In [215…

```
# Import libraries
import pandas as pd
import numpy as np
import datetime as dt
import calendar
import statistics
from matplotlib import pyplot as plt
%matplotlib inline
from IPython.display import display
```

In [84]:

```
# Define functions
def getNextMonth(d):
    """
    getNextMonth function gets the date of the next month of the input da

    :param d: the date to get the next month
    :return: the date of the next month of the input date
    """
    _year = d.year+(d.month//12)
    _month =  1 if (d.month//12) else d.month + 1
    next_month_len = calendar.monthrange(_year,_month)[1]
    next_month = d
    if d.day > next_month_len:
        next_month = next_month.replace(day=next_month_len)
    next_month = next_month.replace(year=_year, month=_month)
    return next_month

# Example
# d = dt.datetime.strptime('2022-12-04', "%Y-%m-%d")
# print(getNextMonth(d))
# 2023-01-04 00:00:00

def isNextMonth(date1, date2):
    """
    isNextMonth function checks if date2 is the next month of date1.

    :param date1: the original date
    :param date2: the date to be checked
    :return: True/False, True if date2 is the next month of date1
    """
    d1 = dt.datetime.strptime(date1, "%Y-%m-%d")
    next_d1 = getNextMonth(d1)
    d2 = dt.datetime.strptime(date2, "%Y-%m-%d")

    next_date1_year = next_d1.year
    next_date1_month = next_d1.month
    date2_year = d2.year
    date2_month = d2.month

    if next_date1_year == date2_year and next_date1_month == date2_month:
        return True
    else:
        return False

# Example
```

```
# print(isNextMonth('2022-12-1', '2022-10-1'))
# print(isNextMonth('2022-12-1', '2023-1-1'))
# False
# True

def isThreeConsecutiveMonths(date1, date2, date3):
    """
    isThreeConsecutiveMonths function checks if date1, date2, and date3 a

    :param date1: the original date
    :param date2: the date to be the next month of date1
    :param date3: the date to be the next month of date2
    :return: True/False, True if date1, date2, and date3 are the three co
    """
    if isNextMonth(date1, date2) and isNextMonth(date2, date3):
        return True
    else:
        return False

# Example
# print(isThreeConsecutiveMonths('2022-12-1', '2022-10-1', '2022-11-1'))
# print(isThreeConsecutiveMonths('2022-12-1', '2023-1-1', '2023-2-1'))
# False
# True

def getNextDate(d):
    """
    getNextDate function gets the next date of the input date.

    :param d: the date to get the next date
    :return: the next date of the input date
    """
    date = dt.datetime.strptime(d, "%Y-%m-%d")
    date += dt.timedelta(days=1)
    r = str(date.year) + "-" + str(date.month) + "-" + str(date.day)
    return r

# Example
# print(getNextDate('2022-12-31'))
# 2023-1-1

def computeDistance(date1, date2):
    """
    computeDistance function compute the number of months which is differ

    :param date1: the original date
    :param date2: the date after date1
    :return: the number of months which is different between date1 and da
    """
    d1 = dt.datetime.strptime(date1, "%Y-%m-%d")
    d2 = dt.datetime.strptime(date2, "%Y-%m-%d")

    dis = (d2.year - d1.year)*12 + (d2.month-d1.month)

    return dis

# Example
```

```
# print(computeDistance('2022-12-1', '2023-10-1'))
# print(computeDistance('2022-12-1', '2022-12-4'))
# 10
# 0
```

In [85]:
```
# Load data
transactions = pd.read_csv("transactions.csv")
display(transactions.head(5))
display(len(transactions))
```

	donor_id	date	status	method	amount
0	3010968710038526988	2000-09-11	Success	Credit Card	10.0
1	3010968710038526988	2000-10-11	Success	Credit Card	10.0
2	3010968710038526988	2000-11-11	Success	Credit Card	10.0
3	3010968710038526988	2000-12-11	Success	Credit Card	10.0
4	3010968710038526988	2001-01-11	Success	Credit Card	10.0

651560

In [86]:
```
# 1. Clean and process the data
# 1.1. Add more columns
transactions.insert(loc=0,
          column='transaction_id',
          value=0)
# Duration to the next successful transaction, unit is month, 100 for the
transactions.insert(loc=6,
          column='duration',
          value='')
transactions.insert(loc=7,
          column='churn_date',
          value='')
transactions.insert(loc=8,
          column='variation',
          value='')
transactions.insert(loc=9,
          column='activate',
          value='')
display(transactions.head(5))
```

	transaction_id	donor_id	date	status	method	amount	duration	ch
0	0	3010968710038526988	2000-09-11	Success	Credit Card	10.0		
1	0	3010968710038526988	2000-10-11	Success	Credit Card	10.0		
2	0	3010968710038526988	2000-11-11	Success	Credit Card	10.0		
3	0	3010968710038526988	2000-12-11	Success	Credit Card	10.0		
4	0	3010968710038526988	2001-01-11	Success	Credit Card	10.0		

In [87]:
```
# 1.2. Upate status to Failed for transactions with amount <= 0
transactions.loc[transactions['amount'] <= 0,'status'] = 'Failed'
display(transactions.loc[transactions['status'] == 'Failed'])
```

	transaction_id	donor_id	date	status	method	amount	duratio
196	0	-7882208113119762257	2007-09-17	Failed	Credit Card	0.0	
5059	0	-2625869298489482735	2002-02-19	Failed	Credit Card	0.0	
5060	0	-2625869298489482735	2002-03-19	Failed	Credit Card	0.0	
7486	0	3826088184594753164	2007-01-11	Failed	Credit Card	0.0	
7487	0	3826088184594753164	2007-06-11	Failed	Credit Card	0.0	
...	...	...	...	...	...	...	
651400	0	-5819989599172667185	2012-06-28	Failed	Direct Debit	0.0	
651404	0	-5819989599172667185	2012-11-29	Failed	Direct Debit	0.0	
651405	0	-5819989599172667185	2012-12-20	Failed	Direct Debit	0.0	
651406	0	-5819989599172667185	2013-02-27	Failed	Direct Debit	0.0	
651407	0	-5819989599172667185	2013-08-29	Failed	Direct Debit	0.0	

13816 rows × 10 columns

In [88]:
```
# 1.3. Sort the data
transactions = transactions.sort_values(['donor_id', 'date'], ascending=[
transactions.head(5)
```

Out[88]:

	transaction_id	donor_id	date	status	method	amount	dura
201849	0	-9222334905648926039	2002-10-17	Success	Credit Card	12.0	
201850	0	-9222334905648926039	2002-11-17	Success	Credit Card	12.0	
201851	0	-9222334905648926039	2002-12-17	Success	Credit Card	12.0	
201852	0	-9222334905648926039	2003-01-17	Success	Credit Card	12.0	
201853	0	-9222334905648926039	2003-02-17	Success	Credit Card	12.0	

In [89]:
```
# 1.4. Set transactions ids
n = len(transactions)
transactions['transaction_id'] = range(n)
transactions.head(5)
```

Out[89]:

	transaction_id	donor_id	date	status	method	amount	dura
201849	0	-9222334905648926039	2002-10-17	Success	Credit Card	12.0	
201850	1	-9222334905648926039	2002-11-17	Success	Credit Card	12.0	
201851	2	-9222334905648926039	2002-12-17	Success	Credit Card	12.0	
201852	3	-9222334905648926039	2003-01-17	Success	Credit Card	12.0	
201853	4	-9222334905648926039	2003-02-17	Success	Credit Card	12.0	

In [101…
```
# 2. Identify churns
# 2.1. Set duration column
t = transactions.copy()
n = len(t)
cur_donor = t.loc[t.transaction_id == 0,'donor_id'].values[0]
if t.loc[t.transaction_id == 0,'status'].values[0] == 'Success':
    cur_suc_tran = 0
    t.loc[t.transaction_id == 0,'duration'] = 100 # see as the last succe
else:
    cur_suc_tran = -1
for i in range(1,n):
    if t.loc[t.transaction_id == i,'donor_id'].values[0] == cur_donor:
        if t.loc[t.transaction_id == i,'status'].values[0] == 'Success':
            if cur_suc_tran != -1:
                t.loc[t.transaction_id == cur_suc_tran,'duration'] = comp
            t.loc[t.transaction_id == i,'duration'] = 100 # see as the la
            cur_suc_tran = i
    else:
        cur_donor = t.loc[t.transaction_id == i,'donor_id'].values[0]
        if t.loc[t.transaction_id == i,'status'].values[0] == 'Success':
            cur_suc_tran = i
            t.loc[t.transaction_id == i,'duration'] = 100 # see as the la
        else:
            cur_suc_tran = -1

t.to_csv('transactions_suc_duration.csv')
```

In [108…
```
# 2.2. Identify churn dates and churns
tran_duration = pd.read_csv("transactions_suc_duration.csv")
tran_duration = tran_duration.drop(tran_duration.columns[[0]], axis=1)
n = len(tran_duration)
for i in range(n):
    if tran_duration.loc[tran_duration.transaction_id == i,'duration'].va
        tran_duration.loc[tran_duration.transaction_id == i,'churn_date']

tran_duration.to_csv('transactions_churn.csv')

churn = tran_duration.copy()
churn = churn[['donor_id', 'churn_date']]
churn = churn.dropna(subset=['churn_date'])[['donor_id','churn_date' ]]
churn.to_csv('churn.csv')
```

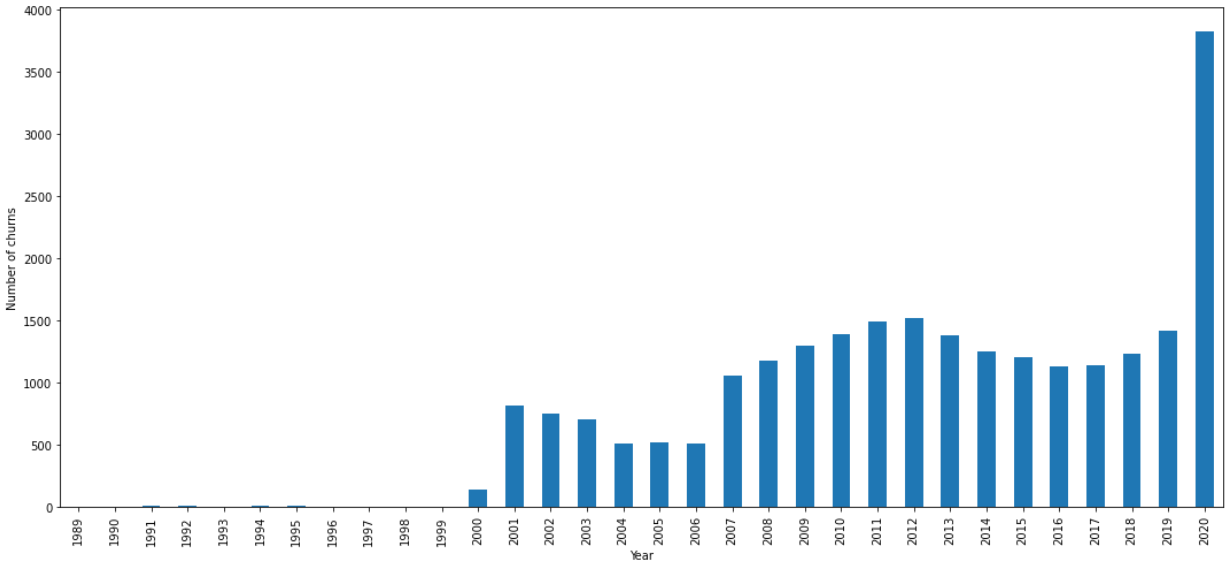
In [112…
```
# 2.3. Identify variation
tran_churn = pd.read_csv("transactions_churn.csv")
tran_churn = tran_churn.drop(tran_churn.columns[[0]], axis=1)
n = len(tran_churn)
tran_churn = tran_churn.reset_index()  # make sure indexes pair with numb
cur_donor = tran_churn.loc[0,'donor_id']
for i in range(1, n):
    donor_id = tran_churn.loc[i,'donor_id']
    if donor_id == cur_donor:
        if tran_churn['status'].iloc[i] == 'Success' and tran_churn['stat
            if tran_churn['amount'].iloc[i] > tran_churn['amount'].iloc[i
                tran_churn.loc[i,'variation'] = 'Upgrade'
            elif tran_churn['amount'].iloc[i] < tran_churn['amount'].iloc
                tran_churn.loc[i,'variation'] = 'Downgrade'
    else:
        cur_donor = donor_id

tran_churn = tran_churn.drop(tran_churn.columns[[0]], axis=1)
tran_churn.to_csv('transactions_variation.csv')
```

In [130…
```
# 2.3 Identify activate/reactivate
tran_var = pd.read_csv("transactions_variation.csv")
tran_var = tran_var.drop(tran_var.columns[[0]], axis=1)
n = len(tran_var)
tran_var = tran_var.reset_index()  # make sure indexes pair with number o
cur_donor = tran_var.loc[0,'donor_id']
tran_var.loc[0,'activate'] = 'Activate'
cur_type = 'Activate'
if not pd.isna(tran_var['churn_date'].iloc[0]):
    tran_var.loc[0,'activate'] = 'Deactivate'
    cur_type = 'Deactivate'
for i in range(1, n):
    if tran_var.loc[i,'status'] == 'Success':
        donor_id = tran_var.loc[i,'donor_id']
        if donor_id == cur_donor:
            if not pd.isna(tran_var['churn_date'].iloc[i]):
                tran_var.loc[i,'activate'] = 'Deactivate'
                cur_type = 'Deactivate'
            elif cur_type == 'Deactivate':
                tran_var.loc[i,'activate'] = 'Reactivate'
                cur_type = 'Reactivate'
        else:
            cur_donor = donor_id
            tran_var.loc[i,'activate'] = 'Activate'
            cur_type = 'Activate'
            if not pd.isna(tran_var['churn_date'].iloc[i]):
                tran_var.loc[i,'activate'] = 'Deactivate'
                cur_type = 'Deactivate'

tran_var = tran_var.drop(tran_var.columns[[0]], axis=1)
tran_var.to_csv('processed_transactions.csv')
```

In [174…
```
# 3. Charts and analysis
# 3.1. How big of a problem is donor churn?
churn = pd.read_csv("churn.csv")
churn = churn.drop(churn.columns[[0]], axis=1)
churn = churn.sort_values(['churn_date'], ascending=[True])
n = len(churn)
churn.insert(loc=2,
          column='year',
          value=0)
churn = churn.reset_index()  # make sure indexes pair with number of rows
for i in range(n):
    d = dt.datetime.strptime(churn.loc[i,'churn_date'], "%Y-%m-%d")
    churn.loc[i,'year'] = d.year

churn.to_csv('churn_with_year.csv')

duration = max(churn['year']) - min(churn['year'])
average_churn = n/(max(churn['year']) - min(churn['year']))
total = n/(max(churn['year']) - min(churn['year'])) * 12 * 20
print("The total number of churns: " + str(n))
print("The duration for the evaluation of the churns: " + str(duration) +
print("The average number of churns per year: " + str(average_churn))
print("Suppose that the amount for each donation per month is $20, the to
```

```
The total number of churns: 24589
The duration for the evaluation of the churns: 31 years, from year 1989 t
o year 2020
The average number of churns per year: 793.1935483870968
Suppose that the amount for each donation per month is $20, the total amo
unt has been lost per year due to the churns = the average number of chur
ns per year * 12 months * $20 per month = $190366.45161290327
```

In [200…
```
# 3.2. The progress of churns over time
churn = pd.read_csv("churn_with_year.csv")
churn = churn.drop(churn.columns[[0]], axis=1)
churn = churn.sort_values(['year'], ascending=[True])

plt.rcParams["figure.figsize"] = [15, 7]
plt.rcParams["figure.autolayout"] = True
fig, ax = plt.subplots()
churn['year'].value_counts().sort_index().plot(ax=ax, kind='bar', xlabel=
plt.savefig("churn_problem.pdf", format="pdf", bbox_inches="tight")
plt.savefig("churn_problem.png", format="png", bbox_inches="tight")
plt.show()

print("We can see that the churns are worse over time, with an significan
```



We can see that the churns are worse over time, with an significant increase from 2001. Especially, the number of churns was sharply increased from about 1,500 in 2019 to nearly 4,000 in 2020.

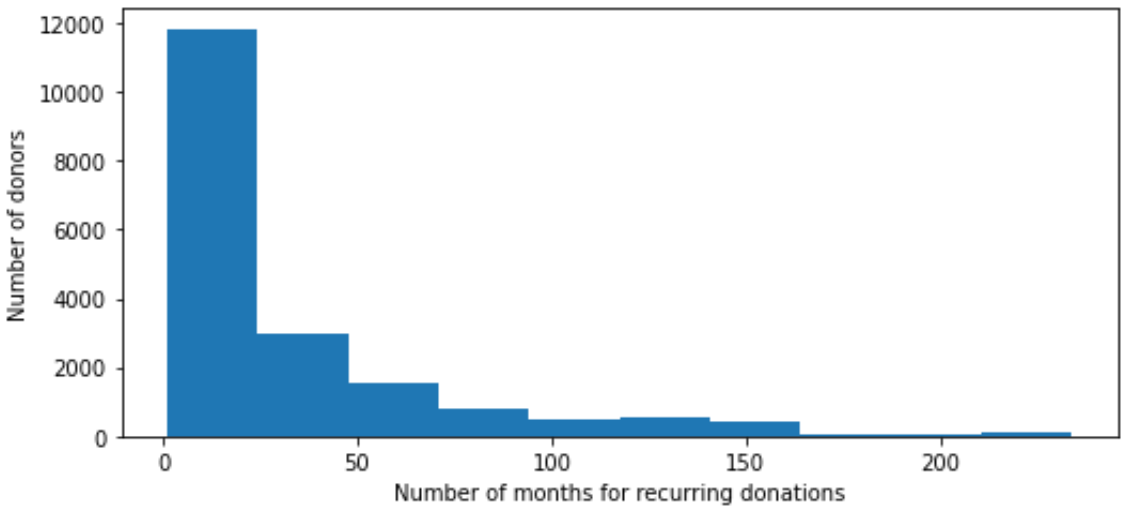
In [203…

```
# 3.3. Downgrade and churns
tran = pd.read_csv("processed_transactions.csv")
tran = tran.drop(tran.columns[[0]], axis=1)
t = tran.loc[tran['variation'].isin(['Downgrade'])]
t2 = t.loc[t['activate'].isin(['Deactivate'])]

print("The number of churns which are after a downgrade is: " + str(len(t
```

The number of churns which are after a downgrade is: 296. Although it is a small number, we may need to follow up the cases of Downgrade to avoid unnecessary churns.

In [223…

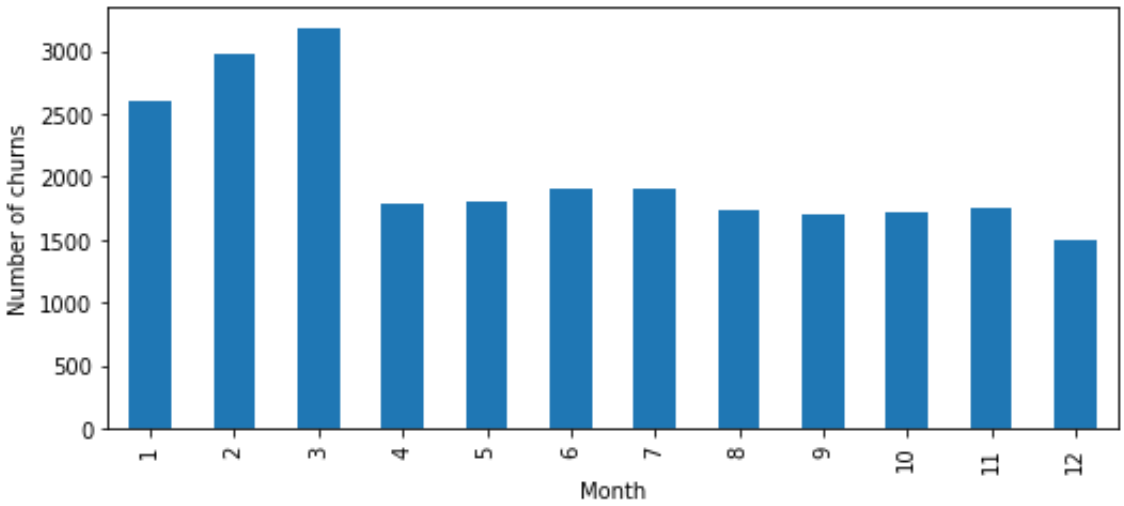
```
# 3.4. The duration for recurring donations
tran = pd.read_csv("processed_transactions.csv")
tran = tran.drop(tran.columns[[0]], axis=1)
t = tran.loc[tran['activate'].isin(['Activate', 'Deactivate', 'Reactivate
t.insert(loc=10,
         column='donation_duration',
         value=0)
t = t.reset_index()  # make sure indexes pair with number of rows
n = len(t)

cur_donor = t.loc[0,'donor_id']
cur_type = t.loc[0,'activate']

for i in range(1, n):
    donor_id = t.loc[i,'donor_id']
    if donor_id == cur_donor:
        if cur_type in ['Activate', 'Reactivate'] and t['activate'].iloc[
            t.loc[i,'donation_duration'] = computeDistance(t['date'].iloc
            cur_type = 'Deactivate'
        else:
            cur_type = t.loc[i,'activate']
    else:
        cur_donor = donor_id
        cur_type = t.loc[i,'activate']

t = t.loc[t['donation_duration'] > 0]
durations = t.loc[:,'donation_duration']
mean = statistics.mean(durations)

plt.rcParams["figure.figsize"] = [7.5,3.5]
plt.rcParams["figure.autolayout"] = True
fig, ax = plt.subplots()
ax.set_xlabel('Number of months for recurring donations')
ax.set_ylabel('Number of donors')
plt.hist(durations)
plt.savefig("durations.pdf", format="pdf", bbox_inches="tight")
plt.savefig("durations.png", format="png", bbox_inches="tight")
plt.show()

print("The average number of months for recurring donations is: " + str(m
```



```
The average number of months for recurring donations is: 32.2183325413168
6. Thus, we may need to follow up with donors who have their donations ov
er continuous 30 months.
```

In [229…

```
# 3.5. The churns over months
churn = pd.read_csv("churn.csv")
churn = churn.drop(churn.columns[[0]], axis=1)
churn = churn.sort_values(['churn_date'], ascending=[True])
n = len(churn)
churn.insert(loc=2,
          column='month',
          value=0)
churn = churn.reset_index()  # make sure indexes pair with number of rows
for i in range(n):
    d = dt.datetime.strptime(churn.loc[i,'churn_date'], "%Y-%m-%d")
    churn.loc[i,'month'] = d.month

churn.to_csv('churn_with_month.csv')

plt.rcParams["figure.figsize"] = [7.5, 3.5]
plt.rcParams["figure.autolayout"] = True
fig, ax = plt.subplots()
churn['month'].value_counts().sort_index().plot(ax=ax, kind='bar', xlabel
plt.savefig("churn_month.pdf", format="pdf", bbox_inches="tight")
plt.savefig("churn_month.png", format="png", bbox_inches="tight")
plt.show()

print("We can see that the churns in January, February, and March are sig
```




```
We can see that the churns in January, February, and March are significan
tly more than those in other months. Thus, we may also need to focus on t
hese months.
```

In [ ]: