

# LOAN PREDICTION

In finance, a loan is the lending of money by one or more individuals, organizations, or other entities to other individuals, organizations, etc. The recipient (i.e. the borrower) incurs a debt, and is usually liable to pay interest on that debt until it is repaid, and also to repay the principal amount borrowed. To read more check out Wikipedia. The whole process of ascertaining if a borrower would pay back loans might be tedious hence the need to automate the procedure.

In this, I'd be doing some Loan prediction using some selected Machine Learning Algorithms.

The dataset for this project is retrieved from kaggle <https://www.kaggle.com/altruistdelhite04/loan-prediction-problem-dataset/notebooks>

The major aim of this project is to predict which of the customers will have their loan paid or not. Therefore, this is a supervised classification problem

## IMPORTING THE LIBRARIES

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

## LOADING THE DATASET IN GOOGLE DRIVE

```
In [ ]: from google.colab import files
```

```
uploaded=files.upload()
```

No file chosen

Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to enable.

Saving test.csv to test.csv  
Saving train.csv to train.csv

## LOADING THE DATASET

```
In [ ]: import io
test=pd.read_csv(io.BytesIO(uploaded["test.csv"]))
train=pd.read_csv(io.BytesIO(uploaded["train.csv"]))
```

## EDA

Size of the training data and testing data

```
In [ ]: train.shape
```

```
Out[ ]: (614, 13)
```

```
In [ ]: test.shape
```

```
Out[ ]: (367, 12)
```

Display few rows of training and testing data

```
In [ ]: train.head()
```

```
Out[ ]:
```

Loan_ID	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
---------	--------	---------	------------	-----------	---------------	-----------------	-------------------

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
0	LP001002	Male	No	0	Graduate	No	5849	
1	LP001003	Male	Yes	1	Graduate	No	4583	
2	LP001005	Male	Yes	0	Graduate	Yes	3000	
3	LP001006	Male	Yes	0	Not Graduate	No	2583	
4	LP001008	Male	No	0	Graduate	No	6000	

In [ ]: `test.head()`

Out[ ]:

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
0	LP001015	Male	Yes	0	Graduate	No	5720	
1	LP001022	Male	Yes	1	Graduate	No	3076	
2	LP001031	Male	Yes	2	Graduate	No	5000	
3	LP001035	Male	Yes	2	Graduate	No	2340	
4	LP001051	Male	No	0	Not Graduate	No	3276	

Get and statistical info of the data

In [ ]: `train.describe()`

Out[ ]:

	ApplicantIncome	CoapplicantIncome	LoanAmount	Loan_Amount_Term	Credit_History
count	614.000000	614.000000	592.000000	600.000000	564.000000
mean	5403.459283	1621.245798	146.412162	342.000000	0.842199
std	6109.041673	2926.248369	85.587325	65.12041	0.364878

	ApplicantIncome	CoapplicantIncome	LoanAmount	Loan_Amount_Term	Credit_History
min	150.000000	0.000000	9.000000	12.00000	0.000000
25%	2877.500000	0.000000	100.000000	360.00000	1.000000
50%	3812.500000	1188.500000	128.000000	360.00000	1.000000
75%	5795.000000	2297.250000	168.000000	360.00000	1.000000
max	81000.000000	41667.000000	700.000000	480.00000	1.000000

In [ ]: test.describe()

Out[ ]:

	ApplicantIncome	CoapplicantIncome	LoanAmount	Loan_Amount_Term	Credit_History
count	367.000000	367.000000	362.000000	361.000000	338.000000
mean	4805.599455	1569.577657	136.132597	342.537396	0.825444
std	4910.685399	2334.232099	61.366652	65.156643	0.380150
min	0.000000	0.000000	28.000000	6.000000	0.000000
25%	2864.000000	0.000000	100.250000	360.000000	1.000000
50%	3786.000000	1025.000000	125.000000	360.000000	1.000000
75%	5060.000000	2430.500000	158.000000	360.000000	1.000000
max	72529.000000	24000.000000	550.000000	480.000000	1.000000

Get info about the features

In [ ]: train.info()

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 614 entries, 0 to 613
Data columns (total 13 columns):
#   Column          Non-Null Count  Dtype
---  -
0   Loan_ID         614 non-null   object
1   Gender          601 non-null   object
```

```

2   Married          611 non-null    object
3   Dependents       599 non-null    object
4   Education         614 non-null    object
5   Self_Employed     582 non-null    object
6   ApplicantIncome   614 non-null    int64
7   CoapplicantIncome 614 non-null    float64
8   LoanAmount        592 non-null    float64
9   Loan_Amount_Term  600 non-null    float64
10  Credit_History    564 non-null    float64
11  Property_Area     614 non-null    object
12  Loan_Status       614 non-null    object
dtypes: float64(4), int64(1), object(8)
memory usage: 62.5+ KB

```

```
In [ ]: test.info()
```

```

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 367 entries, 0 to 366
Data columns (total 12 columns):
#   Column                Non-Null Count  Dtype
---  -
0   Loan_ID                367 non-null    object
1   Gender                 356 non-null    object
2   Married                367 non-null    object
3   Dependents             357 non-null    object
4   Education              367 non-null    object
5   Self_Employed          344 non-null    object
6   ApplicantIncome        367 non-null    int64
7   CoapplicantIncome      367 non-null    int64
8   LoanAmount             362 non-null    float64
9   Loan_Amount_Term       361 non-null    float64
10  Credit_History         338 non-null    float64
11  Property_Area          367 non-null    object
dtypes: float64(3), int64(2), object(7)
memory usage: 34.5+ KB

```

```
In [ ]: train.columns
```

```
Out[ ]: Index(['Loan_ID', 'Gender', 'Married', 'Dependents', 'Education',
```

```
        'Self_Employed', 'ApplicantIncome', 'CoapplicantIncome', 'LoanAmount',  
        'Loan_Amount_Term', 'Credit_History', 'Property_Area', 'Loan_Status'],  
        dtype='object')
```

Missing data

```
In [ ]: train.isnull().sum()
```

```
Out[ ]: Loan_ID          0  
        Gender          13  
        Married         3  
        Dependents      15  
        Education       0  
        Self_Employed   32  
        ApplicantIncome  0  
        CoapplicantIncome 0  
        LoanAmount      22  
        Loan_Amount_Term 14  
        Credit_History   50  
        Property_Area    0  
        Loan_Status     0  
        dtype: int64
```

```
In [ ]: test.isnull().sum()
```

```
Out[ ]: Loan_ID          0  
        Gender          11  
        Married         0  
        Dependents      10  
        Education       0  
        Self_Employed   23  
        ApplicantIncome  0  
        CoapplicantIncome 0  
        LoanAmount       5  
        Loan_Amount_Term 6  
        Credit_History   29
```

```
Property_Area      0
dtype: int64
```

```
In [ ]: train['Gender'] = train['Gender'].fillna(train['Gender'].dropna().mode().values[0] )

train['Married'] = train['Married'].fillna(train['Married'].dropna().mode().values[0] )

train['Dependents'] = train['Dependents'].fillna(train['Dependents'].dropna().mode().values[0] )

train['Self_Employed'] = train['Self_Employed'].fillna(train['Self_Employed'].dropna().mode().values[0] )

train['LoanAmount'] = train['LoanAmount'].fillna(train['LoanAmount'].dropna().median() )

train['Loan_Amount_Term'] = train['Loan_Amount_Term'].fillna(train['Loan_Amount_Term'].dropna().mode().values[0] )

train['Credit_History'] = train['Credit_History'].fillna(train['Credit_History'].dropna().mode().values[0] )
```

```
In [ ]: train.isnull().sum()
```

```
Out[ ]: Loan_ID      0
Gender      0
Married     0
Dependents  0
Education   0
Self_Employed  0
ApplicantIncome  0
CoapplicantIncome  0
LoanAmount  0
Loan_Amount_Term  0
Credit_History  0
Property_Area  0
```

```
Loan_Status      0  
dtype: int64
```

```
In [ ]: train['Gender'].value_counts()
```

```
Out[ ]: Male      502  
        Female    112  
        Name: Gender, dtype: int64
```

```
In [ ]: train['Married'].value_counts()
```

```
Out[ ]: Yes      401  
        No       213  
        Name: Married, dtype: int64
```

```
In [ ]: train['Dependents'].value_counts()
```

```
Out[ ]: 0      360  
        1      102  
        2      101  
        3+      51  
        Name: Dependents, dtype: int64
```

```
In [ ]: train['Education'].value_counts()
```

```
Out[ ]: Graduate      480  
        Not Graduate   134  
        Name: Education, dtype: int64
```

```
In [ ]: train['Self_Employed'].value_counts()
```

```
Out[ ]: No      532  
        Yes      82  
        Name: Self_Employed, dtype: int64
```

```
In [ ]: train['Credit_History'].value_counts()
```

```
Out[ ]: 1.0      525
```



```
0.0      89
Name: Credit_History, dtype: int64
```

```
In [ ]: train['Property_Area'].value_counts()
```

```
Out[ ]: Semiurban    233
Urban              202
Rural              179
Name: Property_Area, dtype: int64
```

## ONE HOT ENCODING

```
In [ ]: from sklearn.preprocessing import OneHotEncoder
        from sklearn.preprocessing import LabelEncoder
        label_encoder = LabelEncoder()

        train['Gender'] = label_encoder.fit_transform(train['Gender'])
        train['Married'] = label_encoder.fit_transform(train['Married'])
        train['Dependents'] = label_encoder.fit_transform(train['Dependents'])
        train['Education'] = label_encoder.fit_transform(train['Education'])
        train['Self_Employed'] = label_encoder.fit_transform(train['Self_Employed'])
        train['Credit_History'] = label_encoder.fit_transform(train['Credit_History'])
        train['Property_Area'] = label_encoder.fit_transform(train['Property_Area'])
        train['Loan_Status'] = label_encoder.fit_transform(train['Loan_Status'])
```

```
In [ ]: train.head()
```

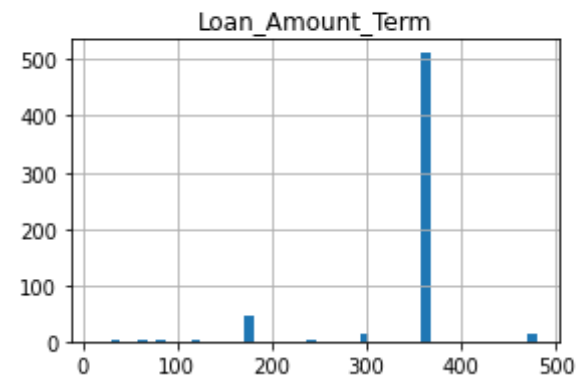
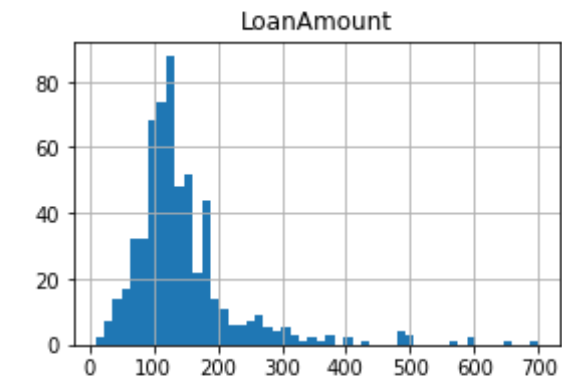
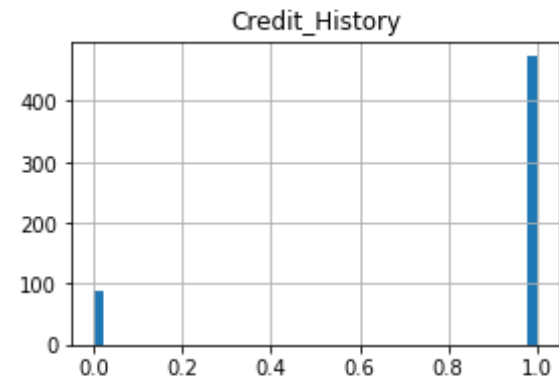
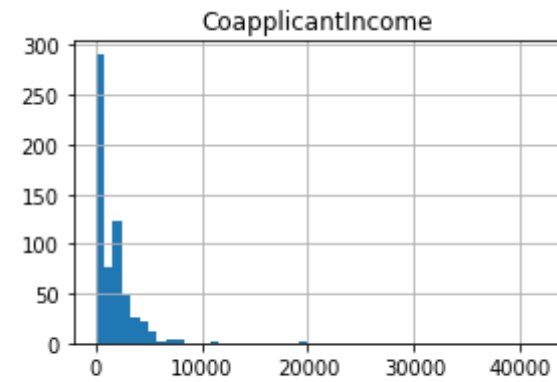
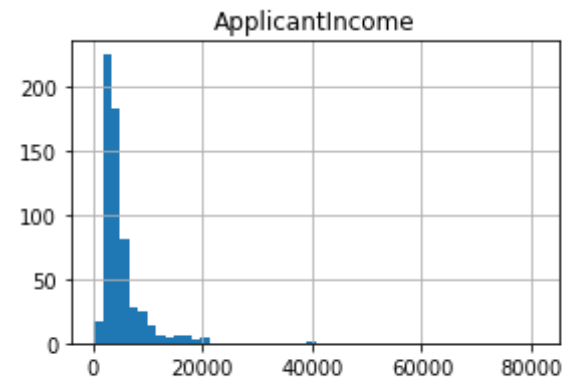
```
Out[ ]:
```

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
0	LP001002	1	0	0	0	0	5849	
1	LP001003	1	1	1	0	0	4583	
2	LP001005	1	1	0	0	1	3000	
3	LP001006	1	1	0	1	0	2583	
4	LP001008	1	0	0	0	0	6000	

## PLOTTING FEW GRAPHS

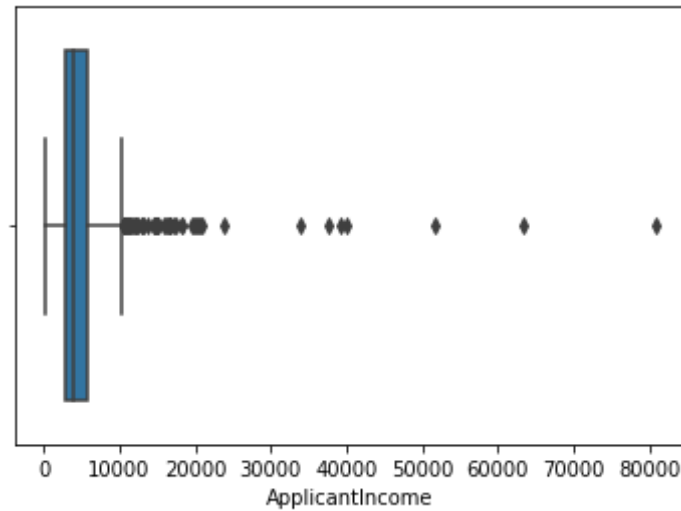
```
In [ ]: train.hist(bins=50,figsize=(10,10))
```

```
Out[ ]: array([[<matplotlib.axes._subplots.AxesSubplot object at 0x7fd5fa053198
>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5fa001240
>],
               [<matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9fb04a8
>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9fe1710
>],
               [<matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9f92978
>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9f44be0
>]],
              dtype=object)
```



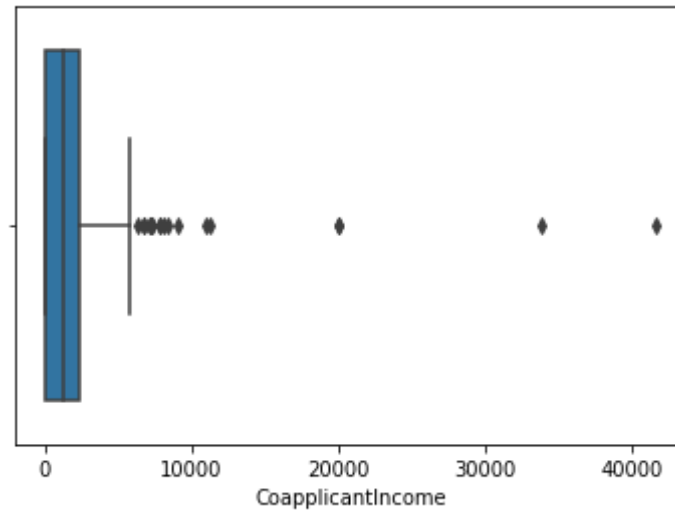
```
In [ ]: sns.boxplot(x=train['ApplicantIncome'])
```

```
Out[ ]: <matplotlib.axes._subplots.AxesSubplot at 0x7fd5f9b7a6a0>
```



```
In [ ]: sns.boxplot(x=train['CoapplicantIncome'])
```

```
Out[ ]: <matplotlib.axes._subplots.AxesSubplot at 0x7fd5f9b2c710>
```



Correlation matrix

```
In [ ]: corr=data.corr()
corr.style.background_gradient(cmap='coolwarm').set_precision(2)
```

Out[ ]:

	ApplicantIncome	CoapplicantIncome	LoanAmount	Loan_Amount_Term	Credit_History
ApplicantIncome	1.00	-0.12	0.57	-0.05	-0.01
CoapplicantIncome	-0.12	1.00	0.19	-0.06	-0.00
LoanAmount	0.57	0.19	1.00	0.04	-0.01
Loan_Amount_Term	-0.05	-0.06	0.04	1.00	0.00
Credit_History	-0.01	-0.00	-0.01	0.00	1.00

```
In [ ]: from pandas.plotting import scatter_matrix
scatter_matrix(train, figsize=(10, 6))
```

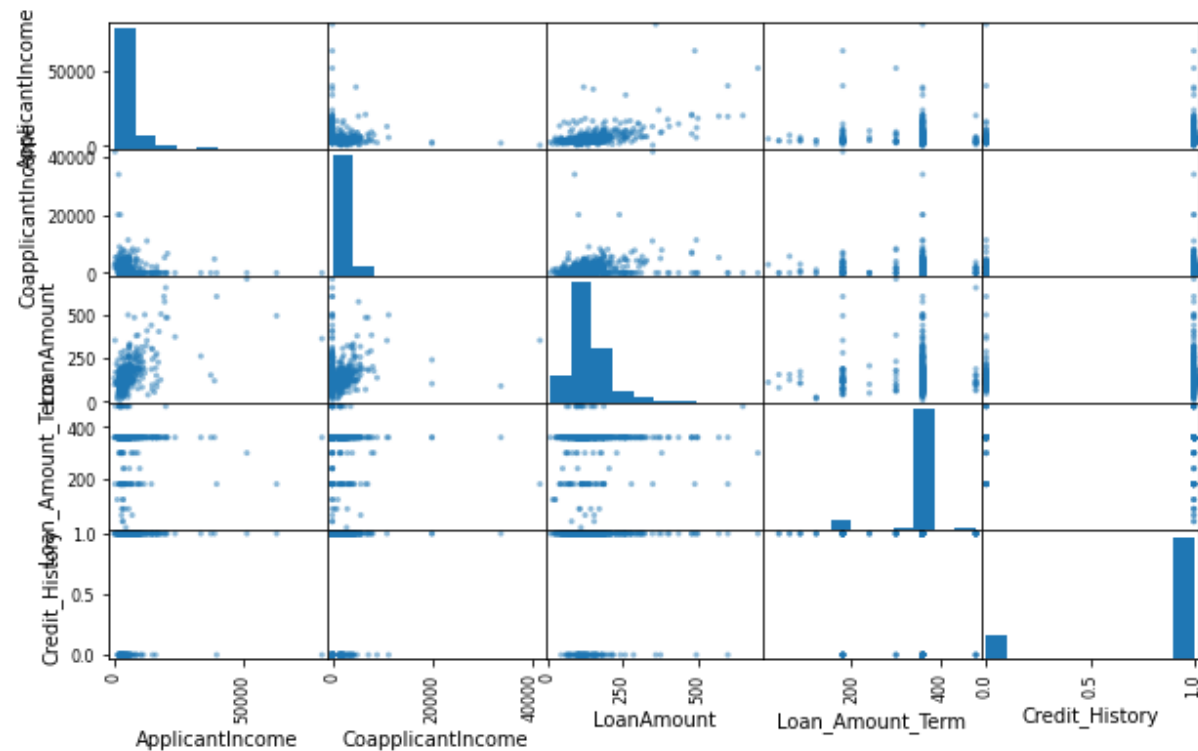
Out[ ]: array([[<matplotlib.axes.\_subplots.AxesSubplot object at 0x7fd5f97ce2b0

```
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9782518
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f972d780
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd602e8c208
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f97e3f28
>],
[<matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f96bf438
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f96726a0
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f96278d0
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9627940
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f960edd8
>],
[<matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f95d1080
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f95832e8
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9536550
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f94ea7b8
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f951ea20
>],
[<matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f94d2c88
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9485ef0
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9447198
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f93f9400
>,
    <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f93ad668
>],
```

```

[<matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f93e28d0
>,
 <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f9396b38
>,
 <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f934ada0
>,
 <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f92fefd0
>,
 <matplotlib.axes._subplots.AxesSubplot object at 0x7fd5f92bf2b0
>]],
dtype=object)

```



## SPLITTING THE DATASET INTO X features and y labels

```
In [ ]: X_train=train.drop('Loan_Status',axis=1)
```

```
In [ ]: X_train=X_train.drop('Loan_ID',axis=1)
```

```
In [ ]: X_train
```

Out[ ]:

	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
0	1	0	0	0	0	5849	0
1	1	1	1	0	0	4583	1508
2	1	1	0	0	1	3000	0
3	1	1	0	1	0	2583	2358
4	1	0	0	0	0	6000	0
...	...	...	...	...	...	...	...
609	0	0	0	0	0	2900	0
610	1	1	3	0	0	4106	0
611	1	1	1	0	0	8072	240
612	1	1	2	0	0	7583	0



	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
613	0	0	0	0	1	4583	0

614 rows × 11 columns

```
In [ ]: y_train=train['Loan_Status']
```

```
In [ ]: y_train
```

```
Out[ ]: 0      1
        1      0
        2      1
        3      1
        4      1
        ..
        609    1
        610    1
        611    1
        612    1
        613    0
        Name: Loan_Status, Length: 614, dtype: int64
```

## SPLITTING THE TRAINING DATA INTO TESTING AND TRAINING DATA

```
In [ ]: from sklearn.model_selection import train_test_split
        X_train,X_test,y_train,y_test=train_test_split(X_train,y_train,test_size=0.1,random_state=0)
```

```
In [ ]: y_test
```

```
Out[ ]: 454    1
        52     0
```

```
536    1
469    0
55     1
      ..
365    0
8      1
194    1
122    1
210    0
Name: Loan_Status, Length: 62, dtype: int64
```

```
In [ ]: X_train.shape,y_train.shape,y_test.shape,X_test.shape
```

```
Out[ ]: ((552, 11), (552,), (62,), (62, 11))
```

## MODEL

## LOGISTIC REGRESSION

```
In [ ]: from sklearn.linear_model import LogisticRegression
log_regressor=LogisticRegression()
log_regressor.fit(X_train,y_train)
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/linear_model/_logistic.p
y:940: ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.
```

Increase the number of iterations (max\_iter) or scale the data as shown in:

```
https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
extra_warning_msg=_LOGISTIC_SOLVER_CONVERGENCE_MSG)
```

```
Out[ ]: LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=
```

```
True,
                                intercept_scaling=1, ll_ratio=None, max_iter=100,
                                multi_class='auto', n_jobs=None, penalty='l2',
                                random_state=None, solver='lbfgs', tol=0.0001, verbo
se=0,
                                warm_start=False)
```

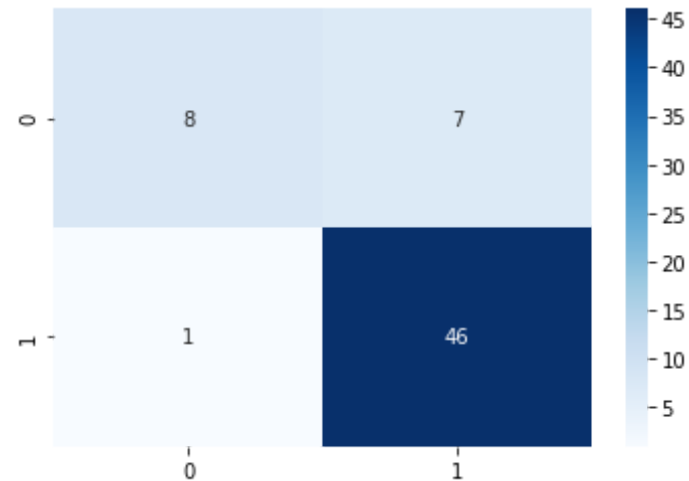
```
In [ ]: y_log_pred = log_regressor.predict(X_test)
```

```
In [ ]: y_log_pred
```

```
Out[ ]: array([1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0,
1,
              1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
1,
              1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1])
```

```
In [ ]: from sklearn.metrics import confusion_matrix, accuracy_score
cm=confusion_matrix(y_test,y_log_pred)
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
log_accuracy_score=accuracy_score(y_test,y_log_pred)
print('accuracy_score=',accuracy_score(y_test,y_log_pred))
```

```
accuracy_score= 0.8709677419354839
```



## DECISION TREE

```
In [ ]: from sklearn.tree import DecisionTreeClassifier
        tree=DecisionTreeClassifier()
        tree.fit(X_train,y_train)
```

```
Out[ ]: DecisionTreeClassifier(ccp_alpha=0.0, class_weight=None, criterion='gini',
                                max_depth=None, max_features=None, max_leaf_node
                                s=None,
                                min_impurity_decrease=0.0, min_impurity_split=No
                                ne,
                                min_samples_leaf=1, min_samples_split=2,
                                min_weight_fraction_leaf=0.0, presort='deprecate
                                d',
                                random_state=None, splitter='best')
```

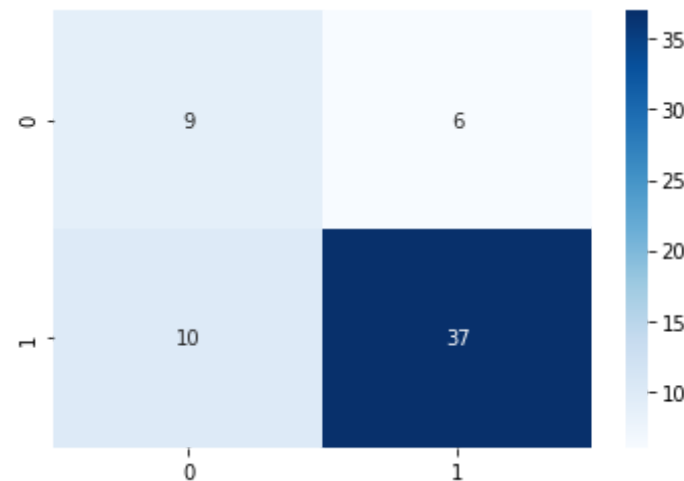
```
In [ ]: y_tree_pred = tree.predict(X_test)
```

```
In [ ]: y_tree_pred
```

```
Out[ ]: array([1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0,
1,
1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1])
```

```
In [ ]: from sklearn.metrics import confusion_matrix, accuracy_score
cm=confusion_matrix(y_test, y_tree_pred)
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
tree_accuracy_score=accuracy_score(y_test, y_tree_pred)
print('accuracy_score=', accuracy_score(y_test, y_tree_pred))
```

accuracy\_score= 0.7419354838709677



Hyper parameter tuning

```
In [ ]: from sklearn.model_selection import GridSearchCV
params = {'max_leaf_nodes': list(range(2, 100)), 'min_samples_split': [
2, 3, 4]}
grid_search_cv = GridSearchCV(DecisionTreeClassifier(random_state=42),
params, verbose=1, cv=3)
```

```
In [ ]: grid_search_cv.fit(X_train, y_train)
```

Fitting 3 folds for each of 294 candidates, totalling 882 fits

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
```

```
[Parallel(n_jobs=1)]: Done 882 out of 882 | elapsed: 4.5s finished
```

```
Out[ ]: GridSearchCV(cv=3, error_score=nan,
                    estimator=DecisionTreeClassifier(ccp_alpha=0.0, class_weight=None,
                                                    criterion='gini', max_depth=None,
                                                    max_features=None,
                                                    max_leaf_nodes=None,
                                                    min_impurity_decrease=0.0,
                                                    min_impurity_split=None,
                                                    min_samples_leaf=1,
                                                    min_samples_split=2,
                                                    min_weight_fraction_leaf=0.0,
                                                    presort='deprecated',
                                                    random_state=42,
                                                    splitter='best'),
                    iid='deprecated', n_jobs=None,
                    param_grid={'max_leaf_nodes': [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, ...],
                                'min_samples_split': [2, 3, 4]},
                    pre_dispatch='2*n_jobs', refit=True, return_train_score=False,
                    scoring=None, verbose=1)
```

```
In [ ]: grid_search_cv.best_estimator_
```

```
Out[ ]: DecisionTreeClassifier(ccp_alpha=0.0, class_weight=None, criterion='gini',
                               max_depth=None, max_features=None, max_leaf_node
s=2,
                               min_impurity_decrease=0.0, min_impurity_split=None,
                               min_samples_leaf=1, min_samples_split=2,
                               min_weight_fraction_leaf=0.0, presort='deprecated',
d',
                               random_state=42, splitter='best')
```

```
In [ ]: dc=GridSearchCV(cv=3, error_score='raise-deprecating',
                        estimator=DecisionTreeClassifier(class_weight=None, criterion='gini', max_depth=None,
max_features=None, max_leaf_nodes=None,
min_impurity_decrease=0.0, min_impurity_split=None,
min_samples_leaf=1, min_samples_split=2,
min_weight_fraction_leaf=0.0, presort=False, random_state=42,
                        splitter='best'),
                        iid='warn', n_jobs=None,
                        param_grid={'max_leaf_nodes': [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99], 'min_samples_split': [2, 3, 4]},
                        pre_dispatch='2*n_jobs', refit=True, return_train_score='warn',
                        scoring=None, verbose=1)
```

```
In [ ]: dc.fit(X_test,y_test)
```

Fitting 3 folds for each of 294 candidates, totalling 882 fits

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent workers.
/usr/local/lib/python3.6/dist-packages/sklearn/tree/_classes.py:319: FutureWarning: The parameter 'presort' is deprecated and has no effect
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FutureWarning)

```



```
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```

```
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FutureWarning)
```



```
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FutureWarning)
```

```

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FutureWarning: The parameter 'presort' is deprecated and has no effect. It will be removed in v0.24. You can suppress this warning by not passing any value to the 'presort' parameter.  
FutureWarning)
```







```

FutureWarning)
[Parallel(n_jobs=1)]: Done 882 out of 882 | elapsed: 4.9s finished
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_search.py:823: FutureWarning: The parameter 'iid' is deprecated in 0.22 and will be removed in 0.24.
  "removed in 0.24.", FutureWarning
/usr/local/lib/python3.6/dist-packages/sklearn/tree/_classes.py:319: FutureWarning: The parameter 'presort' is deprecated and has no effect. It will be removed in v0.24. You can suppress this warning by not passing any value to the 'presort' parameter.
FutureWarning)

```

```

Out[ ]: GridSearchCV(cv=3, error_score='raise-deprecating',
                    estimator=DecisionTreeClassifier(ccp_alpha=0.0, class_weight=None,
                                                    criterion='gini', max_depth=None,
                                                    max_features=None,
                                                    max_leaf_nodes=None,
                                                    min_impurity_decrease=0.0,
                                                    min_impurity_split=None,
                                                    min_samples_leaf=1,
                                                    min_samples_split=2,
                                                    min_weight_fraction_leaf=0.0,
                                                    presort=False, random_state=42,
                                                    splitter='best'),
                    iid='warn', n_jobs=None,
                    param_grid={'max_leaf_nodes': [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, ...],
                                'min_samples_split': [2, 3, 4]},
                    pre_dispatch='2*n_jobs', refit=True, return_train_score='warn')

```

```
arn',  
        scoring=None, verbose=1)
```

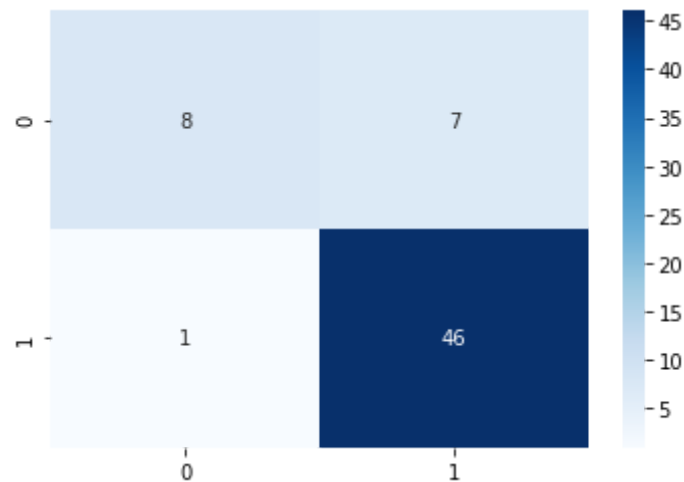
```
In [ ]: y_dc_pred=dc.predict(X_test)
```

```
In [ ]: y_dc_pred
```

```
Out[ ]: array([1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0,  
1,  
1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1,  
1,  
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1])
```

```
In [ ]: from sklearn.metrics import confusion_matrix, accuracy_score  
cm=confusion_matrix(y_test, y_dc_pred)  
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')  
dc_accuracy_score=accuracy_score(y_test, y_dc_pred)  
print('accuracy_score=', accuracy_score(y_test, y_dc_pred))
```

```
accuracy_score= 0.8709677419354839
```



## Random Forest Classifier

```
In [ ]: from sklearn.ensemble import RandomForestClassifier
rf=RandomForestClassifier()
rf.fit(X_train,y_train)
```

```
Out[ ]: RandomForestClassifier(bootstrap=True, ccp_alpha=0.0, class_weight=None,
                               criterion='gini', max_depth=None, max_features='auto',
                               max_leaf_nodes=None, max_samples=None,
                               min_impurity_decrease=0.0, min_impurity_split=None,
                               min_samples_leaf=1, min_samples_split=2,
                               min_weight_fraction_leaf=0.0, n_estimators=100,
                               n_jobs=None, oob_score=False, random_state=None,
                               verbose=0, warm_start=False)
```

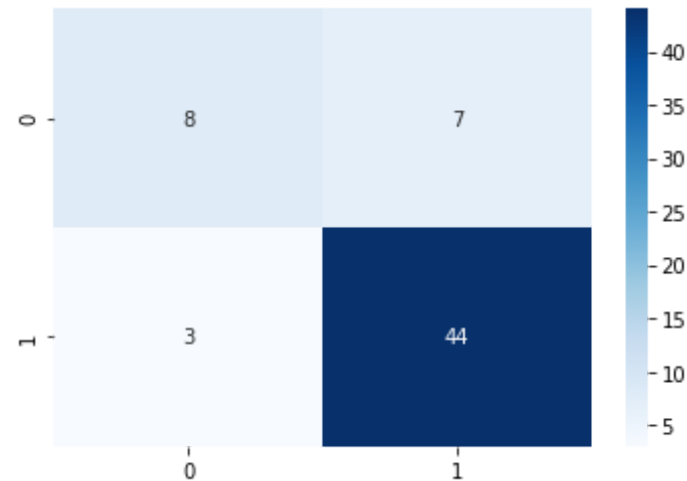
```
In [ ]: y_rf_pred = rf.predict(X_test)
```

```
In [ ]: y_rf_pred
```

```
Out[ ]: array([1, 1, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0,
1,
              1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1,
1,
              1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1])
```

```
In [ ]: from sklearn.metrics import confusion_matrix, accuracy_score
cm=confusion_matrix(y_test,y_rf_pred)
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
rf_accuracy_score=accuracy_score(y_test,y_rf_pred)
print('accuracy_score=',accuracy_score(y_test,y_rf_pred))

accuracy_score= 0.8387096774193549
```



Hyper parameter tuning

```
In [ ]: from sklearn.model_selection import RandomizedSearchCV
# Number of trees in random forest
n_estimators = [int(x) for x in np.linspace(start = 200, stop = 2000, num = 10)]
# Number of features to consider at every split
max_features = ['auto', 'sqrt']
# Maximum number of levels in tree
max_depth = [int(x) for x in np.linspace(10, 110, num = 11)]
max_depth.append(None)
# Minimum number of samples required to split a node
min_samples_split = [2, 5, 10]
# Minimum number of samples required at each leaf node
min_samples_leaf = [1, 2, 4]
# Method of selecting samples for training each tree
bootstrap = [True, False]
# Create the random grid
random_grid = {'n_estimators': n_estimators,
               'max_features': max_features,
               'max_depth': max_depth,
               'min_samples_split': min_samples_split,
               'min_samples_leaf': min_samples_leaf,
```

```
        'bootstrap': bootstrap}
print(random_grid)
```

```
{'n_estimators': [200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800, 2000], 'max_features': ['auto', 'sqrt'], 'max_depth': [10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, None], 'min_samples_split': [2, 5, 10], 'min_samples_leaf': [1, 2, 4], 'bootstrap': [True, False]}
```

```
In [ ]: # Use the random grid to search for best hyperparameters
# First create the base model to tune
rf = RandomForestClassifier()
# Random search of parameters, using 3 fold cross validation,
# search across 100 different combinations, and use all available cores
rf_random = RandomizedSearchCV(estimator = rf, param_distributions = random_grid, n_iter = 100, cv = 3, verbose=2, random_state=42, n_jobs = -1)
# Fit the random search model
rf_random.fit(X_train, y_train)
```

Fitting 3 folds for each of 100 candidates, totalling 300 fits

```
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 2 concurrent workers.
[Parallel(n_jobs=-1)]: Done 37 tasks      | elapsed: 53.9s
[Parallel(n_jobs=-1)]: Done 158 tasks     | elapsed: 3.6min
[Parallel(n_jobs=-1)]: Done 300 out of 300 | elapsed: 6.9min finished
```

```
Out[ ]: RandomizedSearchCV(cv=3, error_score=nan,
                           estimator=RandomForestClassifier(bootstrap=True,
                                                                ccp_alpha=0.0,
                                                                class_weight=None,
                                                                criterion='gini',
                                                                max_depth=None,
                                                                max_features='auto',
                                                                max_leaf_nodes=None,
                                                                max_samples=None,
                                                                min_impurity_decrease=0.0,
```

```

None,
2,
_leaf=0.0,
param_distributions={'bootstrap': [True, False],
                    'max_depth': [10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, None],
                    'max_features': ['auto', 'sqrt'],
                    'min_samples_leaf': [1, 2, 4],
                    'min_samples_split': [2, 5, 10],
                    'n_estimators': [200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800, 2000]},
pre_dispatch='2*n_jobs', random_state=42, refit=True,
return_train_score=False, scoring=None, verbose=2)

```

```
In [ ]: rf_val=rf_random.predict(X_test)
```

```
In [ ]: rf_val
```

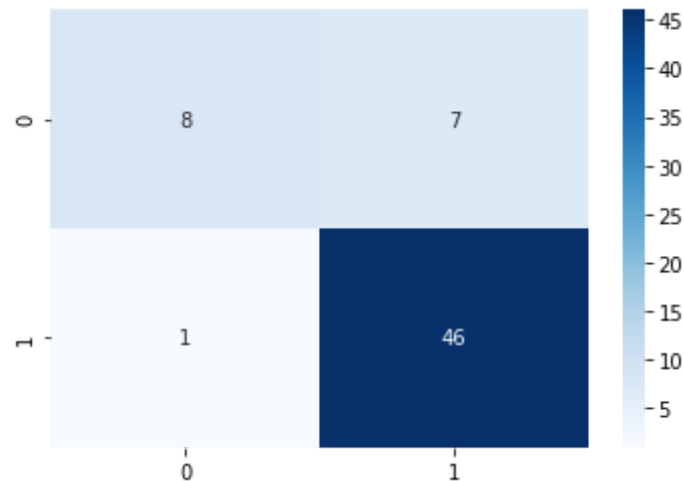
```
Out[ ]: array([1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0,
1,
1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
1,
1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1])
```

```
In [ ]: rf_random.best_params_
```

```
Out[ ]: {'bootstrap': True,  
        'max_depth': 10,  
        'max_features': 'auto',  
        'min_samples_leaf': 4,  
        'min_samples_split': 5,  
        'n_estimators': 200}
```

```
In [ ]: from sklearn.metrics import confusion_matrix, accuracy_score  
cm=confusion_matrix(y_test, rf_val)  
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')  
rfr_accuracy_score=accuracy_score(y_test, rf_val)  
print('accuracy_score=', accuracy_score(y_test, rf_val))
```

accuracy\_score= 0.8709677419354839



## KNN

```
In [ ]: from sklearn.neighbors import KNeighborsClassifier  
knn_classifier = KNeighborsClassifier(n_neighbors = 5, metric = 'minkow
```

```
ski', p = 2)
knn_classifier.fit(X_train, y_train)
```

```
Out[ ]: KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',
                             metric_params=None, n_jobs=None, n_neighbors=5, p=
                             2,
                             weights='uniform')
```

```
In [ ]: y_knn_pred=knn_classifier.predict(X_test)
```

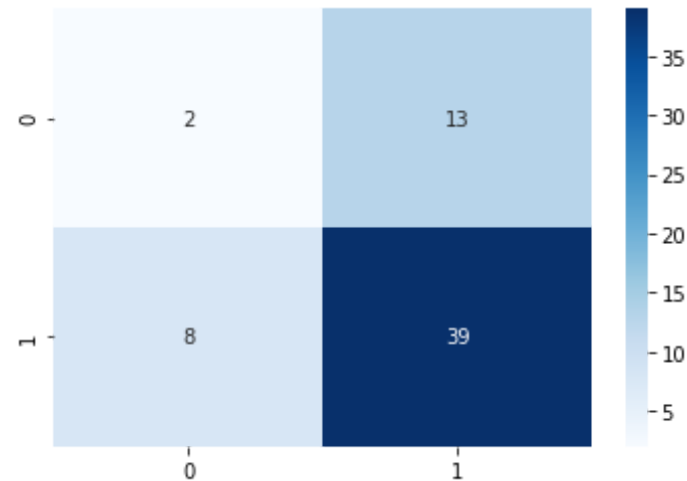
```
In [ ]: y_knn_pred
```

```
Out[ ]: array([1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
                1,
                1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
                1,
                1, 0, 1, 0, 1, 1, 1, 0, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1])
```

```
In [ ]: from sklearn.metrics import confusion_matrix, accuracy_score
cm=confusion_matrix(y_test, y_knn_pred)
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
knn_accuracy_score=accuracy_score(y_test, y_knn_pred)
print('accuracy_score=', accuracy_score(y_test, y_knn_pred))
```

```
accuracy_score= 0.6612903225806451
```





```
In [ ]: from sklearn.neighbors import KNeighborsClassifier
```

```
grid_params={
    'n_neighbors':[3,5,11,19],
    'weights':['uniform','distance'],
    'metric':['euclidean','manhattan']
}
```

```
gs=GridSearchCV(
    KNeighborsClassifier(),
    grid_params,
    verbose=1,
    cv=3,
    n_jobs = -1
)
```

```
gs_results=gs.fit(X_train,y_train)
```

Fitting 3 folds for each of 16 candidates, totalling 48 fits

```
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 2 concurrent work
ers.
```

```
[Parallel(n_jobs=-1)]: Done 48 out of 48 | elapsed: 1.7s finished
```

```
In [ ]: gs.best_params_
```

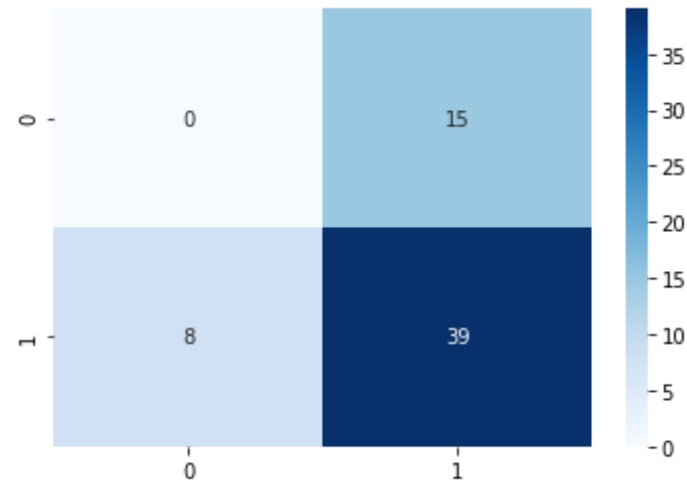
```
Out[ ]: {'metric': 'manhattan', 'n_neighbors': 11, 'weights': 'uniform'}
```

```
In [ ]: # Use the random grid to search for best hyperparameters  
# First create the base model to tune  
knn = KNeighborsClassifier()  
# Random search of parameters, using 3 fold cross validation,  
# search across 100 different combinations, and use all available cores  
knn_r = KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='ma  
nhattan',  
                             metric_params=None, n_jobs=None, n_neighbors=11, p  
=2,  
                             weights='uniform')  
# Fit the random search model  
knn_r.fit(X_train, y_train)
```

```
Out[ ]: KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='manhatta  
n',  
                             metric_params=None, n_jobs=None, n_neighbors=11, p  
=2,  
                             weights='uniform')
```

```
In [ ]: y_pred_knnr=knn_r.predict(X_test)
```

```
In [ ]: from sklearn.metrics import confusion_matrix, accuracy_score  
cm=confusion_matrix(y_test, y_pred_knnr)  
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')  
knnr_accuracy_score=accuracy_score(y_test, y_pred_knnr)  
print('accuracy_score=', accuracy_score(y_test, y_pred_knnr))  
  
accuracy_score= 0.6290322580645161
```



## CHOOSING THE BEST MODEL

```
In [ ]: accuracy=[log_accuracy_score,tree_accuracy_score,dc_accuracy_score,rf_accuracy_score,rfr_accuracy_score,knn_accuracy_score,knnr_accuracy_score]
```

```
In [ ]: accuracy
```

```
Out[ ]: [0.8709677419354839,  
         0.7419354838709677,  
         0.8709677419354839,  
         0.8387096774193549,  
         0.8709677419354839,  
         0.6612903225806451,  
         0.6290322580645161]
```

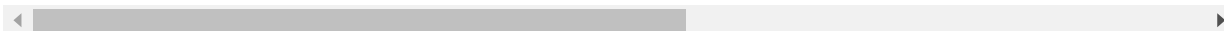
Observing the accuracy we observe that logistic regression has the best accuracy

```
In [ ]: test
```

```
Out[ ]:
```

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	Coap
0	LP001015	Male	Yes	0	Graduate	No	5720	
1	LP001022	Male	Yes	1	Graduate	No	3076	
2	LP001031	Male	Yes	2	Graduate	No	5000	
3	LP001035	Male	Yes	2	Graduate	No	2340	
4	LP001051	Male	No	0	Not Graduate	No	3276	
...	...	...	...	...	...	...	...	...
362	LP002971	Male	Yes	3+	Not Graduate	Yes	4009	
363	LP002975	Male	Yes	0	Graduate	No	4158	
364	LP002980	Male	No	0	Graduate	No	3250	
365	LP002986	Male	Yes	0	Graduate	No	5000	
366	LP002989	Male	No	0	Graduate	Yes	9200	

367 rows × 12 columns



```
In [ ]: test['Gender'] = test['Gender'].fillna(test['Gender'].dropna().mode().values[0] )

test['Married'] = test['Married'].fillna(test['Married'].dropna().mode().values[0] )

test['Dependents'] = test['Dependents'].fillna(test['Dependents'].dropna().mode().values[0] )

test['Self_Employed'] = test['Self_Employed'].fillna(test['Self_Employed'].dropna().mode().values[0] )

test['LoanAmount'] = test['LoanAmount'].fillna(test['LoanAmount'].dropna().median() )
```

```
test['Loan_Amount_Term'] = test['Loan_Amount_Term'].fillna(test['Loan_Amount_Term'].dropna().mode().values[0] )

test['Credit_History'] = test['Credit_History'].fillna(test['Credit_History'].dropna().mode().values[0] )
```

```
In [ ]: from sklearn.preprocessing import OneHotEncoder
        from sklearn.preprocessing import LabelEncoder
        label_encoder = LabelEncoder()

        test['Gender'] = label_encoder.fit_transform(test['Gender'])
        test['Married'] = label_encoder.fit_transform(test['Married'])
        test['Dependents'] = label_encoder.fit_transform(test['Dependents'])
        test['Education'] = label_encoder.fit_transform(test['Education'])
        test['Self_Employed'] = label_encoder.fit_transform(test['Self_Employed'])
        test['Credit_History'] = label_encoder.fit_transform(test['Credit_History'])
        test['Property_Area'] = label_encoder.fit_transform(test['Property_Area'])
```

```
In [ ]: test
```

```
Out[ ]:
```

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	Coap
0	LP001015	1	1	0	0	0	5720	
1	LP001022	1	1	1	0	0	3076	
2	LP001031	1	1	2	0	0	5000	
3	LP001035	1	1	2	0	0	2340	
4	LP001051	1	0	0	1	0	3276	

	Loan_ID	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
...	...	...	...	...	...	...	...	...
362	LP002971	1	1	3	1	1	4009	
363	LP002975	1	1	0	0	0	4158	
364	LP002980	1	0	0	0	0	3250	
365	LP002986	1	1	0	0	0	5000	
366	LP002989	1	0	0	0	1	9200	

367 rows × 12 columns



```
In [ ]: test=test.drop('Loan_ID',axis=1)
```

```
In [ ]: test
```

```
Out[ ]:
```

	Gender	Married	Dependents	Education	Self_Employed	ApplicantIncome	CoapplicantIncome
0	1	1	0	0	0	5720	
1	1	1	1	0	0	3076	1500
2	1	1	2	0	0	5000	1800
3	1	1	2	0	0	2340	2500
4	1	0	0	1	0	3276	
...	...	...	...	...	...	...	...
362	1	1	3	1	1	4009	1700
363	1	1	0	0	0	4158	700
364	1	0	0	0	0	3250	1900
365	1	1	0	0	0	5000	2300
366	1	0	0	0	1	9200	

367 rows × 11 columns

```
In [ ]: y_pred=model.predict(test)
```

```
In [ ]: y_pred
```

```
Out[ ]: array([[1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1,
1,
            1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1,
1,
            1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 0, 1,
1,
            0, 0, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1,
1,
            1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1,
1,
            1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1,
1,
            1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1,
0,
            1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 1, 0, 0,
1,
            1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0,
1,
            0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1,
1,
            1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1,
0,
            1, 0, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1,
1,
            1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1,
1,
            1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1,
1,
            1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1,
1,
            1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1,
```

```
0,  
1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1])
```

In [ ]: