_PAID', 'DATE_ACC_OPEN',
       'DATE_ACC_CLOSE', 'INSTALMENT_LOAN_TYPE', 'loan_status',
       'ASSET_CLASSIFICATION', 'REASON_FOR_CLOSURE', 'NO_OF_DAYS_PAST_DUE',
       'LOAN_TENURE', 'EXPECTED_END_DATE_OF_LOAN'],
      dtype='object')
```

[6]:
```
# Check the datatypes

df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 6000 entries, 0 to 5999
Data columns (total 21 columns):
 #   Column                      Non-Null Count  Dtype
---  ------                      --------------  -----
 0   subject_id                  6000 non-null   int64
 1   account_id                  6000 non-null   int64
 2   DATE_REPORTED               6000 non-null   object
 3   currency_code               6000 non-null   object
 4   REPAYMENT_FREQUENCY         5982 non-null   object
 5   NUMBER_OF_INSTALLMENTS      5921 non-null   float64
 6   SANCTION_AMT                6000 non-null   float64
 7   TOT_OUTSTD_BAL              5981 non-null   float64
 8   OVER_DUE_AMT                5993 non-null   float64
 9   AMOUNT_OF_INSTALLMENT       5972 non-null   float64
 10  DATE_LATEST_PAY_RECEIVED    4647 non-null   object
 11  LAST_AMOUNT_PAID            0 non-null      float64
 12  DATE_ACC_OPEN               6000 non-null   object
 13  DATE_ACC_CLOSE              2934 non-null   object
 14  INSTALMENT_LOAN_TYPE        5920 non-null   object
 15  loan_status                 6000 non-null   object
 16  ASSET_CLASSIFICATION        0 non-null      float64
 17  REASON_FOR_CLOSURE          0 non-null      float64
 18  NO_OF_DAYS_PAST_DUE         5929 non-null   float64
 19  LOAN_TENURE                 0 non-null      float64
 20  EXPECTED_END_DATE_OF_LOAN   6000 non-null   object
dtypes: float64(10), int64(2), object(9)
memory usage: 984.5+ KB
```

4 Data Cleaning

[7]:
```
# Drop the fields which are completely NULL

df1 = df.drop(columns=['LAST_AMOUNT_PAID', 'ASSET_CLASSIFICATION',␣
 ↪'REASON_FOR_CLOSURE', 'LOAN_TENURE'])
df1.shape
```

[7]:
```
(6000, 17)
```

[8]:
```
# Drop duplicated records from the dataframe
```

```
df1 = df1.drop_duplicates()
df1.shape
```

[8]:
```
(5982, 17)
```

[9]:
```
# Rename the fields uniformly.

df1.rename(columns={'subject_id': 'SUBJECT_ID', 'account_id': 'ACCOUNT_ID',
                    'currency_code': 'CURR_CODE', 'INSTALMENT_LOAN_TYPE':␣
 ↪'LOAN_TYPE',
                    'AMOUNT_OF_INSTALLMENT': 'INSTALLMENT_AMT',
                    'DATE_LATEST_PAY_RECEIVED': 'DATE_LATEST_PAYMENT',
                    'loan_status': 'LOAN_STATUS', 'NO_OF_DAYS_PAST_DUE': 'DPD',
                    'EXPECTED_END_DATE_OF_LOAN': 'DATE_EXP_LOAN_CLOSURE'},␣
 ↪inplace=True)
```

[10]:
```
# Correct the date fields to the right formats

df1['DATE_REPORTED'] = pd.to_datetime(df1['DATE_REPORTED'])
df1['DATE_ACC_OPEN'] = pd.to_datetime(df1['DATE_ACC_OPEN'])
df1['DATE_ACC_CLOSE'] = pd.to_datetime(df1['DATE_ACC_CLOSE'])
df1['DATE_EXP_LOAN_CLOSURE'] = pd.to_datetime(df1['DATE_EXP_LOAN_CLOSURE'])
df1['DATE_LATEST_PAYMENT'] = pd.to_datetime(df1['DATE_LATEST_PAYMENT'])

df1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 5982 entries, 0 to 5999
Data columns (total 17 columns):
 #   Column                 Non-Null Count  Dtype
---  ------                 --------------  -----
 0   SUBJECT_ID             5982 non-null   int64
 1   ACCOUNT_ID             5982 non-null   int64
 2   DATE_REPORTED          5982 non-null   datetime64[ns]
 3   CURR_CODE              5982 non-null   object
 4   REPAYMENT_FREQUENCY    5964 non-null   object
 5   NUMBER_OF_INSTALLMENTS 5903 non-null   float64
 6   SANCTION_AMT           5982 non-null   float64
 7   TOT_OUTSTD_BAL         5963 non-null   float64
 8   OVER_DUE_AMT           5975 non-null   float64
 9   INSTALLMENT_AMT        5954 non-null   float64
 10  DATE_LATEST_PAYMENT    4631 non-null   datetime64[ns]
 11  DATE_ACC_OPEN          5982 non-null   datetime64[ns]
 12  DATE_ACC_CLOSE         2927 non-null   datetime64[ns]
 13  LOAN_TYPE              5902 non-null   object
 14  LOAN_STATUS            5982 non-null   object
 15  DPD                    5911 non-null   float64
 16  DATE_EXP_LOAN_CLOSURE   5982 non-null   datetime64[ns]
dtypes: datetime64[ns](5), float64(6), int64(2), object(4)
memory usage: 841.2+ KB
```

[11]:

```
# Note that the Account_ID is repeatedly reported on multiple date.

df1[df1['ACCOUNT_ID']== 2201170002918195]
```

[11]:

```
              SUBJECT_ID        ACCOUNT_ID DATE_REPORTED CURR_CODE  \
137   1101170100023844O6  2201170002918195    2018-03-08       TZS
4369  1101170100023844O6  2201170002918195    2018-06-10       TZS

         REPAYMENT_FREQUENCY  NUMBER_OF_INSTALLMENTS  SANCTION_AMT  \
137   MonthlyInstalments30Days                    61.0    10200000.0
4369  MonthlyInstalments30Days                    61.0    10200000.0

      TOT_OUTSTD_BAL  OVER_DUE_AMT  INSTALLMENT_AMT DATE_LATEST_PAYMENT  \
137       8192765.61           0.0        270237.61          2018-02-27
4369      7787140.81           0.0        270237.61          2018-05-25

     DATE_ACC_OPEN DATE_ACC_CLOSE     LOAN_TYPE LOAN_STATUS  DPD  \
137     2016-08-19     2021-09-01  ConsumerLoan    Existing  0.0
4369    2016-08-19     2021-09-01  ConsumerLoan    Existing  0.0

     DATE_EXP_LOAN_CLOSURE
137             2021-09-01
4369            2021-09-01
```

[12]:

```
# Remove multiple entries for same Account_ID reported on different dates to␣
 ↪make it unique.

df2 = df1.merge(df1.groupby('ACCOUNT_ID')['DATE_REPORTED'].max().reset_index(),
                             on=['ACCOUNT_ID', 'DATE_REPORTED'], how='inner')
df2.shape
```

[12]: (5969, 17)

[13]:

```
# Drop the records with SANCTION_AMT = 0, which doesnt add value to dataset.

df2.drop(df2[df2['SANCTION_AMT'] == 0].index, inplace = True)
df2.shape
```

[13]: (5960, 17)

5 Handle Missing Values

[14]:
```
# Check the NULL values in the dataframe

df2.isnull().sum()
```

[14]:
```
SUBJECT_ID                 0
ACCOUNT_ID                 0
DATE_REPORTED              0
CURR_CODE                  0
REPAYMENT_FREQUENCY       12
NUMBER_OF_INSTALLMENTS    70
SANCTION_AMT               0
TOT_OUTSTD_BAL            13
OVER_DUE_AMT               7
INSTALLMENT_AMT           22
DATE_LATEST_PAYMENT     1345
DATE_ACC_OPEN              0
DATE_ACC_CLOSE          3046
LOAN_TYPE                 80
LOAN_STATUS                0
DPD                       71
DATE_EXP_LOAN_CLOSURE      0
dtype: int64
```

[15]:
```
# Find the values in REPAYMENT_FREQUENCY.

df2['REPAYMENT_FREQUENCY'].value_counts()
```

[15]:
```
MonthlyInstalments30Days              5684
AtTheFinalDayOfThePeriodOfContract     197
IrregularInstalments                    40
FortnightlyInstalments15Days            25
AnnualInstalments360Days                 1
SixMonthInstalments180Days               1
Name: REPAYMENT_FREQUENCY, dtype: int64
```

[16]:
```
# Find the values in LOAN_TYPE.

df2['LOAN_TYPE'].value_counts()
```

[16]:
```
ConsumerLoan               3795
BusinessLoan               1678
OtherInstalmentOperation    310
CreditCard                   58
MortgageLoan                 16
Overdraft                    12
```

```
LeasingFinancial              11
Name: LOAN_TYPE, dtype: int64
```

[17]:

```python
# Find the values in LOAN_STATUS.

df2['LOAN_STATUS'].value_counts()
```

[17]:

```
Existing                            4914
TerminatedAccordingTheContract       760
TerminatedInAdvanceCorrectly         279
TerminatedInAdvanceIncorrectly         7
Name: LOAN_STATUS, dtype: int64
```

[19]:

```python
# Fill the missing the 'REPAYMENT_FREQUENCY' field values

# For LOAN_TYPE == 'Overdraft', the payment cannot have installments but 1␣
 ↪single payment.
df2['REPAYMENT_FREQUENCY'] = np.where(df2['LOAN_TYPE'] == "Overdraft",
                                      'AtTheFinalDayOfThePeriodOfContract',
                                      df2['REPAYMENT_FREQUENCY'])

# # For the rest, lets fill it with the mode of the field values.
# df2['REPAYMENT_FREQUENCY'].fillna(df2['REPAYMENT_FREQUENCY'].mode()[0],␣
 ↪inplace=True)
```

[22]:

```python
# Create a function which calculates the number of installments based on the␣
 ↪DATE_ACC_OPEN and DATE_EXP_LOAN_CLOSURE

def calc_instal_count(freq, end_date, open_date):
    if freq == 'FortnightlyInstalments15Days':
        tenure = (end_date - open_date) / np.timedelta64(1, 'D') / 15
        return tenure
    elif freq == 'MonthlyInstalments30Days':
        tenure = (end_date - open_date) / np.timedelta64(1, 'D') / 30
        return tenure
    elif freq == 'AnnualInstalments360Days':
        tenure = (end_date - open_date) / np.timedelta64(1, 'D') / 360
        return tenure
    elif freq == 'SixMonthInstalments180Days':
        tenure = (end_date - open_date) / np.timedelta64(1, 'D') / 180
        return tenure
    elif freq == 'AtTheFinalDayOfThePeriodOfContract':
        tenure = 1
        return tenure
    else:
      return 1
```

[23]:

```
# Replace the Number of Installments field with calculated NON NULL values

df2['NUMBER_OF_INSTALLMENTS'] = df2.apply(lambda x:␣
 ↪calc_instal_count(x['REPAYMENT_FREQUENCY'],
                                                                           ␣
 ↪x['DATE_EXP_LOAN_CLOSURE'],
                                                                           ␣
 ↪x['DATE_ACC_OPEN']), axis=1)
df2['NUMBER_OF_INSTALLMENTS'] = df2['NUMBER_OF_INSTALLMENTS'].apply(np.floor)
```

[25]:

```
# Fill in the INSTALLMENT_AMT field by dividing SANCTION_AMT with␣
 ↪NUMBER_OF_INSTALLMENTS

df2['INSTALLMENT_AMT'].fillna(df2['SANCTION_AMT'] /␣
 ↪df2['NUMBER_OF_INSTALLMENTS'], inplace=True)
```

[29]:

```
# Fill in missing the OVER_DUE_AMT

# For the loans which are Terminated properly, there should not be any Over-Due␣
 ↪Amount
df2.loc[df2['LOAN_STATUS']=='TerminatedAccordingTheContract','OVER_DUE_AMT'] = 0

# The loans with DPD ==0, there should not be Over_Due_Amount
df2.loc[(df2['OVER_DUE_AMT'].isnull()) & (df2['DPD']==0),'OVER_DUE_AMT'] = 0

# For the rest of the loans with status "Existing", since they all have␣
 ↪Repayment Frequency of 30 days &
# since the DPDs are less than 30, their OVER_DUE should be equal to␣
 ↪INSTALLMENT_AMT
df2['OVER_DUE_AMT'].fillna(df2['INSTALLMENT_AMT'], inplace=True)
```

[36]:

```
# Fill in the TOT-OUTSTD_BAL field with 2 logics.

# For DPD >0 customers, their Oust_Bal must be greater than Over_Due.
# However, we shall consider the same amount here as we dont have the␣
 ↪Total_Paid on date.
df2.loc[(df2['TOT_OUTSTD_BAL'].isnull()) & (df2['DPD']>0),'TOT_OUTSTD_BAL'] =␣
 ↪df2['OVER_DUE_AMT']

# For DPD ==0 customers, their oustanding is at the least their next␣
 ↪INSTALLMENT_AMT
df2.loc[(df2['TOT_OUTSTD_BAL'].isnull()) & (df2['DPD']==0),'TOT_OUTSTD_BAL'] =␣
 ↪df2['INSTALLMENT_AMT']
```

[39]:

```
# Fill in the missing LOAN_TYPE with the mode value.
# Because, find the the correct Loan_type using the Number of Installments␣
 ↪seems difficult
# as even the loans from Credit Cards are allowed to pay in longer installments

df2['LOAN_TYPE'].fillna(df2['LOAN_TYPE'].mode()[0], inplace=True)
```

[40]:

```
# Fill in the missing DPD days.

# For those loans which have valid LATEST_PAYMENT_DATE, if the OVER_DUE exists,␣
 ↪find the days_diff from reporting date.
df2.loc[(df2['OVER_DUE_AMT']>0) &
        (df2['DATE_LATEST_PAYMENT'].notnull()) &
        (df2['DPD'].isnull()), 'DPD'] = (df2['DATE_REPORTED'] -␣
 ↪df2['DATE_LATEST_PAYMENT']) / np.timedelta64(1, 'D')
```

[41]:

```
# Loans which are to be paid at the end of the contract, DPD should be 0
df2.loc[(df2['DPD'].isnull()) &
       ␣
 ↪(df2['REPAYMENT_FREQUENCY']=='AtTheFinalDayOfThePeriodOfContract'),'DPD'] = 0

# Notice that for the rest records with NULL DPD, REPAYMENY_FREQ is every month.
# So, if the Overdue_Amount is greater than 3 times of the installment, it has␣
 ↪DPD > 90
df2.loc[(df2['DPD'].isnull()) &
        ((df2['OVER_DUE_AMT']/df2['INSTALLMENT_AMT'])>=3),'DPD'] = 91

# Else, it has lesser than 90 days DPD. Fill the rest NULL DPD with 0.
df2['DPD'].fillna(0, inplace=True)
```

[43]:

```
# Thus cleaned all the NULL values on necessary fields.

df2.isnull().sum()
```

[43]:

```
SUBJECT_ID                0
ACCOUNT_ID                0
DATE_REPORTED             0
CURR_CODE                 0
REPAYMENT_FREQUENCY       0
NUMBER_OF_INSTALLMENTS    0
SANCTION_AMT              0
TOT_OUTSTD_BAL            0
OVER_DUE_AMT              0
INSTALLMENT_AMT           0
DATE_LATEST_PAYMENT    1345
DATE_ACC_OPEN             0
DATE_ACC_CLOSE         3046
LOAN_TYPE                 0
```

```
LOAN_STATUS                0
DPD                        0
DATE_EXP_LOAN_CLOSURE      0
dtype: int64
```

[44]:

```
# Adding a new feature 'LOAN_TENURE', which originally had all NULL values in␣
 ↪the dataset.

df2['LOAN_TENURE'] = (df2['DATE_EXP_LOAN_CLOSURE'] - df2['DATE_ACC_OPEN']) / np.
 ↪timedelta64(1, 'D')
df2.head()
```

[44]:

```
           SUBJECT_ID        ACCOUNT_ID DATE_REPORTED CURR_CODE  \
0  110113010000498773  2201160002396407    2018-01-02       TZS
1  110115010001596750  2201170002990772    2018-01-08       TZS
2  110114010000832340  2201140001177207    2018-01-02       TZS
3  110114010000740514  2201160002371670    2018-01-02       TZS
4  110114010000811717  2201140001161294    2018-01-08       TZS

        REPAYMENT_FREQUENCY  NUMBER_OF_INSTALLMENTS  SANCTION_AMT  \
0  MonthlyInstalments30Days                     6.0      400000.0
1  MonthlyInstalments30Days                    61.0     3500000.0
2  MonthlyInstalments30Days                    57.0     4200000.0
3  MonthlyInstalments30Days                    24.0    60000000.0
4  MonthlyInstalments30Days                    69.0     3400000.0

   TOT_OUTSTD_BAL  OVER_DUE_AMT  INSTALLMENT_AMT DATE_LATEST_PAYMENT  \
0            0.00      205609.4             0.00          2016-11-29
1      3272849.49           0.0        100243.11          2017-12-29
2       870462.93           0.0        106652.40          2017-12-28
3     15740676.93           0.0       2987342.81          2017-12-18
4       828981.51           0.0         99164.00          2017-12-29

  DATE_ACC_OPEN DATE_ACC_CLOSE                 LOAN_TYPE LOAN_STATUS    DPD  \
0    2016-06-29     2016-12-29  OtherInstalmentOperation    Existing  399.0
1    2017-06-29     2022-07-05              ConsumerLoan    Existing    0.0
2    2013-12-27            NaT              ConsumerLoan    Existing    0.0
3    2016-05-11            NaT              BusinessLoan    Existing   18.0
4    2013-02-20     2018-11-16              ConsumerLoan    Existing    0.0

  DATE_EXP_LOAN_CLOSURE  LOAN_TENURE
0            2016-12-29        183.0
1            2022-07-05       1832.0
2            2018-09-27       1735.0
3            2018-05-11        730.0
4            2018-11-16       2095.0
```

[45]:
```
# Select only the relevant attributes for further steps

features = ['SUBJECT_ID', 'ACCOUNT_ID', 'CURR_CODE', 'REPAYMENT_FREQUENCY',␣
 ↪'NUMBER_OF_INSTALLMENTS', 'SANCTION_AMT',
            'TOT_OUTSTD_BAL', 'OVER_DUE_AMT', 'INSTALLMENT_AMT', 'LOAN_TYPE',␣
 ↪'LOAN_STATUS', 'LOAN_TENURE', 'DPD']
df3 = df2[features]
df3.head()
```

[45]:
```
           SUBJECT_ID         ACCOUNT_ID CURR_CODE       REPAYMENT_FREQUENCY  \
0  110113010000498773  2201160002396407       TZS  MonthlyInstalments30Days
1  110115010001596750  2201170002990772       TZS  MonthlyInstalments30Days
2  110114010000832340  2201140001177207       TZS  MonthlyInstalments30Days
3  110114010000740514  2201160002371670       TZS  MonthlyInstalments30Days
4  110114010000811717  2201140001161294       TZS  MonthlyInstalments30Days

   NUMBER_OF_INSTALLMENTS  SANCTION_AMT  TOT_OUTSTD_BAL  OVER_DUE_AMT  \
0                     6.0      400000.0            0.00      205609.4
1                    61.0     3500000.0      3272849.49           0.0
2                    57.0     4200000.0       870462.93           0.0
3                    24.0    60000000.0     15740676.93           0.0
4                    69.0     3400000.0       828981.51           0.0

   INSTALLMENT_AMT                 LOAN_TYPE LOAN_STATUS  LOAN_TENURE    DPD
0             0.00  OtherInstalmentOperation    Existing        183.0  399.0
1        100243.11              ConsumerLoan    Existing       1832.0    0.0
2        106652.40              ConsumerLoan    Existing       1735.0    0.0
3       2987342.81              BusinessLoan    Existing        730.0   18.0
4         99164.00              ConsumerLoan    Existing       2095.0    0.0
```

[46]:
```
df3.shape
```

[46]:
```
(5960, 13)
```

6 Data Analysis & Visualisation

[47]:
```
# Account_ID becomes the unique identifier for the dataframe.

df3['ACCOUNT_ID'].nunique()
```

[47]:
```
5960
```

[48]:
```
# Note that some Subject_IDs are repeated in the dataframe, meaning some␣
 ↪Customers availed more than 1 loan.
```

```
df3['SUBJECT_ID'].nunique()
```

[48]:

```
5923
```

[56]:

```
# Check the customers who availed multiple loans and their default

df_multiple_loans = df3.groupby(['SUBJECT_ID'])['ACCOUNT_ID'].count().
 ↪sort_values(ascending=False).reset_index()
df_multiple_loans = df_multiple_loans[df_multiple_loans['ACCOUNT_ID'] > 1]
df_multiple_loans = df3[df3['SUBJECT_ID'].isin(df_multiple_loans['SUBJECT_ID'])]
df_multiple_loans.sort_values(by=['DPD', 'SUBJECT_ID'], ascending=False,␣
 ↪inplace=True)
df_multiple_loans[['SUBJECT_ID', 'ACCOUNT_ID', 'LOAN_TYPE', 'LOAN_STATUS',␣
 ↪'DPD']]
```

```
/usr/local/lib/python3.7/dist-packages/pandas/util/_decorators.py:311:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  return func(*args, **kwargs)
```

[56]:

```
             SUBJECT_ID        ACCOUNT_ID     LOAN_TYPE LOAN_STATUS    DPD
588   110113010000508823  2201150001612310  ConsumerLoan    Existing  286.0
4451  110118010002814358  2201180003748597  BusinessLoan    Existing    0.0
5011  110118010002814358  2201180003748608  BusinessLoan    Existing    0.0
3537  110118010002810117  2201180003993041  BusinessLoan    Existing    0.0
4486  110118010002810117  2201180003719814  BusinessLoan    Existing    0.0
…                      …                 …             …           …     …
124   110113010000300324  2201180003234962  ConsumerLoan    Existing    0.0
5689  110113010000300324  2201180004039449  ConsumerLoan    Existing    0.0
2905  110113010000272956  2201180003748591  BusinessLoan    Existing    0.0
3227  110113010000272956  2201180003748599  BusinessLoan    Existing    0.0
3570  110113010000272956  2201180003869980  BusinessLoan    Existing    0.0

[73 rows x 5 columns]
```

[58]:

```
df_multiple_loans['SUBJECT_ID'].nunique()
```

[58]:

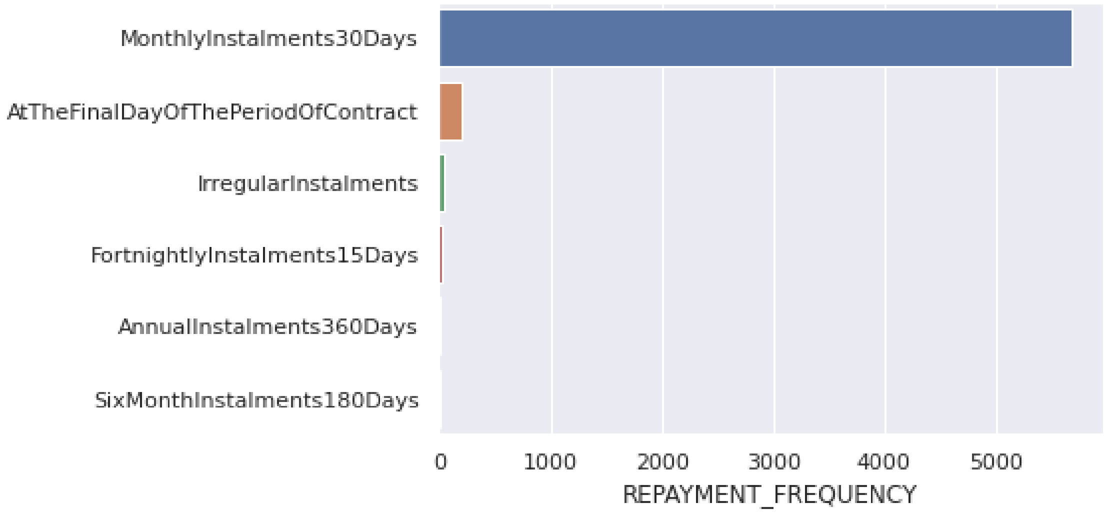
```
36
```

6.1 Understanding the Categorical variables

[59]:
```
# Function to plot Value Counts for Categorical variables

def cat_valcount_plot(df, fld):
    plt.figure(figsize=(6, 4))
    sns.barplot(df[fld].value_counts(), df[fld].value_counts().index)
    plt.show()
```

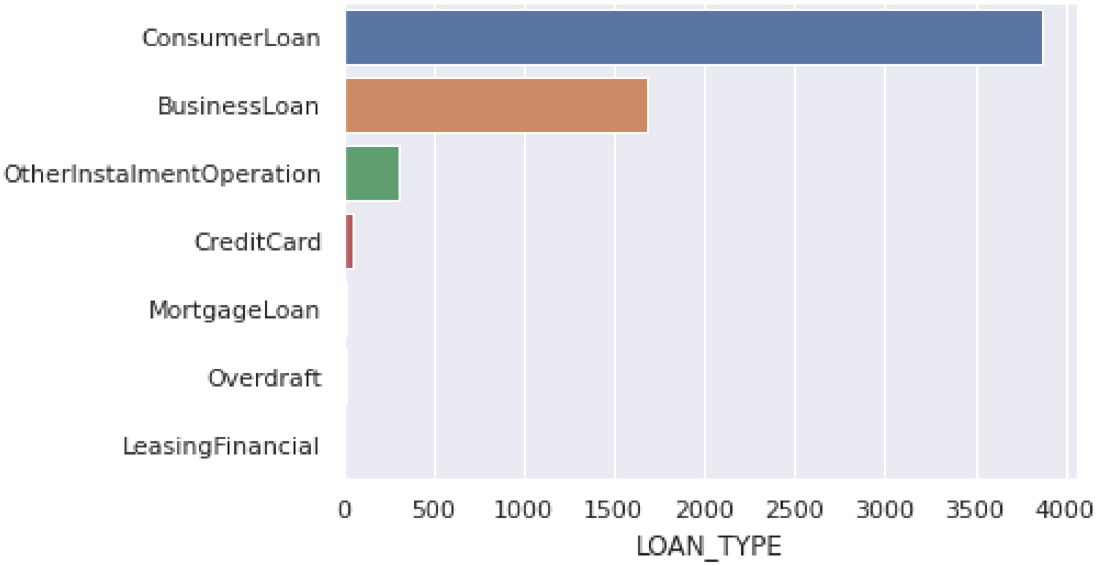
[60]:
```
# Check the distribution of multiple Repayment_Frequency

cat_valcount_plot(df3, 'REPAYMENT_FREQUENCY')
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43: FutureWarning:
Pass the following variables as keyword args: x, y. From version 0.12, the only
valid positional argument will be `data`, and passing other arguments without an
explicit keyword will result in an error or misinterpretation.
  FutureWarning
```



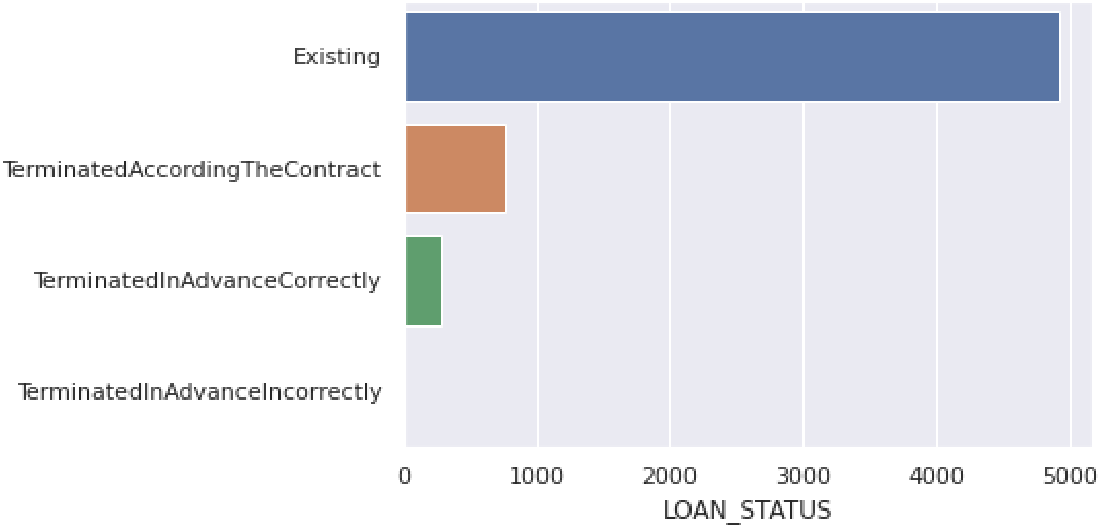
[61]:
```
# Check the distribution of different Loan_Type

cat_valcount_plot(df3, 'LOAN_TYPE')
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43: FutureWarning:
Pass the following variables as keyword args: x, y. From version 0.12, the only
valid positional argument will be `data`, and passing other arguments without an
explicit keyword will result in an error or misinterpretation.
  FutureWarning
```



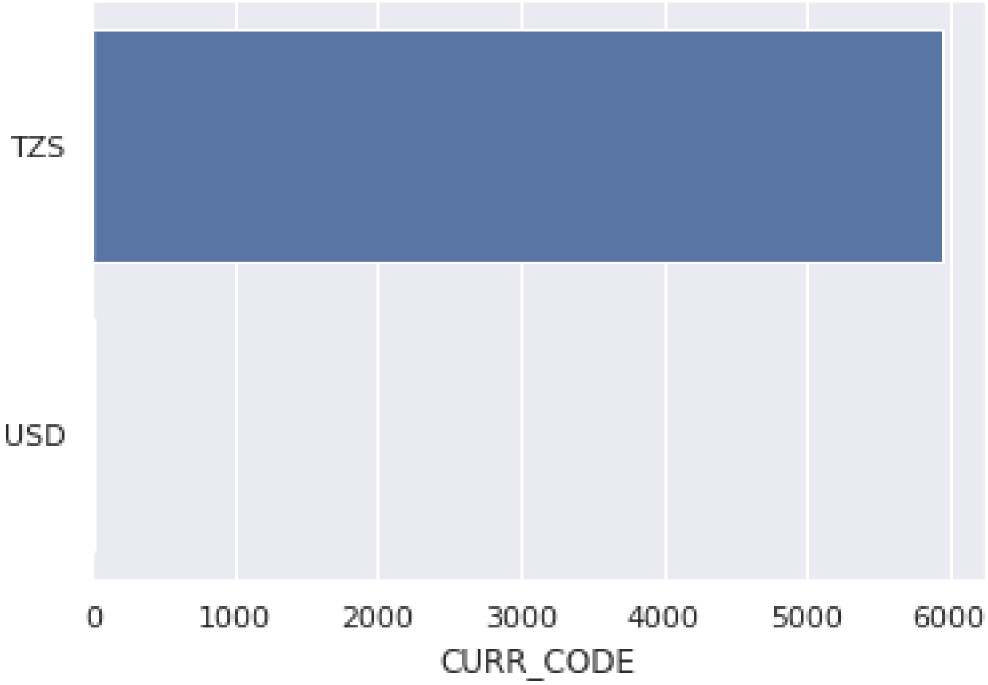
```
[62]: # Check the distribution of different Loan_Status

      cat_valcount_plot(df3, 'LOAN_STATUS')
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43: FutureWarning:
Pass the following variables as keyword args: x, y. From version 0.12, the only
valid positional argument will be `data`, and passing other arguments without an
explicit keyword will result in an error or misinterpretation.
  FutureWarning
```



[63]:
```
# Check the distribution of different Currencies

cat_valcount_plot(df3, 'CURR_CODE')
```

```
/usr/local/lib/python3.7/dist-packages/seaborn/_decorators.py:43: FutureWarning:
Pass the following variables as keyword args: x, y. From version 0.12, the only
valid positional argument will be `data`, and passing other arguments without an
explicit keyword will result in an error or misinterpretation.
  FutureWarning
```



[64]:
```
df3['CURR_CODE'].value_counts()
```

[64]:
```
TZS    5955
USD       5
Name: CURR_CODE, dtype: int64
```

[65]:
```
# Check the records which have currency in USD

df3[df3['CURR_CODE']=='USD'][['SANCTION_AMT', 'TOT_OUTSTD_BAL',
                               'OVER_DUE_AMT', 'INSTALLMENT_AMT']]
```

[65]:
```
     SANCTION_AMT  TOT_OUTSTD_BAL  OVER_DUE_AMT  INSTALLMENT_AMT
599       44500.0        37510.66          0.00           967.90
649      100000.0            0.00          0.00           775.00
```

```
902        60000.0         1484.13       1484.13          1484.13
4010       40000.0        15815.56          0.00          1309.55
4338       35000.0        33958.13          0.00           657.26
```

[66]:
```
# Since there are only 5 Loans in USD, let's convert all USD Loans into TZS

# Exchange rate from USD TO TZS (today's rate is 2332)
usd_tzs_conv_rate = 2335

df3.loc[df3['CURR_CODE']=='USD', ['SANCTION_AMT', 'TOT_OUTSTD_BAL',
                                  'OVER_DUE_AMT', 'INSTALLMENT_AMT']] *=␣
 ↪usd_tzs_conv_rate
```

```
/usr/local/lib/python3.7/dist-packages/pandas/core/indexing.py:1884:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  self._setitem_single_column(loc, val, pi)
```

[67]:
```
# Below USD values are now converted to TZS amounts
df3[df3['CURR_CODE']=='USD'][['SANCTION_AMT', 'TOT_OUTSTD_BAL',
                              'OVER_DUE_AMT', 'INSTALLMENT_AMT']]
```

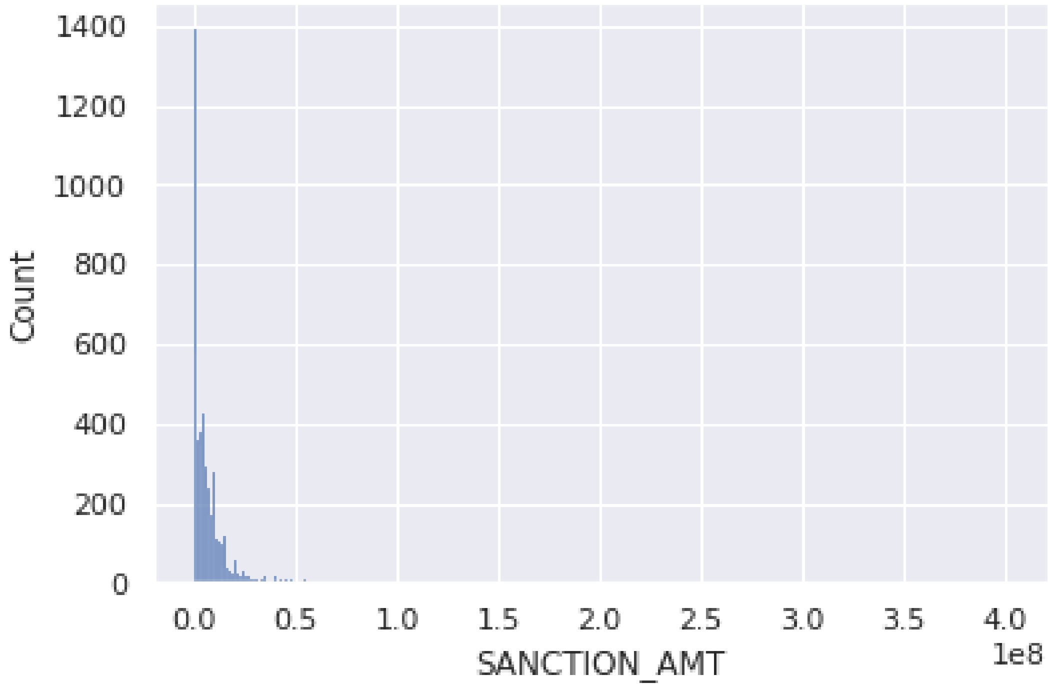
[67]:
```
      SANCTION_AMT  TOT_OUTSTD_BAL  OVER_DUE_AMT  INSTALLMENT_AMT
599    103907500.0     87587391.10          0.00       2260046.50
649    233500000.0            0.00          0.00       1809625.00
902    140100000.0      3465443.55    3465443.55       3465443.55
4010    93400000.0     36929332.60          0.00       3057799.25
4338    81725000.0     79292233.55          0.00       1534702.10
```

[68]:
```
# Correcting the USD Currency code to TZS for the converted records
df3['CURR_CODE'].replace(['USD','TZS'], inplace=True)
```

7 Visualise & Normalise the Numerical Variables

[69]:
```
sns.histplot(df3['SANCTION_AMT'])
```

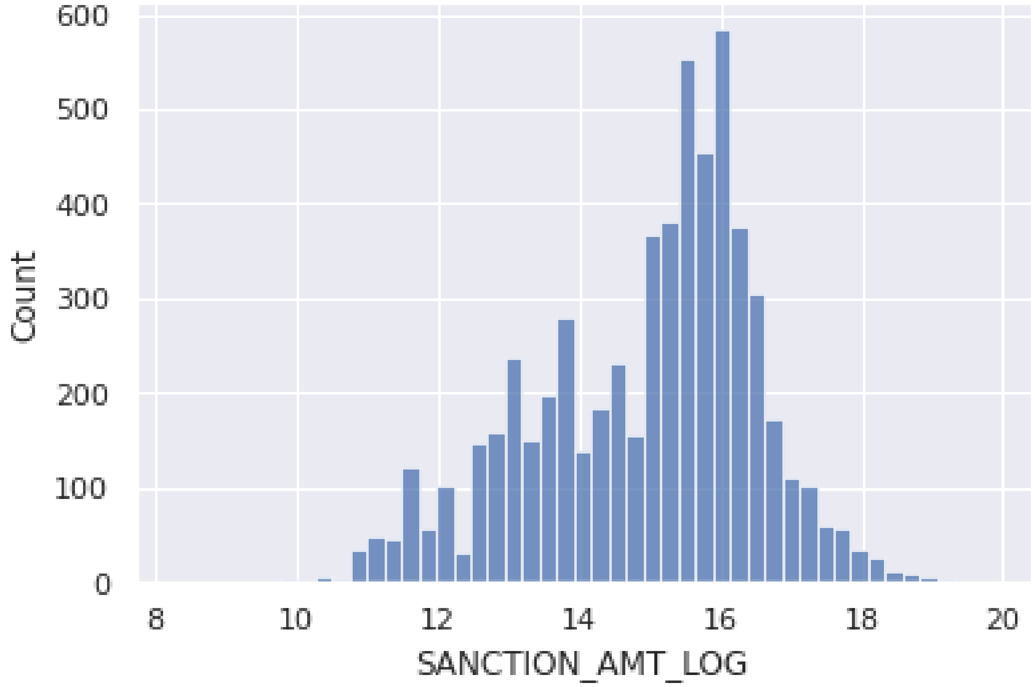
[69]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fc29df51210>
```



[70]:
```
# Applying log transformation to the attributes to normalise the data

df3['SANCTION_AMT_LOG'] = np.log(df3['SANCTION_AMT'])
sns.histplot(df3['SANCTION_AMT_LOG'])
```

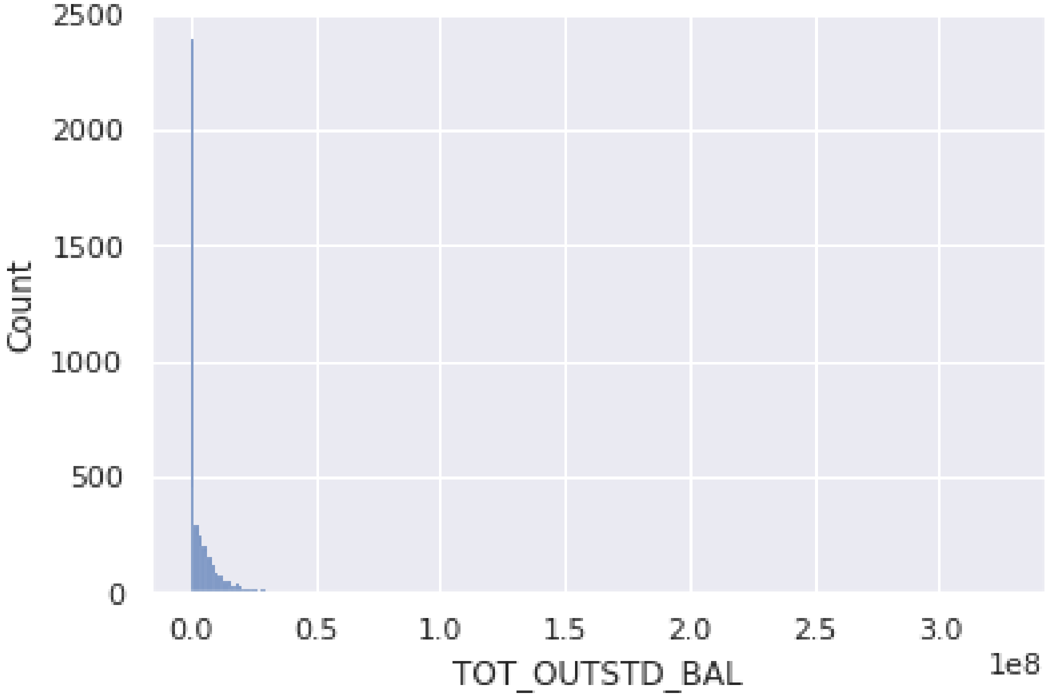
```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:3:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  This is separate from the ipykernel package so we can avoid doing imports
until
```

[70]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fc29d41e550>
```



[71]:
```
sns.histplot(df3['TOT_OUTSTD_BAL'])
```

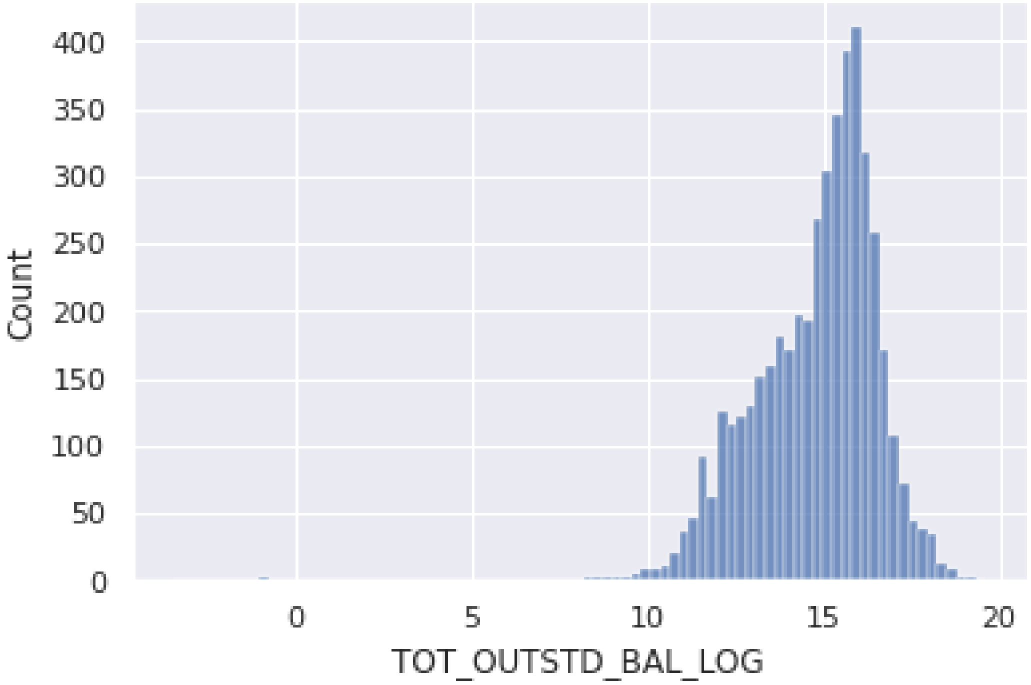
[71]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fc29df8f3d0>
```



[72]:
```
# Applying log transformation to the attributes to normalise the data

# df3.replace([np.inf, -np.inf], np.nan, inplace=True)

df3['TOT_OUTSTD_BAL_LOG'] = np.log(df3['TOT_OUTSTD_BAL'])
sns.histplot(df3['TOT_OUTSTD_BAL_LOG'])
```

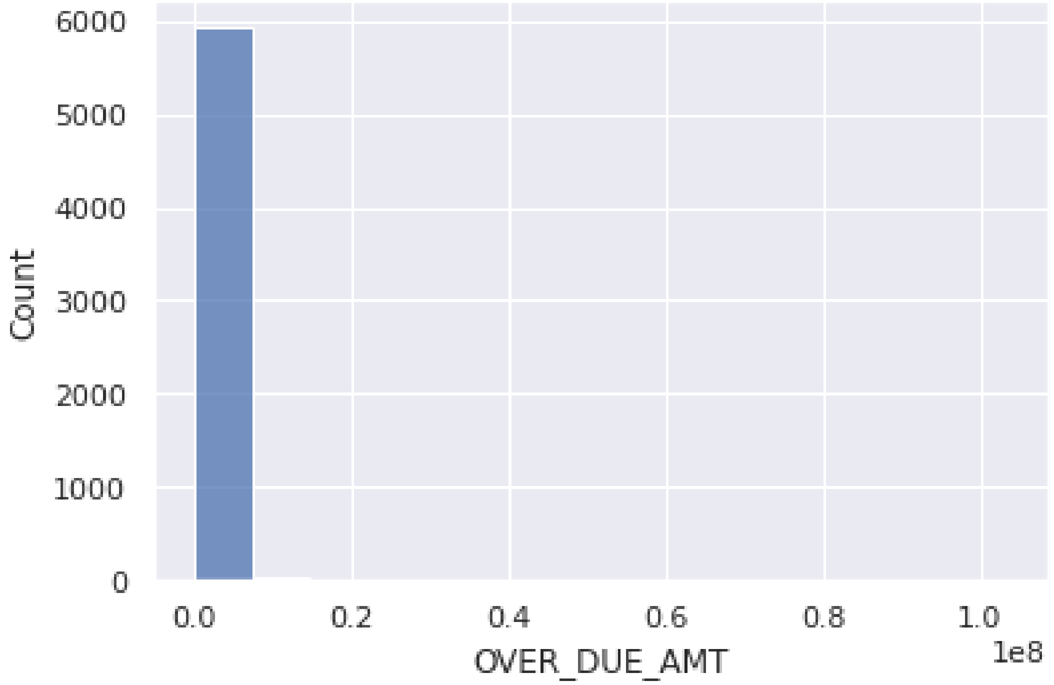
```
/usr/local/lib/python3.7/dist-packages/pandas/core/arraylike.py:364:
RuntimeWarning: divide by zero encountered in log
  result = getattr(ufunc, method)(*inputs, **kwargs)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:5:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  """
```

[72]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fc29cfe72d0>
```



[73]:
```
sns.histplot(df3['OVER_DUE_AMT'])
```

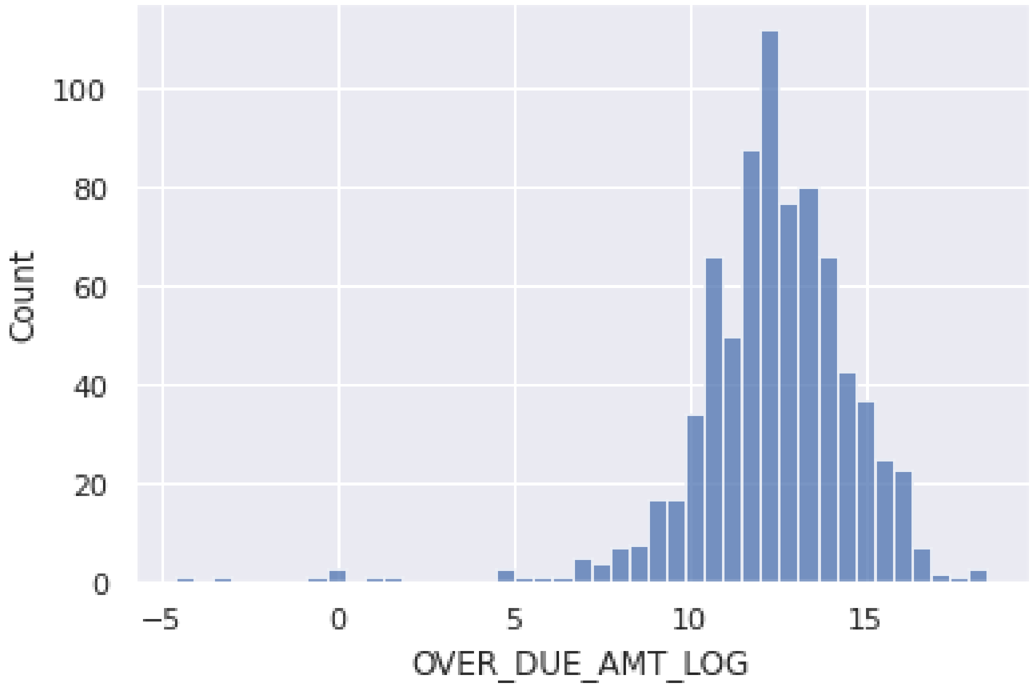
```
[73]: <matplotlib.axes._subplots.AxesSubplot at 0x7fc29cecf050>
```



```
[74]: # Applying log transformation to the attributes to normalise the data

      df3['OVER_DUE_AMT_LOG'] = np.log(df3['OVER_DUE_AMT'])
      sns.histplot(df3['OVER_DUE_AMT_LOG'])
```

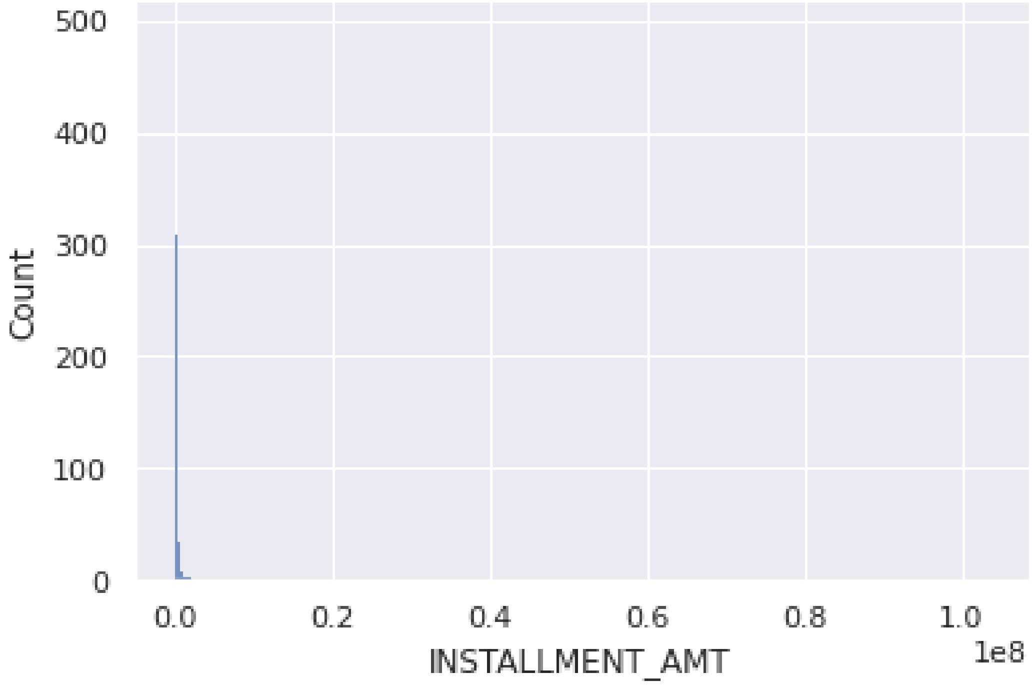
```
/usr/local/lib/python3.7/dist-packages/pandas/core/arraylike.py:364:
RuntimeWarning: divide by zero encountered in log
  result = getattr(ufunc, method)(*inputs, **kwargs)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:3:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  This is separate from the ipykernel package so we can avoid doing imports
until
```

```
[74]: <matplotlib.axes._subplots.AxesSubplot at 0x7fc29ce643d0>
```



```
[75]: sns.histplot(df3['INSTALLMENT_AMT'])
```

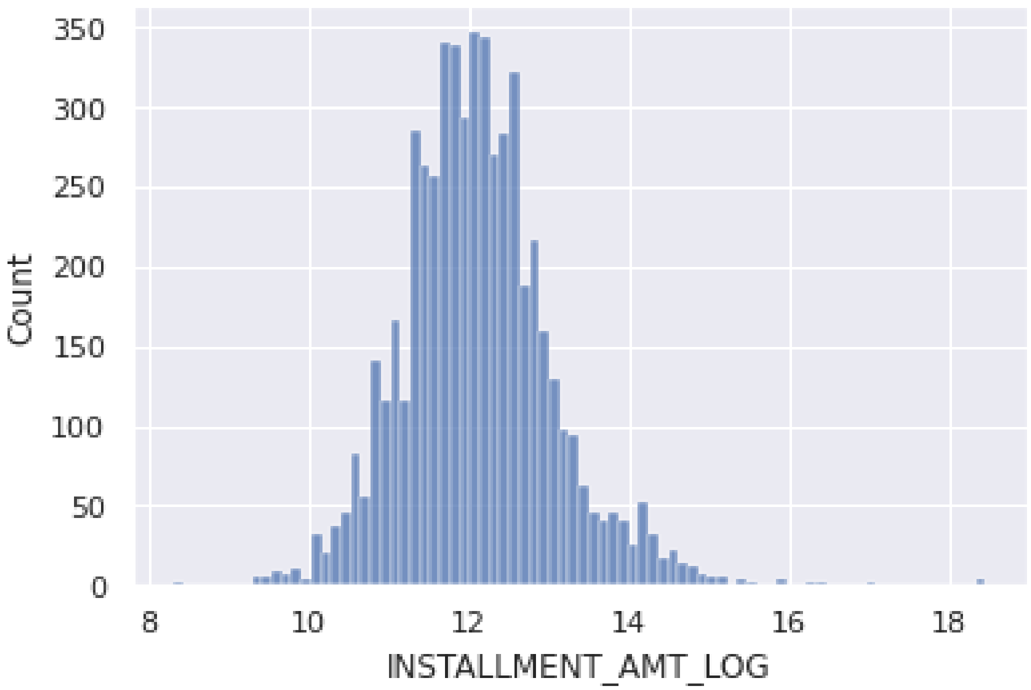
```
[75]: <matplotlib.axes._subplots.AxesSubplot at 0x7fc29cd52c90>
```



[76]:
```
# Applying log transformation to the attributes to normalise the data

df3['INSTALLMENT_AMT_LOG'] = np.log(df3['INSTALLMENT_AMT'])
sns.histplot(df3['INSTALLMENT_AMT_LOG'])
```

```
/usr/local/lib/python3.7/dist-packages/pandas/core/arraylike.py:364:
RuntimeWarning: divide by zero encountered in log
  result = getattr(ufunc, method)(*inputs, **kwargs)
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:3:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  This is separate from the ipykernel package so we can avoid doing imports
until
```

[76]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fc29cb23e50>
```



[77]:
```
# Handle the inifinity values created from log functions.
```

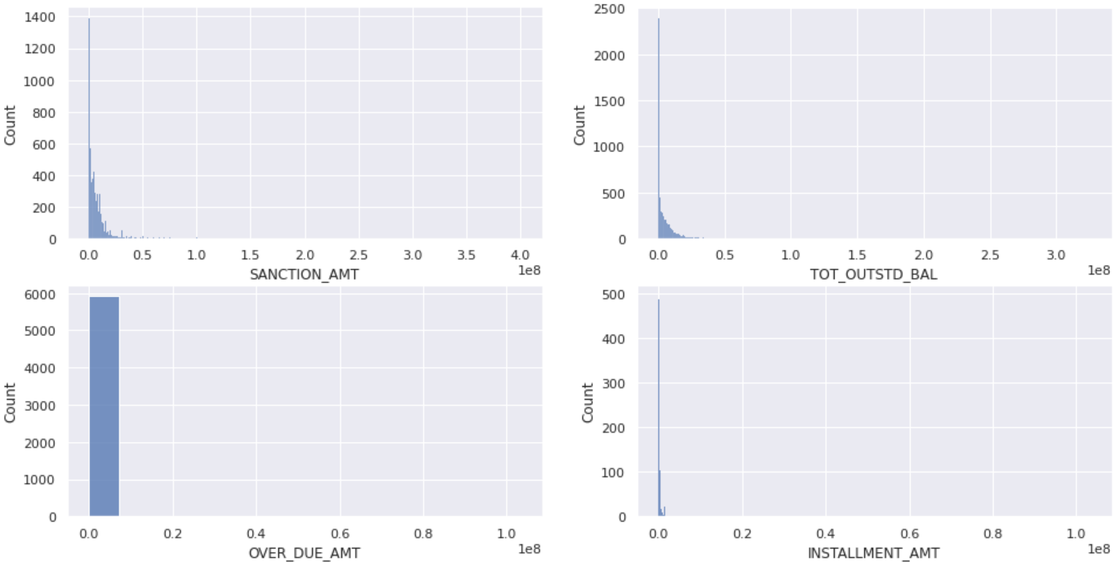
```
df3.replace([np.inf, -np.inf], 0, inplace=True)
df3.head()
```

```
/usr/local/lib/python3.7/dist-packages/pandas/core/frame.py:5244:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  method=method,
```

```
[77]:            SUBJECT_ID         ACCOUNT_ID CURR_CODE       REPAYMENT_FREQUENCY  \
      0  110113010000498773  2201160002396407       TZS  MonthlyInstalments30Days
      1  110115010001596750  2201170002990772       TZS  MonthlyInstalments30Days
      2  110114010000832340  2201140001177207       TZS  MonthlyInstalments30Days
      3  110114010000740514  2201160002371670       TZS  MonthlyInstalments30Days
      4  110114010000811717  2201140001161294       TZS  MonthlyInstalments30Days

         NUMBER_OF_INSTALLMENTS  SANCTION_AMT  TOT_OUTSTD_BAL  OVER_DUE_AMT  \
      0                     6.0      400000.0            0.00      205609.4
      1                    61.0     3500000.0      3272849.49           0.0
      2                    57.0     4200000.0       870462.93           0.0
      3                    24.0    60000000.0     15740676.93           0.0
      4                    69.0     3400000.0       828981.51           0.0

         INSTALLMENT_AMT                 LOAN_TYPE LOAN_STATUS  LOAN_TENURE    DPD  \
      0             0.00  OtherInstalmentOperation    Existing        183.0  399.0
      1        100243.11              ConsumerLoan    Existing       1832.0    0.0
      2        106652.40              ConsumerLoan    Existing       1735.0    0.0
      3       2987342.81              BusinessLoan    Existing        730.0   18.0
      4         99164.00              ConsumerLoan    Existing       2095.0    0.0

         SANCTION_AMT_LOG  TOT_OUTSTD_BAL_LOG  OVER_DUE_AMT_LOG  INSTALLMENT_AMT_LOG
      0         12.899220            0.000000         12.233734             0.000000
      1         15.068274           15.001172          0.000000            11.515354
      2         15.250595           13.676780          0.000000            11.577330
      3         17.909855           16.571759          0.000000            14.909895
      4         15.039286           13.627953          0.000000            11.504530
```

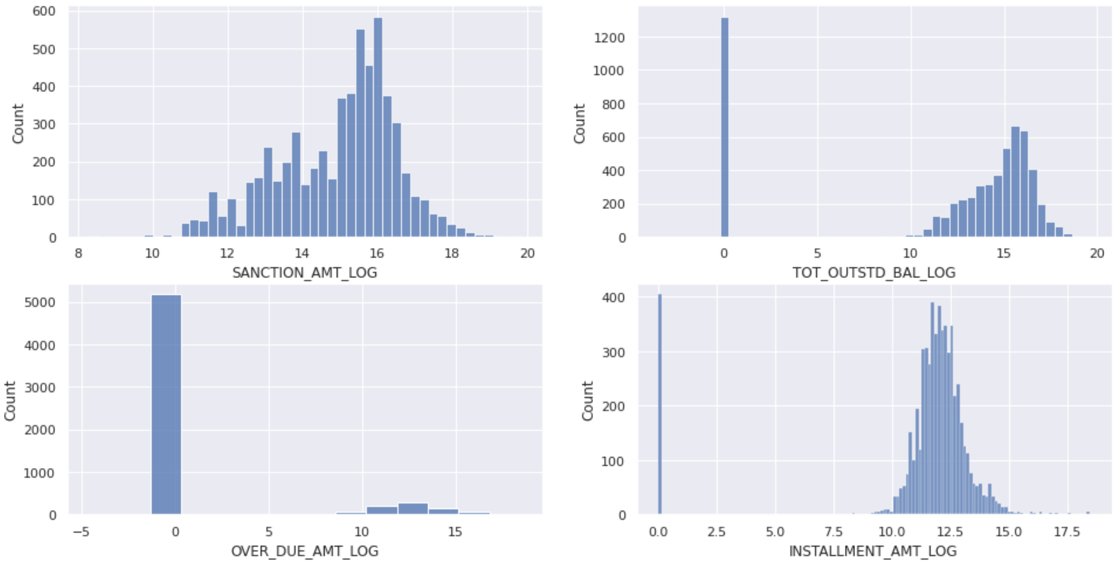
```
[110]: fig = plt.figure(figsize=(16,8))

       plt.subplot(2, 2, 1)
       sns.histplot(df3['SANCTION_AMT'])

       plt.subplot(2, 2, 2)
       sns.histplot(df3['TOT_OUTSTD_BAL'])
```

```python
plt.subplot(2, 2, 3)
sns.histplot(df3['OVER_DUE_AMT'])

plt.subplot(2, 2, 4)
sns.histplot(df3['INSTALLMENT_AMT'])

plt.show()
```



[111]:

```python
fig = plt.figure(figsize=(16,8))

plt.subplot(2, 2, 1)
sns.histplot(df3['SANCTION_AMT_LOG'])

plt.subplot(2, 2, 2)
sns.histplot(df3['TOT_OUTSTD_BAL_LOG'])

plt.subplot(2, 2, 3)
sns.histplot(df3['OVER_DUE_AMT_LOG'])

plt.subplot(2, 2, 4)
sns.histplot(df3['INSTALLMENT_AMT_LOG'])

plt.show()
```



```
[83]: # Create the Risk Identifier Dependant Variable from DPD
      # Logic: A Loan is default if has DPD > 90 days

      df3['IS_DEFAULT'] = np.where(df3['DPD'] >= 90, 1, 0)
      df3.head()
```

```
[83]:            SUBJECT_ID         ACCOUNT_ID CURR_CODE       REPAYMENT_FREQUENCY  \
      0  110113010000498773  2201160002396407       TZS  MonthlyInstalments30Days
      1  110115010001596750  2201170002990772       TZS  MonthlyInstalments30Days
      2  110114010000832340  2201140001177207       TZS  MonthlyInstalments30Days
      3  110114010000740514  2201160002371670       TZS  MonthlyInstalments30Days
      4  110114010000811717  2201140001161294       TZS  MonthlyInstalments30Days

         NUMBER_OF_INSTALLMENTS  SANCTION_AMT  TOT_OUTSTD_BAL  OVER_DUE_AMT  \
      0                     6.0      400000.0            0.00      205609.4
      1                    61.0     3500000.0      3272849.49           0.0
      2                    57.0     4200000.0       870462.93           0.0
      3                    24.0    60000000.0     15740676.93           0.0
      4                    69.0     3400000.0       828981.51           0.0

         INSTALLMENT_AMT                  LOAN_TYPE LOAN_STATUS  LOAN_TENURE    DPD  \
      0             0.00  OtherInstalmentOperation    Existing        183.0  399.0
      1        100243.11              ConsumerLoan    Existing       1832.0    0.0
      2        106652.40              ConsumerLoan    Existing       1735.0    0.0
      3       2987342.81              BusinessLoan    Existing        730.0   18.0
      4         99164.00              ConsumerLoan    Existing       2095.0    0.0

         SANCTION_AMT_LOG  TOT_OUTSTD_BAL_LOG  OVER_DUE_AMT_LOG  \
      0          12.899220            0.000000         12.233734
      1          15.068274           15.001172          0.000000
      2          15.250595           13.676780          0.000000
      3          17.909855           16.571759          0.000000
      4          15.039286           13.627953          0.000000

         INSTALLMENT_AMT_LOG  IS_DEFAULT
      0             0.000000           1
      1            11.515354           0
      2            11.577330           0
      3            14.909895           0
      4            11.504530           0
```

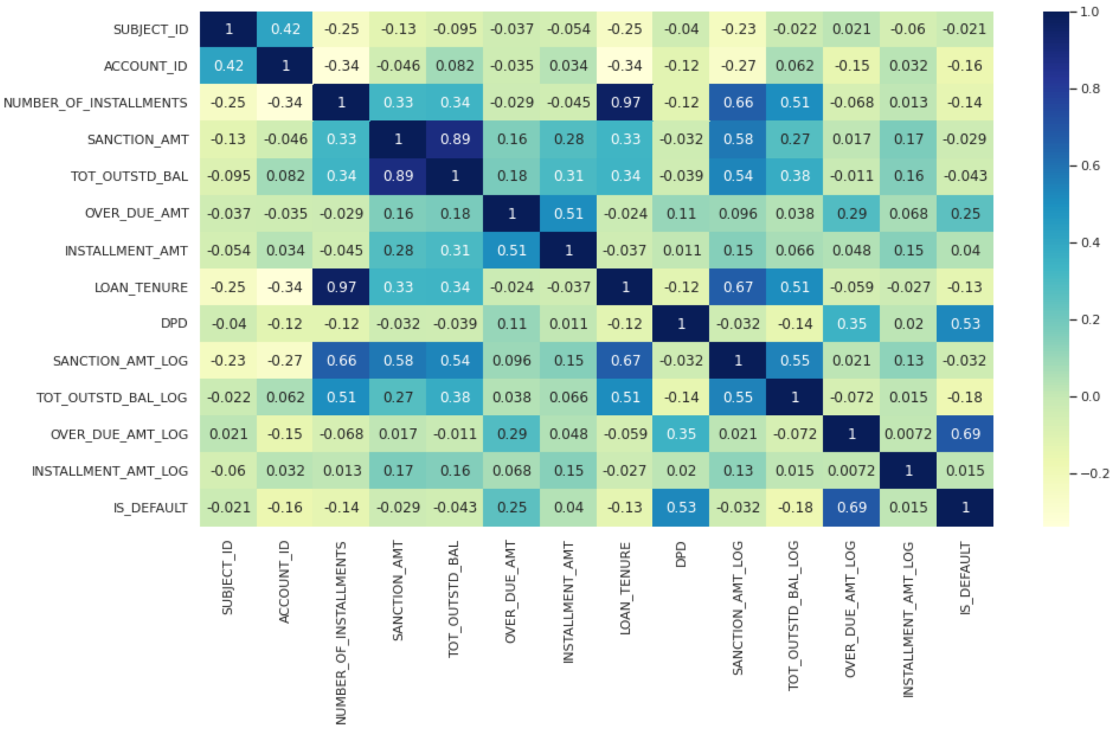
8 Correlation Matrix

[120]:

```
# Keep a copy of the dataframe

df4 = df3.copy()


# Plot the heatmap to see the best correlated variables

corr = df4.corr()
plt.figure(figsize=(15,8))
sns.heatmap(corr, annot=True, cmap='YlGnBu')
```

[120]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7fc289629ed0>
```



[121]:
```
# Subset only the relevant variables for the modelling

features = ['REPAYMENT_FREQUENCY', 'NUMBER_OF_INSTALLMENTS', 'SANCTION_AMT_LOG',
            'TOT_OUTSTD_BAL_LOG', 'OVER_DUE_AMT_LOG', 'INSTALLMENT_AMT',
            'LOAN_TYPE', 'LOAN_STATUS', 'LOAN_TENURE','IS_DEFAULT']
df4 = df4[features]
df4.head()
```

[121]:
```
       REPAYMENT_FREQUENCY  NUMBER_OF_INSTALLMENTS  SANCTION_AMT_LOG  \
0  MonthlyInstalments30Days                     6.0         12.899220
1  MonthlyInstalments30Days                    61.0         15.068274
2  MonthlyInstalments30Days                    57.0         15.250595
3  MonthlyInstalments30Days                    24.0         17.909855
4  MonthlyInstalments30Days                    69.0         15.039286

   TOT_OUTSTD_BAL_LOG  OVER_DUE_AMT_LOG  INSTALLMENT_AMT  \
0            0.000000         12.233734             0.00
1           15.001172          0.000000        100243.11
2           13.676780          0.000000        106652.40
3           16.571759          0.000000       2987342.81
4           13.627953          0.000000         99164.00

                  LOAN_TYPE LOAN_STATUS  LOAN_TENURE  IS_DEFAULT
0  OtherInstalmentOperation    Existing        183.0           1
```

```
1               ConsumerLoan    Existing       1832.0           0
2               ConsumerLoan    Existing       1735.0           0
3               BusinessLoan    Existing        730.0           0
4               ConsumerLoan    Existing       2095.0           0
```

9 Label Encoding

[122]:

```
from sklearn.preprocessing import LabelEncoder

cols = ['REPAYMENT_FREQUENCY', 'LOAN_TYPE','LOAN_STATUS']
le = LabelEncoder()
for col in cols:
  df4[col] = le.fit_transform(df4[col])

df4.head()
```

[122]:

```
   REPAYMENT_FREQUENCY  NUMBER_OF_INSTALLMENTS  SANCTION_AMT_LOG  \
0                    4                     6.0         12.899220
1                    4                    61.0         15.068274
2                    4                    57.0         15.250595
3                    4                    24.0         17.909855
4                    4                    69.0         15.039286

   TOT_OUTSTD_BAL_LOG  OVER_DUE_AMT_LOG  INSTALLMENT_AMT  LOAN_TYPE  \
0            0.000000         12.233734             0.00          5
1           15.001172          0.000000        100243.11          1
2           13.676780          0.000000        106652.40          1
3           16.571759          0.000000       2987342.81          0
4           13.627953          0.000000         99164.00          1

   LOAN_STATUS  LOAN_TENURE  IS_DEFAULT
0            0        183.0           1
1            0       1832.0           0
2            0       1735.0           0
3            0        730.0           0
4            0       2095.0           0
```

10 Train Test Split

[123]:

```
# Specifying the input and output attributes

X = df4.drop(columns=['IS_DEFAULT'], axis=1)
y = df4['IS_DEFAULT']
```

[124]:

```
from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25,␣
 ↪random_state=42)
```

11 Model Training

[125]:

```
# Classify function
from sklearn.model_selection import cross_val_score

def classify_model(model, x, y):
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25,␣
 ↪random_state=42)
    model.fit(X_train, y_train)
    print('Accuracy is: ', model.score(X_test, y_test)*100)

    # Cross validation
    score = cross_val_score(model, X, y, cv=5)
    print('Cross Validation Score: ', np.mean(score)*100)
```

[126]:

```
# Logistic Regression Model
from sklearn.linear_model import LogisticRegression

model = LogisticRegression()
classify_model(model, X, y)
```

```
Accuracy is:  93.8255033557047
Cross Validation Score:  94.12751677852349
```

[127]:

```
# DecisionTree Classifier Model

from sklearn.tree import DecisionTreeClassifier

model = DecisionTreeClassifier()
classify_model(model, X, y)
```

```
Accuracy is:  97.71812080536913
Cross Validation Score:  97.09731543624163
```

[128]:

```
# RandomForest Classifier Model

from sklearn.ensemble import RandomForestClassifier

model = RandomForestClassifier()
classify_model(model, X, y)
```

```
Accuracy is:  98.45637583892616
Cross Validation Score:  98.02013422818791
```

12 Confusion Matrix

```
[129]: # Since the RandomForest Model perfoms better, we shall use it further

       model = RandomForestClassifier()
       model.fit(X_train, y_train)
```

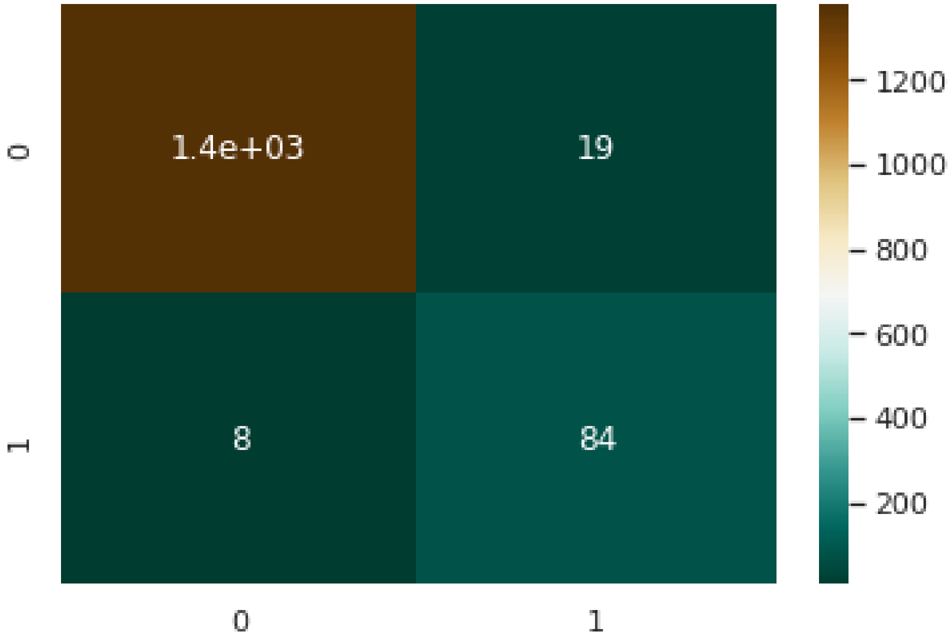
```
[129]: RandomForestClassifier()
```

```
[130]: from sklearn.metrics import confusion_matrix

       y_pred = model.predict(X_test)
       cm = confusion_matrix(y_test, y_pred)
       cm
```

```
[130]: array([[1379,   19],
              [   8,   84]])
```

```
[131]: sns.heatmap(cm, annot=True, cmap='BrBG_r')
```

```
[131]: <matplotlib.axes._subplots.AxesSubplot at 0x7fc289406cd0>
```


1.4e+03
19
8
84
0
1
0
1
1200
1000
800
600
400
200