AIML Capstone Project: Automatic Ticket Assignment(NLP)

Problem Statement

One of the key activities of any IT function is to “Keep the lights on” to ensure there is no impact to the Business operations. IT leverages Incident Management process to achiev something that is unplanned interruption to an IT service or reduction in the quality of an IT service that affects the Users and the Business. The main goal of Incident Manageme workarounds or solutions that resolves the interruption and restores the service to its full capacity to ensure no business impact. In most of the organizations, incidents are create End Users/ Vendors if they have access to ticketing systems, and from the integrated monitoring systems and tools. Assigning the incidents to the appropriate person or unit in th importance to provide improved user satisfaction while ensuring better allocation of support resources. The assignment of incidents to appropriate IT groups is still a manual proc Manual assignment of incidents is time consuming and requires human efforts. There may be mistakes due to human errors and resource consumption is carried out ineffectively the other hand, manual assignment increases the response and resolution times which result in user satisfaction deterioration / poor customer service.

Business Domain Value

In the support process, incoming incidents are analyzed and assessed by organization’s support teams to fulfill the request. In many organizations, better allocation and effective resources will directly result in substantial cost savings. Currently the incidents are created by various stakeholders (Business Users, IT Users and Monitoring Tools) within IT Se assigned to Service Desk teams (L1 / L2 teams). This team will review the incidents for right ticket categorization, priorities and then carry out initial diagnosis to see if they can r are resolved by L1 / L2 teams. Incase L1 / L2 is unable to resolve, they will then escalate / assign the tickets to Functional teams from Applications and Infrastructure (L3 teams) directly assigned to L3 teams by either Monitoring tools or Callers / Requestors. L3 teams will carry out detailed diagnosis and resolve the incidents. Around ~56% of incidents a Incase if vendor support is needed, they will reach out for their support towards incident closure. L1 / L2 needs to spend time reviewing Standard Operating Procedures (SOPs) b (Minimum ~25-30% of incidents needs to be reviewed for SOPs before ticket assignment). 15 min is being spent for SOP review for each incident. Minimum of ~1 FTE effort nee L3 teams.

During the process of incident assignments by L1 / L2 teams to functional groups, there were multiple instances of incidents getting assigned to wrong functional groups. Around assigned to functional teams. Additional effort needed for Functional teams to re-assign to right functional groups. During this process, some of the incidents are in queue and nc customer service

Guided by powerful AI techniques that can classify incidents to right functional groups can help organizations to reduce the resolving time of the issue and can focus on more pro

In [ ]:
```
# Mounting Google Drive
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

Project Description & Dataset

Details about the data and dataset files are given in below link, https://drive.google.com/open?id=1OZNJm81JXucV3HmZroMq6qCT2m7ez7IJ (https://drive.google.com/open?id=1OZNJm81JXucV3HmZroMq6qCT2m7ez7IJ)

- Pre-Processing, Data Visualization and EDA:
  - Exploring the given Data files.
  - Understanding the structure of data.
  - Missing points in data.
  - Finding inconsistencies in the data.
  - Visualizing different patterns.
  - Visualizing different text features.
  - Dealing with missing values.
  - Text preprocessing.
  - Creating word vocabulary from the corpus of report text data.
  - Creating tokens as required.
- Model Building:
  - Building a model architecture which can classify.
  - Trying different model architectures by researching state of the art for similar tasks.
  - Train the model.
  - To deal with large training time, save the weights so that you can use them when training the model for the second time without starting from scratch.
- Test the Model, Fine-tuning and Repeat:
  - Test the model and report as per evaluation metrics.
  - Try different models.
  - Try different evaluation metrics.
  - Set different hyper parameters, by trying different. optimizers, loss functions, epochs, learning rate, batch size, checkpointing, early stopping etc..for these models to fin
  - Report evaluation metrics for these models along with your observation on how changing different hyper parameters leads to change in the final evaluation metric.

Goal

In this capstone project, the goal is to build a classifier that can classify the tickets by analyzing text.

Project Objectives

The objective of the project is,

- Learn how to use different classification models.
- Use transfer learning to use pre-built models.
- Learn to set the optimizers, loss functions, epochs, learning rate, batch size, checkpointing, early stopping etc.
- Read different research papers of given domain to obtain the knowledge of advanced models for the given problem.

In [ ]:
```
# Setting the current working directory
import os; os.chdir('/content/drive/My Drive/AIML/CapstoneProject')
```

In [ ]:
```
#Install libraries which are not available
!pip install preprocessing
!pip install googletrans
!pip install langdetect
!pip install -U gensim
!pip install ftfy wordcloud goslate spacy plotly cufflinks nltk rake-nltk fasttext pyLDAvis
```

Load the dataset & Libraries

Here the dataset is an excel file and use pandas library to load the excel file(dataset) to a pandas dataframe.

In [ ]:
```
%tensorflow_version 2.x
import tensorflow
tensorflow.__version__
```

Out[ ]:
```
'2.3.0'
```

In [ ]:
```
# Import packages
import warnings
warnings.filterwarnings('ignore')
import pandas as pd, numpy as np, tensorflow as tf
import matplotlib.pyplot as plt, seaborn as sns
import matplotlib.style as style
from sklearn import preprocessing
from wordcloud import WordCloud, STOPWORDS
stopwords = set(STOPWORDS)

import random, re
assert tf.__version__ >= '2.0'
%matplotlib inline

from preprocessing import *
from itertools import islice

# Models
from tensorflow.keras.layers import Dense, LSTM, Embedding, Dropout, Flatten, Bidirectional, GlobalMaxPool1D
from tensorflow.keras.callbacks import EarlyStopping, ModelCheckpoint, ReduceLROnPlateau, TensorBoard
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.models import Model, Sequential
from tensorflow.keras.initializers import Constant

from sklearn.metrics import classification_report, confusion_matrix
from sklearn.model_selection import train_test_split

# Set random state
random_state = 42
np.random.seed(random_state)
tf.random.set_seed(random_state)
```

In [ ]:
```
# Loading Dataset
tickets_df = pd.read_excel('input_data.xlsx')
print(f'Data has {tickets_df.shape[0]} rows and {tickets_df.shape[1]} columns. Here are the first five rows of the data...')
print("\n")
display(tickets_df.head())
print("\n")
print("\nHere are the last five rows of the data...\n")
display(tickets_df.tail())
```

```
Data has 8500 rows and 4 columns. Here are the first five rows of the data...
```

	Short description	Description	Caller	Assignment group
0	login issue	-verified user details.(employee# & manager na...	spxjnwir pjlcoqds	GRP_0
1	outlook	\r\n\r\nreceived from: hmjdrvpb.komuaywn@gmail...	hmjdrvpb komuaywn	GRP_0
2	cant log in to vpn	\r\n\r\nreceived from: eylqgodm.ybqkwiam@gmail...	eylqgodm ybqkwiam	GRP_0
3	unable to access hr_tool page	unable to access hr_tool page	xbkucsvz gcpydteq	GRP_0
4	skype error	skype error	owlgqjme qhcozdfx	GRP_0

```
Here are the last five rows of the data...
```

	Short description	Description	Caller	Assignment group
8495	emails not coming in from zz mail	\r\n\r\nreceived from: avglmrts.vhqmtiua@gmail...	avglmrts vhqmtiua	GRP_29
8496	telephony_software issue	telephony_software issue	rbozivdq gmlhrtvp	GRP_0
8497	vip2: windows password reset for tifpdchb pedx...	vip2: windows password reset for tifpdchb pedx...	oybwdsgx oxyhwrfz	GRP_0
8498	machine nÃ£o estÃ¡ funcionando	i am unable to access the machine utilities to...	ufawcgob aowhxjky	GRP_62
8499	an mehreren pc`s lassen sich verschiedene prgr...	an mehreren pc`s lassen sich verschiedene prgr...	kqvbrspl jyzoklfx	GRP_49

Pre-Processing(Feature Engineering and Selection), Data Visualization and EDA

Why is data pre-processing required?

In any Machine Learning process, Data Preprocessing is that step in which the data gets transformed, or Encoded, to bring it to such a state that now the machine can easily par
the data can now be easily interpreted by the algorithm.

What is Feature Engineering and selection?

Feature engineering: The process of creating new features from raw data to increase the predictive power of the learning algorithm. Engineered features should capture addition
apparent in the original feature set.

Feature selection: The process of selecting the key subset of features to reduce the dimensionality of the training problem.

Why data visualization for EDA required?

It provides a high-level interface for drawing attractive and informative statistical graphics. Data visualization is an important part of analysis since it allows even non-programmer
patterns

Here, we start by identifying the basic traits of the data that is rows and columns

In [ ]:
```
#Shape & Size of the dataset
print('No of rows:\033[1m', tickets_df.shape[0], '\033[0m')
print('No of cols:\033[1m', tickets_df.shape[1], '\033[0m')
```

```
No of rows: 8500
No of cols: 4
```

In [ ]:
```
#info on dataset
tickets_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 8500 entries, 0 to 8499
Data columns (total 4 columns):
 #   Column             Non-Null Count  Dtype 
---  ------             --------------  ----- 
 0   Short description  8492 non-null   object
 1   Description        8499 non-null   object
 2   Caller             8500 non-null   object
 3   Assignment group   8500 non-null   object
dtypes: object(4)
memory usage: 265.8+ KB
```

Feature Description

1. Short description: Ticket Issue title or short desciption about the issue. Sometimes, the issue is understood from short desciption itself.
2. Description: Detailed explanation of issue and the scenario.
3. Caller: The person who raised the ticket or raised it behalf of someone.
4. Assignment group: The group/category to which the ticket is assigned.

In [ ]:
```
#detail info on dataset
tickets_df.describe().T
```

Out[ ]:

	count	unique	top	freq
Short description	8492	7481	password reset	38
Description	8499	7817	the	56
Caller	8500	2950	bpctwhsn kzqsbmtp	810
Assignment group	8500	74	GRP_0	3976

In [ ]:
```
# Find out the null value counts in each column
tickets_df.isnull().sum()
```

Out[ ]:
```
Short description    8
Description          1
Caller               0
Assignment group     0
dtype: int64
```

Initial observaion of data set

1. We observe that all columns don't have 8500 non null values, means there are null vales in data that we have to take care of We can observe that the data is higly imbalanc
2. Total records: 8500 & Total Attributes: 4
3. Since our goal is automatic ticket assignment, It doesn't depend on the caller. Also a caller can raise tickets for any issue he/she is facing. Therefore, we can ignore the calle analysis.
4. There are 8 records with null value in short description and 1 record with null value in description.
5. One user/caller has raised 810 tickets.
6. There are 74 unique groups and the group GRP_0 has been assigned 3976 tickets. GRP_0 has maximum instances around ~40%
7. Top description is just the word 'the' which also we have to take care of.
8. Short description & description count doesn't match with the total no of callers or assigned groups.
9. Password Reset is one of the most occuring ticket topic.

In [ ]:
```
# Check the records with null values
tickets_df[pd.isnull(tickets_df).any(axis=1)]
```

Out[ ]:

	Short description	Description	Caller	Assignment group
2604	NaN	\r\n\r\nreceived from: ohdrnswl.rezuibdt@gmail...	ohdrnswl rezuibdt	GRP_34
3383	NaN	\r\n-connected to the user system using teamvi...	qftpazns fxpnytmk	GRP_0
3906	NaN	-user unable tologin to vpn.\r\n-connected to...	awpcmsey ctdiuqwe	GRP_0
3910	NaN	-user unable tologin to vpn.\r\n-connected to...	rhwsmefo tvphyura	GRP_0
3915	NaN	-user unable tologin to vpn.\r\n-connected to...	hxripljo efzounig	GRP_0
3921	NaN	-user unable tologin to vpn.\r\n-connected to...	cziadygo veiosxby	GRP_0
3924	NaN	name:wvqgbdhm fwchqjor\nlanguage:\nbrowser:mic...	wvqgbdhm fwchqjor	GRP_0
4341	NaN	\r\n\r\nreceived from: eqmuniov.ehxkcbgj@gmail...	eqmuniov ehxkcbgj	GRP_0
4395	i am locked out of skype	NaN	viyglzfo ajtfzpkb	GRP_0

Now we will be dropping the caller attribute from the data set since it doesn't make an impact in our task of automatic ticket assignment, and then find out the unique groups that

In [ ]:
```
# Drop the 'Caller' attribute, since it doesn't make an impact in our task of automatic ticket assignment
df_incidents = tickets_df.drop('Caller',axis=1)
```

In [ ]:
```
#Unique Groups
unique_grp = df_incidents['Assignment group'].unique()
unique_grp
```

Out[ ]:
```
array(['GRP_0', 'GRP_1', 'GRP_3', 'GRP_4', 'GRP_5', 'GRP_6', 'GRP_7',
       'GRP_8', 'GRP_9', 'GRP_10', 'GRP_11', 'GRP_12', 'GRP_13', 'GRP_14',
       'GRP_15', 'GRP_16', 'GRP_17', 'GRP_18', 'GRP_19', 'GRP_2',
       'GRP_20', 'GRP_21', 'GRP_22', 'GRP_23', 'GRP_24', 'GRP_25',
       'GRP_26', 'GRP_27', 'GRP_28', 'GRP_29', 'GRP_30', 'GRP_31',
       'GRP_33', 'GRP_34', 'GRP_35', 'GRP_36', 'GRP_37', 'GRP_38',
       'GRP_39', 'GRP_40', 'GRP_41', 'GRP_42', 'GRP_43', 'GRP_44',
       'GRP_45', 'GRP_46', 'GRP_47', 'GRP_48', 'GRP_49', 'GRP_50',
       'GRP_51', 'GRP_52', 'GRP_53', 'GRP_54', 'GRP_55', 'GRP_56',
       'GRP_57', 'GRP_58', 'GRP_59', 'GRP_60', 'GRP_61', 'GRP_32',
       'GRP_62', 'GRP_63', 'GRP_64', 'GRP_65', 'GRP_66', 'GRP_67',
       'GRP_68', 'GRP_69', 'GRP_70', 'GRP_71', 'GRP_72', 'GRP_73'],
      dtype=object)
```

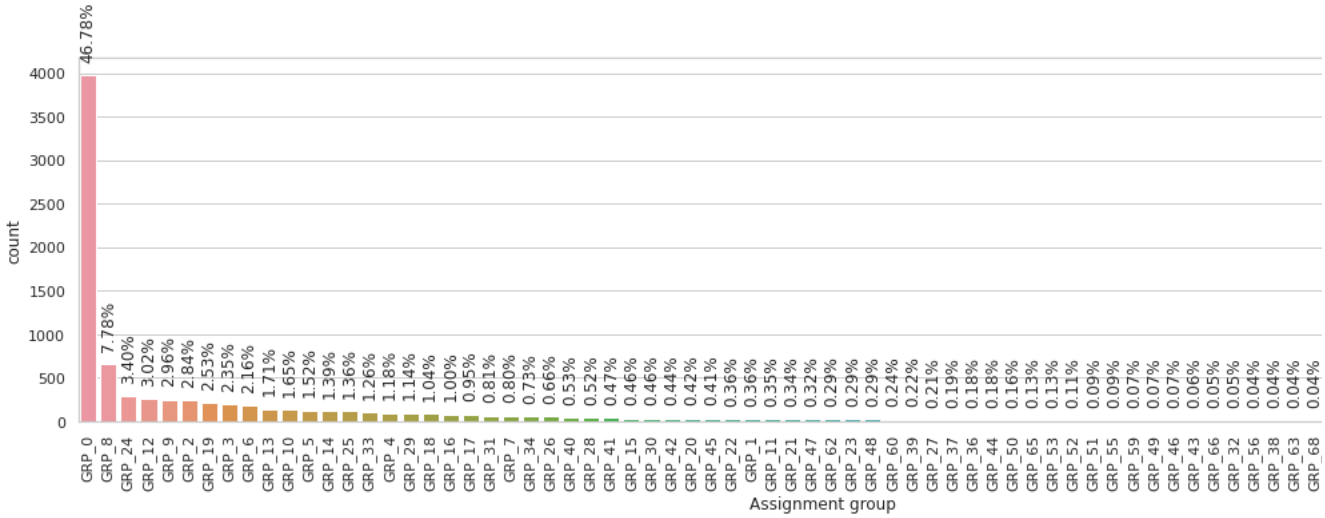
Here we are creating a dataframe which shows us the percentage of data present in the given groups

In [ ]:
```
df_inc = df_incidents['Assignment group'].value_counts().reset_index()
df_inc['percentage'] = (df_inc['Assignment group']/df_inc['Assignment group'].sum())*100
df_inc.head()
```

Out[ ]:

	index	Assignment group	percentage
0	GRP_0	3976	46.776471
1	GRP_8	661	7.776471
2	GRP_24	289	3.400000
3	GRP_12	257	3.023529
4	GRP_9	252	2.964706

In [ ]:
```
# Plot to visualize the percentage data distribution across different groups
sns.set(style="whitegrid")
plt.figure(figsize=(20,5))
ax = sns.countplot(x="Assignment group", data=df_incidents, order=df_incidents["Assignment group"].value_counts().index)
ax.set_xticklabels(ax.get_xticklabels(), rotation=90)
for p in ax.patches:
  ax.annotate(str(format(p.get_height()/len(df_incidents.index)*100, '.2f')+"%"), (p.get_x() + p.get_width() / 2., p.get_height()
m', rotation=90, xytext = (0, 10), textcoords = 'offset points')
```



This plot above, shows the percentage of data distribution across different groups within the data. The data below shows us the top 20 groups that have the most number of recc

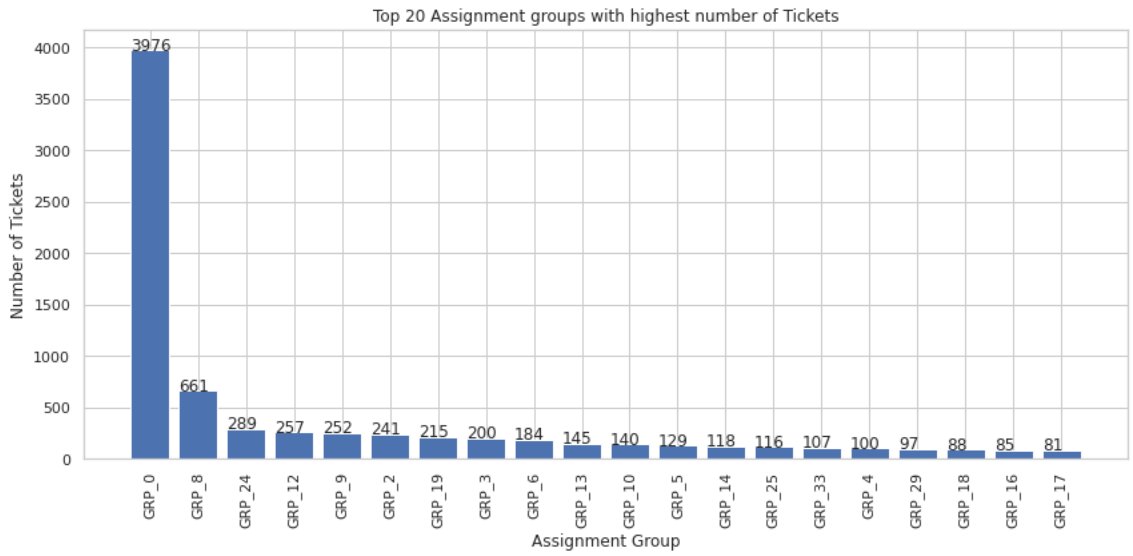
In [ ]:
```
df_top_20 = df_incidents['Assignment group'].value_counts().nlargest(20).reset_index()
df_top_20
```

Out[ ]:

	index	Assignment group
0	GRP_0	3976
1	GRP_8	661
2	GRP_24	289
3	GRP_12	257
4	GRP_9	252
5	GRP_2	241
6	GRP_19	215
7	GRP_3	200
8	GRP_6	184
9	GRP_13	145
10	GRP_10	140
11	GRP_5	129
12	GRP_14	118
13	GRP_25	116
14	GRP_33	107
15	GRP_4	100
16	GRP_29	97
17	GRP_18	88
18	GRP_16	85
19	GRP_17	81

In [ ]:
```
plt.figure(figsize=(12,6))
bars = plt.bar(df_top_20['index'],df_top_20['Assignment group'])
plt.title('Top 20 Assignment groups with highest number of Tickets')
plt.xlabel('Assignment Group')
plt.xticks(rotation=90)
plt.ylabel('Number of Tickets')

for bar in bars:
    yval = bar.get_height()
    plt.text(bar.get_x(), yval + .005, yval)
plt.tight_layout()
plt.show()
```



Here we have the plot of the top 20 groups that have the data assigned to them.

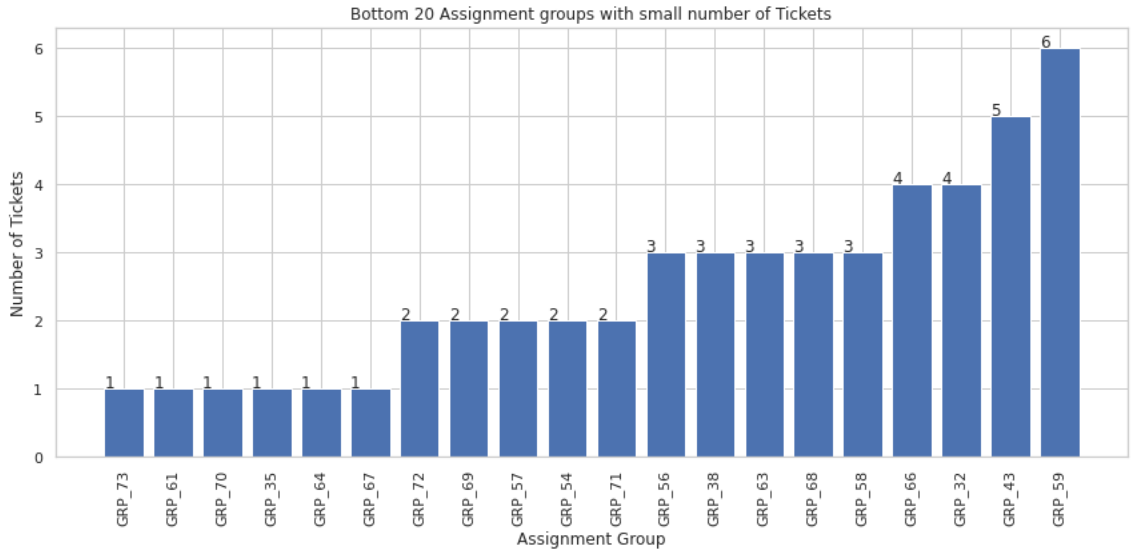
Below, we are checking the data that has the least number of groups assigned.

In [ ]:
```
df_bottom_20 = df_incidents['Assignment group'].value_counts().nsmallest(20).reset_index()
df_bottom_20
```

Out[ ]:

	index	Assignment group
0	GRP_73	1
1	GRP_61	1
2	GRP_70	1
3	GRP_35	1
4	GRP_64	1
5	GRP_67	1
6	GRP_72	2
7	GRP_69	2
8	GRP_57	2
9	GRP_54	2
10	GRP_71	2
11	GRP_56	3
12	GRP_38	3
13	GRP_63	3
14	GRP_68	3
15	GRP_58	3
16	GRP_66	4
17	GRP_32	4
18	GRP_43	5
19	GRP_59	6

In [ ]:
```
plt.figure(figsize=(12,6))
bars = plt.bar(df_bottom_20['index'],df_bottom_20['Assignment group'])
plt.title('Bottom 20 Assignment groups with small number of Tickets')
plt.xlabel('Assignment Group')
plt.xticks(rotation=90)
plt.ylabel('Number of Tickets')
for bar in bars:
    yval = bar.get_height()
    plt.text(bar.get_x(), yval + .005, yval)
plt.tight_layout()
plt.show()
```



Here we have the plot of the bottom 20 groups that have the data assigned to them.

In [ ]:
```
df_bins = pd.DataFrame(columns=['Description','Ticket Count'])
one_ticket = {'Description':'1 ticket','Ticket Count':len(df_inc[df_inc['Assignment group'] < 2])}
_2_5_ticket = {'Description':'2-5 ticket',
               'Ticket Count':len(df_inc[(df_inc['Assignment group'] > 1)& (df_inc['Assignment group'] < 6) ])}
_10_ticket = {'Description':' 6-10 ticket',
               'Ticket Count':len(df_inc[(df_inc['Assignment group'] > 5)& (df_inc['Assignment group'] < 11)])}
_10_20_ticket = {'Description':' 11-20 ticket',
               'Ticket Count':len(df_inc[(df_inc['Assignment group'] > 10)& (df_inc['Assignment group'] < 21)])}
_20_50_ticket = {'Description':' 21-50 ticket',
               'Ticket Count':len(df_inc[(df_inc['Assignment group'] > 20)& (df_inc['Assignment group'] < 51)])}
_51_100_ticket = {'Description':' 51-100 ticket',
               'Ticket Count':len(df_inc[(df_inc['Assignment group'] > 50)& (df_inc['Assignment group'] < 101)])}
_100_ticket = {'Description':' >100 ticket',
               'Ticket Count':len(df_inc[(df_inc['Assignment group'] > 100)])}
#append row to the dataframe
df_bins = df_bins.append([one_ticket,_2_5_ticket,_10_ticket,
                          _10_20_ticket,_20_50_ticket,_51_100_ticket,_100_ticket], ignore_index=True)

df_bins
```

Out[ ]:

	Description	Ticket Count
0	1 ticket	6
1	2-5 ticket	13
2	6-10 ticket	6
3	11-20 ticket	9
4	21-50 ticket	16
5	51-100 ticket	9
6	>100 ticket	15

In the dataframe above, we identify the number of groups that have tickets assigned to them in specific ranges. Ex : There are 6 groups that have just 1 ticket assigned to them.

Null Value Treatment.

1. Drop the missing values: The number of complete cases i.e. observation with no missing data must be sufficient for the selected analysis technique then we can se this. Hov quite skewed data and a long tail. So ignoring null rows can be fatal in totally missing out some groups
2. Imputation: If the missing values in a column or feature are numerical, the values can be imputed by the mean or median of the complete cases of the variable. But in our ca
3. COnjoining/ custom replacement: The cases where we can find anoher custom solution to give a logical value to null. In our case fortunately the we observed that wherever have proper input in short column and vice versa. Hence we can make a readable combined description and make NaN replaceable and combine short and description as o

Thus to eliminate the null values, we'll be replacing them with space.

In [ ]:
```
df_incidents[df_incidents['Short description'].isnull()]
```

Out[ ]:

	Short description	Description	Assignment group
2604	NaN	\r\n\r\nreceived from: ohdrnswl.rezuibdt@gmail...	GRP_34
3383	NaN	\r\n-connected to the user system using teamvi...	GRP_0
3906	NaN	-user unable tologin to vpn.\r\n-connected to...	GRP_0
3910	NaN	-user unable tologin to vpn.\r\n-connected to...	GRP_0
3915	NaN	-user unable tologin to vpn.\r\n-connected to...	GRP_0
3921	NaN	-user unable tologin to vpn.\r\n-connected to...	GRP_0
3924	NaN	name:wvqgbdhm fwchqjor\nlanguage:\nbrowser:mic...	GRP_0
4341	NaN	\r\n\r\nreceived from: eqmuniov.ehxkcbgj@gmail...	GRP_0

In [ ]:
```
df_incidents[df_incidents['Description'].isnull()]
```

Out[ ]:

	Short description	Description	Assignment group
4395	i am locked out of skype	NaN	GRP_0

Thus to eliminate the null values, we'll be replacing them with space.

In [ ]:
```
#Replace NaN values in Short Description and Description columns
df_incidents['Short description'] = df_incidents['Short description'].replace(np.nan, '', regex=True)
df_incidents['Description'] = df_incidents['Description'].replace(np.nan, '', regex=True)
```

In [ ]:
```
df_incidents.describe().T
```

Out[ ]:

	count	unique	top	freq
Short description	8500	7482	password reset	38
Description	8500	7818	the	56
Assignment group	8500	74	GRP_0	3976

Joining the two columns short description and description.

Here, we are joining the two columns into a new columns because of the null values we replaced above, some of the short description/description columns have just spaces as t would have to join the columns, so that while making the vocabulary, we can refer to a single column to work with.

In [ ]:
```
#Concatenate Short Description and Description columns
df_incidents['New_Description'] = df_incidents['Short description'] + ' ' +df_incidents['Description']
```

We do this concatenation here, to help with data pre-processing & data cleansing.

Later we will remove the repeated words in each combined description.

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

Out[ ]:

	Short description	Description	Assignment group	New_Description
0	login issue	-verified user details.(employee# & manager na...	GRP_0	login issue -verified user details.(employee# ...
1	outlook	\r\n\r\nreceived from: hmjdrvpb.komuaywn@gmail...	GRP_0	outlook \r\n\r\nreceived from: hmjdrvpb.komuay...
2	cant log in to vpn	\r\n\r\nreceived from: eylqgodm.ybqkwiam@gmail...	GRP_0	cant log in to vpn \r\n\r\nreceived from: eylq...
3	unable to access hr_tool page	unable to access hr_tool page	GRP_0	unable to access hr_tool page unable to access...
4	skype error	skype error	GRP_0	skype error skype error

Creating a wordcloud.

A wordcloud is an image composed of words used in a particular text or subject, in which the size of each word indicates its frequency or importance. Here in the below wordclou

In [ ]:
```
def f_word_cloud(column):

    comment_words = ' '
    stopwords = set(STOPWORDS)

    # iterate through the csv file
    for val in column:

        # typecaste each val to string
        val = str(val)

        # split the value
        tokens = val.split()

        # Converts each token into lowercase
        for i in range(len(tokens)):
            tokens[i] = tokens[i].lower()

        for words in tokens:
            comment_words = comment_words + words + ' '


    wordcloud = WordCloud(width = 800, height = 800,
                    background_color ='black',
                    stopwords = stopwords,
                    min_font_size = 10).generate(comment_words)

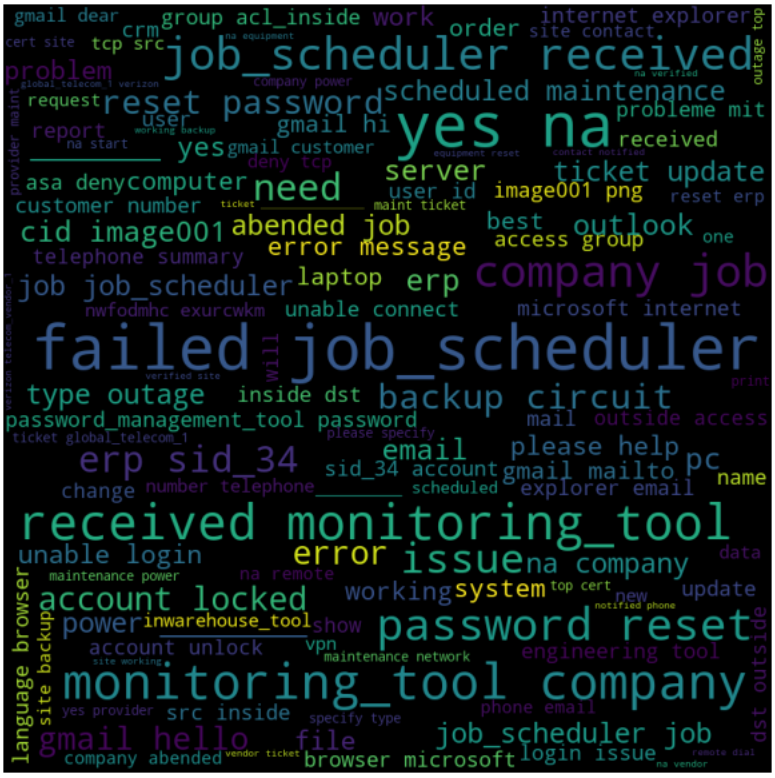
    return wordcloud
```

Wordcloud image of the description.

In [ ]:
```
from wordcloud import WordCloud, STOPWORDS


wordcloud = f_word_cloud(df_incidents.New_Description)
# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

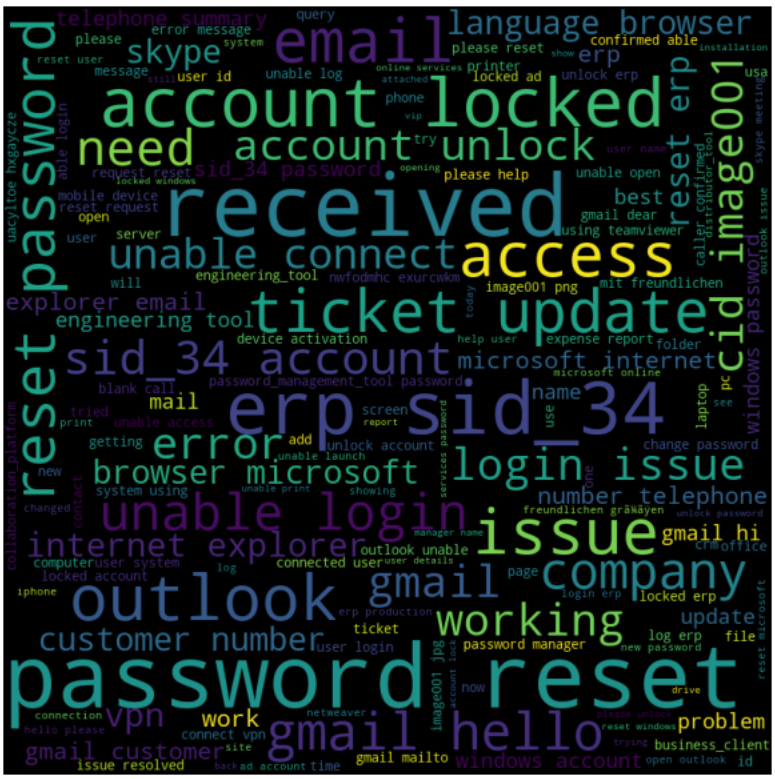
plt.show()
```



Lets view the word cloud of top 4 assignment groups to see the kind of tickets assigned to them Word Cloud for tickets with Assignment group 'GRP_0'

In [ ]:
```
wordcloud = f_word_cloud(df_incidents[df_incidents['Assignment group']=='GRP_0'].New_Description)
# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

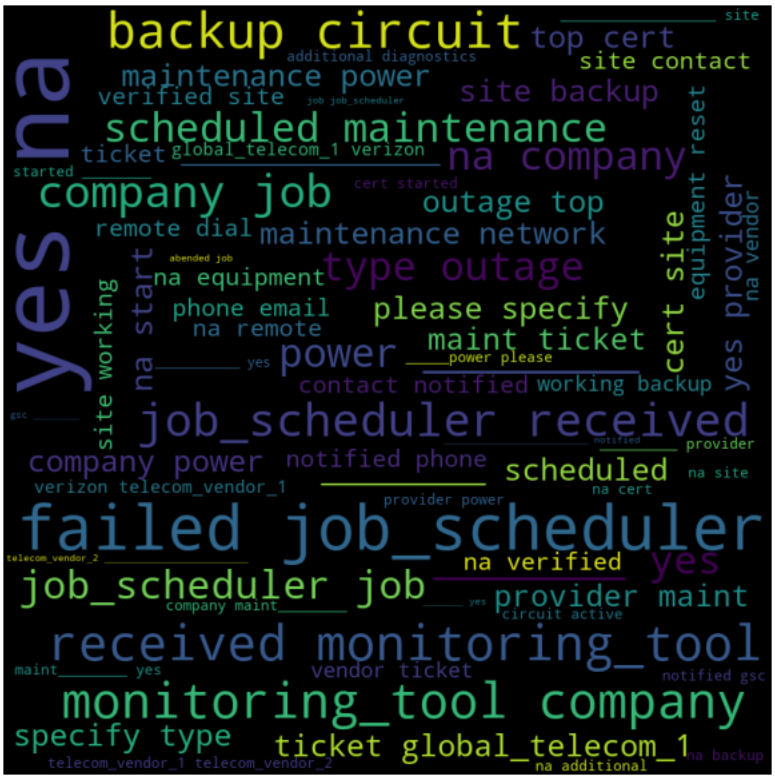
plt.show()
```



Word Cloud for tickets with Assignment group 'GRP_8'.

In [ ]:
```
wordcloud = f_word_cloud(df_incidents[df_incidents['Assignment group']=='GRP_8'].New_Description)
# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```

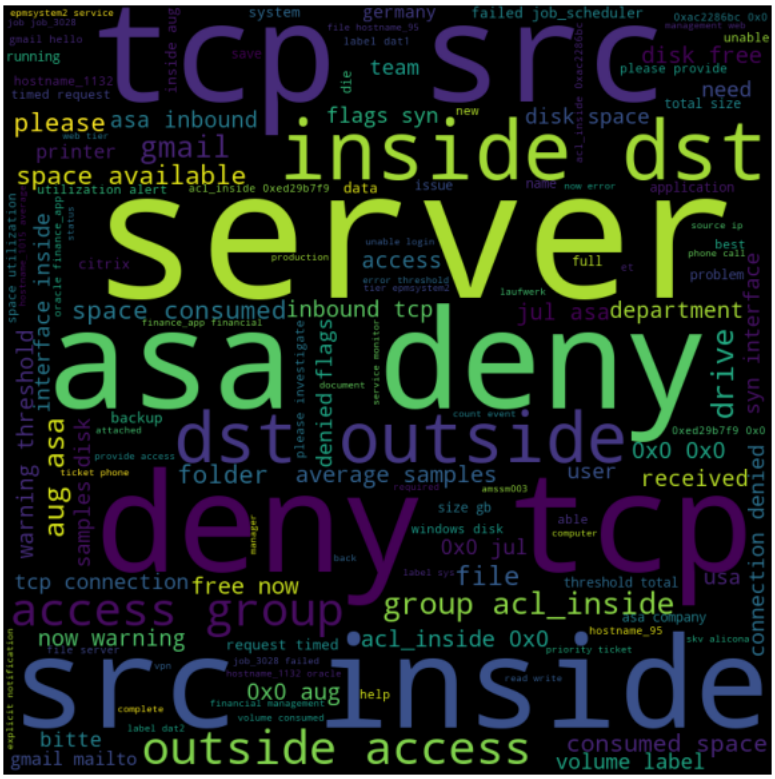


GRP_8 seems to have tickets related to outage, job failures, monitoring tool etc.

Word Cloud for tickets with Assignment group 'GRP_12'

In [ ]:
```
wordcloud = f_word_cloud(df_incidents[df_incidents['Assignment group']=='GRP_12'].New_Description)
# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```



GRP_12 contains tickets related to systems like disk space issues, t network issues like tie out, citrix issue, connectivity timeout etc.

Word Cloud for tickets with Assignment group 'GRP_24'.

In [ ]:
```
wordcloud = f_word_cloud(df_incidents[df_incidents['Assignment group']=='GRP_24'].New_Description)
# plot the WordCloud image
plt.figure(figsize = (8, 8), facecolor = None)
plt.imshow(wordcloud)
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```

GRP_24 - Tickets are mainly in german, these tickets need to be translated to english before passing it to our model.

Seems like there are few tickets with description in some other language, probably in German.

Data Encoding and translation

Text encoding transforms words into numbers and texts into number vectors. And in the given data set we also found that ther are a lot of entries/records that are in multiple lang translate as well to one language, that is easily understandable. Here we choose english. Also, there are some special characters in some records, so we will be translating them

In [ ]:
```
df_incidents[df_incidents['Assignment group']=='GRP_24'].New_Description
```

Out[ ]:
```
222     support fÃ¼r fa.gstry \arexjftu ohxdwngl suppo...
223     probleme mit bluescreen . hallo ,\n\nes ist er...
255     probleme mit laufwerk z: \laeusvjo fvaihgpx pr...
302     EU_tool ist sehr langsadgtym \ywqgrbnx jwnsyzb...
304     alte eq abholen \wrcktgbd wzrgyunp alte eq abh...
                              ...
8413    pobleme mit we_combi \jionmpsf wnkpzcmv poblem...
8414    langsamer rechner \Ã¼berprÃ¼fung \niptbwdq cse...
8416    setup new ws \kebogxzp difnjlkp  setup new ws ...
8417    bluetooth keybankrd defekt \dardabthyr bluetoo...
8419    probleme mit bildschirmschoner \ we91 \jionmps...
Name: New_Description, Length: 289, dtype: object
```

In [ ]:
```
df_incidents.shape
```

Out[ ]:
```
(8500, 4)
```

Language Detection

In [ ]:
```
#Lets encode the string, to make it easier to be passed to language detection api.
def fn_decode_to_ascii(df):
  text = df.encode().decode('utf-8').encode('ascii', 'ignore')
  return text.decode("utf-8")

df_incidents['New_Description'] = df_incidents['New_Description'].apply(fn_decode_to_ascii)
```

In the below code, we are now using langdetect library to detect the languages used in the data set.

In [ ]:
```
from langdetect import detect

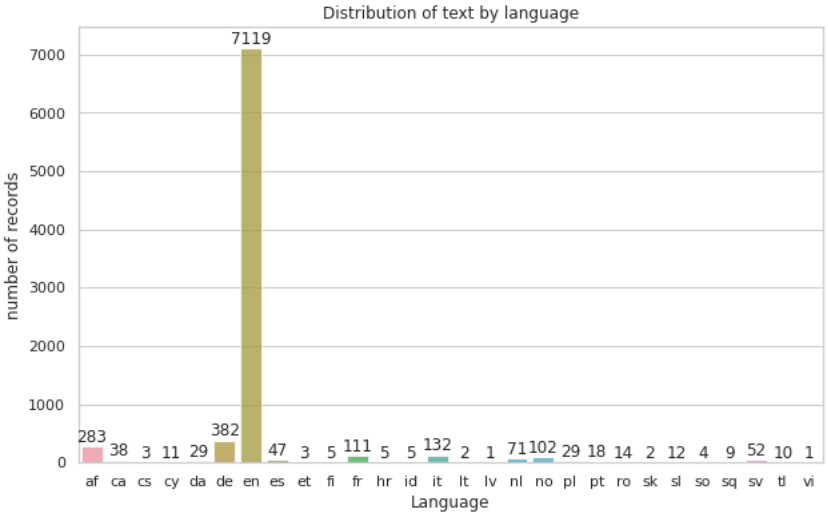
def fn_lan_detect(df):
   try:
      return detect(df)
   except:
      return 'no'

df_incidents['language'] = df_incidents['New_Description'].apply(fn_lan_detect)
```

In [ ]:
```
#Languages detected
df_incidents["language"].value_counts()
```

Out[ ]:
```
en    7119
de     382
af     283
it     132
fr     111
no     102
nl      71
sv      52
es      47
ca      38
da      29
pl      29
pt      18
ro      14
sl      12
cy      11
tl      10
sq       9
hr       5
fi       5
id       5
so       4
cs       3
et       3
sk       2
lt       2
vi       1
lv       1
Name: language, dtype: int64
```

In [ ]:
```
x = df_incidents["language"].value_counts()
x=x.sort_index()
plt.figure(figsize=(10,6))
ax= sns.barplot(x.index, x.values, alpha=0.8)
plt.title("Distribution of text by language")
plt.ylabel('number of records')
plt.xlabel('Language')
rects = ax.patches
labels = x.values
for rect, label in zip(rects, labels):
    height = rect.get_height()
    ax.text(rect.get_x() + rect.get_width()/2, height + 5, label, ha='center', va='bottom')
plt.show();
```



Language Translation

We can see that most of the tickets are in english, followed by tickets in German language. We need to translate these into english. We will be using google translate package to

In [ ]:
```
import googletrans
from googletrans import Translator
translator = Translator()
# Function to translate the text to english.
def fn_translate(df,lang):
  try:
    if lang == 'en':
        return df
    else:
        return translator.translate(df,dest='en', src=lang).text
  except:
    return df
```

In [ ]:
```
df_incidents['English_Description'] = df_incidents.apply(lambda x: fn_translate(x['New_Description'], x['language']), axis=1)
```

Google Translate API is used for translating the non-english text. However, there is limit imposed due to garbage values and non-ascii symbols preventing proper translation.

So the traslation was done in 2 batches:

- Before data cleansing.
- After data cleansing.

In [ ]:
```
df_incidents[df_incidents["Short description"].str.contains("account lock")]["Assignment group"].value_counts()
```

Out[ ]:
```
GRP_0     226
GRP_2       3
GRP_72      1
GRP_34      1
Name: Assignment group, dtype: int64
```

In [ ]:
```
df_incidents[df_incidents["Short description"].str.contains("oneteam")]["Assignment group"].value_counts()
```

Out[ ]:
```
GRP_0     3
GRP_73    1
Name: Assignment group, dtype: int64
```

In [ ]:
```
df_incidents.head(10)
```

Out[ ]:

	Short description	Description	Assignment group	New_Description
0	login issue	-verified user details.(employee# & manager na...	GRP_0	login issue -verified user details.(employee# ...
1	outlook	\r\n\r\nreceived from: hmjdrvpb.komuaywn@gmail...	GRP_0	outlook \r\n\r\nreceived from: hmjdrvpb.komuay...
2	cant log in to vpn	\r\n\r\nreceived from: eylqgodm.ybqkwiam@gmail...	GRP_0	cant log in to vpn \r\n\r\nreceived from: eylq...
3	unable to access hr_tool page	unable to access hr_tool page	GRP_0	unable to access hr_tool page unable to access...
4	skype error	skype error	GRP_0	skype error skype error
5	unable to log in to engineering tool and skype	unable to log in to engineering tool and skype	GRP_0	unable to log in to engineering tool and skype...
6	event: critical:HostName_221.company.com the v...	event: critical:HostName_221.company.com the v...	GRP_1	event: critical:HostName_221.company.com the v...
7	ticket_no1550391- employment status - new non-...	ticket_no1550391- employment status - new non-...	GRP_0	ticket_no1550391- employment status - new non-...
8	unable to disable add ins on outlook	unable to disable add ins on outlook	GRP_0	unable to disable add ins on outlook unable to...
9	ticket update on inplant_874773	ticket update on inplant_874773	GRP_0	ticket update on inplant_874773 ticket update ...

In [ ]:
```
df_incidents[df_incidents.language=='no']['Assignment group'].unique()
```

Out[ ]:
```
array(['GRP_0', 'GRP_24', 'GRP_27', 'GRP_14', 'GRP_48', 'GRP_30',
       'GRP_33', 'GRP_31', 'GRP_13', 'GRP_19', 'GRP_12', 'GRP_3'],
      dtype=object)
```

In [ ]:
```
lang_list = df_incidents.language.unique().tolist()
list_groups=[]
for lang in lang_list:
    if not lang=='en':
        #print(lang)
        list_groups=list_groups+(df_incidents[df_incidents.language==lang]['Assignment group'].unique().tolist())

print(len(list(set(list_groups))))
```

```
42
```

In [ ]:
```
len(list(set(list_groups)))
```

Out[ ]:
```
42
```

In [ ]:
```
list_groups
```

Out[ ]:
```
['GRP_0',
 'GRP_24',
 'GRP_27',
 'GRP_14',
 'GRP_48',
 'GRP_30',
 'GRP_33',
 'GRP_31',
 'GRP_13',
 'GRP_19',
 'GRP_12',
 'GRP_3',
 'GRP_0',
 'GRP_1',
 'GRP_14',
 'GRP_24',
 'GRP_19',
 'GRP_3',
 'GRP_31',
 'GRP_40',
 'GRP_65',
 'GRP_13',
 'GRP_9',
 'GRP_0',
 'GRP_42',
 'GRP_24',
 'GRP_12',
 'GRP_31',
 'GRP_40',
 'GRP_9',
 'GRP_30',
 'GRP_62',
 'GRP_19',
 'GRP_15',
 'GRP_18',
 'GRP_0',
 'GRP_19',
 'GRP_2',
 'GRP_25',
 'GRP_28',
 'GRP_62',
 'GRP_24',
 'GRP_34',
 'GRP_0',
 'GRP_24',
 'GRP_12',
 'GRP_2',
 'GRP_26',
 'GRP_42',
 'GRP_48',
 'GRP_31',
 'GRP_19',
 'GRP_34',
 'GRP_17',
 'GRP_30',
 'GRP_27',
 'GRP_3',
 'GRP_62',
 'GRP_45',
 'GRP_0',
 'GRP_24',
 'GRP_48',
 'GRP_0',
 'GRP_24',
 'GRP_30',
 'GRP_3',
 'GRP_31',
 'GRP_15',
 'GRP_1',
 'GRP_0',
 'GRP_3',
 'GRP_25',
 'GRP_24',
 'GRP_17',
 'GRP_49',
 'GRP_13',
 'GRP_40',
 'GRP_33',
 'GRP_30',
 'GRP_42',
 'GRP_44',
 'GRP_16',
 'GRP_34',
 'GRP_46',
 'GRP_8',
 'GRP_0',
```

```
 'GRP_24',
 'GRP_28',
 'GRP_25',
 'GRP_33',
 'GRP_2',
 'GRP_42',
 'GRP_34',
 'GRP_12',
 'GRP_13',
 'GRP_14',
 'GRP_10',
 'GRP_26',
 'GRP_11',
 'GRP_59',
 'GRP_16',
 'GRP_29',
 'GRP_18',
 'GRP_5',
 'GRP_20',
 'GRP_52',
 'GRP_32',
 'GRP_46',
 'GRP_49',
 'GRP_0',
 'GRP_12',
 'GRP_24',
 'GRP_19',
 'GRP_0',
 'GRP_24',
 'GRP_31',
 'GRP_8',
 'GRP_0',
 'GRP_30',
 'GRP_24',
 'GRP_30',
 'GRP_0',
 'GRP_31',
 'GRP_19',
 'GRP_24',
 'GRP_30',
 'GRP_24',
 'GRP_31',
 'GRP_0',
 'GRP_24',
 'GRP_62',
 'GRP_0',
 'GRP_36',
 'GRP_24',
 'GRP_12',
 'GRP_31',
 'GRP_0',
 'GRP_33',
 'GRP_5',
 'GRP_24',
 'GRP_9',
 'GRP_34',
 'GRP_42',
 'GRP_19',
 'GRP_6',
 'GRP_0',
 'GRP_48',
 'GRP_34',
 'GRP_24',
 'GRP_0',
 'GRP_3',
 'GRP_0',
 'GRP_10',
 'GRP_62',
 'GRP_30',
 'GRP_8',
 'GRP_19',
 'GRP_20',
 'GRP_26',
 'GRP_8',
 'GRP_0',
 'GRP_48',
 'GRP_31',
 'GRP_30',
 'GRP_24',
 'GRP_31',
 'GRP_0',
 'GRP_48',
 'GRP_31',
 'GRP_30',
 'GRP_0']
```

In [ ]:
```
df_incidents.to_csv("inc_tranlated.csv",index=False)
```

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

Out[ ]:

	Short description	Description	Assignment group	New_Description	language	
0	login issue	-verified user details.(employee# & manager na...	GRP_0	login issue -verified user details.(employee# ...	en	login i
1	outlook	\r\n\r\nreceived from: hmjdrvpb.komuaywn@gmail...	GRP_0	outlook \r\n\r\nreceived from: hmjdrvpb.komuay...	en	outlook \
2	cant log in to vpn	\r\n\r\nreceived from: eylqgodm.ybqkwiam@gmail...	GRP_0	cant log in to vpn \r\n\r\nreceived from: eylq...	en	cant
3	unable to access hr_tool page	unable to access hr_tool page	GRP_0	unable to access hr_tool page unable to access...	en	unable to
4	skype error	skype error	GRP_0	skype error skype error	no	

In [ ]:
```
df_tranlated_text = pd.read_csv('inc_tranlated.csv',encoding='utf-8')
df_tranlated_inc = df_tranlated_text.drop(['Short description','Description','New_Description'],axis=1)
df_tranlated_inc.English_Description=df_tranlated_inc.English_Description.astype(str)
df_tranlated_inc.head()
```

Out[ ]:

	Assignment group	language	English_Description
0	GRP_0	en	login issue -verified user details.(employee# ...
1	GRP_0	en	outlook \r\n\r\nreceived from: hmjdrvpb.komuay...
2	GRP_0	en	cant log in to vpn \r\n\r\nreceived from: eylq...
3	GRP_0	en	unable to access hr_tool page unable to access...
4	GRP_0	no	skype error skype error

In [ ]:
```
df_tranlated_text.tail()
```

Out[ ]:

	Short description	Description	Assignment group	New_Description
8495	emails not coming in from zz mail	\r\n\r\nreceived from: avglmrts.vhqmtiua@gmail...	GRP_29	emails not coming in from zz mail \r\n\r\nrece...
8496	telephony_software issue	telephony_software issue	GRP_0	telephony_software issue telephony_software issue
8497	vip2: windows password reset for tifpdchb pedx...	vip2: windows password reset for tifpdchb pedx...	GRP_0	vip2: windows password reset for tifpdchb pedx...
8498	machine nÃ£o estÃ¡ funcionando	i am unable to access the machine utilities to...	GRP_62	machine no est funcionando i am unable to acce...
8499	an mehreren pc`s lassen sich verschiedene prgr...	an mehreren pc`s lassen sich verschiedene prgr...	GRP_49	an mehreren pc`s lassen sich verschiedene prgr...

Exploring the different language disribution in the Dataset

In [ ]:
```
#Unique Languages & Unique grps
det_lang = df_tranlated_text['language']
det_lang2 = np.array(det_lang)
det_lang2 = np.unique(det_lang)
det_lang2
```

Out[ ]:
```
array(['af', 'ca', 'cs', 'cy', 'da', 'de', 'en', 'es', 'et', 'fi', 'fr',
       'hr', 'id', 'it', 'lt', 'lv', 'nl', 'no', 'pl', 'pt', 'ro', 'sk',
       'sl', 'so', 'sq', 'sv', 'tl', 'vi'], dtype=object)
```

In [ ]:
```
print("Total No: of languages detected: ", det_lang2.size)
```

```
Total No: of languages detected:  28
```

In [ ]:
```
# Value Counts of Language distribution
lang_valcount = df_tranlated_text['language'].value_counts()
print(lang_valcount)
```

```
en    7119
de     382
af     283
it     132
fr     111
no     102
nl      71
sv      52
es      47
ca      38
da      29
pl      29
pt      18
ro      14
sl      12
cy      11
tl      10
sq       9
hr       5
fi       5
id       5
so       4
cs       3
et       3
sk       2
lt       2
vi       1
lv       1
Name: language, dtype: int64
```

In [ ]:
```
det_lang3  = np.array(det_lang)
occurrences = np.count_nonzero(det_lang3 != 'en')
print("Non-English language count: ", occurrences)
```

```
Non-English language count:  1381
```

In [ ]:
```
# Find Language Distribution in Groups
grplang_df = pd.DataFrame(df_tranlated_text['Assignment group'].unique(),columns=['AsgnGrp'])
asgLngGrp = []

for ct2 in grplang_df.itertuples():
  strVar = []
  for ct1 in df_tranlated_text.itertuples():
    if ct2.AsgnGrp == ct1._3:
      strVar.append(ct1.language)
  strArrVar = str(np.unique(strVar))
  asgLngGrp.append(strArrVar)
```

Group-wise Language Distribution

In [ ]:
```
grplang_df['AsgnLang'] = asgLngGrp
pd.set_option('display.max_rows', None)
print(grplang_df)
```

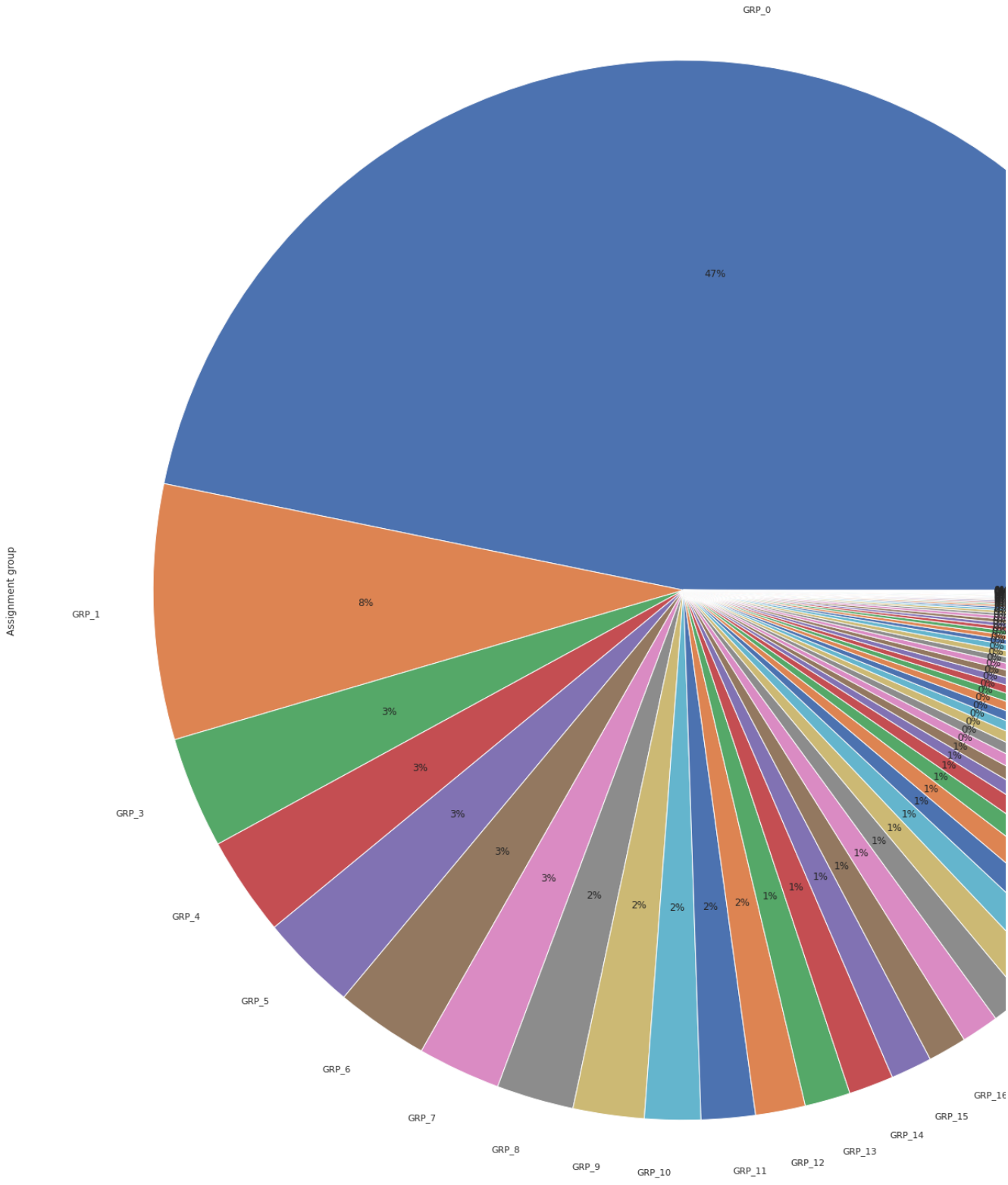
```
   AsgnGrp                                          AsgnLang
0    GRP_0  ['af' 'ca' 'cs' 'cy' 'da' 'de' 'en' 'es' 'fi' ...
1    GRP_1                                  ['ca' 'en' 'fr']
2    GRP_3              ['af' 'ca' 'en' 'fr' 'hr' 'nl' 'no']
3    GRP_4                                       ['en']
4    GRP_5                                  ['da' 'de' 'en']
5    GRP_6                                       ['da' 'en']
6    GRP_7                                       ['en']
7    GRP_8                         ['en' 'nl' 'pt' 'sl' 'so']
8    GRP_9                              ['da' 'en' 'fr' 'it']
9   GRP_10                                  ['de' 'en' 'pt']
10  GRP_11                                       ['de' 'en']
11  GRP_12              ['af' 'de' 'en' 'id' 'it' 'no' 'pl']
12  GRP_13                         ['de' 'en' 'fr' 'nl' 'no']
13  GRP_14                              ['de' 'en' 'fr' 'no']
14  GRP_15                                  ['ca' 'en' 'it']
15  GRP_16                                  ['de' 'en' 'nl']
16  GRP_17                                  ['af' 'en' 'nl']
17  GRP_18                                  ['de' 'en' 'it']
18  GRP_19  ['af' 'cy' 'da' 'en' 'es' 'fi' 'fr' 'it' 'no' ...
19   GRP_2                              ['af' 'de' 'en' 'es']
20  GRP_20                                  ['de' 'en' 'pt']
21  GRP_21                                       ['en']
22  GRP_22                                       ['en']
23  GRP_23                                       ['en']
24  GRP_24  ['af' 'ca' 'cs' 'cy' 'da' 'de' 'en' 'es' 'et' ...
25  GRP_25                              ['de' 'en' 'es' 'nl']
26  GRP_26                              ['af' 'de' 'en' 'pt']
27  GRP_27                                   ['af' 'en' 'no']
28  GRP_28                                   ['de' 'en' 'es']
29  GRP_29                                       ['de' 'en']
30  GRP_30  ['af' 'ca' 'cy' 'en' 'et' 'it' 'nl' 'no' 'pt' ...
31  GRP_31  ['af' 'ca' 'cs' 'cy' 'en' 'fr' 'it' 'no' 'pl' ...
32  GRP_33                         ['da' 'de' 'en' 'nl' 'no']
33  GRP_34              ['af' 'da' 'de' 'en' 'es' 'nl' 'tl']
34  GRP_35                                       ['en']
35  GRP_36                                  ['en' 'pl']
36  GRP_37                                       ['en']
37  GRP_38                                       ['en']
38  GRP_39                                       ['en']
39  GRP_40                              ['en' 'fr' 'it' 'nl']
40  GRP_41                                       ['en']
41  GRP_42                   ['af' 'da' 'de' 'en' 'it' 'nl']
42  GRP_43                                       ['en']
43  GRP_44                                  ['en' 'nl']
44  GRP_45                                  ['af' 'en']
45  GRP_46                                  ['de' 'en' 'nl']
46  GRP_47                                       ['en']
47  GRP_48              ['af' 'en' 'lv' 'no' 'so' 'sv' 'tl']
48  GRP_49                                  ['de' 'en' 'nl']
49  GRP_50                                       ['en']
50  GRP_51                                       ['en']
51  GRP_52                                  ['de' 'en']
52  GRP_53                                       ['en']
53  GRP_54                                       ['en']
54  GRP_55                                       ['en']
55  GRP_56                                       ['en']
56  GRP_57                                       ['en']
57  GRP_58                                       ['en']
58  GRP_59                                  ['de' 'en']
59  GRP_60                                       ['en']
60  GRP_61                                       ['en']
61  GRP_32                                  ['de' 'en']
62  GRP_62                   ['af' 'en' 'es' 'it' 'pt' 'ro']
63  GRP_63                                       ['en']
64  GRP_64                                       ['en']
65  GRP_65                                  ['en' 'fr']
66  GRP_66                                       ['en']
67  GRP_67                                       ['en']
68  GRP_68                                       ['en']
69  GRP_69                                       ['en']
70  GRP_70                                       ['en']
71  GRP_71                                       ['en']
72  GRP_72                                       ['en']
73  GRP_73                                       ['en']
```

Observation:

From above table and bar chart, we can observe that the language is distributed across groups and are not specific to certain groups alone.

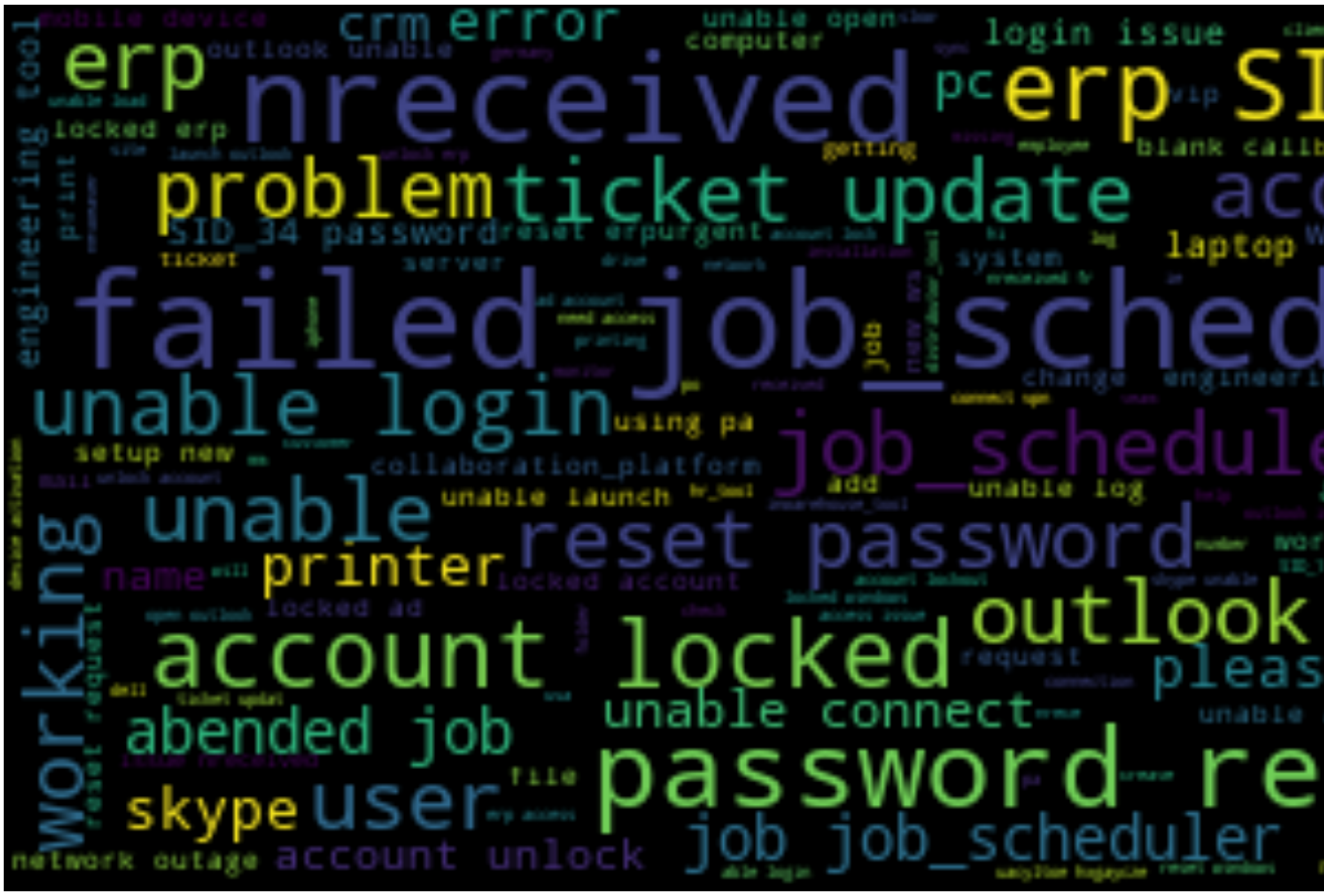
In [ ]:
```
#Pie Chart of target group
df_tranlated_text['Assignment group'].value_counts().plot(kind = 'pie', autopct = '%.0f%%', labels = grplang_df['AsgnGrp'], figsi
```

Out[ ]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff0252fab38>
```



In [ ]:
```
# Wordcloud before data cleaning & after language translation
wordcloudImg2 = WordCloud().generate(str(df_tranlated_text["English_Description"]))
plt.figure(figsize=(30,20))
plt.imshow(wordcloudImg2, interpolation='bilinear')
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```



Data Cleansing

- In NLP, the first step before building the machine learning model, is to pre-process the data.If the data is fairly pre-processed the results would be reliable
- We need to make sure the data passed to any algorithm should be well translated from Natural human conversational form to what the computer is able to understand.
- Without the cleaning process, the dataset is often a cluster of words that the computer doesn't understand.

In [ ]:
```
df_tranlated_inc.shape
```

Out[ ]:
```
(8500, 3)
```

In [ ]:
```
import string
import spacy
from nltk import tokenize
```

Various different steps that are followed while preprocessing the data:

1. Lowercasing: converting the words into lower case format. (NLU -> nlu). Words having the same meaning like nlp and NLP if they are not converted into lowercase then thes words in the vector space model.
2. Stop words removal: These are the most often used that do not have any significance while determining the two different documents like (a, an, the, etc.) so they are to be r
3. Contextual conversational words removal: In our case, words like 'recieved from','to','regards','subject','email address', which are identified as words used in an standard em
4. Punctuation: The text has several punctuations. Punctuations are often unnecessary as it doesn't add value or meaning to the NLP model.
5. Other steps: Other cleaning steps can be performed based on the data. Listed a few of them below,Remove URLs, Remove HTML tags, Remove numbers, Remove hashta

In [ ]:
```
# Define a function to clean the data
import re

def clean_data(text):
    text = text.lower()
    text = ' '.join([w for w in text.split()])
    text = re.sub(r"received from:",' ',text)
    text = re.sub(r"from:",' ',text)
    text = re.sub(r"to:",' ',text)
    text = re.sub(r"subject:",' ',text)
    text = re.sub(r"sent:",' ',text)
    text = re.sub(r"ic:",' ',text)
    text = re.sub(r"cc:",' ',text)
    text = re.sub(r"bcc:",' ',text)
    text = re.sub(r"email:",' ',text)
    text = re.sub(r"from:",' ',text)
    text = re.sub(r"email address:",' ',text)
    text = re.sub(r"subject:",' ',text)
    text = re.sub(r"cid:image",' ',text)
    text = re.sub(r"this message was sent from an unmonitored email address",' ',text)
    text = re.sub(r"please do not reply to this message",' ',text)
    text = re.sub(r"monitoring_tool@company.com",' ',text)
    text = re.sub(r"MonitoringTool",' ',text)
    text = re.sub(r"select the following link to view the disclaimer in an alternate language",' ',text)
    text = re.sub(r"description problem",' ',text)
    text = re.sub(r"steps taken far",' ',text)
    text = re.sub(r"customer job title",' ',text)
    text = re.sub(r"sales engineer contact",' ',text)
    text = re.sub(r"description of problem:",' ',text)
    text = re.sub(r"steps taken so far",' ',text)
    text = re.sub(r"please do the needful",' ',text)
    text = re.sub(r"please note that",' ',text)
    text = re.sub(r"please find below",' ',text)
    text = re.sub(r"date and time",' ',text)
    text = re.sub(r"kindly refer mail",' ',text)
    text = re.sub(r"name:",' ',text)
    text = re.sub(r"language:",' ',text)
    text = re.sub(r"customer number:",' ',text)
    text = re.sub(r"telephone:",' ',text)
    text = re.sub(r"summary:",' ',text)
    text = re.sub(r"sincerely",' ',text)
    text = re.sub(r"company inc",' ',text)
    text = re.sub(r"importance:",' ',text)
    text = re.sub(r"gmail.com",' ',text)
    text = re.sub(r"company.com",' ',text)
    text = re.sub(r"microsoftonline.com",' ',text)
    text = re.sub(r"company.onmicrosoft.com",' ',text)
    text = re.sub(r"hello",' ',text)
    text = re.sub(r"hallo",' ',text)
    text = re.sub(r"hi it team",' ',text)
    text = re.sub(r"hi team",' ',text)
    text = re.sub(r"hi",' ',text)
    text = re.sub(r"best regards",' ',text)
    text = re.sub(r"kind regards",' ',text)
    text = re.sub(r"regards",' ',text)
    text = re.sub(r"good morning",' ',text)
    text = re.sub(r"please",' ',text)
    text = re.sub(r"kindly",' ',text)

    #Remove email
    text = re.sub(r'\S*@\S*\s?', '', text)
    # Remove numbers
    text = re.sub(r'\d+','' ,text)
    # Remove new line characters
    text = re.sub(r'\n',' ',text)
    # Remove hashtag while keeping hashtag text
    text = re.sub(r'#','', text)
    text = re.sub(r'&;?', 'and',text)
    # Remove HTML special entities (e.g. &amp;)
    text = re.sub(r'\&\w*;', '', text)
    # Remove hyperlinks
    text = re.sub(r'https?:\/\/.*\/\w*', '', text)
    # Remove characters beyond Readable formart by Unicode:
    text= ''.join(c for c in text if c <= '\uFFFF')
    text = text.strip()
    # Remove unreadable characters  (also extra spaces)
    text = ' '.join(re.sub("[^\u0030-\u0039\u0041-\u005a\u0061-\u007a]", " ", text).split())


    text = re.sub(r"\s+[a-zA-Z]\s+", ' ', text)
    text = re.sub(' +', ' ', text)
    text = text.strip()
    return text
```

In [ ]:
```
df_tranlated_inc['cleaned_description'] = df_tranlated_inc['English_Description'].apply(lambda x: clean_data(x))
df_tranlated_inc.drop(['English_Description'],axis=1,inplace=True)
```

In [ ]:
```
df_tranlated_inc['cleaned_description'].head()
```

Out[ ]:
```
0    login issue verified user details employee and...
1    outlook team my meetings skype meetings etc ar...
2         cant log in to vpn cannot log on to vpn best
3    unable to access hr tool page unable to access...
4                              skype error skype error
Name: cleaned_description, dtype: object
```

Language Translation after cleaning & before stop words removal & tokenization

In [ ]:
```
df_tranlated_inc['cleaned_description'] = df_tranlated_inc.apply(lambda x: fn_translate(x['cleaned_description'], x['language']),
```

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

Out[ ]:

	Assignment group	language	cleaned_description
0	GRP_0	en	login issue verified user details employee and...
1	GRP_0	en	outlook team my meetings skype meetings etc ar...
2	GRP_0	en	cant log in to vpn cannot log on to vpn best
3	GRP_0	en	unable to access hr tool page unable to access...
4	GRP_0	no	skype error skype error

In [ ]:
```
## Removal of Stop Words
import nltk
nltk.download('stopwords')
from nltk.corpus import stopwords
stop = stopwords.words('english')
df_tranlated_inc['cleaned_description'] = df_tranlated_inc['cleaned_description'].apply(lambda x: " ".join(x for x in str(x).spli
df_tranlated_inc['cleaned_description'].head()
```

```
[nltk_data] Downloading package stopwords to /root/nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
```

Out[ ]:
```
0    login issue verified user details employee man...
1    outlook team meetings skype meetings etc appea...
2                      cant log vpn cannot log vpn best
3    unable access hr tool page unable access hr to...
4                              skype error skype error
Name: cleaned_description, dtype: object
```

Remove duplicates in combined descriptions

In [ ]:
```
desc_Arr = []
for tk1 in df_tranlated_inc.itertuples():
  texArr = []
  texArr = list(tk1.cleaned_description.split(" "))
  str1 = " "
  texStr = str1.join(np.unique(texArr))
  desc_Arr.append(texStr)
```

This step was necessary to remove the duplicate words which were formed due to the concatenation of short description & long description columns of the dataset.

These duplicate words would increase the word counts and possibly impact the model building steps and the performance of models.

In [ ]:
```
desc_Arr[4]
```

Out[ ]:
```
'error skype'
```

In [ ]:
```
df_tranlated_inc['cleaned_description'] = desc_Arr
df_tranlated_inc.head()
```

Out[ ]:

	Assignment group	language	cleaned_description
0	GRP_0	en	able ad advised caller check checked confirmed...
1	GRP_0	en	advise appearing calendar correct etc kind mee...
2	GRP_0	en	best cannot cant log vpn
3	GRP_0	en	access hr page tool unable
4	GRP_0	no	error skype

Deriving n-grams

N-grams of texts are extensively used in text mining and natural language processing tasks.

They are basically a set of co-occuring words within a given window. N-grams is a contiguous sequence of N items from a given sample of text or speech, in the fields of comput items can be phonemes, syllables, letters, words or base pairs according to the application. N-grams are used to describe the number of words used as observation points, e.g., bigram means 2-worded phrase, and trigram means 3-worded phrase. We'll be using scikit-learn's CountVectorizer function to derive n-grams We will write a generic method to

In [ ]:
```
# Generic function to derive top N n-grams from the corpus
from sklearn.feature_extraction.text import CountVectorizer

def get_top_n_ngrams(corpus, top_n=None, ngram_range=(1,1), stopwords=None):
    vec = CountVectorizer(ngram_range=ngram_range,
                          stop_words=stopwords).fit(corpus)
    bag_of_words = vec.transform(corpus)
    sum_words = bag_of_words.sum(axis=0)
    words_freq = [(word, sum_words[0, idx]) for word, idx in vec.vocabulary_.items()]
    words_freq = sorted(words_freq, key = lambda x: x[1], reverse=True)
    return words_freq[:top_n]
```

In [ ]:
```
# Top Unigrams after removing stop words
top_n = 50
ngram_range = (1,1)
uni_grams_sw = get_top_n_ngrams(df_tranlated_inc.cleaned_description, top_n, ngram_range, stopwords=stop)

unigram_df = pd.DataFrame(uni_grams_sw, columns = ['Summary' , 'count'])
figure = unigram_df.groupby('Summary').sum()['count'].sort_values(ascending=False)
figure.head(10)
```

Out[ ]:
```
Summary
erp          1081
password     1053
job          1010
scheduler     969
tool          946
failed        884
unable        879
reset         871
issue         850
sid           741
Name: count, dtype: int64
```

In [ ]:
```
# Top Bigrams after removing stop words
top_n = 50
ngram_range = (2,2)
bi_grams_sw = get_top_n_ngrams(df_tranlated_inc.cleaned_description, top_n, ngram_range, stopwords=stop)

bigrams_df = pd.DataFrame(bi_grams_sw, columns = ['Summary' , 'count'])
figure2 = bigrams_df.groupby('Summary').sum()['count'].sort_values(ascending=False)
figure2.head(10)
```

Out[ ]:
```
Summary
job scheduler         778
failed job            587
password reset        360
erp error             170
company contact       156
ticket update         155
scheduler sid         154
password passwords    147
start started         146
reset sid             146
Name: count, dtype: int64
```

In [ ]:
```
# Wordcloud after data cleaning
wordcloudImg3 = WordCloud().generate(str(df_tranlated_inc["cleaned_description"]))
plt.figure(figsize=(30,20))
plt.imshow(wordcloudImg3, interpolation='bilinear')
plt.axis("off")
plt.tight_layout(pad = 0)

plt.show()
```

Lemmatization

1.Lemmatization is the process of process of reducing a word to its root form by grouping together the different inflected forms of a word so they can be analysed as a single iten

2.It helps to reduce variations of the same word, thereby reducing the corpus of words to be included in the model.

So,it returns the base or dictionary form of a word, which is known as the lemma.It is important when clean the data of all words of a given root.Lemmatizing considers the contex into its root form based on the dictionary definition.

In [ ]:
```
    # Lemmatization
import nltk
nltk.download('wordnet')
nltk.download('punkt')
nltk.download('averaged_perceptron_tagger')

nlp = spacy.load('en', disable=['parser', 'ner'])
allowed_postags=['NOUN', 'ADJ', 'VERB', 'ADV']
def lemmatize_text(text):
    doc = nlp(text)
    return ' '.join([token.lemma_ for token in doc if token.lemma_ !='-PRON-'])

df_tranlated_inc["cleaned_description"] = df_tranlated_inc["cleaned_description"].apply(lemmatize_text)
```

```
[nltk_data] Downloading package wordnet to /root/nltk_data...
[nltk_data]   Unzipping corpora/wordnet.zip.
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
[nltk_data] Downloading package averaged_perceptron_tagger to
[nltk_data]     /root/nltk_data...
[nltk_data]   Unzipping taggers/averaged_perceptron_tagger.zip.
```

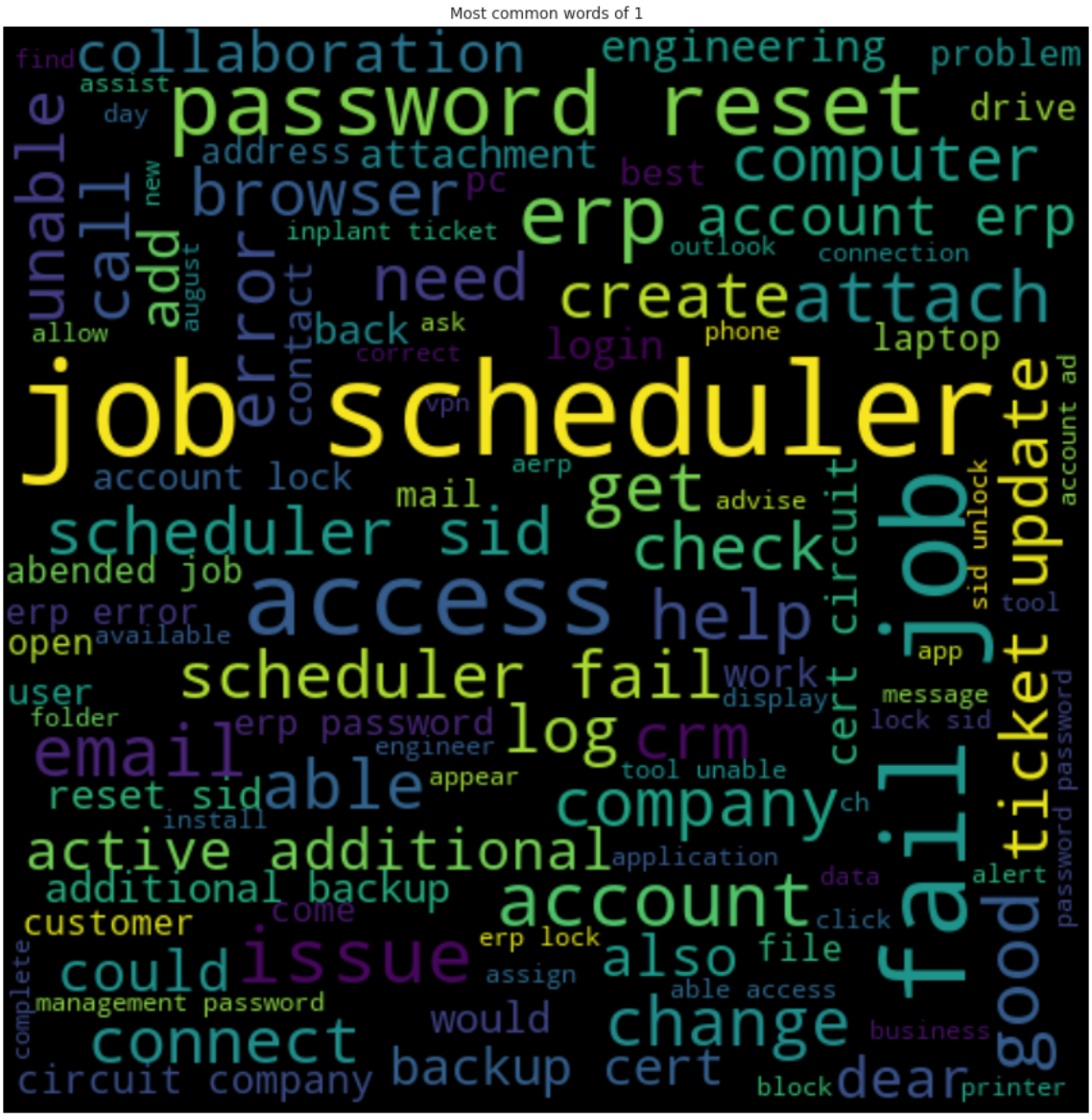
In [ ]:
```
df_tranlated_inc['cleaned_description'].head()
```

Out[ ]:
```
0    able ad advise caller check check confirm deta...
1    advise appear calendar correct etc kind meetin...
2                        good can not can not log vpn
3                          access hr page tool unable
4                                       error skype
Name: cleaned_description, dtype: object
```

In [ ]:
```
# Wordcloud for corpus after data cleaning, removal of stop words & lemmatization
from wordcloud import WordCloud
def generate_word_cloud(corpus,x):
    wordcloudImg4 = WordCloud(width = 500, height = 500,
                    background_color ='black',
                    stopwords=stop,
                    min_font_size = 10).generate(corpus)

    # plot the WordCloud image
    plt.figure(figsize = (12, 12), facecolor = None)
    plt.imshow(wordcloudImg4, interpolation="bilinear")
    plt.axis("off")
    plt.title("Most common words of {}".format(x))
    plt.tight_layout(pad = 0)
    plt.show()
```

In [ ]:
```
generate_word_cloud(str(df_tranlated_inc['cleaned_description']),1)
```



In [ ]:
```
valueCts = df_tranlated_inc['Assignment group'].value_counts().sort_values(ascending=False).index
valueCts
```

Out[ ]:
```
Index(['GRP_0', 'GRP_8', 'GRP_24', 'GRP_12', 'GRP_9', 'GRP_2', 'GRP_19',
       'GRP_3', 'GRP_6', 'GRP_13', 'GRP_10', 'GRP_5', 'GRP_14', 'GRP_25',
       'GRP_33', 'GRP_4', 'GRP_29', 'GRP_18', 'GRP_16', 'GRP_17', 'GRP_31',
       'GRP_7', 'GRP_34', 'GRP_26', 'GRP_40', 'GRP_28', 'GRP_41', 'GRP_15',
       'GRP_30', 'GRP_42', 'GRP_20', 'GRP_45', 'GRP_1', 'GRP_22', 'GRP_11',
       'GRP_21', 'GRP_47', 'GRP_62', 'GRP_23', 'GRP_48', 'GRP_60', 'GRP_39',
       'GRP_27', 'GRP_37', 'GRP_44', 'GRP_36', 'GRP_50', 'GRP_65', 'GRP_53',
       'GRP_52', 'GRP_51', 'GRP_55', 'GRP_49', 'GRP_46', 'GRP_59', 'GRP_43',
       'GRP_66', 'GRP_32', 'GRP_56', 'GRP_38', 'GRP_63', 'GRP_68', 'GRP_58',
       'GRP_72', 'GRP_69', 'GRP_57', 'GRP_54', 'GRP_71', 'GRP_70', 'GRP_35',
       'GRP_64', 'GRP_61', 'GRP_73', 'GRP_67'],
      dtype='object')
```

In [ ]:
```
# Generate Worldcloud
for i in range(16):
    generate_word_cloud(' '.join(df_tranlated_inc[df_tranlated_inc['Assignment group'] == valueCts[i]].cleaned_description.str.st
```

Observations

It is clear from the n-gram analysis and the word cloud that in the dataset, most issues are related to:

- password reset
- fail job & scheduler

Sample Analysis on GRP_0: It is the most frequent group and most of the tickets assigned to this group, shows us that this group deals with mostly the maintenance problems su
login issue, ticket update etc.

Maximum of the tickets from GRP_0 for human intervention can be reduced by putting automation scripts/mechanisms to help resolve these common maintenance issues. This w
service tickets which need human intervention and thereby saving the resource/hour efforts spend and reducing cost involved for man hours.

In [ ]:
```
df_tranlated_inc['num_wds'] = df_tranlated_inc['cleaned_description'].apply(lambda x: len(x.split()))
df_tranlated_inc['num_wds'].mean()
```

Out[ ]:
```
13.306588235294118
```

In [ ]:
```
print(df_tranlated_inc['num_wds'].max())
print(df_tranlated_inc['num_wds'].min())
```

```
469
0
```

In [ ]:
```
len(df_tranlated_inc[df_tranlated_inc['num_wds']==0])
```

Out[ ]:
```
36
```

Here we remove those records from our dataframe for which the no of words in the cleaned description is less than 2 words

Hence we have considered those records where the 'num_wds' is greater than 1

In [ ]:
```
df_tranlated_inc= df_tranlated_inc[df_tranlated_inc['num_wds']>1]
```

In [ ]:
```
df_tranlated_inc.shape
```

Out[ ]:
```
(8425, 4)
```

The new dataframe has 8424 records now.

76 records had no: of words less than 2 and hence they were removed.

In [ ]:
```
print(df_tranlated_inc['num_wds'].max())
print(df_tranlated_inc['num_wds'].min())
```

```
469
2
```

In [ ]:
```
def avg_word(sentence):
  words = sentence.split()
  return (sum(len(word) for word in words)/len(words))

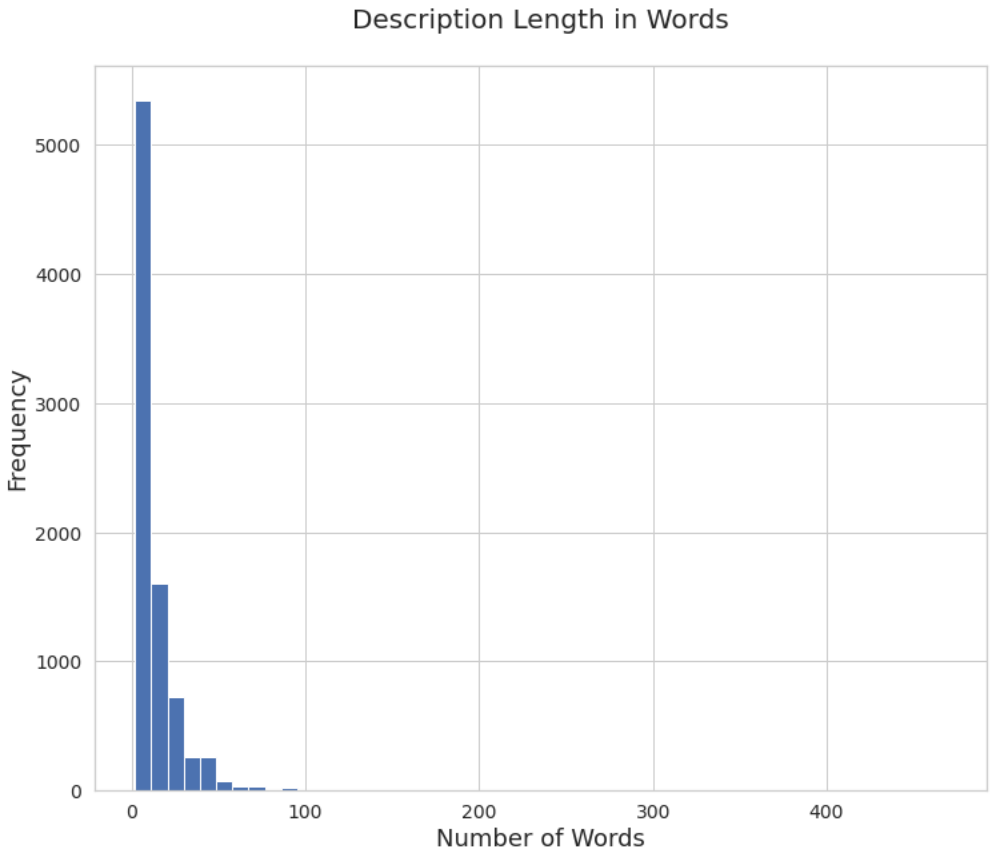

df_tranlated_inc['avg_word'] = df_tranlated_inc['cleaned_description'].apply(lambda x: avg_word(str(x)))
df_tranlated_inc.head()
```

Out[ ]:

	Assignment group	language	cleaned_description	num_wds	avg_word
0	GRP_0	en	able ad advise caller check check confirm deta...	18	5.555556
1	GRP_0	en	advise appear calendar correct etc kind meetin...	11	5.909091
2	GRP_0	en	good can not can not log vpn	7	3.142857
3	GRP_0	en	access hr page tool unable	5	4.400000
4	GRP_0	no	error skype	2	5.000000

Visualize a distribution of the description word counts to see how skewed our average might be by outliers. Let's generate another plot to take a look

In [ ]:
```
ax=df_tranlated_inc['num_wds'].plot(kind='hist', bins=50, fontsize=14, figsize=(12,10))
ax.set_title('Description Length in Words\n', fontsize=20)
ax.set_ylabel('Frequency', fontsize=18)
ax.set_xlabel('Number of Words', fontsize=18);
```



Number of unique words in each article

In [ ]:
```
df_tranlated_inc['uniq_wds'] = df_tranlated_inc['cleaned_description'].str.split().apply(lambda x: len(set(x)))
df_tranlated_inc['uniq_wds'].head()
```

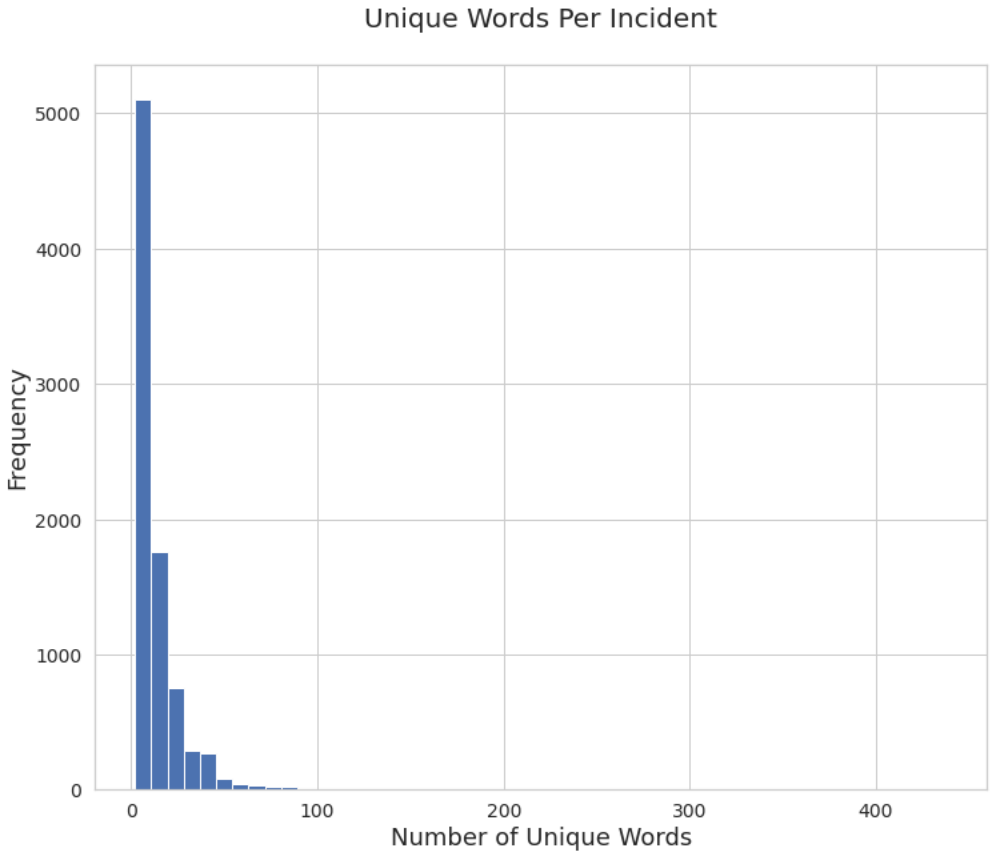
Out[ ]:
```
0    17
1    11
2     5
3     5
4     2
Name: uniq_wds, dtype: int64
```

average (mean) number of unique words per incident, and the minimum and maximum unique word counts.

In [ ]:
```
print("Mean: ",df_tranlated_inc['uniq_wds'].mean())
print("Min: ",df_tranlated_inc['uniq_wds'].min())
print("Max: ",df_tranlated_inc['uniq_wds'].max())
```

```
Mean:  13.12913946587537
Min:  2
Max:  438
```

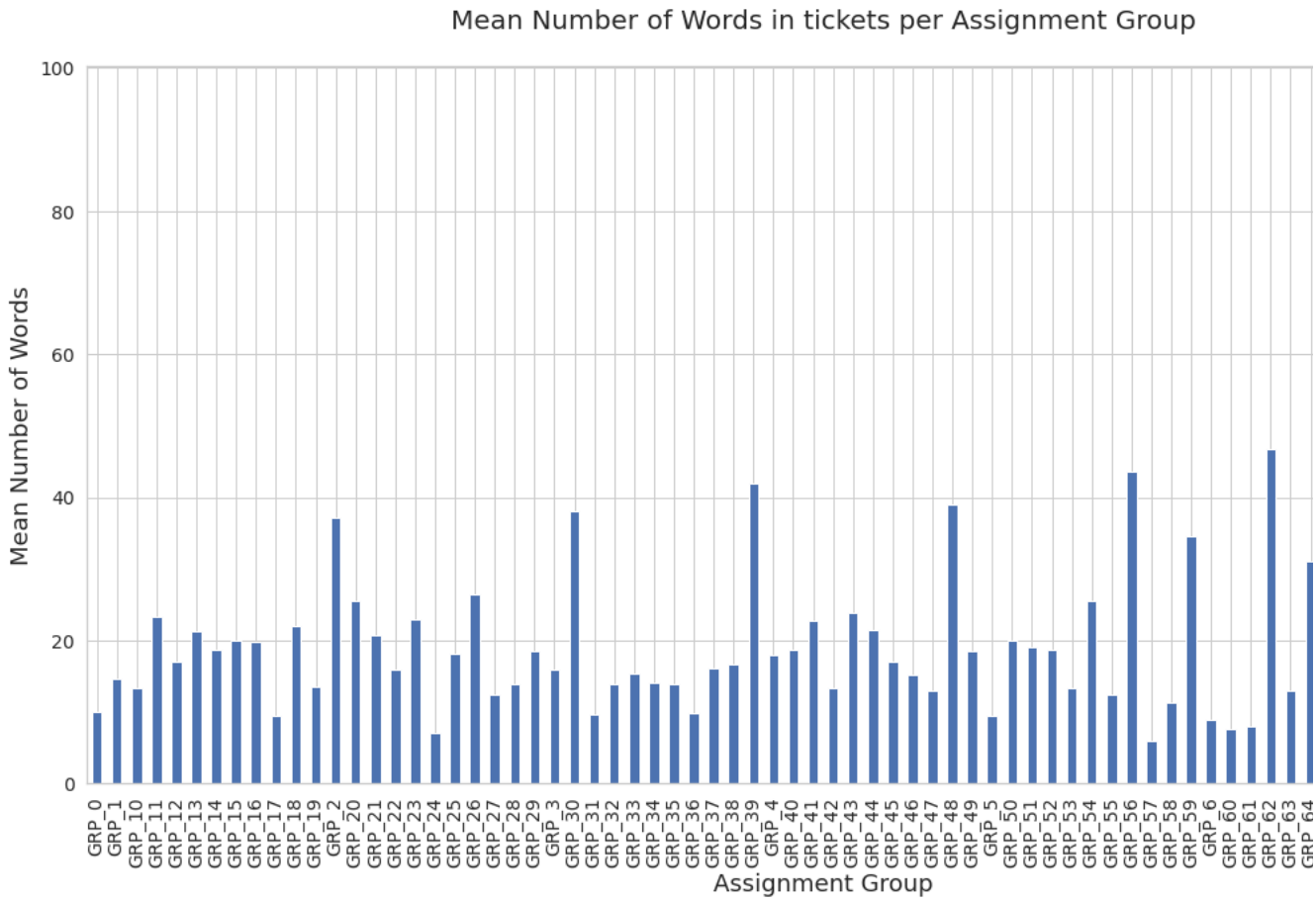
In [ ]:
```
ax=df_tranlated_inc['uniq_wds'].plot(kind='hist', bins=50, fontsize=14, figsize=(12,10))
ax.set_title('Unique Words Per Incident\n', fontsize=20)
ax.set_ylabel('Frequency', fontsize=18)
ax.set_xlabel('Number of Unique Words', fontsize=18);
```



When we plot this into a chart, we can see that while the distribution of unique words is not skewed..

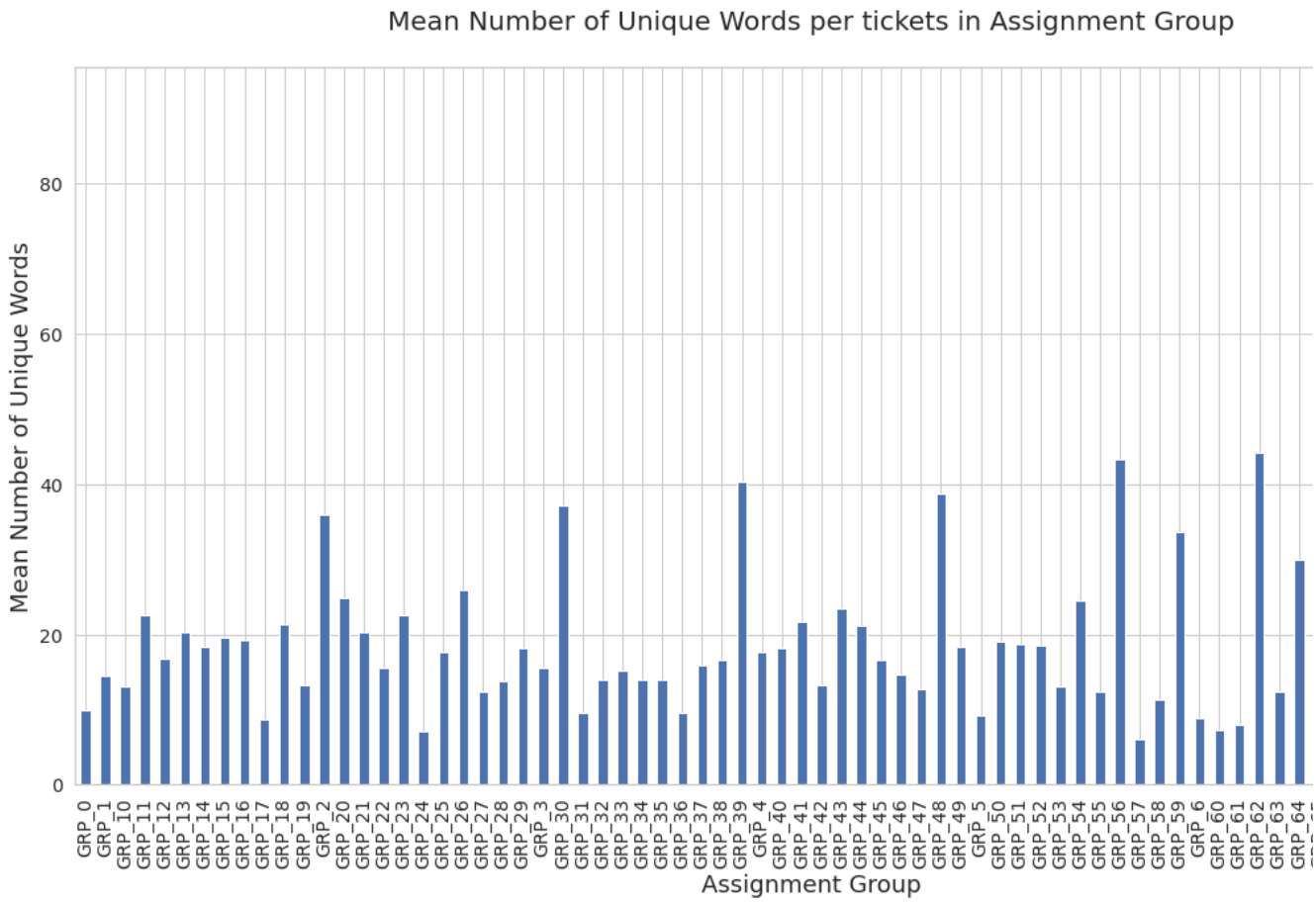
Mean Number of Words in tickets per Assignment Group

In [ ]:
```
assign_grps = df_tranlated_inc.groupby('Assignment group')
ax=assign_grps['num_wds'].aggregate(np.mean).plot(kind='bar', fontsize=14, figsize=(20,10))
ax.set_title('Mean Number of Words in tickets per Assignment Group\n', fontsize=20)
ax.set_ylabel('Mean Number of Words', fontsize=18)
ax.set_xlabel('Assignment Group', fontsize=18);
```



Mean Number of Unique Words in tickets per Assignment Group

In [ ]:
```
ax=assign_grps['uniq_wds'].aggregate(np.mean).plot(kind='bar', fontsize=14, figsize=(20,10))
ax.set_title('Mean Number of Unique Words per tickets in Assignment Group\n', fontsize=20)
ax.set_ylabel('Mean Number of Unique Words', fontsize=18)
ax.set_xlabel('Assignment Group', fontsize=18);
```



Finally, let's look at the most common words over the entire corpus.

In [ ]:
```
from collections import Counter
wd_counts = Counter()
for i, row in df_tranlated_inc.iterrows():
    wd_counts.update(row['cleaned_description'].split())

wd_counts.most_common(20)
```

Out[ ]:
```
[('password', 1181),
 ('erp', 1079),
 ('job', 1035),
 ('tool', 1009),
 ('issue', 1007),
 ('scheduler', 969),
 ('fail', 926),
 ('reset', 882),
 ('unable', 879),
 ('user', 878),
 ('work', 860),
 ('access', 745),
 ('sid', 741),
 ('need', 736),
 ('error', 734),
 ('account', 693),
 ('company', 671),
 ('ticket', 644),
 ('help', 627),
 ('get', 625)]
```

In [ ]:
```
df_tranlated_inc.tail()
```

Out[ ]:

	Assignment group	language	cleaned_description	num_wds	avg_word	uniq_wds
8495	GRP_29	en	advise afternoon come email good mail receivin...	9	5.222222	9
8496	GRP_0	en	issue software telephony	3	7.333333	3
8497	GRP_0	en	password pedxruyf reset tifpdchb vip window	6	6.333333	6
8498	GRP_62	en	access adjustment drawer e finish funcionando ...	12	6.000000	12
8499	GRP_49	de	area can not cnc different open pc program sev...	10	4.600000	10

Tokenization

Tokenization is a process that splits an input sequence into so-called tokens where the tokens can be a word, sentence, paragraph etc.

In [ ]:
```
import nltk
# Tokenizing the training and the test set
tokenizer = nltk.tokenize.RegexpTokenizer(r'\w+')
df_tranlated_inc['token_desc'] = df_tranlated_inc['cleaned_description'].apply(lambda x: tokenizer.tokenize(x))
```

In [ ]:
```
df_tranlated_inc['token_desc'].head()
```

Out[ ]:
```
0    [able, ad, advise, caller, check, check, confi...
1    [advise, appear, calendar, correct, etc, kind,...
2                 [good, can, not, can, not, log, vpn]
3                     [access, hr, page, tool, unable]
4                                    [error, skype]
Name: token_desc, dtype: object
```

In [ ]:
```
# After preprocessing, the text format
def combine_text(list_of_text):
    '''Takes a list of text and combines them into one large chunk of text.'''
    combined_text = ' '.join(list_of_text)
    return combined_text

df_tranlated_inc['token_desc'] = df_tranlated_inc['token_desc'].apply(lambda x : combine_text(x))
```

In [ ]:
```
df_tranlated_inc.describe().T
```

Out[ ]:

	count	mean	std	min	25%	50%	75%	max
num_wds	8425.0	13.420415	20.282487	2.0	4.000000	8.000000	16.000000	469.000000
avg_word	8425.0	5.707930	0.923351	2.5	5.173913	5.636364	6.294118	10.970588
uniq_wds	8425.0	13.129139	19.345166	2.0	4.000000	8.000000	16.000000	438.000000

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

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 8425 entries, 0 to 8499
Data columns (total 7 columns):
 #   Column               Non-Null Count  Dtype  
---  ------               --------------  -----  
 0   Assignment group     8425 non-null   object 
 1   language             8425 non-null   object 
 2   cleaned_description  8425 non-null   object 
 3   num_wds              8425 non-null   int64  
 4   avg_word             8425 non-null   float64
 5   uniq_wds             8425 non-null   int64  
 6   token_desc           8425 non-null   object 
dtypes: float64(1), int64(2), object(4)
memory usage: 526.6+ KB
```

In [ ]:
```
df_tranlated_inc.to_csv("cleaned_data.csv",index=False)
```

In [ ]:
```
df_tranlated_inc = pd.read_csv('cleaned_data.csv')
df_tranlated_inc.head()
```

Out[ ]:

	Assignment group	language	cleaned_description	num_wds	avg_word	uniq_wds	token_desc
0	GRP_0	en	able ad advise caller check check confirm deta...	18	5.555556	17	able ad advise caller check check confirm deta...
1	GRP_0	en	advise appear calendar correct etc kind meetin...	11	5.909091	11	advise appear calendar correct etc kind meetin...
2	GRP_0	en	good can not can not log vpn	7	3.142857	5	good can not can not log vpn
3	GRP_0	en	access hr page tool unable	5	4.400000	5	access hr page tool unable
4	GRP_0	no	error skype	2	5.000000	2	error skype

Let's create a copy of the clean df for modeling purpose.

In [ ]:
```
ticket_df = df_tranlated_inc
ticket_df.head()
```

Out[ ]:

	Assignment group	language	cleaned_description	num_wds	avg_word	uniq_wds	token_desc
0	GRP_0	en	able ad advise caller check check confirm deta...	18	5.555556	17	able ad advise caller check check confirm deta...
1	GRP_0	en	advise appear calendar correct etc kind meetin...	11	5.909091	11	advise appear calendar correct etc kind meetin...
2	GRP_0	en	good can not can not log vpn	7	3.142857	5	good can not can not log vpn
3	GRP_0	en	access hr page tool unable	5	4.400000	5	access hr page tool unable
4	GRP_0	no	error skype	2	5.000000	2	error skype

In [ ]:
```
#Recalling the top 10 grouops with highest ticket count
df_top_10 = ticket_df['Assignment group'].value_counts().nlargest(10).reset_index()
df_top_10
```

Out[ ]:

	index	Assignment group
0	GRP_0	3970
1	GRP_8	661
2	GRP_24	289
3	GRP_12	257
4	GRP_9	252
5	GRP_2	241
6	GRP_19	215
7	GRP_3	200
8	GRP_6	184
9	GRP_13	145

Topic Modeling & LDA

What is topic modelling?

Topic modeling provides methods for automatically organizing, understanding, searching, and summarizing large electronic archives. It can help with the following:

- discovering the hidden themes in the collection.
- classifying the documents into the discovered themes.
- using the classification to organize/ summarize/ search the documents.

For example, let's say a document belongs to the topics food, dogs and health. So if a user queries "dog food", they might find the above-mentioned document relevant because topics). We are able to figure its relevance with respect to the query without even going through the entire document.

Therefore, by annotating the document, based on the topics predicted by the modeling method, we are able to optimize our search process.

Topic Modeling

Here for topic modeliing, we are using **Genism**.

Gensim = "Generate Similar" is a popular open source natural language processing (NLP) library used for unsupervised topic modeling. It uses top academic models and moder perform various complex tasks such as −

- Building document or word vectors
- Corpora
- Performing topic identification
- Performing document comparison (retrieving semantically similar documents)
- Analysing plain-text documents for semantic structure

Apart from performing the above complex tasks, Gensim, implemented in Python and Cython, is designed to handle large text collections using data streaming as well as increm different from those machine learning software packages that target only in-memory processing.

In [ ]:
```
# Gensim
import gensim
import gensim.corpora as corpora
#Remove stemming(snowball stemming) add lemmatistaion using simple_process from gensim
from gensim.utils import simple_preprocess
from gensim.models.ldamodel import LdaModel
from gensim.models import CoherenceModel

# spacy for lemmatization
import spacy

# Plotting tools
import pyLDAvis
import pyLDAvis.gensim
```

In [ ]:
```
#to process the simple_process gensim package as input needed as string
combined_text=ticket_df.cleaned_description.values.tolist()
#Convert the combined text from each sentense to the words. use of simple_process as it tokenize() internally
def sent_to_words(sentences):
    for sentence in sentences:
        yield(gensim.utils.simple_preprocess(str(sentence), deacc=True))  # deacc=True removes punctuations

data_words = list(sent_to_words(combined_text))
```

Note : Bigram is 2 consecutive words in a sentence. Trigram is 3 consecutive words in a sentence.

In [ ]:
```
# Build the bigram and trigram models
bigram = gensim.models.Phrases(data_words, min_count=5, threshold=100) # higher threshold fewer phrases.
trigram = gensim.models.Phrases(bigram[data_words], threshold=100)

# Faster way to get a sentence clubbed as a trigram/bigram
bigram_mod = gensim.models.phrases.Phraser(bigram)
trigram_mod = gensim.models.phrases.Phraser(trigram)
def make_bigrams(texts):
    return [bigram_mod[doc] for doc in texts]

def make_trigrams(texts):
    return [trigram_mod[bigram_mod[doc]] for doc in texts]
# Form Bigrams
data_words_bigrams = make_bigrams(data_words)
wordclouds=' '.join(map(str, data_words_bigrams))
```

In [ ]:
```
#Copying to new dataframe to create wordclouds on target class
new_df = ticket_df.copy()
new_df['words'] = data_words_bigrams
```

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

Out[ ]:

	Assignment group	language	cleaned_description	num_wds	avg_word	uniq_wds	token_desc	
0	GRP_0	en	able ad advise caller check check confirm deta...	18	5.555556	17	able ad advise caller check check confirm deta...	[able, a
1	GRP_0	en	advise appear calendar correct etc kind meetin...	11	5.909091	11	advise appear calendar correct etc kind meetin...	[advise
2	GRP_0	en	good can not can not log vpn	7	3.142857	5	good can not can not log vpn	
3	GRP_0	en	access hr page tool unable	5	4.400000	5	access hr page tool unable	
4	GRP_0	no	error skype	2	5.000000	2	error skype	

In [ ]:
```
new_df.tail()
```

Out[ ]:

	Assignment group	language	cleaned_description	num_wds	avg_word	uniq_wds	token_desc	
8420	GRP_29	en	advise afternoon come email good mail receivin...	9	5.222222	9	advise afternoon come email good mail receivin...	[a
8421	GRP_0	en	issue software telephony	3	7.333333	3	issue software telephony	
8422	GRP_0	en	password pedxruyf reset tifpdchb vip window	6	6.333333	6	password pedxruyf reset tifpdchb vip window	
8423	GRP_62	en	access adjustment drawer e finish funcionando ...	12	6.000000	12	access adjustment drawer e finish funcionando ...	[a
8424	GRP_49	de	area can not cnc different open pc program sev...	10	4.600000	10	area can not cnc different open pc program sev...	

In [ ]:
```
#Sorting based on frequency of target class Assignment group
value = new_df['Assignment group'].value_counts().sort_values(ascending=False).index
value
```

Out[ ]:
```
Index(['GRP_0', 'GRP_8', 'GRP_24', 'GRP_12', 'GRP_9', 'GRP_2', 'GRP_19',
       'GRP_3', 'GRP_6', 'GRP_13', 'GRP_10', 'GRP_5', 'GRP_14', 'GRP_25',
       'GRP_33', 'GRP_4', 'GRP_29', 'GRP_18', 'GRP_16', 'GRP_17', 'GRP_7',
       'GRP_34', 'GRP_26', 'GRP_31', 'GRP_40', 'GRP_28', 'GRP_41', 'GRP_15',
       'GRP_42', 'GRP_20', 'GRP_45', 'GRP_22', 'GRP_1', 'GRP_11', 'GRP_21',
       'GRP_47', 'GRP_62', 'GRP_23', 'GRP_60', 'GRP_39', 'GRP_27', 'GRP_37',
       'GRP_36', 'GRP_44', 'GRP_50', 'GRP_65', 'GRP_53', 'GRP_52', 'GRP_30',
       'GRP_55', 'GRP_51', 'GRP_46', 'GRP_59', 'GRP_49', 'GRP_43', 'GRP_48',
       'GRP_32', 'GRP_66', 'GRP_63', 'GRP_56', 'GRP_38', 'GRP_58', 'GRP_68',
       'GRP_71', 'GRP_54', 'GRP_72', 'GRP_69', 'GRP_57', 'GRP_70', 'GRP_35',
       'GRP_64', 'GRP_73', 'GRP_67', 'GRP_61'],
      dtype='object')
```

LDA - Latent Dirichlet Allocation

It is one of the most popular topic modeling methods. Each document is made up of various words, and each topic also has various words belonging to it. **The aim of LDA is to based on the words in it.**

In [ ]:
```
# Create Dictionary
id2word = corpora.Dictionary(data_words_bigrams)

# Create Corpus from post clean data
texts = data_words_bigrams

# Term Document Frequency and Bag of words
corpus = [id2word.doc2bow(text) for text in texts]

# Build LDA model
lda_model = LdaModel(corpus=corpus,id2word=id2word,num_topics=7,random_state=200,update_every=1,chunksize=800,passes=10,alpha='au

#top 7 topics from the corpus
from pprint import pprint
pprint(lda_model.print_topics())
doc_lda = lda_model[corpus]
texts=data_words_bigrams

# Compute Perplexity
print('\nPerplexity: ', lda_model.log_perplexity(corpus))  # a measure of how good the model is. lower the better.
```

```
[(0,
  '0.033*"account" + 0.019*"lock" + 0.014*"new" + 0.013*"user" + 0.012*"check" '
  '+ 0.012*"name" + 0.012*"exurcwkm" + 0.011*"window" + 0.010*"ad" + '
  '0.010*"confirm"'),
 (1,
  '0.059*"unable" + 0.030*"outlook" + 0.027*"login" + 0.024*"connect" + '
  '0.019*"microsoft" + 0.018*"internet" + 0.017*"issue" + 0.015*"skype" + '
  '0.014*"user" + 0.014*"access"'),
 (2,
  '0.028*"company" + 0.023*"platform" + 0.022*"collaboration" + 0.020*"work" + '
  '0.020*"email" + 0.019*"ticket" + 0.018*"yes" + 0.017*"reset" + '
  '0.016*"global_gsc" + 0.016*"start"'),
 (3,
  '0.017*"error" + 0.015*"issue" + 0.014*"work" + 0.013*"need" + 0.013*"get" + '
  '0.012*"access" + 0.011*"erp" + 0.011*"help" + 0.010*"see" + 0.010*"tool"'),
 (4,
  '0.080*"password" + 0.078*"job" + 0.073*"scheduler" + 0.054*"reset" + '
  '0.050*"fail" + 0.049*"sid" + 0.040*"erp" + 0.023*"account" + 0.022*"tool" + '
  '0.020*"abended"'),
 (5,
  '0.012*"hostname" + 0.007*"type" + 0.007*"print" + 0.007*"would" + '
  '0.006*"mit" + 0.006*"notification" + 0.006*"printer" + 0.005*"name" + '
  '0.005*"eu" + 0.005*"ticket"'),
 (6,
  '0.036*"update" + 0.033*"ticket" + 0.011*"august" + 0.007*"complete" + '
  '0.006*"indicate" + 0.006*"tool" + 0.006*"mail" + 0.006*"query" + '
  '0.006*"company" + 0.005*"engineering"')]

Perplexity:  -7.655203072168261
```

In natural language processing, perplexity is a way of evaluating language models.

A language model is a probability distribution over entire sentences or texts.

A low perplexity indicates the probability distribution is good at predicting the sample.

In [ ]:
```
# Compute Coherence Score
coherence_model_lda = CoherenceModel(model=lda_model, texts=texts, dictionary=id2word, coherence='c_v')
coherence_lda = coherence_model_lda.get_coherence()
print('\nCoherence Score: ', coherence_lda)
```

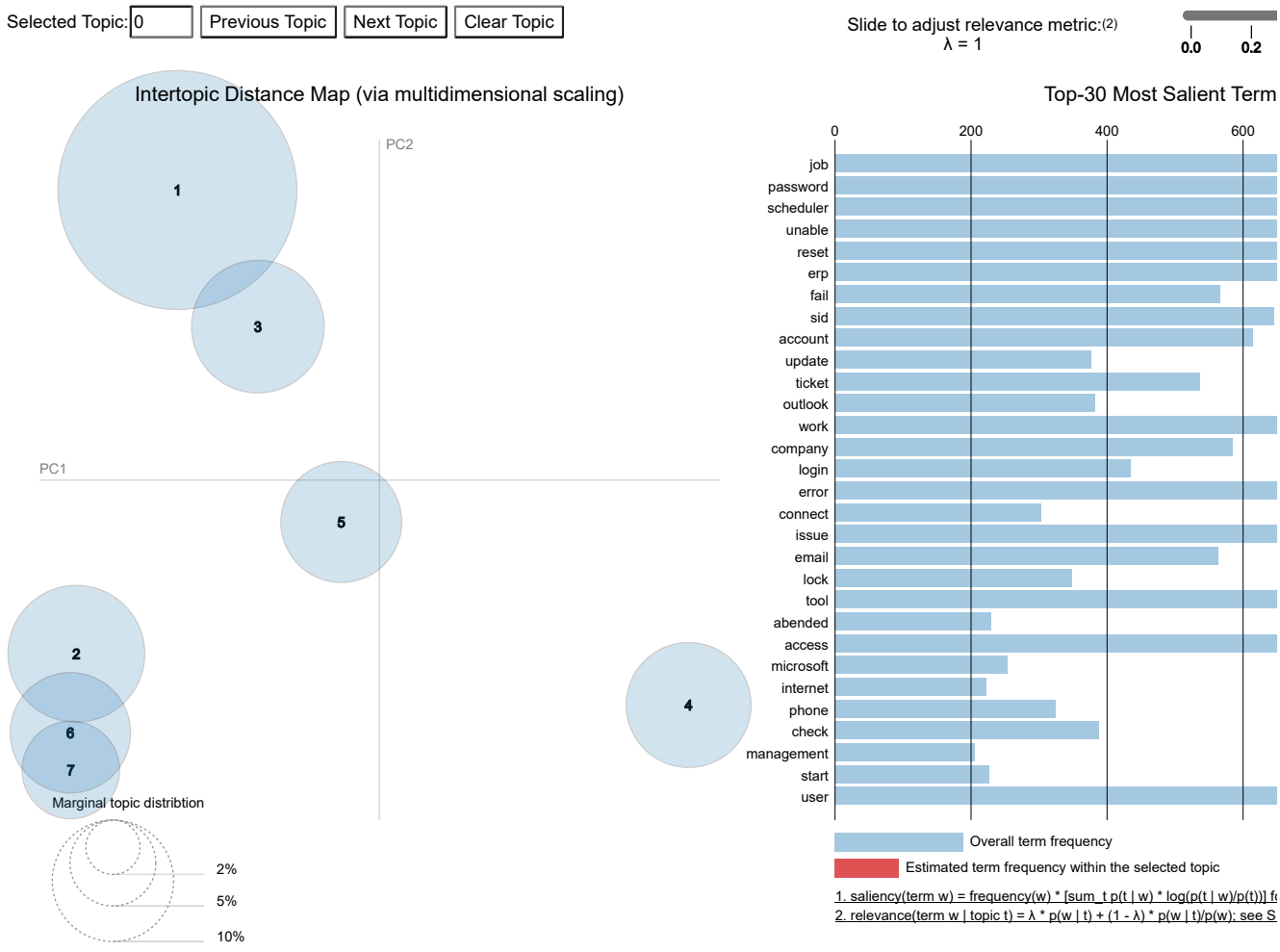
```
Coherence Score:  0.4524751106168094
```

What is pyLDavis?

pyLDAvis is designed to help users interpret the topics in a topic model that has been fit to a corpus of text data. The package extracts information from a fitted LDA topic model visualization.

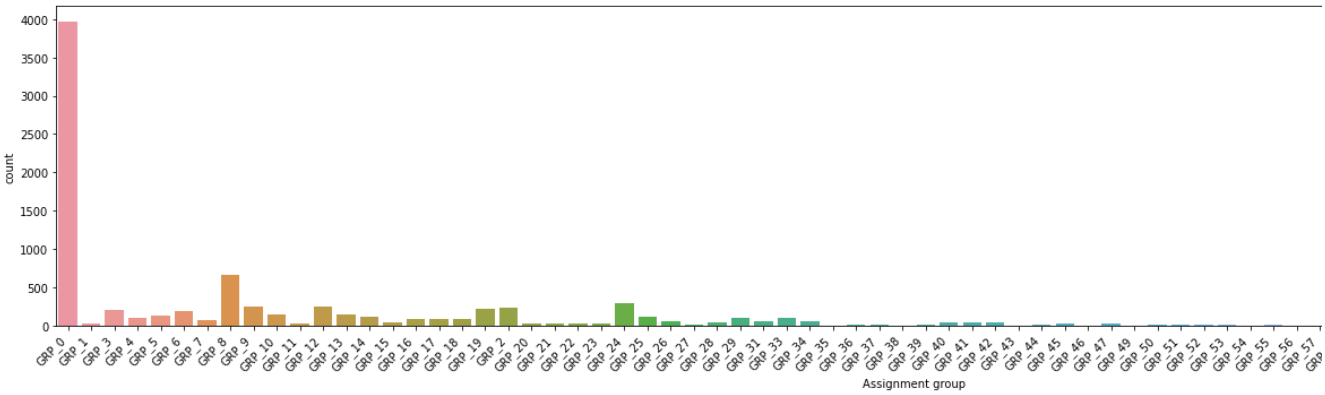
In [ ]:
```
# Visualize the topics
pyLDAvis.enable_notebook()
LDAvis_prepared = pyLDAvis.gensim.prepare(lda_model, corpus, id2word)
LDAvis_prepared
```

Out[ ]:



Visualize data distribution in the dataset

In [ ]:
```
#Lets get the visual representation
descending_order = ticket_df['Assignment group'].value_counts().sort_values(ascending=False).index
plt.subplots(figsize=(22,5))
ax=sns.countplot(x='Assignment group', data=ticket_df)
ax.set_xticklabels(ax.get_xticklabels(), rotation=45, ha="right")
plt.tight_layout()
plt.show()
```



Even after data cleaning process we can observe a lot of imbalance in the data distribution.

This imbalance in the dataset demands for further processing of the dataset with proper measures like resampling to build better performing prediction models.

In [ ]:
```
# shape before resampling
ticket_df.shape
```

Out[ ]: (8425, 7)

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

Out[ ]:

	Assignment group	language	cleaned_description	num_wds	avg_word	uniq_wds	token_desc
0	GRP_0	en	able ad advise caller check check confirm deta...	18	5.555556	17	able ad advise caller check check confirm deta...
1	GRP_0	en	advise appear calendar correct etc kind meetin...	11	5.909091	11	advise appear calendar correct etc kind meetin...
2	GRP_0	en	good can not can not log vpn	7	3.142857	5	good can not can not log vpn
3	GRP_0	en	access hr page tool unable	5	4.400000	5	access hr page tool unable
4	GRP_0	no	error skype	2	5.000000	2	error skype

Build Models & Evaluate

Overview of this step:

- Traditional machine learning algorithms meant for classification problem solving will be tried against the vectorized features generated out of TF-IDF.
- Comparison of the model accuracy for selecting best performing model.
- Analyse & check for possible improvements, if required.

In [ ]:
```
import warnings
# Traditional Modeling
from sklearn.naive_bayes import MultinomialNB
from sklearn.neighbors import KNeighborsClassifier
from sklearn.pipeline import Pipeline
from sklearn.svm import SVC, LinearSVC
from sklearn.tree import DecisionTreeClassifier
from sklearn.linear_model import LogisticRegression
import xgboost as xgb
from sklearn.ensemble import AdaBoostClassifier, BaggingClassifier
from xgboost.sklearn import XGBClassifier

# Tools & Evaluation metrics
from sklearn import metrics
from sklearn.metrics import confusion_matrix, classification_report, auc, roc_auc_score
from sklearn.metrics import roc_curve, accuracy_score, precision_recall_curve, f1_score, recall_score, precision_score
from sklearn.model_selection import train_test_split

from sklearn.feature_extraction.text import CountVectorizer, TfidfVectorizer, TfidfTransformer
```

In [ ]:
```
def multiclass_logloss(actual, predicted, eps=1e-15):
    """Multi class version of Logarithmic Loss metric.
    :param actual: Array containing the actual target classes
    :param predicted: Matrix with class predictions, one probability per class
    """
    # Convert 'actual' to a binary array if it's not already:
    if len(actual.shape) == 1:
        actual2 = np.zeros((actual.shape[0], predicted.shape[1]))
        for i, val in enumerate(actual):
            actual2[i, val] = 1
        actual = actual2

    clip = np.clip(predicted, eps, 1 - eps)
    rows = actual.shape[0]
    vsota = np.sum(actual * np.log(clip))
    return -1.0 / rows * vsota
```

In [ ]:
```
log_cols=["Classifier","Training accuracy","Testing accuracy","f1-score","Recall"]
log = pd.DataFrame(columns=log_cols)

emptyArr = []
cbArr = []
```

In [ ]:
```
import sys
# A method to train and test the model
def run_classification(Prediction_model, X_train, X_test, y_train, y_test, cbArr, arch_name=None, pipelineRequired=True, isDeepMo
  clf = Prediction_model

  if pipelineRequired :
     clf = Pipeline([('vect', CountVectorizer()), ('tfidf', TfidfTransformer()), ('clf', Prediction_model),])

  if isDeepModel :
     if cbArr:
       clf.fit(X_train, y_train, validation_data=(X_test, y_test),epochs=10, batch_size=128, verbose=True, callbacks=cbArr)
     else:
       clf.fit(X_train, y_train, validation_data=(X_test, y_test),epochs=10, batch_size=128,verbose=1)
     # predict from the classifier
     y_pred = clf.predict(X_test)
     y_predOrginal = clf
     y_pred = np.argmax(y_pred, axis=1)
     y_train_pred = clf.predict(X_train)
     y_train_pred = np.argmax(y_train_pred, axis=1)
  else :
    clf.fit(X_train, y_train)
    # predict from the classifier
    y_pred = clf.predict(X_test)
    y_predOrginal = clf
    y_train_pred = clf.predict(X_train)

  np.set_printoptions(threshold=np.inf)
  print('Prediction Model:', Prediction_model)
  print('-'*80)
  print('Training accuracy: %.2f%%' % (accuracy_score(y_train,y_train_pred) * 100))
  print('Testing accuracy: %.2f%%' % (accuracy_score(y_test, y_pred) * 100))
  print('-'*80)
  #print('Confusion matrix:\n %s' % (confusion_matrix(y_test, y_pred)))
  cm = confusion_matrix(y_test, y_pred)
  print(cm.shape)
  print('Confusion Matrix:\n')
  print(cm)
  print("\n")
  print('-'*80)
  print('Classification report:\n %s' % (classification_report(y_test, y_pred)))
  log_entry = []
  nameVar = ""
  nameVar = str(Prediction_model)
  predModName = []
  predModName = nameVar.split("(")[0]
  log_entry = pd.DataFrame([[predModName,accuracy_score(y_train,y_train_pred),accuracy_score(y_test,y_pred),f1_score(y_test,y_pre
core(y_test,y_pred,average='weighted')]], columns=log_cols)
  return log_entry, y_predOrginal
  # return log.append(log_entry)
```

In [ ]:
```
df_inc_sample2 = ticket_df[ticket_df['Assignment group'].map(ticket_df['Assignment group'].value_counts()) > 0]
x2 = ticket_df['cleaned_description']
y2 = ticket_df['Assignment group']
```

Traditional ML Models - without resampling

Traditional ML Models considered:

- Multinomial Naive Bayes
- K Nearest neighbor (KNN)
- Support Vector Machine
- Decision Tree
- Random Forest
- Logistic Regression
- Ada Boost Classifier
- Bagging Classifier
- XG Boost Classifier

In [ ]:
```
# Create training and test datasets with 80:20 ratio
X_train2, X_test2, y_train2, y_test2 = train_test_split(x2,
                                                        y2,
                                                        test_size=0.20,
                                                        random_state=13)
print('\033[1mShape of the training set:\033[0m', X_train2.shape, X_test2.shape)
print('\033[1mShape of the test set:\033[0m', y_train2.shape, y_test2.shape)
```

```
Shape of the training set: (6740,) (1685,)
Shape of the test set: (6740,) (1685,)
```

In [ ]:
```
# Copy of Original X_train2 & X_test2
X_trainOrg2 = X_train2
X_testOrg2 = X_test2
# Copy of Original of y_train2 & y_test2
y_trainOrg2 = y_train2
y_testOrg2 = y_test2
```

In [ ]:
```
from sklearn import preprocessing
encoder = preprocessing.LabelEncoder()
# encoding train labels
y_train2 = encoder.fit_transform(y_trainOrg2)
y_test2 = encoder.fit_transform(y_testOrg2)
```

Naive Bayes

Naive Bayes method is a probabilistic model on set of supervised learning algorithms based on applying Bayes' theorem with the "naive" assumption of conditional independenc given the value of the class variable.Naive Bayes classifier can be extremely fast compared to more sophisticated methods.

In [ ]:
```
log_cols3=["Classifier","Training accuracy","Testing accuracy","f1-score","Recall"]
log3 = pd.DataFrame(columns=log_cols3)

emptyArr = []
cbArr = []
```

In [ ]:
```
logTmp = []
logTmp, y_pred_MultinomialNB2 = run_classification(MultinomialNB(), X_train2, X_test2, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "Naive Bayes Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: MultinomialNB(alpha=1.0, class_prior=None, fit_prior=True)
----------------------------------------------------------------------------
Training accuracy: 57.61%
Testing accuracy: 48.19%
----------------------------------------------------------------------------
(64, 64)
Confusion Matrix:

[[781   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2]
 [ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0  11]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 35   0   0   0   7   0   0   0   0   0   0   0   3   0   0   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   3]
 [ 19   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1]
 [ 17   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 16   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1]
 [ 56   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 42   0   0   0   0   0   0   0   0   0   0   0   6   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 35   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  18
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 15   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 26   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1]
[ 31   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 19   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   2]
[  3   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 22   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   4]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   3]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
```

```
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0  21]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0  23]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 11   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   2   0   0   0   0   0   0   0 129]
 [ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0  46]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]]


---------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.56      1.00      0.72       781
           1       0.00      0.00      0.00         6
           2       0.00      0.00      0.00        24
           3       0.00      0.00      0.00         3
           4       0.58      0.14      0.23        49
           5       0.00      0.00      0.00        20
           6       0.00      0.00      0.00        17
           7       0.00      0.00      0.00        13
           8       0.00      0.00      0.00        14
           9       0.00      0.00      0.00        16
          10       0.00      0.00      0.00        12
          11       0.00      0.00      0.00        56
          12       0.43      0.12      0.19        48
          13       0.00      0.00      0.00         9
          14       0.00      0.00      0.00        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.95      0.34      0.50        53
          18       0.00      0.00      0.00        15
          19       0.00      0.00      0.00        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.00      0.00      0.00        27
          23       0.00      0.00      0.00        32
          24       0.00      0.00      0.00         1
          25       0.00      0.00      0.00        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
          59       0.00      0.00      0.00        11
          60       0.00      0.00      0.00         1
          61       0.00      0.00      0.00       145
          62       0.00      0.00      0.00        60
          69       0.00      0.00      0.00         0

    accuracy                           0.48      1685
   macro avg       0.04      0.03      0.03      1685
weighted avg       0.32      0.48      0.36      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899

K-Nearest Neighbor (KNN)- Without Sampling

The principle behind nearest neighbor methods is to find a predefined number of training samples closest in distance to the new point, and predict the label from these.Being a n successful in classification situations where the decision boundary is very irregular.

In [ ]:
```
logTmp = []
logTmp, y_pred_KNeighbors2 = run_classification(KNeighborsClassifier(), X_train2, X_test2, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "KNN Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',
                     metric_params=None, n_jobs=None, n_neighbors=5, p=2,
                     weights='uniform')
--------------------------------------------------------------------------------
Training accuracy: 70.65%
Testing accuracy: 54.12%
--------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[769   0   0   0   3   0   0   0   0   0   1   1   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2   0   1]
 [  0   2   0   0   1   0   0   0   0   0   0   1   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  5   0  13   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   4   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 20   0   0   0  15   0   0   0   0   0   0   1   3   0   0   0   0   2
    1   0   0   0   0   2   0   0   0   0   2   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   2   0]
 [  9   0   0   0   1   7   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   0]
 [  9   0   0   0   0   0   8   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 12   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 12   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 16   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   1   0   1   0   0   0   0   0   4   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [ 42   0   0   0   0   0   1   0   0   0   0   8   0   0   0   0   0   0
    2   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 27   0   0   0   0   0   0   0   0   0   1   1  18   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  9   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  7   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0  45
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    6   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
```

```
[ 11   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 13   0   1   0   0   1   1   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   1   0]
[ 23   0   0   0   0   0   0   0   0   0   0   4   1   0   0   0   0   0
   0   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   2   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   1
   1   0   0   0   0   0   0   0   0   4   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  9   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[ 17   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   6   0]
[  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   4   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   1   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   1]
[  0   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0  12   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0  10   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   4   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0  10   0   0   0   0   0   0   0   0  17   0]
[  2   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   1   4   0   5   0   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   1   0   0
   0   0   0   0   0   0   0   0   4   0   0   0   0   0   0   0   0   0
   0   2   0   0   0   0   0   0   0   0 121   1]
```

```
 [ 11   0   3   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0  40   5]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.66      0.98      0.79       781
           1       0.33      0.33      0.33         6
           2       0.48      0.54      0.51        24
           3       0.00      0.00      0.00         3
           4       0.45      0.31      0.37        49
           5       0.58      0.35      0.44        20
           6       0.73      0.47      0.57        17
           7       0.00      0.00      0.00        13
           8       1.00      0.07      0.13        14
           9       0.00      0.00      0.00        16
          10       0.50      0.33      0.40        12
          11       0.42      0.14      0.21        56
          12       0.56      0.38      0.45        48
          13       0.00      0.00      0.00         9
          14       0.00      0.00      0.00        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.88      0.85      0.87        53
          18       0.60      0.40      0.48        15
          19       1.00      0.08      0.14        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.73      0.30      0.42        27
          23       0.25      0.09      0.14        32
          24       1.00      1.00      1.00         1
          25       1.00      0.18      0.31        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       1.00      0.11      0.20         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
          59       0.00      0.00      0.00        11
          60       0.00      0.00      0.00         1
          61       0.00      0.00      0.00       145
          62       0.00      0.00      0.00        60
          64       0.00      0.00      0.00         0
```

```
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.54      1685
       macro avg       0.18      0.10      0.12      1685
    weighted avg       0.45      0.54      0.47      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246

Support Vector Machine (SVM)- Without Sampling

Support vector machines (SVMs) are a set of supervised learning methods used for classification, regression and outliers detection.

Linear SVM

The algorithm creates a line or a hyperplane which separates the data into classes.

The advantages of support vector machines are:

- Effective in high dimensional spaces.
- Still effective in cases where number of dimensions is greater than the number of samples.
- Uses a subset of training points in the decision function (called support vectors), so it is also memory efficient.
- Versatile: different Kernel functions can be specified for the decision function.

In [ ]:
```
# SVM with Linear kernel
logTmp = []
logTmp, y_pred_LinearSVC2 = run_classification(LinearSVC(), X_train2, X_test2, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "Linear SVM Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: LinearSVC(C=1.0, class_weight=None, dual=True, fit_intercept=True,
          intercept_scaling=1, loss='squared_hinge', max_iter=1000,
          multi_class='ovr', penalty='l2', random_state=None, tol=0.0001,
          verbose=0)
--------------------------------------------------------------------------------
Training accuracy: 92.97%
Testing accuracy: 56.26%
--------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[743   0   1   0   6   1   2   0   0   0   1   5   2   1   1   1   0   2
    0   1   0   0   0   6   0   0   0   0   0   0   0   0   1   1   0
    1   0   0   0   0   0   0   0   0   1   0   0   0   0   1   0   0   0
    0   1   0   0   0   0   0   0   0   2   0   0]
 [  1   2   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  2   0  15   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 11   0   0   0  21   0   0   0   1   0   0   1   6   0   0   0   0   3
    1   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  2   0   0   0   0  17   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  4   0   0   0   0   0   9   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   1   0   0   0   0   0   0   0   1   1]
 [  6   0   0   0   0   1   0   4   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   1   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 13   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0  14   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   1   0   0   0   0   5   0   0   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   1]
 [ 35   0   0   0   0   1   1   0   0   1   0  12   0   0   0   0   0   0
    1   0   0   0   0   3   0   0   0   1   0   0   0   0   0   1   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 23   0   0   0   0   0   0   0   1   0   1   1  20   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0
    0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   1   0   0   0   0   2   0   1   0   0   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0  45
    0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  9   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   2   0   0   2   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0  15   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[ 11   0   0   0   1   0   0   0   0   0   0   8   0   0   0   0   0   0
   0   0   0   0   0  10   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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[  6   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   1   0   0   0   8   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  9   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   2   0]
[  0   0   0   0   1   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 14   0   0   0   1   0   0   0   1   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   3   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   1   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   3
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   1   0   1   0   0   0   6   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   1   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   0   1   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   4   0]
[  0   0   0   0   0   0   0   1   0   0   0   0   1   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0  12   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0  10   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   1   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   2   0   0   1   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0  10   0   0   0   0   0   0   0   0  17   4]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   1   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   2   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0]
[  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   1   0   4   0   3   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   3   0   0
   0   0   0   0   0   1   0   0   3   0   0   0   0   0   0   0   0   0   0
```

```
   0   2   0   0   0   0   0   0   0   0 123   3]
 [  5   0   0   0   0   1   0   0   0   0   0   1   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0  38  14]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.75      0.95      0.84       781
           1       0.67      0.33      0.44         6
           2       0.75      0.62      0.68        24
           3       0.00      0.00      0.00         3
           4       0.53      0.43      0.47        49
           5       0.61      0.85      0.71        20
           6       0.53      0.53      0.53        17
           7       0.80      0.31      0.44        13
           8       0.11      0.07      0.09        14
           9       0.93      0.88      0.90        16
          10       0.50      0.42      0.45        12
          11       0.41      0.21      0.28        56
          12       0.50      0.42      0.45        48
          13       0.33      0.11      0.17         9
          14       0.50      0.10      0.17        10
          15       0.50      0.25      0.33         4
          16       0.00      0.00      0.00         6
          17       0.83      0.85      0.84        53
          18       0.67      0.40      0.50        15
          19       0.67      0.15      0.25        13
          20       0.00      0.00      0.00         2
          21       0.50      0.08      0.14        12
          22       0.75      0.56      0.64        27
          23       0.33      0.31      0.32        32
          24       0.50      1.00      0.67         1
          25       0.67      0.18      0.29        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
          59       0.00      0.00      0.00        11
          60       0.00      0.00      0.00         1
          61       0.00      0.00      0.00       145
          62       0.00      0.00      0.00        60
```

```
              64       0.00      0.00      0.00         0
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.56      1685
       macro avg       0.20      0.15      0.16      1685
    weighted avg       0.50      0.56      0.52      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
0	Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611

Decision Trees- Without Sampling

Decision Trees Decision Trees (DTs) are a non-parametric supervised learning method used for classification and regression. The goal is to create a model that predicts the valu simple decision rules inferred from the data features.DecisionTreeClassifier is a class capable of performing multi-class classification on a dataset.

In [ ]:
```
logTmp = []
logTmp, y_pred_DecisionTree2 = run_classification(DecisionTreeClassifier(), X_train2, X_test2, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "Decision Trees Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: 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=None, splitter='best')
--------------------------------------------------------------------------------
Training accuracy: 95.31%
Testing accuracy: 48.84%
--------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[649   0   2   0   7   6   6   2   8   1   2  10  16   0   0   2   1   6
    5   5   3   5   2  12   0   3   0   9   3   0   0   1   0   1   1   2
    0   0   1   1   0   0   0   0   0   0   0   0   0   0   1   0   0   0
    0   1   0   0   0   1   0   0   0   2   1   3]
 [  1   1   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  1   0  10   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   2   0   0   1   0   0   0   0   0   0   0   0   1   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    1   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   1   0   0  23   0   0   0   0   0   0   1   3   0   0   0   0   1
    0   0   0   0   0   0   2   0   0   1   2   0   0   0   1   1   0   0
    0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  7   0   1   0   0   9   0   0   0   0   0   0   1   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  6   0   0   0   1   0   6   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   1]
 [  3   0   0   0   0   0   0   5   0   0   0   1   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   1   0   0   0   0   0   2   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   0   0   1   5   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1]
 [  0   0   0   0   0   0   0   0   0  16   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   0   0   0   0   0   3   0   0   0   1   0   0   0
    0   0   0   0   1   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   2   0   0   0   0   0   0   0   0   1   0]
 [ 27   0   1   0   0   0   0   0   0   0   0  11   2   0   0   0   0   0
    1   0   0   2   0   5   0   0   0   3   0   0   0   0   0   2   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0   0]
 [ 20   0   0   0   1   0   0   0   0   0   1   1  17   0   0   0   0   0
    0   1   1   1   1   0   0   0   0   0   2   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1]
 [  1   0   0   0   0   1   0   1   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   2]
 [  5   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   1
    0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   1   0   0   0   0   0   0   0   2   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   0   0   0   0   0   0   0   3   1   0   0   0   0  33
    1   0   0   0   0   3   0   1   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  5   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0
```

```
   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  8   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   1   0   0   0   0   0   2   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   1
   1   0   0   0   0   1   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   2   0   0   2   1   0   0   0   0   1   1   0   0   0   0   0
   0   0   0   0   8   1   0   0   0   0   0   0   0   0   0   0   2   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  9   0   0   0   2   0   0   1   1   0   0   5   0   0   0   0   0   0
   0   0   0   0   0   7   1   0   0   1   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   1   0   0   1   1   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   5   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   0   0   1   0   0   0   0   0   1   0   0   0   0   0   0   3
   0   0   0   0   0   4   0   0   0   3   1   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  6   0   0   0   2   0   0   0   1   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   1   1]
[  1   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   1   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   2   0   0   0   1   0   0   0   0   0   8   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0]
[  3   0   0   0   0   0   0   3   1   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   1   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   3
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   4   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   1   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   4   1]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   1   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0  15   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   6   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   1   0   0   0   0   1   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   1   0   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   9   0   0   0   0   0   0   0   0  18   4]
[  0   1   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   1   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   1   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   7   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   1   1   0   8   0   1   0   0   0   0   2   0   0   0   0   0   0
```

```
   0   0   0   0   0   1   0   0   0   0   0   0   0   2   1   7   0   0
   0   0   0   0   0   0   0   0   6   0   0   0   0   0   0   0   0   0
   0   2   1   0   0   0   0   0   0   0 107   4]
 [ 4   0   1   0   2   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   1   0   0   0   0   0   0  38  12]
 [ 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.76      0.83      0.79       781
           1       0.20      0.17      0.18         6
           2       0.56      0.42      0.48        24
           3       0.00      0.00      0.00         3
           4       0.44      0.47      0.46        49
           5       0.35      0.45      0.39        20
           6       0.40      0.35      0.38        17
           7       0.31      0.38      0.34        13
           8       0.31      0.36      0.33        14
           9       0.94      1.00      0.97        16
          10       0.43      0.25      0.32        12
          11       0.28      0.20      0.23        56
          12       0.33      0.35      0.34        48
          13       0.00      0.00      0.00         9
          14       0.25      0.10      0.14        10
          15       0.40      0.50      0.44         4
          16       0.67      0.33      0.44         6
          17       0.73      0.62      0.67        53
          18       0.42      0.53      0.47        15
          19       0.12      0.08      0.10        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.40      0.30      0.34        27
          23       0.17      0.22      0.19        32
          24       0.25      1.00      0.40         1
          25       0.50      0.45      0.48        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
          59       0.00      0.00      0.00        11
          60       0.00      0.00      0.00         1
```

```
              61       0.00      0.00      0.00       145
              62       0.00      0.00      0.00        60
              64       0.00      0.00      0.00         0
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.49      1685
       macro avg       0.14      0.14      0.13      1685
    weighted avg       0.46      0.49      0.47      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
0	Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611
0	Decision Trees Model - without Sampling	0.953116	0.488427	0.473343	0.488427

Random Forest Classifier- Without Sampling

A random forest is a meta estimator that fits a number of decision tree classifiers on various sub-samples of the dataset and uses averaging to improve the predictive accuracy a Random Forest is a good model if we want high performance with less need for interpretation.

In [ ]:
```
from sklearn.ensemble import RandomForestClassifier

logTmp = []
logTmp, y_pred_RandomForest2 = run_classification(RandomForestClassifier(n_estimators=100), X_train2, X_test2, y_train2, y_test2,
logTmp['Classifier'] = "Random Forest Classifier Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: 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)
--------------------------------------------------------------------------------
Training accuracy: 95.31%
Testing accuracy: 54.84%
--------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[768   0   0   0   2   1   0   0   0   0   0   1   1   0   0   0   1   2
    1   1   0   0   0   1   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  1   2   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  6   0  10   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 [ 15   0   0   0  22   0   1   0   0   0   0   0   5   0   0   0   0   1
    1   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   3   0]
 [  8   0   0   0   0  10   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   0]
 [  8   0   0   0   0   0   8   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [ 11   0   0   0   0   1   0   1   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 12   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   0   0   0   0   0   7   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   4   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   0]
 [ 49   0   0   0   0   1   0   0   0   0   0   4   0   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 28   0   0   0   0   0   0   0   0   0   1   0  18   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   2   0   0   0   0   0   0   0   1   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 13   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0  39
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0]
[  8   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   1
   5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   4   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0  10   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   1   0]
[ 23   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   0   7   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   3   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   1   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   1   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 19   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   3   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   4   0]
[  9   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   1   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   4   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  3  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0 13  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  8  0]
 [ 3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  1  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  1  0]
 [ 1  0  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0 11  0  0  0  0  0  0  0  0 17  4]
 [ 1  0  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  1  0  0  0  0  0  0  0  2  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 6  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  1  0  0  0  0]
 [ 0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0
   0  0  0  0  0  1  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0]
 [ 7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  4  0  0]
 [ 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
   0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   1   0   6   0   1   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   3   0   0
    0   0   0   0   0   0   0   0   4   0   0   0   0   0   0   0   0   0
    0   2   0   0   0   0   0   0   0   0 119   4]
 [ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0  39   7]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.65      0.98      0.79       781
           1       1.00      0.33      0.50         6
           2       0.91      0.42      0.57        24
           3       0.00      0.00      0.00         3
           4       0.56      0.45      0.50        49
           5       0.45      0.50      0.48        20
           6       0.80      0.47      0.59        17
           7       1.00      0.08      0.14        13
           8       1.00      0.14      0.25        14
           9       1.00      0.44      0.61        16
          10       0.80      0.33      0.47        12
          11       0.67      0.07      0.13        56
          12       0.62      0.38      0.47        48
          13       1.00      0.11      0.20         9
          14       1.00      0.10      0.18        10
          15       0.00      0.00      0.00         4
          16       0.50      0.17      0.25         6
          17       0.83      0.74      0.78        53
          18       0.56      0.33      0.42        15
          19       0.00      0.00      0.00        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.71      0.37      0.49        27
          23       0.64      0.22      0.33        32
          24       0.50      1.00      0.67         1
          25       1.00      0.27      0.43        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
```

```
              59       0.00      0.00      0.00        11
              60       0.00      0.00      0.00         1
              61       0.00      0.00      0.00       145
              62       0.00      0.00      0.00        60
              64       0.00      0.00      0.00         0
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.55      1685
       macro avg       0.25      0.12      0.14      1685
    weighted avg       0.50      0.55      0.48      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
0	Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611
0	Decision Trees Model - without Sampling	0.953116	0.488427	0.473343	0.488427
0	Random Forest Classifier Model - without Sampling	0.953116	0.548368	0.478831	0.548368

Logistic Regression- Without Sampling

Logistic Regression is a Machine Learning classification algorithm that is used to predict the probability of a categorical dependent variable. In logistic regression, the dependent contains data coded as 1 (yes, success, etc.) or 0 (no, failure, etc.).

In [ ]:
```
from sklearn.linear_model import LogisticRegression

logTmp = []
logTmp, y_pred_LogReg2 = run_classification(LogisticRegression(), X_train2, X_test2, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "Logistic Regression Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
                   intercept_scaling=1, l1_ratio=None, max_iter=100,
                   multi_class='auto', n_jobs=None, penalty='l2',
                   random_state=None, solver='lbfgs', tol=0.0001, verbose=0,
                   warm_start=False)
--------------------------------------------------------------------------------
Training accuracy: 69.17%
Testing accuracy: 53.95%
--------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[772   0   0   0   3   1   0   0   0   2   0   0   0   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2   0   0]
 [  2   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  8   0   9   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 15   0   0   0  22   0   0   0   0   0   0   0   5   0   0   0   0   3
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [ 11   0   0   0   0   8   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  9   0   0   0   0   0   7   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [ 12   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0  12   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   1   0   0   0   0   1   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   0]
 [ 49   0   0   0   0   0   0   0   0   0   0   4   1   0   0   0   0   2
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 28   0   0   0   0   0   0   0   0   0   1   0  19   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 15   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  37
    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 17   0   0   0   0   3   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[ 21   0   0   0   0   0   0   0   0   0   0   2   1   0   0   0   0   0
   0   0   0   0   0   8   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 15   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 21   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   4   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   2   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0]
```

```
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0  11   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0  10   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0  10   0   0   0   0   0   0   0   0  17   4]
[  2   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  8   0   1   0   6   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
```

```
   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0   0   0   0
   0   2   0   0   0   0   0   0   0   0 120   3]
 [ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0  38   9]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.63      0.99      0.77       781
           1       0.00      0.00      0.00         6
           2       0.90      0.38      0.53        24
           3       0.00      0.00      0.00         3
           4       0.51      0.45      0.48        49
           5       0.38      0.40      0.39        20
           6       0.88      0.41      0.56        17
           7       0.00      0.00      0.00        13
           8       0.00      0.00      0.00        14
           9       0.86      0.75      0.80        16
          10       0.33      0.08      0.13        12
          11       0.67      0.07      0.13        56
          12       0.54      0.40      0.46        48
          13       0.00      0.00      0.00         9
          14       0.00      0.00      0.00        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.79      0.70      0.74        53
          18       0.83      0.33      0.48        15
          19       0.00      0.00      0.00        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.83      0.19      0.30        27
          23       0.80      0.25      0.38        32
          24       0.00      0.00      0.00         1
          25       0.00      0.00      0.00        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
          59       0.00      0.00      0.00        11
          60       0.00      0.00      0.00         1
          61       0.00      0.00      0.00       145
```

```
                62       0.00      0.00      0.00        60
                64       0.00      0.00      0.00         0
                69       0.00      0.00      0.00         0
                70       0.00      0.00      0.00         0

          accuracy                           0.54      1685
         macro avg       0.14      0.08      0.09      1685
      weighted avg       0.44      0.54      0.46      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
0	Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611
0	Decision Trees Model - without Sampling	0.953116	0.488427	0.473343	0.488427
0	Random Forest Classifier Model - without Sampling	0.953116	0.548368	0.478831	0.548368
0	Logistic Regression Model - without Sampling	0.691691	0.539466	0.455573	0.539466

ADA Boost Classifier- Without Classifier

An AdaBoost classifier is a meta-estimator that begins by fitting a classifier on the original dataset and then fits additional copies of the classifier on the same dataset but where t instances are adjusted such that subsequent classifiers focus more on difficult cases.

In [ ]:
```
logTmp = []
dtc2 = DecisionTreeClassifier(max_depth=7)

logTmp, y_pred_AdaBoost2 = run_classification(AdaBoostClassifier(n_estimators= 200, base_estimator=dtc2, learning_rate=0.1, rando
, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "ADA Boost Classifier Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: AdaBoostClassifier(algorithm='SAMME.R',
                  base_estimator=DecisionTreeClassifier(ccp_alpha=0.0,
                                                        class_weight=None,
                                                        criterion='gini',
                                                        max_depth=7,
                                                        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=None,
                                                        splitter='best'),
                  learning_rate=0.1, n_estimators=200, random_state=22)
---------------------------------------------------------------------------------
Training accuracy: 66.11%
Testing accuracy: 50.21%
---------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[771   0   0   0   2   0   0   0   1   0   0   2   1   0   0   0   0   0
    1   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1]
 [  3   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   2   0]
 [  9   0   8   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1   4]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 20   0   0   0  18   0   0   0   0   0   0   0   1   4   0   0   0   0   1
    0   0   0   0   0   1   0   0   0   1   0   0   0   0   0   2   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   1]
 [ 17   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   1]
 [ 10   0   0   0   4   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   2   0]
 [ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 13   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 16   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   0   1   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   1]
 [ 52   0   0   0   0   0   0   0   0   0   0   0   1   1   0   0   0   0   0
    1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 33   0   0   0   0   0   0   0   0   0   0   0   0  14   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 30   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  21
   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
   2   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 20   0   1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   0   1]
[ 28   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 17   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 20   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   4   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   2   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   1]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   7   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0  10   3]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  9   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   4   0   0   0   0   0   0   0   0   0   0  21]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   1   1]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   1   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
 [ 12   0   1   0   6   0   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  16   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   1   0   0   0  69  39]
 [ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1  45]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.60      0.99      0.75       781
           1       1.00      0.17      0.29         6
           2       0.73      0.33      0.46        24
           3       0.00      0.00      0.00         3
           4       0.50      0.37      0.42        49
           5       0.29      0.10      0.15        20
           6       0.50      0.06      0.11        17
           7       0.00      0.00      0.00        13
           8       0.50      0.07      0.12        14
           9       0.00      0.00      0.00        16
          10       1.00      0.08      0.15        12
          11       0.25      0.02      0.03        56
          12       0.52      0.29      0.37        48
          13       0.00      0.00      0.00         9
          14       0.00      0.00      0.00        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.78      0.40      0.53        53
          18       0.33      0.13      0.19        15
          19       0.00      0.00      0.00        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.40      0.07      0.12        27
          23       0.33      0.09      0.15        32
          24       0.00      0.00      0.00         1
          25       0.00      0.00      0.00        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
```

```
              51       0.00      0.00      0.00        36
              52       0.00      0.00      0.00         5
              53       0.00      0.00      0.00         1
              54       0.00      0.00      0.00         7
              55       0.00      0.00      0.00         1
              56       0.00      0.00      0.00         3
              57       0.00      0.00      0.00         2
              58       0.00      0.00      0.00         2
              59       0.00      0.00      0.00        11
              60       0.00      0.00      0.00         1
              61       0.00      0.00      0.00       145
              62       0.00      0.00      0.00        60
              64       0.00      0.00      0.00         0
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.50      1685
       macro avg       0.12      0.05      0.06      1685
    weighted avg       0.39      0.50      0.41      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
0	Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611
0	Decision Trees Model - without Sampling	0.953116	0.488427	0.473343	0.488427
0	Random Forest Classifier Model - without Sampling	0.953116	0.548368	0.478831	0.548368
0	Logistic Regression Model - without Sampling	0.691691	0.539466	0.455573	0.539466
0	ADA Boost Classifier Model - without Sampling	0.661128	0.502077	0.405477	0.502077

Bagging Classifier-Wihout Sampling

A Bagging classifier is an ensemble meta-estimator that fits base classifiers each on random subsets of the original dataset and then aggregate their individual predictions (eithe final prediction. Such a meta-estimator can typically be used as a way to reduce the variance of a black-box estimator (e.g., a decision tree), by introducing randomization into its making an ensemble out of it.

In [ ]:
```
logTmp = []
logTmp, y_pred_Bagging2 = run_classification(BaggingClassifier(n_estimators=100, max_samples= .7, bootstrap=True, oob_score=True,
_train2, X_test2, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "Bagging Classifier Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: BaggingClassifier(base_estimator=None, bootstrap=True, bootstrap_features=False,
                  max_features=1.0, max_samples=0.7, n_estimators=100, n_jobs=4,
                  oob_score=True, random_state=22, verbose=0, warm_start=False)
--------------------------------------------------------------------------------
Training accuracy: 93.62%
Testing accuracy: 54.36%
--------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[746   0   1   0   4   5   1   0   4   0   0   4   2   0   0   0   0   5
    1   0   0   0   0   2   0   0   0   1   0   0   0   0   0   0   0   0
    1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   1   1   0]
 [  1   2   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  5   0   9   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 13   0   0   0  24   0   0   0   0   0   0   0   5   0   0   0   0   1
    0   0   0   0   0   1   0   0   0   0   1   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   3   0]
 [  8   0   0   0   0  10   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   0]
 [  8   0   0   0   0   0   7   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  9   0   0   0   0   1   0   2   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   0   0   0   6   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0  16   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   4   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   0]
 [ 38   0   0   0   0   1   0   0   0   0   0   9   0   0   0   0   0   1
    0   0   0   0   0   4   0   0   0   1   0   0   0   0   0   2   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 28   0   0   0   0   0   0   0   0   0   1   0  18   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0
    0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   0   1   0   1   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 16   0   0   0   1   0   0   0   0   0   0   2   0   0   0   0   0  34
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
```

```
 [ 10   0   0   0   0   1   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 10   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  7   0   0   0   0   4   0   0   0   0   1   0   2   0   0   0   0   0
    0   0   0   0  11   0   0   0   0   0   0   0   0   0   0   0   1   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [ 22   0   0   0   0   1   0   0   0   0   0   3   1   0   0   0   0   0
    0   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   1   0   2   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    1   0   0   0   0   4   0   0   0   3   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 11   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   2   0]
 [  1   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 19   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   3   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  6   0   0   0   0   0   0   2   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   1   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   3
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
    0   0   0   0   0   0   0   0   0   4   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   3   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0  14   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   8   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   1   0]
[  0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   9   0   0   0   0   0   0   0   0  18   4]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   1   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   8   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   1   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   2   0   0   0   0   0   0   0   0   1   0   0   0
   0   0   0   0   0   1   0   0   4   0   0   0   0   0   0   0   0   0
   0   2   0   0   0   0   0   0   0   0 119   4]
```

```
 [ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0  38   9]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.68      0.96      0.80       781
           1       1.00      0.33      0.50         6
           2       0.82      0.38      0.51        24
           3       0.00      0.00      0.00         3
           4       0.55      0.49      0.52        49
           5       0.33      0.50      0.40        20
           6       0.88      0.41      0.56        17
           7       0.50      0.15      0.24        13
           8       0.55      0.43      0.48        14
           9       1.00      1.00      1.00        16
          10       0.57      0.33      0.42        12
          11       0.45      0.16      0.24        56
          12       0.50      0.38      0.43        48
          13       1.00      0.11      0.20         9
          14       1.00      0.10      0.18        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.76      0.64      0.69        53
          18       0.73      0.53      0.62        15
          19       0.00      0.00      0.00        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.58      0.41      0.48        27
          23       0.24      0.16      0.19        32
          24       1.00      1.00      1.00         1
          25       1.00      0.18      0.31        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
          59       0.00      0.00      0.00        11
          60       0.00      0.00      0.00         1
          61       0.00      0.00      0.00       145
          62       0.00      0.00      0.00        60
          64       0.00      0.00      0.00         0
```

```
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.54      1685
       macro avg       0.21      0.13      0.15      1685
    weighted avg       0.47      0.54      0.49      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
0	Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611
0	Decision Trees Model - without Sampling	0.953116	0.488427	0.473343	0.488427
0	Random Forest Classifier Model - without Sampling	0.953116	0.548368	0.478831	0.548368
0	Logistic Regression Model - without Sampling	0.691691	0.539466	0.455573	0.539466
0	ADA Boost Classifier Model - without Sampling	0.661128	0.502077	0.405477	0.502077
0	Bagging Classifier Model - without Sampling	0.936202	0.543620	0.485801	0.543620

XG Boost Classifier-Without Sampling

XGBoost is an optimized distributed gradient boosting library designed to be highly efficient, flexible and portable. It implements machine learning algorithms under the Gradient provides a parallel tree boosting (also known as GBDT, GBM) that solve the problem in a fast and accurate way.

In [ ]:
```
import xgboost as xgb
from xgboost.sklearn import XGBClassifier
```

In [ ]:
```
logTmp = []
logTmp, y_pred_XGBoost2 = run_classification(XGBClassifier(n_estimators=100, max_depth=7, min_child_weight=6, colsample_bytree=0.
rning_rate=0.1), X_train2, X_test2, y_train2, y_test2, emptyArr)
logTmp['Classifier'] = "XG Boost Classifier Model - without Sampling"
log3 = log3.append(logTmp)
```

```
Prediction Model: XGBClassifier(base_score=0.5, booster='gbtree', colsample_bylevel=1,
              colsample_bynode=1, colsample_bytree=0.8, gamma=0,
              learning_rate=0.1, max_delta_step=0, max_depth=7,
              min_child_weight=6, missing=None, n_estimators=100, n_jobs=4,
              nthread=None, objective='multi:softprob', random_state=0,
              reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
              silent=None, subsample=0.8, verbosity=1)
--------------------------------------------------------------------------------
Training accuracy: 71.20%
Testing accuracy: 52.70%
--------------------------------------------------------------------------------
(66, 66)
Confusion Matrix:

[[747   0   0   0   6   2   2   0   6   0   0   5   3   0   0   0   0   1
    1   2   0   0   0   3   0   0   0   0   0   0   0   0   0   2   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1]
 [  2   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  6   0   6   0   0   3   1   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   5   1]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 11   0   0   0  25   0   0   0   0   0   0   0   5   0   0   0   0   2
    0   0   0   0   0   0   0   0   0   0   1   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   4   0]
 [  7   0   0   0   0  12   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   1   0]
 [  9   0   0   0   2   0   5   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1   0]
 [ 12   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   0   0   0   6   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  7   0   0   0   0   0   0   0   0   0   9   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   0   0   0   0   0   0   4   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   0   1   1]
 [ 41   0   0   0   0   0   0   0   0   0   0   9   0   0   0   0   0   0
    1   0   0   0   1   2   0   0   0   2   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 28   0   0   0   0   0   0   0   0   0   0   0  18   0   0   0   0   0
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1]
 [  6   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   1]
 [  7   0   0   0   0   1   1   0   0   0   0   0   0   0   0   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 22   0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0  28
    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
```

```
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 14   0   0   0   0   4   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0   1   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   2   0   0   0   0   0   0   0   0   1   0]
[ 19   0   0   0   2   0   0   0   0   0   0   4   1   0   0   0   0   0   0
   0   0   0   0   0   3   0   0   0   1   1   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 15   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  9   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   2   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   2   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 20   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   4   0]
[  9   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   0   0]
[  3   1   0   0   2   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0  13   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   8   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   2   0   1   0   0   0   0   0
   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   6   0   0   0   0   0   0   0   0  18   4]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   8   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0]
```

```
 [  7   0   1   0   7   0   1   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   4   0   0
    0   0   0   0   0   0   0   0   5   0   0   0   0   0   0   0   0   0
    0   2   0   0   0   0   0   0   0   0 113   4]
 [ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0  39   9]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
               precision    recall  f1-score   support

           0       0.66      0.96      0.78       781
           1       0.00      0.00      0.00         6
           2       0.75      0.25      0.38        24
           3       0.00      0.00      0.00         3
           4       0.50      0.51      0.51        49
           5       0.43      0.60      0.50        20
           6       0.45      0.29      0.36        17
           7       0.00      0.00      0.00        13
           8       0.46      0.43      0.44        14
           9       1.00      0.56      0.72        16
          10       0.67      0.33      0.44        12
          11       0.39      0.16      0.23        56
          12       0.51      0.38      0.43        48
          13       0.00      0.00      0.00         9
          14       0.00      0.00      0.00        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.82      0.53      0.64        53
          18       0.61      0.73      0.67        15
          19       0.25      0.08      0.12        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.57      0.15      0.24        27
          23       0.27      0.09      0.14        32
          24       0.00      0.00      0.00         1
          25       0.00      0.00      0.00        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
          53       0.00      0.00      0.00         1
          54       0.00      0.00      0.00         7
          55       0.00      0.00      0.00         1
          56       0.00      0.00      0.00         3
          57       0.00      0.00      0.00         2
          58       0.00      0.00      0.00         2
          59       0.00      0.00      0.00        11
```

```
              60       0.00      0.00      0.00         1
              61       0.00      0.00      0.00       145
              62       0.00      0.00      0.00        60
              64       0.00      0.00      0.00         0
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.53      1685
       macro avg       0.13      0.09      0.10      1685
    weighted avg       0.43      0.53      0.46      1685
```

In [ ]:
```
log3
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
0	KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
0	Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611
0	Decision Trees Model - without Sampling	0.953116	0.488427	0.473343	0.488427
0	Random Forest Classifier Model - without Sampling	0.953116	0.548368	0.478831	0.548368
0	Logistic Regression Model - without Sampling	0.691691	0.539466	0.455573	0.539466
0	ADA Boost Classifier Model - without Sampling	0.661128	0.502077	0.405477	0.502077
0	Bagging Classifier Model - without Sampling	0.936202	0.543620	0.485801	0.543620
0	XG Boost Classifier Model - without Sampling	0.712018	0.527003	0.458113	0.527003

Comparison of Traditional ML Models - without Sampling

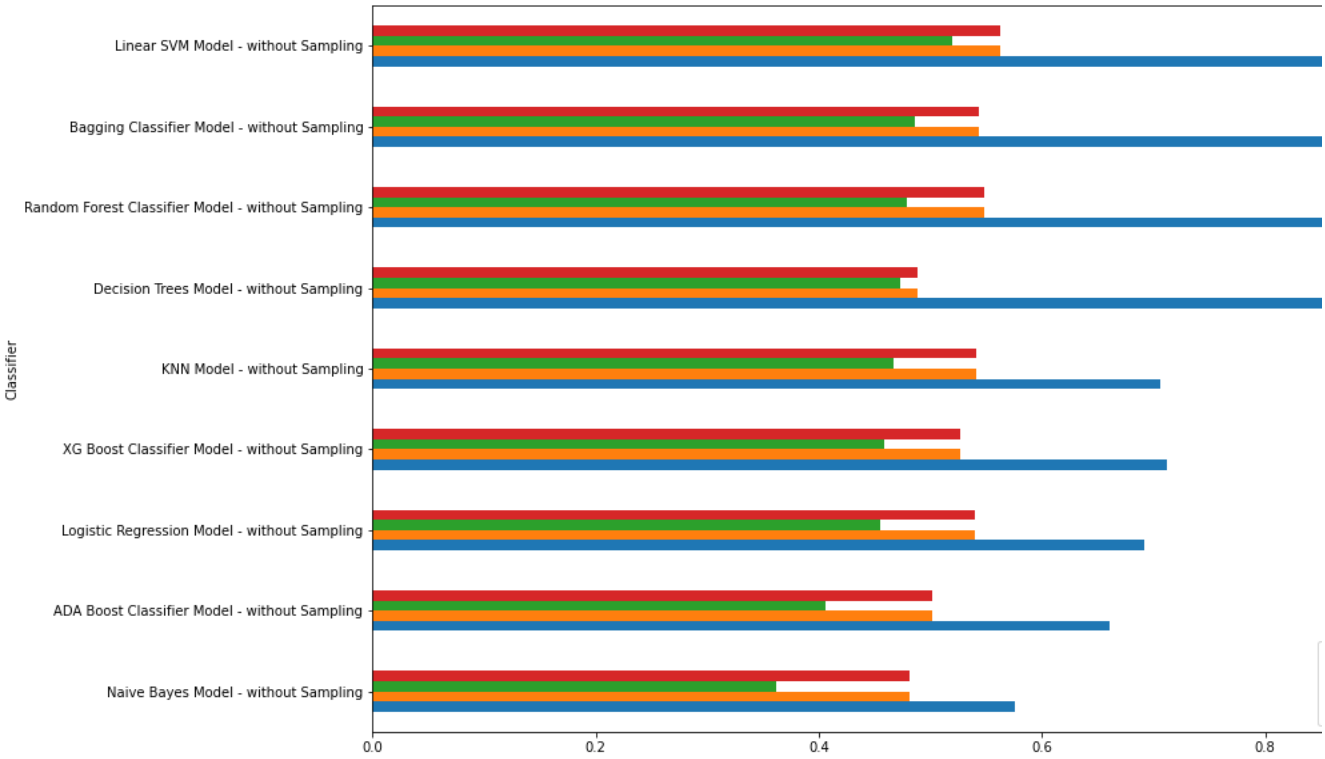
In [ ]:
```
logObs3 = log3
logObs3.set_index(["Classifier"],inplace=True)
logObs3.sort_values(by=['f1-score'])
```

Out[ ]:

Classifier	Training accuracy	Testing accuracy	f1-score	Recall
Naive Bayes Model - without Sampling	0.576113	0.481899	0.361704	0.481899
ADA Boost Classifier Model - without Sampling	0.661128	0.502077	0.405477	0.502077
Logistic Regression Model - without Sampling	0.691691	0.539466	0.455573	0.539466
XG Boost Classifier Model - without Sampling	0.712018	0.527003	0.458113	0.527003
KNN Model - without Sampling	0.706528	0.541246	0.466402	0.541246
Decision Trees Model - without Sampling	0.953116	0.488427	0.473343	0.488427
Random Forest Classifier Model - without Sampling	0.953116	0.548368	0.478831	0.548368
Bagging Classifier Model - without Sampling	0.936202	0.543620	0.485801	0.543620
Linear SVM Model - without Sampling	0.929674	0.562611	0.519584	0.562611

In [ ]:
```
logObs3.sort_values(by=['f1-score']).plot(kind='barh',figsize=[15,10])
```

Out[ ]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fd07d347a58>
```



Observation:

We first analysed the dataset provided to us, undestood the structure of the data provided - number of columns, field , datatypes etc.

We did Exploratory Data Analysis to derive further insights from this data set and we found that Data is very much imbalanced, there are around ~45% of the Groups with less th

Few of the tickets are in foreign language like German The data has lot of noise in it, for eg- few tickets related to account setup are spread across multiple assignment groups. V google translation and preprocessing.

Here in this comparison of different traditional ML models, we can observe a substantial difference in the accuracy of training and test sets. Major reason is possibly the imbalanc used and the inability of the model to learn and adapt during training.

We need to check if these issues can be handled by resampled data and using deep learning techniques.

Model Improvement 1: Utlizing Deep Learning Techniques

Deep Learning Models - without Sampling

Deep learning is a subset of machine learning where artificial neural networks, algorithms inspired by the human brain, learn from large amounts of data. Similarly to how we lea algorithm would perform a task repeatedly, each time tweaking it a little to improve the outcome. We refer to 'deep learning' because the neural networks have various (deep) lay **Learmning Models considered:**

- Recurrent Neural Network(RNN)-LSTM Model: Long Short-Term Memory (LSTM) networks are a modified version of recurrent neural networks, which makes it easier to rem vanishing gradient problem of RNN is resolved here. LSTM is well-suited to classify, process and predict time series given time lags of unknown duration. It trains the model
- Recurrent Neural Network(RNN)-GRU Model: GRU unit does not have to use a memory unit to control the flow of information like the LSTM unit. It can directly makes use o control. GRUs have fewer parameters and thus may train a bit faster or need less data to generalize.They are almost similar to LSTMs except that they have two gates: rese determines how to combine new input to previous memory and update gate determines how much of the previous state to keep. Update gate in GRU is what input gate and have the second non linearity in GRU before calculating the output neither they have the output gate.
- Bidirectional LSTM Model: Bidirectional recurrent neural networks(RNN) are really just putting two independent RNNs together. This structure allows the networks to have b about the sequence at every time step. Using bidirectional will run your inputs in two ways, one from past to future and one from future to past and what differs this approach LSTM that runs backwards you preserve information from the future and using the two hidden states combined you are able in any point in time to preserve information from

Importing needed libraries to create the model:

1. Importing sequence flow
2. Importing Input layers, Droup out module Flattenn layer, Dense layer module, Embedding laye module, LSTM and GRU modules
3. Importing BatchNormalization, TimeDistributed, Conv1D, MaxPooling1D, SpatialDropout1D modules
4. Importing Text Tokenizer module and concatenating module

In [ ]:
```
from keras.models import Sequential, Model
from keras.preprocessing import sequence
from keras.preprocessing.sequence import pad_sequences
from keras.layers import Input, Dropout, Flatten, Dense, Embedding, LSTM, GRU
from keras.layers import BatchNormalization, TimeDistributed, Conv1D, MaxPooling1D, SpatialDropout1D
from keras.preprocessing.text import Tokenizer
from keras.layers.merge import Concatenate
```

Embedding Matrix creation:

- Instead of learning word embeddings jointly with the problem we want to solve, we prefer loading embedding vectors from a pre-computed embedding space known to be hi properties – that captures generic aspects of language structure.
- Such word embeddings are generally computed using word occurrence statistics (observations about what words co-occur in sentences or documents), using a variety of te networks, others not. In our case, we will use GloVe.
- GloVe- developed by Stanford researchers in 2014. It stands for “Global Vectors for Word Representation”, and it is an embedding technique based on factorizing a matrix o developers have made available pre-computed embeddings for millions of English tokens, obtained from Wikipedia data or from Common Crawl data.
- GloVe is an unsupervised learning algorithm for obtaining vector representations for words. Training is performed on aggregated global word-word co-occurrence statistics fr representations showcase interesting linear substructures of the word vector space.
- The GloVe model is trained on the non-zero entries of a global word-word co-occurrence matrix, which tabulates how frequently words co-occur with one another in a given requires a single pass through the entire corpus to collect the statistics.
- We are using glove.6B.200d.txt which is Glove embeddings with 6 Billion words with each word being a 200 dimensional vector.

In [ ]:
```
# Create embedding matrix
EMBEDDING_FILE = 'glove.6B.200d.txt'
MAX_SEQUENCE_LENGTH = 500
EMBEDDING_DIM=200
MAX_NB_WORDS=400000

# Function to generate Embedding
def loadData_Tokenizer(X_train, X_test,filename):
    np.random.seed(7)
    text = np.concatenate((X_train, X_test), axis=0)
    text = np.array(text)
    tokenizer = Tokenizer(num_words=MAX_NB_WORDS,filters='!"#$%&()*+,-./:;<=>?@[\\]^_`{|}~\t\n',lower=True,split=' ', char_level=
    tokenizer.fit_on_texts(text)
    sequences = tokenizer.texts_to_sequences(text)
    word_index = tokenizer.word_index
    text = pad_sequences(sequences, maxlen=MAX_SEQUENCE_LENGTH)
    print('Found %s unique tokens.' % len(word_index))
    indices = np.arange(text.shape[0])
    text = text[indices]
    print(text.shape)
    X_train = text[0:len(X_train), ]
    X_test = text[len(X_train):, ]
    embeddings_index = {}
    f = open(filename, encoding="utf8")
    for line in f:
        values = line.split()
        word = values[0]
        try:
            coefs = np.asarray(values[1:], dtype='float32')
        except:
            pass
        embeddings_index[word] = coefs
    f.close()
    print('Total %s word vectors.' % len(embeddings_index))
    return (X_train, X_test, word_index,embeddings_index)


embedding_matrix = []
```

In [ ]:
```
def buildEmbed_matrices(word_index,embedding_dim):
    embedding_matrix = np.random.random((len(word_index) + 1, embedding_dim))
    for word, i in word_index.items():
        embedding_vector = embeddings_index.get(word)
        if embedding_vector is not None:
            # words not found in embedding index will be all-zeros.
            if len(embedding_matrix[i]) != len(embedding_vector):
                print("Could not broadcast input array from shape",str(len(embedding_matrix[i])), "into shape",str(len(embedding_
                      " Please make sure your"" EMBEDDING_DIM is equal to embedding_vector file ,GloVe,")
                exit(1)
            embedding_matrix[i] = embedding_vector
    return embedding_matrix
```

Load the GloVe embeddings in the model

The embedding layer has a single weight matrix: a 2D float matrix where each entry i is the word vector meant to be associated with index i. Simple enough. Load the GloVe mat
layer, the first layer in the model.

In [ ]:
```
# Generate Glove embedded datasets
X_train_Glove, X_test_Glove, word_index, embeddings_index = loadData_Tokenizer(X_train2,X_test2,EMBEDDING_FILE)
embedding_matrix = buildEmbed_matrices(word_index,EMBEDDING_DIM)
```

```
Found 12183 unique tokens.
(8425, 500)
Total 400000 word vectors.
```

Recurrent Neural Network(RNN) - LSTM Model - without Sampling

Defining the model can be done with below points:

1. we've used Keras' Sequential() to instantiate a model. It takes a group of sequential layers and stacks them together into a single model. Into the Sequential() constructor, w
   we want to use in our model.
2. We've made several Dense layers and a single Dropout layer in this model. We've made the input_shape equal to the Maximum Sequenec Length
3. We defined Embedding Layer on the first layer as the input of that layer.
4. There are 200 neurons in Convolution layers and It has relu as activation funtionand 128 neurosn for LSTM layer.
5. There's 100 neurons in dense layer. This is typically up to testing - putting in more neurons per layer will help extract more features, but these can also sometimes work aga
   funtion
6. Finally, we have a Dense layer with size as the output layer. It has the Softmax activation function.
7. At last, we measure the loss with ategorical cross entropy fucntion, The efficient ADAM optimization algorithm is used to find the weights and the accuracy metric is calculate

In [ ]:
```
def Build_Model_RNN_Text(word_index, embeddings_matrix,ytrain,nclasses,dropout=0.5):
    model = Sequential()
    embedding_layer = Embedding(len(word_index) + 1,
                                EMBEDDING_DIM,
                                weights=[embeddings_matrix],
                                input_length=MAX_SEQUENCE_LENGTH,
                                trainable=True)
    model.add(Input(shape=(MAX_SEQUENCE_LENGTH,),dtype=tf.int64))
    model.add(embedding_layer)
    model.add(Conv1D(200,10,activation='relu'))
    model.add(MaxPooling1D(pool_size=2))
    model.add(Dropout(0.3))
    model.add(Conv1D(200,10,activation='relu'))
    model.add(MaxPooling1D(pool_size=2))
    model.add(LSTM(128))
    model.add(Dropout(0.3))
    model.add(Dense(100,activation='relu'))
    model.add(Dense(len((pd.Series(ytrain)).unique()),activation='softmax'))
    model.compile(loss='sparse_categorical_crossentropy',optimizer="adam",metrics=['accuracy'])

    print(model.summary())
    return model
```

In [ ]:
```
model_RNN = Build_Model_RNN_Text(word_index,embedding_matrix,y_train2,17)
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding (Embedding)        (None, 500, 200)          2436800
_________________________________________________________________
conv1d (Conv1D)              (None, 491, 200)          400200
_________________________________________________________________
max_pooling1d (MaxPooling1D) (None, 245, 200)          0
_________________________________________________________________
dropout (Dropout)            (None, 245, 200)          0
_________________________________________________________________
conv1d_1 (Conv1D)            (None, 236, 200)          400200
_________________________________________________________________
max_pooling1d_1 (MaxPooling1 (None, 118, 200)          0
_________________________________________________________________
lstm (LSTM)                  (None, 128)               168448
_________________________________________________________________
dropout_1 (Dropout)          (None, 128)               0
_________________________________________________________________
dense (Dense)                (None, 100)               12900
_________________________________________________________________
dense_1 (Dense)              (None, 71)                7171
=================================================================
Total params: 3,425,719
Trainable params: 3,425,719
Non-trainable params: 0
_________________________________________________________________
None
```

In [ ]:
```
log_cols2=["Classifier","Training accuracy","Testing accuracy","f1-score","Recall"]
log2 = pd.DataFrame(columns=log_cols2)
```

We have to add some call backs to the model for early stopping and reduce on plateau if we see no improvement in loss

In [ ]:
```
# Adding callbacks
es = EarlyStopping(monitor = 'val_loss', mode = 'min', verbose = 1, patience = 4)
mc = ModelCheckpoint('rnn_model.h5', verbose=1, monitor='val_accuracy',save_best_only=True, mode='auto')
rl = ReduceLROnPlateau(monitor='val_loss', factor=0.2,patience=2, min_lr=0.0001)
```

In [ ]:
```
logTmp2 = []
cbArr = [es, mc, rl]
logTmp2, y_pred_RNNmodel = run_classification(model_RNN, X_train_Glove, X_test_Glove, y_train2, y_test2, cbArr, pipelineRequired
logTmp2['Classifier'] = "RNN-LSTM Model - without Sampling"
log2 = log2.append(logTmp2)
```

```
Epoch 1/10
53/53 [==============================] - ETA: 0s - loss: 2.7141 - accuracy: 0.4660
Epoch 00001: val_accuracy improved from -inf to 0.46350, saving model to rnn_model.h5
53/53 [==============================] - 8s 155ms/step - loss: 2.7141 - accuracy: 0.4660 - val_loss: 3.2162 - val_accuracy: 0.4635
Epoch 2/10
53/53 [==============================] - ETA: 0s - loss: 2.4609 - accuracy: 0.4881
Epoch 00002: val_accuracy did not improve from 0.46350
53/53 [==============================] - 6s 122ms/step - loss: 2.4609 - accuracy: 0.4881 - val_loss: 3.2591 - val_accuracy: 0.4629
Epoch 3/10
53/53 [==============================] - ETA: 0s - loss: 2.3838 - accuracy: 0.4896
Epoch 00003: val_accuracy did not improve from 0.46350
53/53 [==============================] - 6s 122ms/step - loss: 2.3838 - accuracy: 0.4896 - val_loss: 3.2927 - val_accuracy: 0.4617
Epoch 4/10
53/53 [==============================] - ETA: 0s - loss: 2.2980 - accuracy: 0.4917
Epoch 00004: val_accuracy did not improve from 0.46350
53/53 [==============================] - 6s 122ms/step - loss: 2.2980 - accuracy: 0.4917 - val_loss: 3.2820 - val_accuracy: 0.4623
Epoch 5/10
53/53 [==============================] - ETA: 0s - loss: 2.2561 - accuracy: 0.4932
Epoch 00005: val_accuracy improved from 0.46350 to 0.46469, saving model to rnn_model.h5
53/53 [==============================] - 7s 132ms/step - loss: 2.2561 - accuracy: 0.4932 - val_loss: 3.3101 - val_accuracy: 0.4647
Epoch 00005: early stopping
Prediction Model: <tensorflow.python.keras.engine.sequential.Sequential object at 0x7fd050cf3e48>
--------------------------------------------------------------------------------
Training accuracy: 49.64%
Testing accuracy: 46.47%
--------------------------------------------------------------------------------
(64, 64)
Confusion Matrix:

[[777   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2]
 [  5   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 21   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 42   0   0   0   0   6   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 14   0   0   0   0   6   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 15   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 16   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  7   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 52   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 44   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1]
 [  6   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  9   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 53   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   1   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 19   0   0   0   0   8   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 30   0   0   0   0   1   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 19   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   2   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 24   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1]
[  9   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 12   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 24   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [ 31   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  6   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[116   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0  28]
[ 58   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
              precision    recall  f1-score   support

           0       0.49      0.99      0.66       781
           1       0.00      0.00      0.00         6
           2       0.00      0.00      0.00        24
           3       0.00      0.00      0.00         3
           4       0.00      0.00      0.00        49
           5       0.08      0.30      0.13        20
           6       0.00      0.00      0.00        17
           7       0.00      0.00      0.00        13
           8       0.00      0.00      0.00        14
           9       0.00      0.00      0.00        16
          10       0.00      0.00      0.00        12
          11       0.00      0.00      0.00        56
          12       0.00      0.00      0.00        48
          13       0.00      0.00      0.00         9
          14       0.00      0.00      0.00        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.00      0.00      0.00        53
          18       0.00      0.00      0.00        15
          19       0.00      0.00      0.00        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.00      0.00      0.00        27
          23       0.00      0.00      0.00        32
          24       0.00      0.00      0.00         1
          25       0.00      0.00      0.00        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
          49       0.00      0.00      0.00         1
          50       0.00      0.00      0.00         1
          51       0.00      0.00      0.00        36
          52       0.00      0.00      0.00         5
```

```
                53       0.00      0.00      0.00         1
                54       0.00      0.00      0.00         7
                55       0.00      0.00      0.00         1
                56       0.00      0.00      0.00         3
                57       0.00      0.00      0.00         2
                58       0.00      0.00      0.00         2
                59       0.00      0.00      0.00        11
                60       0.00      0.00      0.00         1
                61       0.00      0.00      0.00       145
                62       0.00      0.00      0.00        60
                69       0.00      0.00      0.00         0

          accuracy                           0.46      1685
         macro avg       0.01      0.02      0.01      1685
      weighted avg       0.23      0.46      0.31      1685
```

Performance of the RNN with LSTM

In [ ]:
```
log2
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	RNN-LSTM Model - without Sampling	0.496439	0.464688	0.307287	0.464688

Recurrent Neural Network(RNN) - GRU Model - without Sampling

Model can be defined as:

1. we've used Keras' Sequential() to instantiate a model. It takes a group of sequential layers and stacks them together into a single model. Into the Sequential() constructor, w we want to use in our model.
2. We've made several Dense layers and a single Dropout layer in this model. We've made the input_shape equal to the Maximum Sequence Length
3. We defined Embedding Layer on the first layer as the input of that layer.
4. We added a GRU function layer with 128 neurons.
5. There's 100 neurons in dense layer. This is typically up to testing - putting in more neurons per layer will help extract more features, but these can also sometimes work aga funtion
6. Finally, we have a Dense layer with size as the output layer. It has the Softmax activation function.
7. At last, we measure the loss with ategorical cross entropy fucntion, The efficient ADAM optimization algorithm is used to find the weights and the accuracy metric is calculate

In [ ]:
```
# Build GRU model
def Build_Model_RNNGRU_Text(word_index, embeddings_matrix, ytrain, nclasses, dropout=0.5):

    input_layer = Input(shape=(MAX_SEQUENCE_LENGTH,),dtype=tf.int64)
    embed = Embedding(len(word_index) + 1, EMBEDDING_DIM, weights=[embeddings_matrix], input_length=MAX_SEQUENCE_LENGTH, trainabl
    gru=GRU(128)(embed)
    drop=Dropout(0.3)(gru)
    dense =Dense(100,activation='relu')(drop)
    out=Dense(len((pd.Series(ytrain)).unique()),activation='softmax')(dense)
    model = Model(input_layer,out)
    # Compile the model
    model.compile(loss='sparse_categorical_crossentropy',optimizer="adam",metrics=['accuracy'])
    # Print model summary
    print(model.summary())
    return model
```

We have to add some call backs to the model for early stopping and reduce on plateau if we see no improvement in loss

In [ ]:
```
# Adding callbacks
es = EarlyStopping(monitor = 'val_loss', mode = 'min', verbose = 1, patience = 4)
mc = ModelCheckpoint('rnnGru_model.h5', monitor = 'val_loss', mode = 'min', save_best_only = True, verbose = 1)
rl = ReduceLROnPlateau(monitor='val_loss', factor=0.2,patience=2, min_lr=0.0001)
```

In [ ]:
```
model_RNNGRU = Build_Model_RNNGRU_Text(word_index,embedding_matrix,y_train2,17)
```

```
Model: "functional_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         [(None, 500)]             0
_________________________________________________________________
embedding_1 (Embedding)      (None, 500, 200)          2436800
_________________________________________________________________
gru (GRU)                    (None, 128)               126720
_________________________________________________________________
dropout_2 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_2 (Dense)              (None, 100)               12900
_________________________________________________________________
dense_3 (Dense)              (None, 71)                7171
=================================================================
Total params: 2,583,591
Trainable params: 2,583,591
Non-trainable params: 0
_________________________________________________________________
None
```

In [ ]:
```
logTmp2 = []
cbArr = [es, mc, rl]
logTmp2, y_pred_RNNGRUmodel = run_classification(model_RNNGRU, X_train_Glove, X_test_Glove, y_train2, y_test2, cbArr, pipelineReq
)
logTmp2['Classifier'] = "RNN-GRU Model - without Sampling"
log2 = log2.append(logTmp2)
```

```
Epoch 1/10
53/53 [==============================] - ETA: 0s - loss: 2.6152 - accuracy: 0.4681
Epoch 00001: val_loss improved from inf to 3.04671, saving model to rnnGru_model.h5
53/53 [==============================] - 6s 113ms/step - loss: 2.6152 - accuracy: 0.4681 - val_loss: 3.0467 - val_accuracy: 0.462
Epoch 2/10
53/53 [==============================] - ETA: 0s - loss: 1.9830 - accuracy: 0.5496
Epoch 00002: val_loss did not improve from 3.04671
53/53 [==============================] - 5s 93ms/step - loss: 1.9830 - accuracy: 0.5496 - val_loss: 3.1346 - val_accuracy: 0.4849
Epoch 3/10
53/53 [==============================] - ETA: 0s - loss: 1.7361 - accuracy: 0.5850
Epoch 00003: val_loss did not improve from 3.04671
53/53 [==============================] - 5s 94ms/step - loss: 1.7361 - accuracy: 0.5850 - val_loss: 3.1953 - val_accuracy: 0.5021
Epoch 4/10
53/53 [==============================] - ETA: 0s - loss: 1.5411 - accuracy: 0.6174
Epoch 00004: val_loss did not improve from 3.04671
53/53 [==============================] - 5s 92ms/step - loss: 1.5411 - accuracy: 0.6174 - val_loss: 3.1809 - val_accuracy: 0.5116
Epoch 5/10
53/53 [==============================] - ETA: 0s - loss: 1.4875 - accuracy: 0.6291
Epoch 00005: val_loss did not improve from 3.04671
53/53 [==============================] - 5s 93ms/step - loss: 1.4875 - accuracy: 0.6291 - val_loss: 3.2452 - val_accuracy: 0.5134
Epoch 00005: early stopping
Prediction Model: <tensorflow.python.keras.engine.functional.Functional object at 0x7fd046c8e048>
--------------------------------------------------------------------------------
Training accuracy: 64.39%
Testing accuracy: 51.34%
--------------------------------------------------------------------------------
(65, 65)
Confusion Matrix:

[[759   0   0   0   5   4   0   0   0   0   0   3   2   0   0   0   0   1
    2   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0]
 [  1   0   0   0   2   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2   0]
 [  3   0   6   0   2   1   0   0   0   0   0   0   2   0   0   0   0   0
    2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   8   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 19   0   0   0  15   0   0   0   0   0   0   0   2   0   0   0   0   3
    1   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   7   0]
 [  5   0   0   0   2   9   0   0   0   0   0   0   1   0   0   0   0   0
    2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0]
 [  6   0   1   0   5   0   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   3   0]
 [ 10   0   0   0   0   1   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0]
 [ 14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0  14   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   1   5   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2   0]
 [ 45   0   0   0   1   0   0   0   0   0   0   2   0   0   0   0   0   4
    0   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 32   0   0   0   2   0   0   0   0   0   0   0  11   0   0   0   0   1
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2   0]
 [  2   0   0   0   1   5   0   0   0   0   0   0   0   0   0   0   0   0
    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
```

```
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0  42
   1   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  9   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   1   0   4  12   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[ 24   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   0   0   6   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   3
   0   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   2   0]
[  0   0   0   0   2   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 18   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   5   0]
[  9   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  6   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   5
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   1   0]
[  2   0   0   0   3   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   3   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0  22   0]
[  3   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   2   3   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   6   0   0   0   0   0   0   0  20   4]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   3   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1
```

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   1   0   6   1   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   2   0   0   0   0   0   0   0 129   3]
[ 10   0   0   0   1   2   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0  42   4]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]]
```

Classification report:

	precision	recall	f1-score	support
0	0.68	0.97	0.80	781
1	0.00	0.00	0.00	6
2	0.60	0.25	0.35	24
3	0.00	0.00	0.00	3
4	0.24	0.31	0.27	49
5	0.18	0.45	0.25	20
6	0.00	0.00	0.00	17
7	0.00	0.00	0.00	13
8	0.00	0.00	0.00	14
9	1.00	0.88	0.93	16
10	0.00	0.00	0.00	12
11	0.40	0.04	0.07	56
12	0.32	0.23	0.27	48
13	0.00	0.00	0.00	9
14	0.00	0.00	0.00	10
15	0.00	0.00	0.00	4
16	0.00	0.00	0.00	6
17	0.62	0.79	0.69	53
18	0.09	0.07	0.08	15
19	0.00	0.00	0.00	13
20	0.00	0.00	0.00	2
21	0.00	0.00	0.00	12
22	0.00	0.00	0.00	27
23	0.22	0.19	0.20	32
24	0.00	0.00	0.00	1
25	0.00	0.00	0.00	11
26	0.00	0.00	0.00	19
27	0.00	0.00	0.00	13
28	0.00	0.00	0.00	1
29	0.00	0.00	0.00	1
30	0.00	0.00	0.00	4
31	0.00	0.00	0.00	4
32	0.00	0.00	0.00	26
33	0.00	0.00	0.00	10
34	0.00	0.00	0.00	7
35	0.00	0.00	0.00	12
36	0.00	0.00	0.00	1
37	0.00	0.00	0.00	3
38	0.00	0.00	0.00	4
39	0.00	0.00	0.00	9
40	0.00	0.00	0.00	2
41	0.00	0.00	0.00	1
42	0.00	0.00	0.00	24
43	0.00	0.00	0.00	4
44	0.00	0.00	0.00	2
45	0.00	0.00	0.00	2
46	0.00	0.00	0.00	2
47	0.00	0.00	0.00	2
48	0.00	0.00	0.00	2

```
              49       0.00      0.00      0.00         1
              50       0.00      0.00      0.00         1
              51       0.00      0.00      0.00        36
              52       0.00      0.00      0.00         5
              53       0.00      0.00      0.00         1
              54       0.00      0.00      0.00         7
              55       0.00      0.00      0.00         1
              56       0.00      0.00      0.00         3
              57       0.00      0.00      0.00         2
              58       0.00      0.00      0.00         2
              59       0.00      0.00      0.00        11
              60       0.00      0.00      0.00         1
              61       0.00      0.00      0.00       145
              62       0.00      0.00      0.00        60
              69       0.00      0.00      0.00         0
              70       0.00      0.00      0.00         0

        accuracy                           0.51      1685
       macro avg       0.07      0.06      0.06      1685
    weighted avg       0.39      0.51      0.43      1685
```

Performance of the RNN with LSTM and RNN wih GRU model

In [ ]:
```
log2
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	RNN-LSTM Model - without Sampling	0.496439	0.464688	0.307287	0.464688
0	RNN-GRU Model - without Sampling	0.643917	0.513353	0.431207	0.513353

LSTM model (Bidirectional) - without Sampling

In [ ]:
```
len(word_index) + 1
```

Out[ ]: 12184

Model can be defined as:

1. We created two copies of the hidden layer, one fit in the input sequences as-is and one on a reversed copy of the input sequence. By default, the output values from these L
2. We defined Embedding Layer on the first layer as the input of that layer.
3. We added a LSTM layer with 128 neurons.
4. There's 100 neurons in dense layer. This is typically up to testing - putting in more neurons per layer will help extract more features, but these can also sometimes work aga funtion
5. Finally, we have a Dense layer with size as the output layer. It has the Softmax activation function.
6. At last, we measure the loss with ategorical cross entropy fucntion,The efficient ADAM optimization algorithm is used to find the weights and the accuracy metric is calculate

In [ ]:
```
def Build_Model_BiDirLSTM_Text(word_index, embeddings_matrix,ytrain):
  vocab_size = len(word_index) + 1
  input_layer = Input(shape=(MAX_SEQUENCE_LENGTH,),dtype=tf.int64)
  embed = Embedding(input_dim=vocab_size, output_dim=200, weights=[embeddings_matrix], input_length=MAX_SEQUENCE_LENGTH, trainabl
  lstm = Bidirectional(LSTM(128))(embed)
  drop = Dropout(0.3)(lstm)
  dense = Dense(100,activation='relu')(drop)
  out = Dense(len((pd.Series(ytrain)).unique()),activation='softmax')(dense)
  model = Model(input_layer,out)
  # Compile the model
  model.compile(loss='sparse_categorical_crossentropy',optimizer="adam",metrics=['accuracy'])
  # Print model summary
  print(model.summary())
  return model
```

We have to add some call backs to the model for early stopping and reduce on plateau if we see no improvement in loss

In [ ]:
```
# Adding callbacks
es = EarlyStopping(monitor = 'val_loss', mode = 'min', verbose = 1, patience = 4)
mc = ModelCheckpoint('bidirlstm_model.h5', verbose=1, monitor='val_accuracy',save_best_only=True, mode='auto')
rl = ReduceLROnPlateau(monitor='val_loss', factor=0.2,patience=2, min_lr=0.0001)
```

In [ ]:
```
model_BiDirLSTM = Build_Model_BiDirLSTM_Text(word_index,embedding_matrix,y_train2)
```

```
Model: "functional_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_3 (InputLayer)         [(None, 500)]             0
_________________________________________________________________
embedding_2 (Embedding)      (None, 500, 200)          2436800
_________________________________________________________________
bidirectional (Bidirectional (None, 256)               336896
_________________________________________________________________
dropout_3 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_4 (Dense)              (None, 100)               25700
_________________________________________________________________
dense_5 (Dense)              (None, 71)                7171
=================================================================
Total params: 2,806,567
Trainable params: 2,806,567
Non-trainable params: 0
_________________________________________________________________
None
```

In [ ]:
```
logTmp2 = []
cbArr = [es, mc, rl]
logTmp2, y_pred_BiDirLSTM = run_classification(model_BiDirLSTM, X_train_Glove, X_test_Glove, y_train2, y_test2, cbArr, pipelineRe
e)
logTmp2['Classifier'] = "BiDirectional LSTM Model - without Sampling"
log2 = log2.append(logTmp2)
```

```
Epoch 1/10
53/53 [==============================] - ETA: 0s - loss: 2.5617 - accuracy: 0.4812
Epoch 00001: val_accuracy improved from -inf to 0.47537, saving model to bidirlstm_model.h5
53/53 [==============================] - 10s 191ms/step - loss: 2.5617 - accuracy: 0.4812 - val_loss: 3.0234 - val_accuracy: 0.475
Epoch 2/10
53/53 [==============================] - ETA: 0s - loss: 1.9430 - accuracy: 0.5613
Epoch 00002: val_accuracy improved from 0.47537 to 0.49674, saving model to bidirlstm_model.h5
53/53 [==============================] - 9s 164ms/step - loss: 1.9430 - accuracy: 0.5613 - val_loss: 3.1376 - val_accuracy: 0.496
Epoch 3/10
53/53 [==============================] - ETA: 0s - loss: 1.6776 - accuracy: 0.5981
Epoch 00003: val_accuracy improved from 0.49674 to 0.51217, saving model to bidirlstm_model.h5
53/53 [==============================] - 9s 170ms/step - loss: 1.6776 - accuracy: 0.5981 - val_loss: 3.2174 - val_accuracy: 0.512
Epoch 4/10
53/53 [==============================] - ETA: 0s - loss: 1.4744 - accuracy: 0.6334
Epoch 00004: val_accuracy improved from 0.51217 to 0.51632, saving model to bidirlstm_model.h5
53/53 [==============================] - 9s 163ms/step - loss: 1.4744 - accuracy: 0.6334 - val_loss: 3.2793 - val_accuracy: 0.516
Epoch 5/10
53/53 [==============================] - ETA: 0s - loss: 1.4166 - accuracy: 0.6424
Epoch 00005: val_accuracy improved from 0.51632 to 0.52522, saving model to bidirlstm_model.h5
53/53 [==============================] - 9s 169ms/step - loss: 1.4166 - accuracy: 0.6424 - val_loss: 3.3331 - val_accuracy: 0.525
Epoch 00005: early stopping
Prediction Model: <tensorflow.python.keras.engine.functional.Functional object at 0x7fd0465951d0>
--------------------------------------------------------------------------------
Training accuracy: 65.91%
Testing accuracy: 52.52%
--------------------------------------------------------------------------------
(65, 65)
Confusion Matrix:

[[757   0   0   0   5   4   1   0   0   0   0   0   8   0   0   0   0   1
    0   0   0   0   0   2   0   0   0   0   0   0   0   0   0   2   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0]
 [  1   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2   0]
 [  3   0   6   0   0   5   0   0   0   0   0   0   2   0   0   0   0   0
    2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   6   0]
 [  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 15   0   0   0  22   0   0   0   0   0   0   1   3   0   0   0   0   2
    0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   5   0]
 [  3   0   0   0   0  12   0   0   0   0   0   0   4   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   1   0]
 [  6   0   1   0   3   1   4   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   2   0]
 [  8   0   0   0   0   2   1   0   0   0   0   0   2   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 10   0   0   0   0   0   0   0   0   0   0   0   4   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   0   0   0   0  14   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  3   0   0   0   0   6   0   0   0   0   0   0   1   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   1   0   0   0   0   0   0   0   1   0]
 [ 42   0   0   0   2   0   0   0   0   0   0   1   1   0   0   0   0   1
    0   0   0   0   0   9   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [ 26   0   0   0   0   1   0   0   0   0   0   0  19   0   0   0   0   2
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  2   0   0   0   0   4   0   0   0   0   0   0   2   0   0   0   0   0
    1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0]
 [  5   0   0   0   1   3   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  7   0   0   0   1   1   0   0   0   0   1   0   0   0   0   0   0  42
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   2   0]
[  9   0   0   0   0   0   0   0   0   0   0   0   3   0   0   0   0   0
   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  8   0   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0   2
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  8   0   0   0   0  14   0   0   0   0   0   0   3   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   1   0   0   0   0   0   0   0   1   0]
[ 22   0   0   0   1   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   7   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   1   0   0   0   0   1   0   0   0   0   0   2
   0   0   0   0   0   5   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 10   0   0   0   0   0   0   0   0   0   0   0   0   2   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   2   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 13   0   0   0   2   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   0   0   2   0   0   0   0   0   0   0   0   0   5   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   2   0]
[  9   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  6   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  5   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   4
   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  0   0   2   0   0   2   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   1   1   1   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   4   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0  22   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   1   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   5   0   0   0   0   2   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   4   0   0   0   0   0   0   0  20   4]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   3   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   1   0   0   0   0   0   0   0   1   0   0   0   0   1
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  3   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

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   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  1   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[ 11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  2   0   2   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   2   0   0   0   0   0   0   0 127   3]
[ 10   0   0   0   0   3   0   0   0   0   0   0   0   0   0   0   0   0
   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0  42   4]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0]]


--------------------------------------------------------------------------------
Classification report:
              precision    recall  f1-score   support

           0       0.70      0.97      0.81       781
           1       0.00      0.00      0.00         6
           2       0.50      0.25      0.33        24
           3       0.00      0.00      0.00         3
           4       0.39      0.45      0.42        49
           5       0.17      0.60      0.27        20
           6       0.44      0.24      0.31        17
           7       0.00      0.00      0.00        13
           8       0.00      0.00      0.00        14
           9       1.00      0.88      0.93        16
          10       0.00      0.00      0.00        12
          11       0.33      0.02      0.03        56
          12       0.28      0.40      0.33        48
          13       0.00      0.00      0.00         9
          14       0.00      0.00      0.00        10
          15       0.00      0.00      0.00         4
          16       0.00      0.00      0.00         6
          17       0.72      0.79      0.76        53
          18       0.20      0.07      0.10        15
          19       0.00      0.00      0.00        13
          20       0.00      0.00      0.00         2
          21       0.00      0.00      0.00        12
          22       0.00      0.00      0.00        27
          23       0.24      0.22      0.23        32
          24       0.00      0.00      0.00         1
          25       0.00      0.00      0.00        11
          26       0.00      0.00      0.00        19
          27       0.00      0.00      0.00        13
          28       0.00      0.00      0.00         1
          29       0.00      0.00      0.00         1
          30       0.00      0.00      0.00         4
          31       0.00      0.00      0.00         4
          32       0.00      0.00      0.00        26
          33       0.00      0.00      0.00        10
          34       0.00      0.00      0.00         7
          35       0.00      0.00      0.00        12
          36       0.00      0.00      0.00         1
          37       0.00      0.00      0.00         3
          38       0.00      0.00      0.00         4
          39       0.00      0.00      0.00         9
          40       0.00      0.00      0.00         2
          41       0.00      0.00      0.00         1
          42       0.00      0.00      0.00        24
          43       0.00      0.00      0.00         4
          44       0.00      0.00      0.00         2
          45       0.00      0.00      0.00         2
          46       0.00      0.00      0.00         2
          47       0.00      0.00      0.00         2
          48       0.00      0.00      0.00         2
```

```
                49       0.00      0.00      0.00         1
                50       0.00      0.00      0.00         1
                51       0.00      0.00      0.00        36
                52       0.00      0.00      0.00         5
                53       0.00      0.00      0.00         1
                54       0.00      0.00      0.00         7
                55       0.00      0.00      0.00         1
                56       0.00      0.00      0.00         3
                57       0.00      0.00      0.00         2
                58       0.00      0.00      0.00         2
                59       0.00      0.00      0.00        11
                60       0.00      0.00      0.00         1
                61       0.00      0.00      0.00       145
                62       0.00      0.00      0.00        60
                69       0.00      0.00      0.00         0
                70       0.00      0.00      0.00         0

          accuracy                           0.53      1685
         macro avg       0.08      0.07      0.07      1685
      weighted avg       0.41      0.53      0.45      1685
```

In [ ]:
```
log2
```

Out[ ]:

	Classifier	Training accuracy	Testing accuracy	f1-score	Recall
0	RNN-LSTM Model - without Sampling	0.496439	0.464688	0.307287	0.464688
0	RNN-GRU Model - without Sampling	0.643917	0.513353	0.431207	0.513353
0	BiDirectional LSTM Model - without Sampling	0.659050	0.525223	0.448620	0.525223

Performance comparion of the RNN with LSTM, RNN wih GRU model and Bidirectional LSTM model

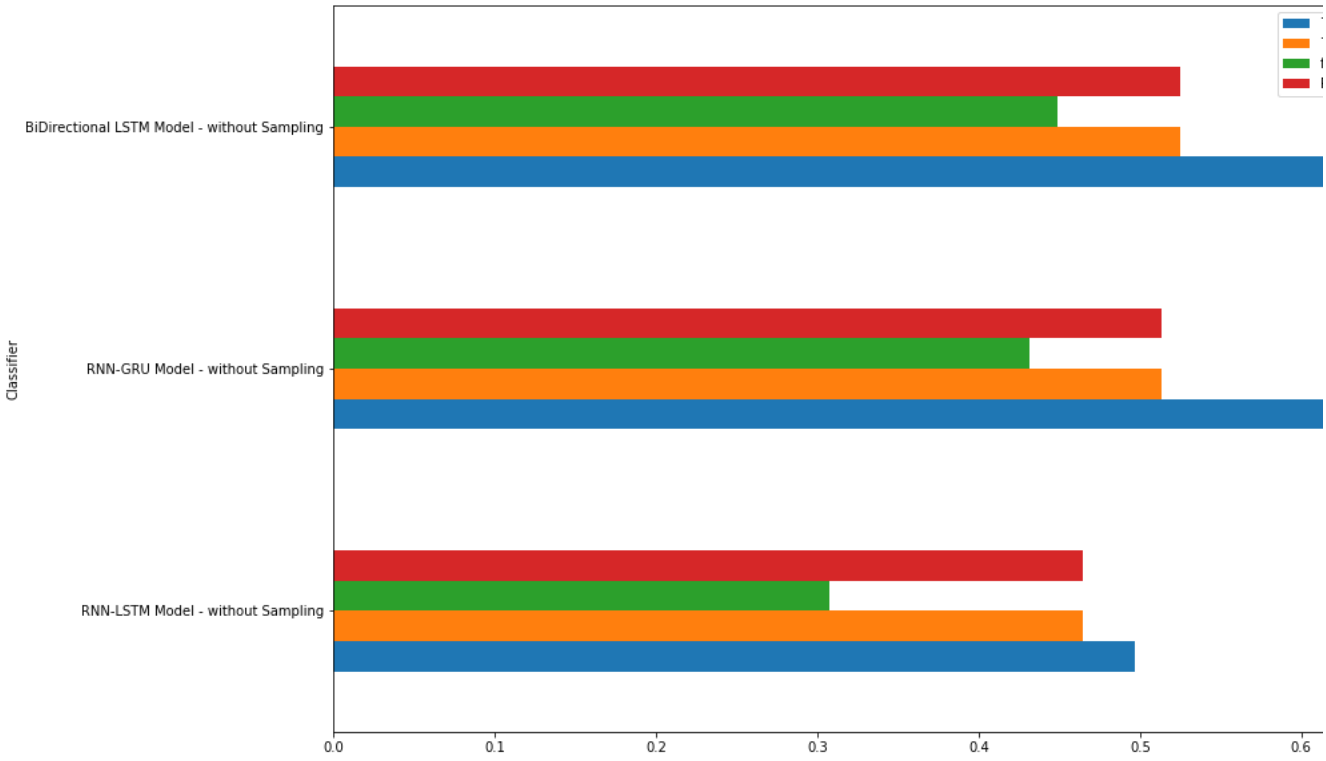
In [ ]:
```
logObs2 = log2
logObs2.set_index(["Classifier"],inplace=True)
logObs2.sort_values(by=['f1-score'])
```

Out[ ]:

Classifier	Training accuracy	Testing accuracy	f1-score	Recall
RNN-LSTM Model - without Sampling	0.496439	0.464688	0.307287	0.464688
RNN-GRU Model - without Sampling	0.643917	0.513353	0.431207	0.513353
BiDirectional LSTM Model - without Sampling	0.659050	0.525223	0.448620	0.525223

In [ ]:
```
logObs2.sort_values(by=['f1-score']).plot(kind='barh',figsize=[15,10])
```

Out[ ]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fd046ca5dd8>
```



Observation:

The difference between training accuracy and testing accuracy is not high. There is scope for much improvement in deep learning models and the testing accuracies of these mo

The model seems to be overfitting even with high need of tuning the model, but we still observe the overfitting already

The low accuracy is suspected to be due to imbalanced dataset used for training and testing.

We have to work upon the resampling the data to make the model work better

If we see in the above results we see that RNN-LSTM MOdel has more room to be tuned without getting overfitted

We need to explore ways to improve & fine tune the model performance without overfitting.

Future steps planned for deriving better results:

1. Data Imbalance Rationalisation: Data set will be resampled based on multiple approaches:

   a. Creating seperate single target group for not well represeted groups(may be with 20 or less assigned tickets) and then classify against highly represented group.

   b. The reclassify the group (cluster of meagre groups) in to the original groups.

   c. May be total drop off of some groups that are very sparsely represented (may be with less than 5 observations).

1. Caution to be taken for avoiding data leak between training and testing runs.
2. Hyper-parameter tuning for both Traditional ML models.
3. Playing with the learning rate to derive optimal speed and avoid minima jumps.
4. Increasing epochs for model to avoid underfitting
5. Will also try to find any new feature that is more defining to the assignment groups.
6. Increasing number of layers in Deep Learning Model
7. Increasing number of neurons in hidden layers