process

December 4, 2021

#read the csv file as dataframe

[1]:
```
import pandas as pd

df = pd.read_csv('/Users/wlk/Desktop/3.Semester/CSS/CSIS/nodes')
df=df['specialty;"city";"patients";"free_time";"community";"friends";
 ↪"adoption_date";"proximity";"med_sch_yr";"jours";"clubs";"meetings";"id";
 ↪"discuss"'].str.split(';', expand=True)

# df[6] == df[""adoption_date""]
df.head(20)
```

[1]:

	0	1	2	3	4	5	6	7	8	9	10	11	12	\
0	9	"Galesburg"	"9"	"9"	"9"	"9"	"99"	"9"	"9"	"9"	"9"	"9"	"246"	
1	9	"Galesburg"	"9"	"9"	"9"	"9"	"99"	"9"	"9"	"9"	"9"	"9"	"245"	
2	9	"Galesburg"	"9"	"9"	"9"	"9"	"99"	"9"	"9"	"9"	"9"	"9"	"244"	
3	4	"Galesburg"	"2"	"1"	"4"	"3"	"98"	"2"	"4"	"4"	"0"	"2"	"243"	
4	4	"Galesburg"	"9"	"1"	"5"	"3"	"98"	"2"	"4"	"5"	"0"	"1"	"242"	
5	1	"Galesburg"	"9"	"9"	"6"	"9"	"16"	"3"	"2"	"4"	"9"	"1"	"241"	
6	4	"Galesburg"	"3"	"1"	"6"	"1"	"98"	"3"	"3"	"9"	"1"	"2"	"240"	
7	4	"Galesburg"	"2"	"3"	"6"	"2"	"98"	"3"	"1"	"5"	"0"	"2"	"239"	
8	4	"Galesburg"	"3"	"1"	"4"	"3"	"98"	"3"	"2"	"6"	"0"	"2"	"238"	
9	4	"Galesburg"	"3"	"1"	"4"	"1"	"98"	"3"	"4"	"4"	"1"	"2"	"237"	
10	4	"Galesburg"	"9"	"1"	"4"	"2"	"98"	"3"	"5"	"4"	"0"	"2"	"236"	
11	4	"Galesburg"	"5"	"1"	"5"	"1"	"98"	"3"	"3"	"7"	"0"	"2"	"235"	
12	4	"Galesburg"	"2"	"1"	"4"	"3"	"98"	"2"	"3"	"3"	"0"	"2"	"234"	
13	4	"Galesburg"	"6"	"3"	"3"	"4"	"98"	"3"	"5"	"4"	"1"	"2"	"233"	
14	4	"Galesburg"	"6"	"3"	"3"	"3"	"98"	"3"	"5"	"5"	"1"	"2"	"232"	
15	4	"Galesburg"	"9"	"1"	"5"	"2"	"98"	"3"	"2"	"8"	"0"	"2"	"231"	
16	4	"Galesburg"	"3"	"3"	"4"	"4"	"98"	"3"	"4"	"7"	"1"	"1"	"230"	
17	3	"Galesburg"	"4"	"1"	"4"	"1"	"7"	"3"	"5"	"4"	"0"	"2"	"229"	
18	1	"Galesburg"	"5"	"2"	"6"	"3"	"98"	"1"	"1"	"2"	"0"	"2"	"228"	
19	3	"Galesburg"	"9"	"2"	"1"	"4"	"14"	"3"	"6"	"6"	"0"	"1"	"227"	

	13
0	"9"
1	"9"
2	"9"

```
3   "1"
4   "2"
5   "9"
6   "1"
7   "2"
8   "1"
9   "2"
10  "1"
11  "1"
12  "2"
13  "1"
14  "2"
15  "1"
16  "1"
17  "2"
18  "1"
19  "2"
```

[2]:
```
num_agents = df.shape[0]
print(num_agents)
```

246

1 rearrange connections into clusters

[3]:
```
import csv

import numpy as np


max_node_array= [116, 166, 210, 246]
cluster_range = [[0,116],[116,166],[166,210],[210,246]]
cluster_size = [116,50,44,36]

cluster_names = ["Peoria","Bloomington" , "Quincy" ,"Galesburg"]



def get_edges_array(cluster_max):

    peoria_cluster_edges = []

    bloomington_cluster_edges = []

    quincy_cluster_edges = []
```

```
    galesburg_cluster_edges = []

    with open('/Users/wlk/Desktop/3.Semester/CSS/CSIS/medical_innovationver3.
↪csv',newline='', encoding='utf-8') as f:

        reader = csv.reader(f)

        row_num = 0

        for row in reader:
            if row_num == 0:
                row_num+=1
            else:
                edge_properties = []
                args = row[0].split(";")

                node1 = int(args[0]) -1



                node2 = int(args[1][1:-1]) -1

                fr_ad_dis = [int(args[2][1:-1]), int(args[3][1:-1]),␣
↪int(args[5][1:-1])]

                id = int(args[4][1:-1])

                edge_properties= [node1, node2, fr_ad_dis[0], fr_ad_dis[1],␣
↪fr_ad_dis[2]]

                if (node1 <= cluster_max[0] and node2 <= cluster_max[0]):



                    peoria_cluster_edges.append(edge_properties)

                elif(node1 <= cluster_max[1] and node2 <= cluster_max[1]):

                    bloomington_cluster_edges.append(edge_properties)

                elif(node1 <= cluster_max[2] and node2 <= cluster_max[2]):

                    quincy_cluster_edges.append(edge_properties)

                else:

                    galesburg_cluster_edges.append(edge_properties)
```

```
    return peoria_cluster_edges, bloomington_cluster_edges,␣
 ↪quincy_cluster_edges, galesburg_cluster_edges



###

# edges arrays arguments:

#   - node1 (from)

#   - node2 (to)

#   - friendship relation

#   - advice relation

#   - discussion relation

#  ###

peoria_edges, bloomington_edges, quincy_edges, galesburg_edges =␣
 ↪get_edges_array(max_node_array)
edge_properties=[]
edge_properties.append(peoria_edges)
edge_properties.append(bloomington_edges)
edge_properties.append(quincy_edges)
edge_properties.append(galesburg_edges)
```

2 get time revolution (of opinion status of an agent) with original data

1. each row represents an agent
2. each column represents the agent's opinion at this timepoint

[4]:
```
ad_time_all_old = df[6]
ad_time_all=[]
for i in range(246):
  ad_time_all.append(int(ad_time_all_old[i][1:-1]))
print(ad_time_all)
ad_time_all=np.asarray(ad_time_all)
```

```
[99, 99, 99, 98, 98, 16, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 7, 98, 14,
4, 7, 14, 6, 3, 6, 13, 8, 3, 4, 8, 5, 4, 18, 18, 99, 99, 99, 99, 99, 99, 99, 99,
99, 99, 98, 2, 3, 8, 11, 13, 3, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98,
```

```
5, 6, 6, 7, 16, 15, 3, 18, 7, 5, 18, 4, 18, 18, 2, 99, 99, 99, 99, 99, 99, 98,
98, 98, 98, 98, 7, 18, 9, 9, 18, 1, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98,
98, 98, 7, 17, 5, 11, 2, 2, 1, 1, 5, 2, 1, 6, 7, 18, 1, 6, 7, 98, 1, 98, 99, 99,
99, 99, 99, 99, 99, 99, 99, 18, 98, 98, 7, 98, 98, 98, 98, 98, 98, 3, 4, 13, 5,
2, 1, 6, 7, 98, 99, 98, 98, 99, 98, 98, 98, 18, 4, 18, 6, 1, 7, 6, 1, 12, 12,
18, 98, 11, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 4, 98, 98, 98, 98, 98,
98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 98, 18, 14, 8, 8, 4, 14, 6, 7,
5, 15, 3, 5, 1, 6, 3, 4, 5, 7, 8, 2, 11, 5, 18, 15, 4, 15, 2, 5, 4, 2, 11, 3,
18, 10, 9, 9, 8, 12, 1]
```

[5]:
```
time_range = ad_time_all.max()
print(time_range)

opinion_timeline_agents = []
for i in range(num_agents):
  opinion_timeline_agent_i = np.zeros(99)
  adoption_timepoint = int(ad_time_all[i])
  opinion_timeline_agent_i=[1 if j >= adoption_timepoint-1 else 0 for j in␣
 ↪range(time_range) ]
  opinion_timeline_agents.append(opinion_timeline_agent_i)
opinion_timeline_agents=np.asarray(opinion_timeline_agents)

print(opinion_timeline_agents)
```

```
99
[[0 0 0 … 0 0 1]
 [0 0 0 … 0 0 1]
 [0 0 0 … 0 0 1]
 …
 [0 0 0 … 1 1 1]
 [0 0 0 … 1 1 1]
 [1 1 1 … 1 1 1]]
```

3 plot the real percentage change

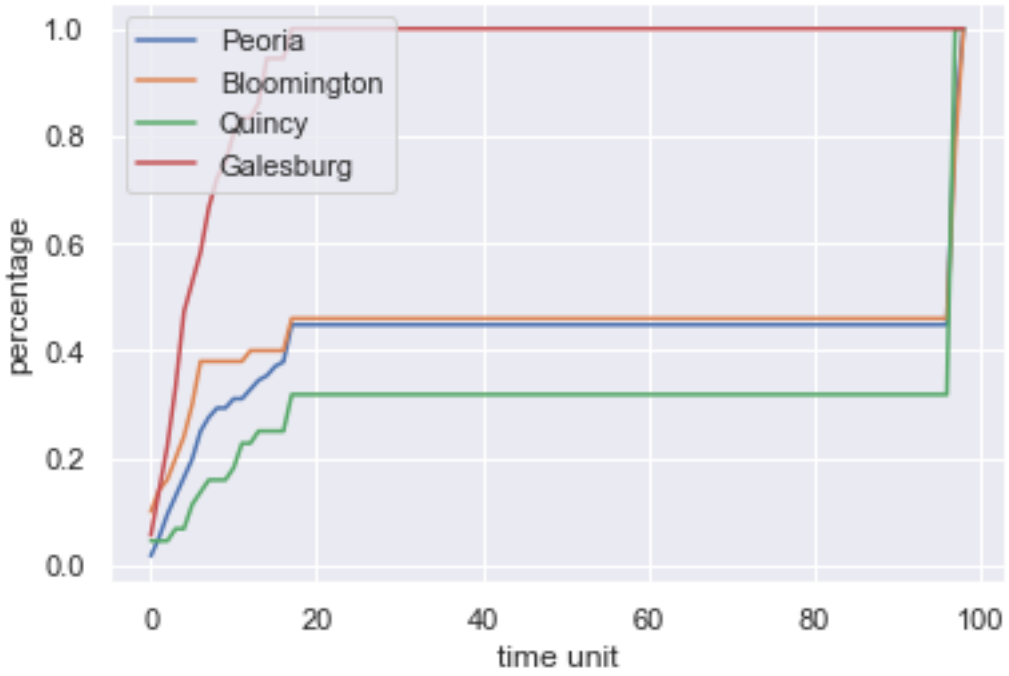
[6]:
```
from sklearn.model_selection import train_test_split
import seaborn as sns

# label : percentage of opinion 1 at each timepoint

def get_change_real(cluster_index):

    real_percentage_overtime = []

    for i in range(99):
```

```
        cluster_column_i =␣
↪opinion_timeline_agents[cluster_range[cluster_index][0]:
↪cluster_range[cluster_index][1],i]
        ones = np.count_nonzero(cluster_column_i)
        percent = ones / cluster_size[cluster_index]

        combined = []
        combined.append(i)
        combined.append(percent)

        real_percentage_overtime.append(combined)

    data = pd.DataFrame(real_percentage_overtime, columns = ['time␣
↪unit','percentage'])

    print("cluster ",cluster_index)
    print(data.head(20))
    print()
    sns.set_theme()
    sns.lineplot(x='time unit', y='percentage', data=data,label =␣
↪cluster_names[cluster_index], ci=None)

    return real_percentage_overtime

real_cluster_0 = get_change_real(0)
real_cluster_1 = get_change_real(1)
real_cluster_2 = get_change_real(2)
real_cluster_3 = get_change_real(3)
```

```
cluster  0
    time unit  percentage
0           0    0.017241
1           1    0.051724
2           2    0.094828
3           3    0.129310
4           4    0.163793
5           5    0.198276
6           6    0.250000
7           7    0.275862
8           8    0.293103
9           9    0.293103
10         10    0.310345
11         11    0.310345
12         12    0.327586
13         13    0.344828
14         14    0.353448
15         15    0.370690
```

```
16          16    0.379310
17          17    0.448276
18          18    0.448276
19          19    0.448276

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.14
2           2        0.16
3           3        0.20
4           4        0.24
5           5        0.30
6           6        0.38
7           7        0.38
8           8        0.38
9           9        0.38
10         10        0.38
11         11        0.38
12         12        0.40
13         13        0.40
14         14        0.40
15         15        0.40
16         16        0.40
17         17        0.46
18         18        0.46
19         19        0.46

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.045455
2           2    0.045455
3           3    0.068182
4           4    0.068182
5           5    0.113636
6           6    0.136364
7           7    0.159091
8           8    0.159091
9           9    0.159091
10         10    0.181818
11         11    0.227273
12         12    0.227273
13         13    0.250000
14         14    0.250000
15         15    0.250000
16         16    0.250000
17         17    0.318182
```

```
18          18    0.318182
19          19    0.318182

cluster  3
    time unit  percentage
0           0    0.055556
1           1    0.138889
2           2    0.222222
3           3    0.333333
4           4    0.472222
5           5    0.527778
6           6    0.583333
7           7    0.666667
8           8    0.722222
9           9    0.750000
10         10    0.805556
11         11    0.833333
12         12    0.833333
13         13    0.861111
14         14    0.944444
15         15    0.944444
16         16    0.944444
17         17    1.000000
18         18    1.000000
19         19    1.000000
```



4 plot the simulated percentage change with fixed parameters

[83]:
```
from sklearn.linear_model import LinearRegression
import math
from scipy import stats


def get_initial_opinions(cluster_number):
    initial_opinions = []

    for i in range(num_agents):
        initial_opinions.append(opinion_timeline_agents[i][0])

    peoria_initials = initial_opinions[0:max_node_array[0]]
    bloomington_initials = initial_opinions[cluster_range[1][0]:
 ↪cluster_range[1][1]]
    quincy_initials = initial_opinions[cluster_range[2][0]:cluster_range[2][1]]
    galesburg_initials = initial_opinions[cluster_range[3][0]:
 ↪cluster_range[3][1]]
    opinion_initials_per_cluster = [peoria_initials, bloomington_initials,␣
 ↪quincy_initials, galesburg_initials]

    return opinion_initials_per_cluster[cluster_number]



# # get percentage of opinion 1 at each timepoint with our model
def get_change_simulated(cluster_index, k_alpha, k_beta, k_gamma, E_profit):
    edge_props = edge_properties[cluster_index]

    simulated_percentage_overtime = []

    # initial state
    #initial_state_all = [0,opinion_timeline_agents[:,0]]
    #initial_state_this_cluster = initial_state_all[cluster_range[i][0]:
 ↪cluster_range[i][1]]

    #simulated_percentage_overtime.append(initial_state_this_cluster)
    initial_state_this_cluster = get_initial_opinions(cluster_index)
    current_state = [0, initial_state_this_cluster ]
    simulated_percentage_overtime.append([0, np.
 ↪count_nonzero(initial_state_this_cluster)/cluster_size[cluster_index]])

    # calculate driving force(cluster specific)
```

```
    driving_force = update_driving_forces_cluster_specific(edge_props,␣
↪cluster_index, current_state[1])

    # later states
    for i in range(25):
        new_opinions, driving_force = update(driving_force, edge_props,␣
↪cluster_index, current_state[1])
        current_state = [i+1, new_opinions ]
        simulated_percentage_overtime.append([i+1, np.
↪count_nonzero(new_opinions)/cluster_size[cluster_index]])


    # plotting
    simulation= pd.DataFrame(simulated_percentage_overtime, columns = ['time␣
↪unit','percentage'])

    print("cluster ",cluster_index)
    print(simulation.head(25))
    print()
    sns.set_theme()
    sns.lineplot(x='time unit', y='percentage', data=simulation, label␣
↪=cluster_names[cluster_index],ci=None)


def update_driving_forces_cluster_specific(edge_props, cluster_number,␣
↪opinions):
    len_cluster = 0
    first_node = 0
    if cluster_number == 0:
        len_cluster = max_node_array[0]
    else:
        len_cluster =␣
↪max_node_array[cluster_number]-max_node_array[cluster_number-1]
        first_node = max_node_array[cluster_number-1]

    updated_driving_force = np.zeros(len_cluster)

    agents_ids = [first_node+i for i in range(len_cluster)]

    for a in agents_ids:
        for edge in edge_props:
            #check that the edge is directed at node a and opinions of agents␣
↪don't match
            if edge[1] == a and  not opinions[a-first_node] ==␣
↪opinions[edge[0]-first_node]:
```

```
                updated_driving_force[a-first_node] += edge[2] * k_alpha +␣
↪edge[3] * k_beta + edge[4]*k_gamma
        updated_driving_force[a-first_node]+=E_profit
        #print("agent {} obtained a driving force of {}".format(a,␣
↪updated_driving_force[a]))

    return updated_driving_force


def prob_of_change(driving_forces):
    driving_forces = normalise_driving_force(driving_forces, -2 ,2)
    probs = stats.norm.cdf(driving_forces)
    #probs = np.repeat(0.01, len(driving_forces))
    #probs = driving_forces/(len(driving_forces) * k_alpha + E_profit)
    #print(probs)
    return probs

def normalise_driving_force(driving_forces, a, b):
    min_val = np.amin(driving_forces)
    #max_val = np.amax(driving_forces)
    max_val = ((len(driving_forces) * (k_alpha+k_beta+k_gamma)) + E_profit)
    #return (b-a) * (driving_forces-min_val)/(max_val-min_val) - a
    return ((b-a)* driving_forces/max_val)+a

def opinion(x, p):
    res = (np.random.rand(1))[0]
    return 1-x if res < p else x

def opinion_no_return(x, p):
    if(x == 1):
        return 1
    else:
        return opinion(x,p)


def update(driving_forces, edge_props, cluster_index, current_state):
    new_states = []
    prob = prob_of_change(driving_forces)
    for agent in range(cluster_size[cluster_index]):
        #new_state = opinion(current_state[agent], prob[agent])
        new_state_no_return = opinion_no_return(current_state[agent],␣
↪prob[agent])
        #new_states.append(new_state)
        new_states.append(new_state_no_return)

    new_driving_force = update_driving_forces_cluster_specific(edge_props,␣
↪cluster_index, current_state)
```

```
    return new_states, new_driving_force
```

5 With return:

[75]:
```
get_change_simulated(0,1,2,3,15)
get_change_simulated(1,1,2,3,15)
get_change_simulated(2,1,2,3,15)
get_change_simulated(3,1,2,3,15)
```

```
cluster  0
    time unit  percentage
0           0    0.017241
1           1    0.034483
2           2    0.051724
3           3    0.077586
4           4    0.086207
5           5    0.094828
6           6    0.094828
7           7    0.112069
8           8    0.112069
9           9    0.120690
10         10    0.129310
11         11    0.146552
12         12    0.163793
13         13    0.172414
14         14    0.198276
15         15    0.206897
16         16    0.232759
17         17    0.241379
18         18    0.250000
19         19    0.250000
20         20    0.293103
21         21    0.267241
22         22    0.275862
23         23    0.284483
24         24    0.301724

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.12
2           2        0.12
3           3        0.22
4           4        0.24
5           5        0.26
```

```
6           6        0.28
7           7        0.28
8           8        0.30
9           9        0.28
10         10        0.30
11         11        0.34
12         12        0.34
13         13        0.38
14         14        0.42
15         15        0.42
16         16        0.48
17         17        0.42
18         18        0.44
19         19        0.50
20         20        0.52
21         21        0.50
22         22        0.52
23         23        0.58
24         24        0.60

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.159091
2           2    0.181818
3           3    0.272727
4           4    0.272727
5           5    0.318182
6           6    0.318182
7           7    0.295455
8           8    0.318182
9           9    0.340909
10         10    0.272727
11         11    0.250000
12         12    0.272727
13         13    0.295455
14         14    0.295455
15         15    0.295455
16         16    0.318182
17         17    0.272727
18         18    0.272727
19         19    0.272727
20         20    0.272727
21         21    0.340909
22         22    0.340909
23         23    0.318182
24         24    0.318182
```

cluster 3

	time unit	percentage
0	0	0.055556
1	1	0.055556
2	2	0.166667
3	3	0.166667
4	4	0.222222
5	5	0.222222
6	6	0.250000
7	7	0.250000
8	8	0.277778
9	9	0.305556
10	10	0.361111
11	11	0.388889
12	12	0.444444
13	13	0.472222
14	14	0.472222
15	15	0.500000
16	16	0.500000
17	17	0.500000
18	18	0.444444
19	19	0.527778
20	20	0.583333
21	21	0.638889
22	22	0.722222
23	23	0.750000
24	24	0.750000

6 no return allowed

[84]:
```
get_change_simulated(0,1,2,3,15)
get_change_simulated(1,1,2,3,15)
get_change_simulated(2,1,2,3,15)
get_change_simulated(3,1,2,3,15)
```

```
cluster  0
    time unit  percentage
0           0    0.017241
1           1    0.068966
2           2    0.103448
3           3    0.129310
4           4    0.137931
5           5    0.146552
6           6    0.172414
7           7    0.189655
8           8    0.206897
9           9    0.215517
10         10    0.232759
11         11    0.250000
12         12    0.284483
13         13    0.284483
14         14    0.293103
```

```
15          15    0.310345
16          16    0.318966
17          17    0.336207
18          18    0.344828
19          19    0.379310
20          20    0.413793
21          21    0.422414
22          22    0.439655
23          23    0.474138
24          24    0.474138

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.12
2           2        0.16
3           3        0.20
4           4        0.20
5           5        0.26
6           6        0.30
7           7        0.34
8           8        0.38
9           9        0.40
10         10        0.40
11         11        0.42
12         12        0.44
13         13        0.44
14         14        0.48
15         15        0.54
16         16        0.58
17         17        0.58
18         18        0.60
19         19        0.60
20         20        0.68
21         21        0.68
22         22        0.68
23         23        0.68
24         24        0.72

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.068182
2           2    0.068182
3           3    0.090909
4           4    0.136364
5           5    0.204545
6           6    0.227273
```

7	7	0.227273
8	8	0.272727
9	9	0.318182
10	10	0.340909
11	11	0.386364
12	12	0.431818
13	13	0.431818
14	14	0.431818
15	15	0.477273
16	16	0.500000
17	17	0.522727
18	18	0.522727
19	19	0.568182
20	20	0.568182
21	21	0.568182
22	22	0.590909
23	23	0.613636
24	24	0.659091

cluster 3

	time unit	percentage
0	0	0.055556
1	1	0.055556
2	2	0.083333
3	3	0.166667
4	4	0.194444
5	5	0.277778
6	6	0.277778
7	7	0.305556
8	8	0.305556
9	9	0.333333
10	10	0.388889
11	11	0.416667
12	12	0.416667
13	13	0.472222
14	14	0.472222
15	15	0.472222
16	16	0.583333
17	17	0.583333
18	18	0.611111
19	19	0.611111
20	20	0.611111
21	21	0.611111
22	22	0.611111
23	23	0.611111
24	24	0.611111

7 set the model

[85]:
```
import torch.nn as nn
import torch
from torch.utils.tensorboard import SummaryWriter

from tqdm import tqdm
class SimpleFCNet(nn.Module):

    def __init__(self, num_layers, in_dim, out_dim, hidden_dim, use_bn=False):
        super(SimpleFCNet, self).__init__()
        self.num_layers = num_layers
        self.sigm = nn.Sigmoid()
        self.fc_in = nn.Linear(in_dim, hidden_dim)
        self.fc_out = nn.Linear(hidden_dim, out_dim)
        self.fc_hidd = nn.Linear(hidden_dim, hidden_dim)

        # self.use_bn = use_bn
        # self.bn = nn.BatchNorm1d()

        layers = []
        for i in range(self.num_layers + 1):
            # if self.use_bn:
            #     layers.append()
```

```
            if i == 0:
                layers.append(self.fc_in)
            elif i == self.num_layers:
                layers.append(self.fc_out)
            else:
                layers.append(self.fc_hidd)
            layers.append(self.sigm)
        self.net = nn.Sequential(*layers)


    def forward(self, x):
        return self.net(x)

# x = [parameters_to_fit, driving_forces]
def train(model, x, y, timestep, all_opinion, writer=None):
    num_epochs = 50
    learning_rate = 1e-2
    optimizer = torch.optim.Adam(params=model.parameters(), lr=learning_rate)
    loss = nn.MSELoss()

    def opinion(x, p):
        res = (np.random.rand(1))[0]
        return 1-x if res < p else x

    def opinion_no_return(x, p):
        if(x == 1):
            return 1
        else:
            return opinion(x,p)

    def get_opinion(current_opinion, res, step):
        opinions = []
        prob = res
        for agent in range(len(res)):
            new_state_no_return = opinion_no_return(current_opinion[agent],␣
 ↪prob[agent])
            opinions.append(new_state_no_return)
        opinions = torch.tensor(opinions).float()
        opinions.requires_grad=True
        return opinions

    dfs = x[1].detach()
    params = x[0]

    res = None

    for i in tqdm(range(num_epochs), desc="training model ..."):
```

```
        optimizer.zero_grad()
        inp = torch.cat((params, dfs))
        inp = inp.float()
        res = model(inp)

        x = get_opinion(all_opinion[timestep-1], res, timestep)

        model_loss = loss(x, y.float()) #TODO: create a meaningful loss function


#         if writer is not None:
#             writer.add_scalar('training loss time step {}'.format(timestep),␣
 ↪model_loss, i)
#         else:
#             print("epoch {}: loss = {}".format(i, model_loss))
        model_loss.backward()

        optimizer.step()
    print(params.grad)

    return params, get_opinion(all_opinion[timestep-1], res, timestep)
```

[86]:
```
# plot function for model
def plot(all_opinions, cluster_index):


    model_percentage_overtime = []
    initial_percent = np.count_nonzero(all_opinions[0])/
 ↪cluster_size[cluster_index]
    model_percentage_overtime.append([0, initial_percent])


    for i in range(len(all_opinions) - 1):

        opinion = all_opinions[i + 1]
        ones = np.count_nonzero(opinion.detach().numpy())
        percent = ones / cluster_size[cluster_index]

        combined = []
        combined.append(i + 1)
        combined.append(percent)

        model_percentage_overtime.append(combined)

    model_data = pd.DataFrame(model_percentage_overtime, columns = ['time␣
 ↪unit','percentage'])
```

```
    print("cluster ",cluster_index)
    print(model_data.head(20))
    print()
    sns.set_theme()
    sns.lineplot(x='time unit', y='percentage', data=model_data,label =␣
↪cluster_names[cluster_index], ci=None)
```

[87]:
```
def update_driving_forces_model(opinions, driving_forces, edge_props,␣
↪cluster_index, k_alpha_model,
        k_beta_model,
        k_gamma_model,E_profit_model):
    len_cluster = 0
    first_node = 0
    if cluster_index == 0:
        len_cluster = max_node_array[0]
    else:
        len_cluster =␣
↪max_node_array[cluster_index]-max_node_array[cluster_index-1]
        first_node = max_node_array[cluster_index-1]

    updated_driving_force = np.zeros(len_cluster)

    agents_ids = [first_node+i for i in range(len_cluster)]

    for a in agents_ids:
        for edge in edge_props:
            #check that the edge is directed at node a and opinions of agents␣
↪don't match
            if edge[1] == a and not opinions[a-first_node] ==␣
↪opinions[edge[0]-first_node]:
                updated_driving_force[a-first_node] += edge[2] * k_alpha_model␣
↪+ edge[3] * k_beta_model + edge[4]*k_gamma_model
        updated_driving_force[a-first_node]+=E_profit_model
        #print("agent {} obtained a driving force of {}".format(a,␣
↪updated_driving_force[a]))

    return updated_driving_force



k_alpha_model =.1
k_beta_model = 1
k_gamma_model = 2
E_profit_model = 15

parameters_to_fit = torch.tensor(
```

```
        [k_alpha_model,
        k_beta_model,
        k_gamma_model,
        E_profit_model]
    )

parameters_to_fit = nn.Parameter(parameters_to_fit)



def run_simulation(cluster_index, parameters_to_fit):

    edge_props_this_cluster = edge_properties[cluster_index]
    num_agents_in_cluster = cluster_size[cluster_index]



    # initialise clusters and agents
    initial_opinion = get_initial_opinions(cluster_index)


    # initialise driving force
    driving_forces =␣
 ↪update_driving_forces_cluster_specific(edge_props_this_cluster,␣
 ↪cluster_index, initial_opinion)
    driving_forces = torch.tensor(driving_forces)

    distribution = SimpleFCNet(
    num_layers=1,
    in_dim=num_agents_in_cluster+4,
    out_dim=num_agents_in_cluster,
    hidden_dim=2*(num_agents_in_cluster)
    )


    all_opinions = []
    all_opinions.append(initial_opinion)

    for step in tqdm(range(25), desc="simulation step "):
        y = opinion_timeline_agents[cluster_range[cluster_index][0]:
 ↪cluster_range[cluster_index][1],step]
        y = torch.tensor(y)
        x = [parameters_to_fit, driving_forces]
        parameters_to_fit, new_opinion = train(distribution, x, y, step,␣
 ↪all_opinions)
        all_opinions.append(new_opinion)
```

```
        driving_forces = update_driving_forces_model(new_opinion,␣
↪driving_forces, edge_props_this_cluster, cluster_index,
                                                     parameters_to_fit[0].float(),
                                                     parameters_to_fit[1].float(),
                                                     parameters_to_fit[2].float(),
                                                     parameters_to_fit[3].float())
        driving_forces = torch.tensor(driving_forces)

    #plot(all_opinions, cluster_index)
```

8 With return:

9 train Peoria, get parameters, predicte other clusters

[79]:
```
run_simulation(0, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 541.55it/s]
simulation step :   4%|         | 1/25 [00:00<00:02,  8.95it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 653.71it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|     | 50/50 [00:00<00:00, 451.69it/s]
simulation step :  12%|         | 3/25 [00:00<00:02,  8.85it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 493.04it/s]
simulation step :  16%|         | 4/25 [00:00<00:02,  8.64it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|     | 50/50 [00:00<00:00, 464.91it/s]
simulation step :  20%|         | 5/25 [00:00<00:02,  8.36it/s]
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 500.12it/s]
simulation step :  24%|         | 6/25 [00:00<00:02,  8.35it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|      | 50/50 [00:00<00:00, 467.77it/s]
simulation step :  28%|         | 7/25 [00:00<00:02,  8.20it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 492.33it/s]
simulation step :  32%|         | 8/25 [00:00<00:02,  8.20it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|      | 50/50 [00:00<00:00, 477.89it/s]
simulation step :  36%|         | 9/25 [00:01<00:01,  8.16it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 492.58it/s]
simulation step :  40%|         | 10/25 [00:01<00:01,  8.16it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|      | 50/50 [00:00<00:00, 465.27it/s]
simulation step :  44%|         | 11/25 [00:01<00:01,  8.06it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 501.52it/s]
simulation step :  48%|         | 12/25 [00:01<00:01,  8.18it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|      | 50/50 [00:00<00:00, 487.18it/s]
simulation step :  52%|         | 13/25 [00:01<00:01,  8.17it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 490.80it/s]
simulation step :  56%|         | 14/25 [00:01<00:01,  8.19it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|      | 50/50 [00:00<00:00, 472.72it/s]
simulation step :  60%|         | 15/25 [00:01<00:01,  8.12it/s]
```

```
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 463.29it/s]
simulation step :  64%|      | 16/25 [00:01<00:01,  8.02it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|     | 50/50 [00:00<00:00, 468.57it/s]
simulation step :  68%|      | 17/25 [00:02<00:01,  7.98it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 503.40it/s]
simulation step :  72%|      | 18/25 [00:02<00:00,  8.13it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|     | 50/50 [00:00<00:00, 475.43it/s]
simulation step :  76%|      | 19/25 [00:02<00:00,  8.10it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 495.46it/s]
simulation step :  80%|      | 20/25 [00:02<00:00,  8.13it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|     | 50/50 [00:00<00:00, 461.42it/s]
simulation step :  84%|      | 21/25 [00:02<00:00,  8.04it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 464.90it/s]
simulation step :  88%|      | 22/25 [00:02<00:00,  7.98it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None


training model …: 100%|     | 50/50 [00:00<00:00, 486.94it/s]
simulation step :  92%|      | 23/25 [00:02<00:00,  8.03it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 503.21it/s]
simulation step :  96%|      | 24/25 [00:02<00:00,  8.15it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None

training model …: 100%|     | 50/50 [00:00<00:00, 501.68it/s]
simulation step : 100%|     | 25/25 [00:03<00:00,  8.19it/s]
```

None
cluster 0

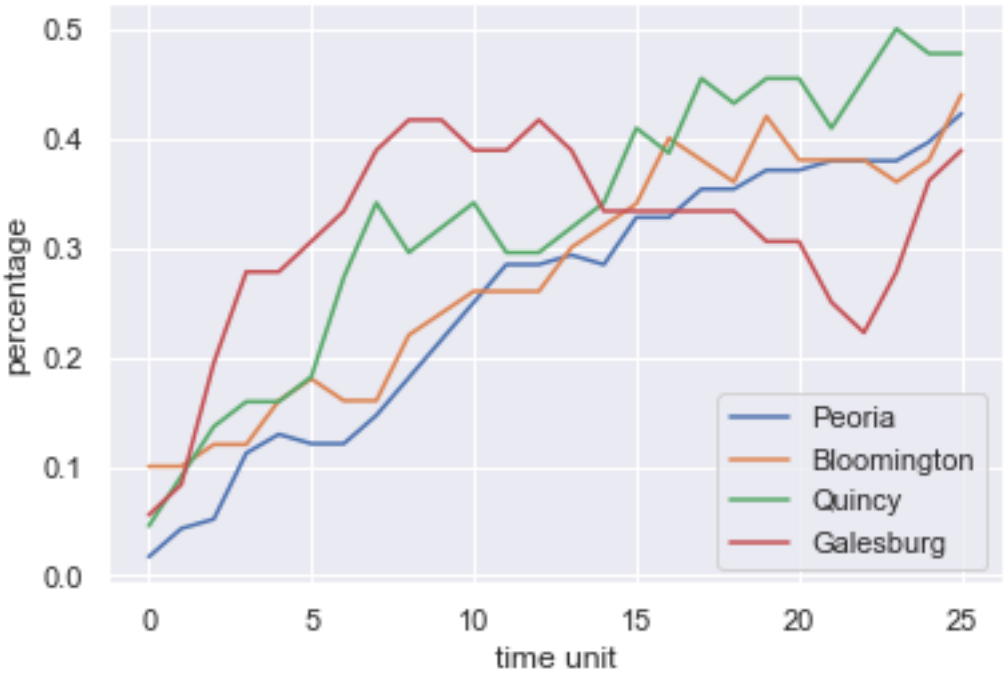
	time unit	percentage
0	0	0.017241
1	1	0.043103
2	2	0.051724
3	3	0.112069
4	4	0.129310
5	5	0.120690
6	6	0.120690
7	7	0.146552
8	8	0.181034
9	9	0.215517
10	10	0.250000
11	11	0.284483
12	12	0.284483
13	13	0.293103
14	14	0.284483
15	15	0.327586
16	16	0.327586
17	17	0.353448
18	18	0.353448
19	19	0.370690
20	20	0.370690
21	21	0.379310
22	22	0.379310
23	23	0.379310
24	24	0.396552

cluster 1

	time unit	percentage
0	0	0.10
1	1	0.10
2	2	0.12
3	3	0.12
4	4	0.16
5	5	0.18
6	6	0.16
7	7	0.16
8	8	0.22
9	9	0.24
10	10	0.26
11	11	0.26
12	12	0.26
13	13	0.30
14	14	0.32
15	15	0.34
16	16	0.40

```
17          17         0.38
18          18         0.36
19          19         0.42
20          20         0.38
21          21         0.38
22          22         0.38
23          23         0.36
24          24         0.38

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.090909
2           2    0.136364
3           3    0.159091
4           4    0.159091
5           5    0.181818
6           6    0.272727
7           7    0.340909
8           8    0.295455
9           9    0.318182
10         10    0.340909
11         11    0.295455
12         12    0.295455
13         13    0.318182
14         14    0.340909
15         15    0.409091
16         16    0.386364
17         17    0.454545
18         18    0.431818
19         19    0.454545
20         20    0.454545
21         21    0.409091
22         22    0.454545
23         23    0.500000
24         24    0.477273

cluster  3
    time unit  percentage
0           0    0.055556
1           1    0.083333
2           2    0.194444
3           3    0.277778
4           4    0.277778
5           5    0.305556
6           6    0.333333
7           7    0.388889
8           8    0.416667
```

9	9	0.416667
10	10	0.388889
11	11	0.388889
12	12	0.416667
13	13	0.388889
14	14	0.333333
15	15	0.333333
16	16	0.333333
17	17	0.333333
18	18	0.333333
19	19	0.305556
20	20	0.305556
21	21	0.250000
22	22	0.222222
23	23	0.277778
24	24	0.361111



10 train Bloomington, get parameters, predicte other clusters

[80]:
```
run_simulation(1, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
↪parameters_to_fit[2], parameters_to_fit[3])
```

```
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1266.59it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1369.23it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1052.98it/s]
simulation step :  12%|         | 3/25 [00:00<00:01, 20.21it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1041.76it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 1020.89it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1021.64it/s]
simulation step :  24%|        | 6/25 [00:00<00:01, 18.45it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1001.91it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1013.95it/s]
simulation step :  32%|        | 8/25 [00:00<00:00, 17.97it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 990.32it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1034.75it/s]
simulation step :  40%|        | 10/25 [00:00<00:00, 17.68it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1027.85it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1038.40it/s]
simulation step :  48%|        | 12/25 [00:00<00:00, 17.66it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
```

```
None
None
training model …: 100%|      | 50/50 [00:00<00:00, 971.85it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1037.09it/s]
simulation step :  56%|       | 14/25 [00:00<00:00, 17.52it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1039.07it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1000.42it/s]
simulation step :  64%|       | 16/25 [00:00<00:00, 17.47it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None
training model …: 100%|      | 50/50 [00:00<00:00, 931.48it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 973.64it/s]
simulation step :  72%|       | 18/25 [00:01<00:00, 17.09it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 978.34it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1012.00it/s]
simulation step :  80%|       | 20/25 [00:01<00:00, 17.05it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None
training model …: 100%|      | 50/50 [00:00<00:00, 971.16it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1013.67it/s]
simulation step :  88%|      | 22/25 [00:01<00:00, 17.02it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1002.95it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1018.44it/s]
simulation step :  96%|      | 24/25 [00:01<00:00, 17.07it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None
training model …: 100%|      | 50/50 [00:00<00:00, 966.35it/s]
simulation step : 100%|      | 25/25 [00:01<00:00, 17.42it/s]
```

None
cluster 0

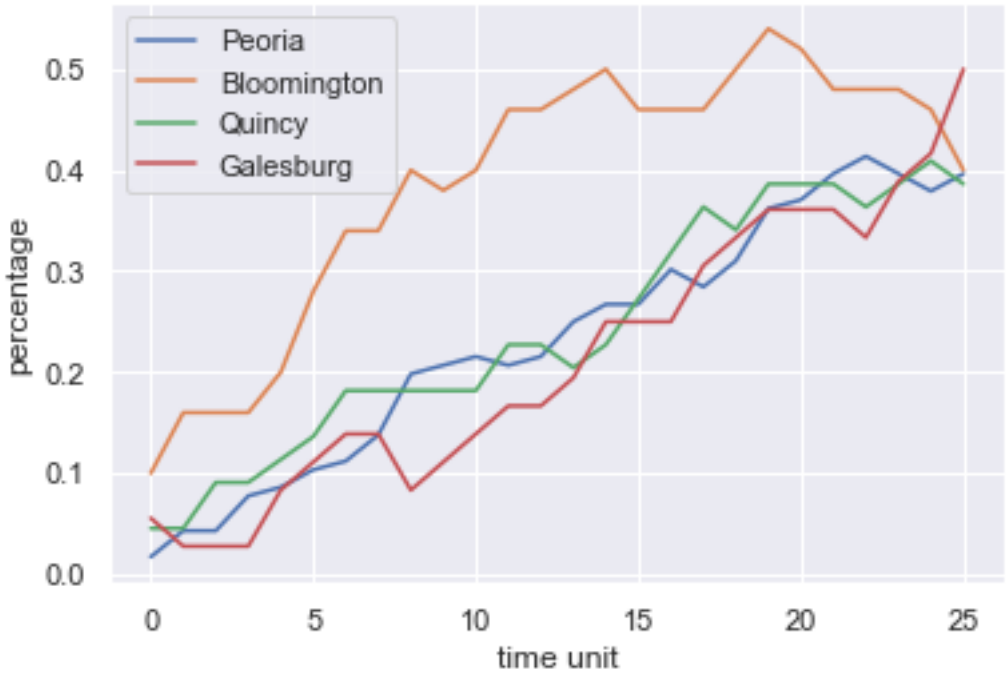
	time unit	percentage
0	0	0.017241
1	1	0.043103
2	2	0.043103
3	3	0.077586
4	4	0.086207
5	5	0.103448
6	6	0.112069
7	7	0.137931
8	8	0.198276
9	9	0.206897
10	10	0.215517
11	11	0.206897
12	12	0.215517
13	13	0.250000
14	14	0.267241
15	15	0.267241
16	16	0.301724
17	17	0.284483
18	18	0.310345
19	19	0.362069
20	20	0.370690
21	21	0.396552
22	22	0.413793
23	23	0.396552
24	24	0.379310

cluster 1

	time unit	percentage
0	0	0.10
1	1	0.16
2	2	0.16
3	3	0.16
4	4	0.20
5	5	0.28
6	6	0.34
7	7	0.34
8	8	0.40
9	9	0.38
10	10	0.40
11	11	0.46
12	12	0.46
13	13	0.48
14	14	0.50
15	15	0.46
16	16	0.46

```
17          17         0.46
18          18         0.50
19          19         0.54
20          20         0.52
21          21         0.48
22          22         0.48
23          23         0.48
24          24         0.46

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.045455
2           2    0.090909
3           3    0.090909
4           4    0.113636
5           5    0.136364
6           6    0.181818
7           7    0.181818
8           8    0.181818
9           9    0.181818
10         10    0.181818
11         11    0.227273
12         12    0.227273
13         13    0.204545
14         14    0.227273
15         15    0.272727
16         16    0.318182
17         17    0.363636
18         18    0.340909
19         19    0.386364
20         20    0.386364
21         21    0.386364
22         22    0.363636
23         23    0.386364
24         24    0.409091

cluster  3
    time unit  percentage
0           0    0.055556
1           1    0.027778
2           2    0.027778
3           3    0.027778
4           4    0.083333
5           5    0.111111
6           6    0.138889
7           7    0.138889
8           8    0.083333
```

9	9	0.111111
10	10	0.138889
11	11	0.166667
12	12	0.166667
13	13	0.194444
14	14	0.250000
15	15	0.250000
16	16	0.250000
17	17	0.305556
18	18	0.333333
19	19	0.361111
20	20	0.361111
21	21	0.361111
22	22	0.333333
23	23	0.388889
24	24	0.416667



11 train Quincy, get parameters, predicte other clusters

[81]:
```
run_simulation(2, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
↪parameters_to_fit[2], parameters_to_fit[3])
```

```
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1451.77it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1476.63it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1102.27it/s]
simulation step :  12%|        | 3/25 [00:00<00:00, 22.18it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1132.50it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1131.07it/s]
```

```
None
None
None
None
None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 1116.10it/s]
simulation step :  24%|       | 6/25 [00:00<00:00, 20.31it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1146.39it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1140.48it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1123.09it/s]
simulation step :  36%|       | 9/25 [00:00<00:00, 19.92it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 1128.85it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1125.76it/s]
simulation step :  44%|       | 11/25 [00:00<00:00, 19.70it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1142.26it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1127.95it/s]
simulation step :  52%|       | 13/25 [00:00<00:00, 19.61it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1121.61it/s]
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1125.63it/s]
simulation step :  60%|       | 15/25 [00:00<00:00, 19.44it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1139.99it/s]
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1129.23it/s]
simulation step :  68%|       | 17/25 [00:00<00:00, 19.45it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1064.51it/s]
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1097.99it/s]
simulation step :  76%|       | 19/25 [00:00<00:00, 19.19it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1084.67it/s]
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1095.31it/s]
simulation step :  84%|       | 21/25 [00:01<00:00, 19.05it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1071.40it/s]
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1051.26it/s]
simulation step :  92%|      | 23/25 [00:01<00:00, 18.76it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1098.24it/s]
```

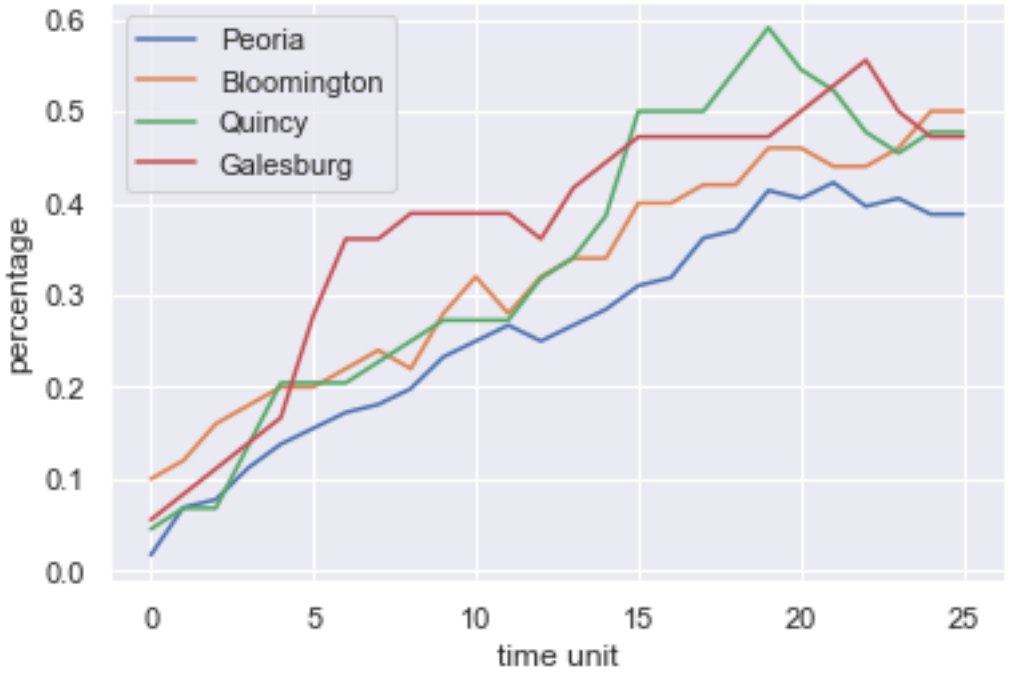
```
training model …: 100%|      | 50/50 [00:00<00:00, 1111.85it/s]
simulation step : 100%|      | 25/25 [00:01<00:00, 19.37it/s]
```

```
None
None
None
None
cluster  0
    time unit  percentage
0           0    0.017241
```

```
1           1    0.068966
2           2    0.077586
3           3    0.112069
4           4    0.137931
5           5    0.155172
6           6    0.172414
7           7    0.181034
8           8    0.198276
9           9    0.232759
10         10    0.250000
11         11    0.267241
12         12    0.250000
13         13    0.267241
14         14    0.284483
15         15    0.310345
16         16    0.318966
17         17    0.362069
18         18    0.370690
19         19    0.413793
20         20    0.405172
21         21    0.422414
22         22    0.396552
23         23    0.405172
24         24    0.387931

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.12
2           2        0.16
3           3        0.18
4           4        0.20
5           5        0.20
6           6        0.22
7           7        0.24
8           8        0.22
9           9        0.28
10         10        0.32
11         11        0.28
12         12        0.32
13         13        0.34
14         14        0.34
15         15        0.40
16         16        0.40
17         17        0.42
18         18        0.42
19         19        0.46
20         20        0.46
```

```
21          21         0.44
22          22         0.44
23          23         0.46
24          24         0.50

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.068182
2           2    0.068182
3           3    0.136364
4           4    0.204545
5           5    0.204545
6           6    0.204545
7           7    0.227273
8           8    0.250000
9           9    0.272727
10         10    0.272727
11         11    0.272727
12         12    0.318182
13         13    0.340909
14         14    0.386364
15         15    0.500000
16         16    0.500000
17         17    0.500000
18         18    0.545455
19         19    0.590909
20         20    0.545455
21         21    0.522727
22         22    0.477273
23         23    0.454545
24         24    0.477273

cluster  3
    time unit  percentage
0           0    0.055556
1           1    0.083333
2           2    0.111111
3           3    0.138889
4           4    0.166667
5           5    0.277778
6           6    0.361111
7           7    0.361111
8           8    0.388889
9           9    0.388889
10         10    0.388889
11         11    0.388889
12         12    0.361111
```

```
13          13     0.416667
14          14     0.444444
15          15     0.472222
16          16     0.472222
17          17     0.472222
18          18     0.472222
19          19     0.472222
20          20     0.500000
21          21     0.527778
22          22     0.555556
23          23     0.500000
24          24     0.472222
```



12 train Galesburg, get parameters, predicte other clusters

[82]:
```
run_simulation(3, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
↪parameters_to_fit[2], parameters_to_fit[3])
```

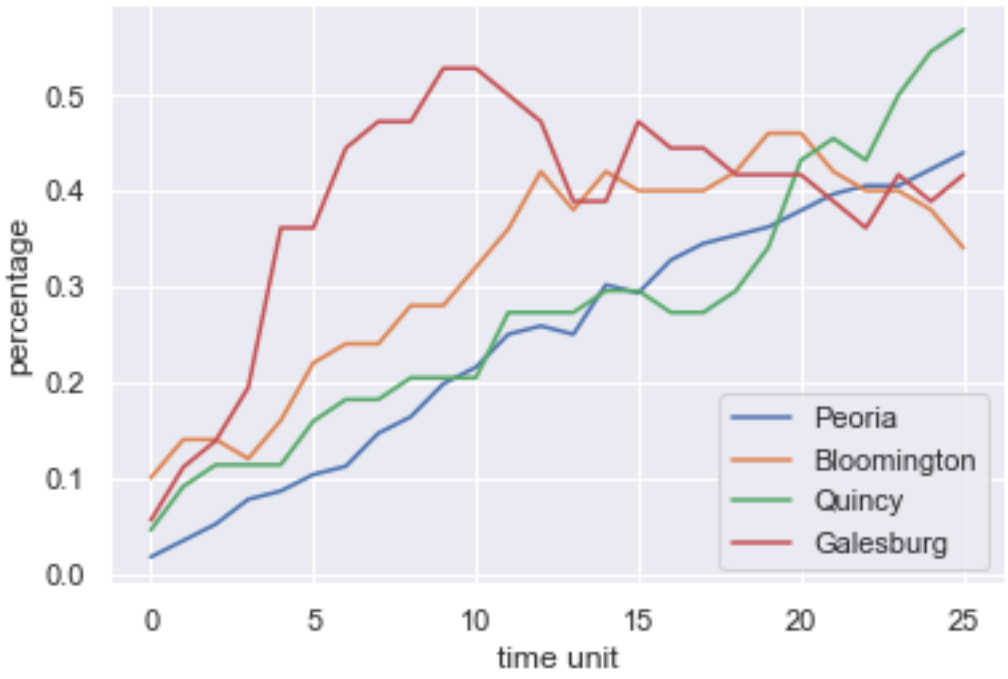
```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1693.19it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None

training model …: 100%|     | 50/50 [00:00<00:00, 1644.09it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1285.55it/s]
simulation step :  12%|         | 3/25 [00:00<00:00, 24.85it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1287.28it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1342.43it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None

training model …: 100%|     | 50/50 [00:00<00:00, 1262.50it/s]
simulation step :  24%|        | 6/25 [00:00<00:00, 23.02it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None

training model …: 100%|     | 50/50 [00:00<00:00, 1270.23it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1298.29it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1321.67it/s]
simulation step :  36%|        | 9/25 [00:00<00:00, 22.50it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1315.37it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None

training model …: 100%|     | 50/50 [00:00<00:00, 1302.43it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 1276.16it/s]
simulation step :  48%|       | 12/25 [00:00<00:00, 22.26it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1298.54it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1295.50it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1296.00it/s]
simulation step :  60%|       | 15/25 [00:00<00:00, 22.07it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None

training model …: 100%|     | 50/50 [00:00<00:00, 1254.14it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None

training model …: 100%|     | 50/50 [00:00<00:00, 1257.65it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1309.07it/s]
simulation step :  72%|      | 18/25 [00:00<00:00, 21.87it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1291.72it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1320.28it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None

training model …: 100%|     | 50/50 [00:00<00:00, 1264.89it/s]
simulation step :  84%|      | 21/25 [00:00<00:00, 21.83it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None

training model …: 100%|     | 50/50 [00:00<00:00, 1258.21it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1322.99it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1318.26it/s]
simulation step :  96%|     | 24/25 [00:01<00:00, 21.82it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1288.36it/s]
simulation step : 100%|     | 25/25 [00:01<00:00, 22.11it/s]

None
```

```
None
None
None
cluster  0
    time unit  percentage
0           0    0.017241
1           1    0.034483
2           2    0.051724
3           3    0.077586
4           4    0.086207
5           5    0.103448
6           6    0.112069
7           7    0.146552
8           8    0.163793
9           9    0.198276
10         10    0.215517
11         11    0.250000
12         12    0.258621
13         13    0.250000
14         14    0.301724
15         15    0.293103
16         16    0.327586
17         17    0.344828
18         18    0.353448
19         19    0.362069
20         20    0.379310
21         21    0.396552
22         22    0.405172
23         23    0.405172
24         24    0.422414

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.14
2           2        0.14
3           3        0.12
4           4        0.16
5           5        0.22
6           6        0.24
7           7        0.24
8           8        0.28
9           9        0.28
10         10        0.32
11         11        0.36
12         12        0.42
13         13        0.38
14         14        0.42
```

```
15          15         0.40
16          16         0.40
17          17         0.40
18          18         0.42
19          19         0.46
20          20         0.46
21          21         0.42
22          22         0.40
23          23         0.40
24          24         0.38

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.090909
2           2    0.113636
3           3    0.113636
4           4    0.113636
5           5    0.159091
6           6    0.181818
7           7    0.181818
8           8    0.204545
9           9    0.204545
10         10    0.204545
11         11    0.272727
12         12    0.272727
13         13    0.272727
14         14    0.295455
15         15    0.295455
16         16    0.272727
17         17    0.272727
18         18    0.295455
19         19    0.340909
20         20    0.431818
21         21    0.454545
22         22    0.431818
23         23    0.500000
24         24    0.545455

cluster  3
    time unit  percentage
0           0    0.055556
1           1    0.111111
2           2    0.138889
3           3    0.194444
4           4    0.361111
5           5    0.361111
6           6    0.444444
```

7	7	0.472222
8	8	0.472222
9	9	0.527778
10	10	0.527778
11	11	0.500000
12	12	0.472222
13	13	0.388889
14	14	0.388889
15	15	0.472222
16	16	0.444444
17	17	0.444444
18	18	0.416667
19	19	0.416667
20	20	0.416667
21	21	0.388889
22	22	0.361111
23	23	0.416667
24	24	0.388889



13 no return allowed:

14 train Peoria, get parameters, predicte other clusters

[88]:
```
run_simulation(0, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 529.46it/s]
simulation step :   4%|         | 1/25 [00:00<00:02,  8.74it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 698.50it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 557.36it/s]

None
None
None

simulation step :  12%|         | 3/25 [00:00<00:02,  9.67it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 529.01it/s]
simulation step :  16%|         | 4/25 [00:00<00:02,  9.38it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 650.03it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 646.95it/s]
simulation step :  24%|        | 6/25 [00:00<00:01, 10.09it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None

training model …: 100%|     | 50/50 [00:00<00:00, 729.88it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 744.52it/s]
simulation step :  32%|        | 8/25 [00:00<00:01, 10.94it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 789.20it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 774.20it/s]
simulation step :  40%|        | 10/25 [00:00<00:01, 11.67it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 797.75it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 826.70it/s]
simulation step :  48%|        | 12/25 [00:01<00:01, 12.31it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None

training model …: 100%|      | 50/50 [00:00<00:00, 801.85it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 835.48it/s]
simulation step :  56%|       | 14/25 [00:01<00:00, 12.75it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 839.20it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None

training model …: 100%|      | 50/50 [00:00<00:00, 794.49it/s]
simulation step :  64%|       | 16/25 [00:01<00:00, 13.07it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 793.03it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 814.50it/s]
simulation step :  72%|      | 18/25 [00:01<00:00, 13.19it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None

training model …: 100%|      | 50/50 [00:00<00:00, 800.42it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 840.32it/s]
simulation step :  80%|      | 20/25 [00:01<00:00, 13.44it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 832.14it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None

training model …: 100%|      | 50/50 [00:00<00:00, 830.72it/s]
simulation step :  88%|      | 22/25 [00:01<00:00, 13.66it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 824.36it/s]
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 848.26it/s]
simulation step :  96%|     | 24/25 [00:01<00:00, 13.83it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None

training model …: 100%|     | 50/50 [00:00<00:00, 825.00it/s]
simulation step : 100%|     | 25/25 [00:02<00:00, 12.48it/s]

None
cluster  0
    time unit  percentage
0           0    0.017241
1           1    0.034483
2           2    0.051724
3           3    0.077586
4           4    0.112069
5           5    0.137931
6           6    0.172414
7           7    0.206897
8           8    0.224138
9           9    0.241379
10         10    0.258621
11         11    0.275862
12         12    0.327586
13         13    0.353448
14         14    0.387931
15         15    0.387931
16         16    0.387931
17         17    0.405172
18         18    0.413793
19         19    0.439655
20         20    0.465517
21         21    0.491379
22         22    0.543103
23         23    0.560345
24         24    0.568966

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.18
2           2        0.22
3           3        0.22
4           4        0.28
5           5        0.32
6           6        0.34
```

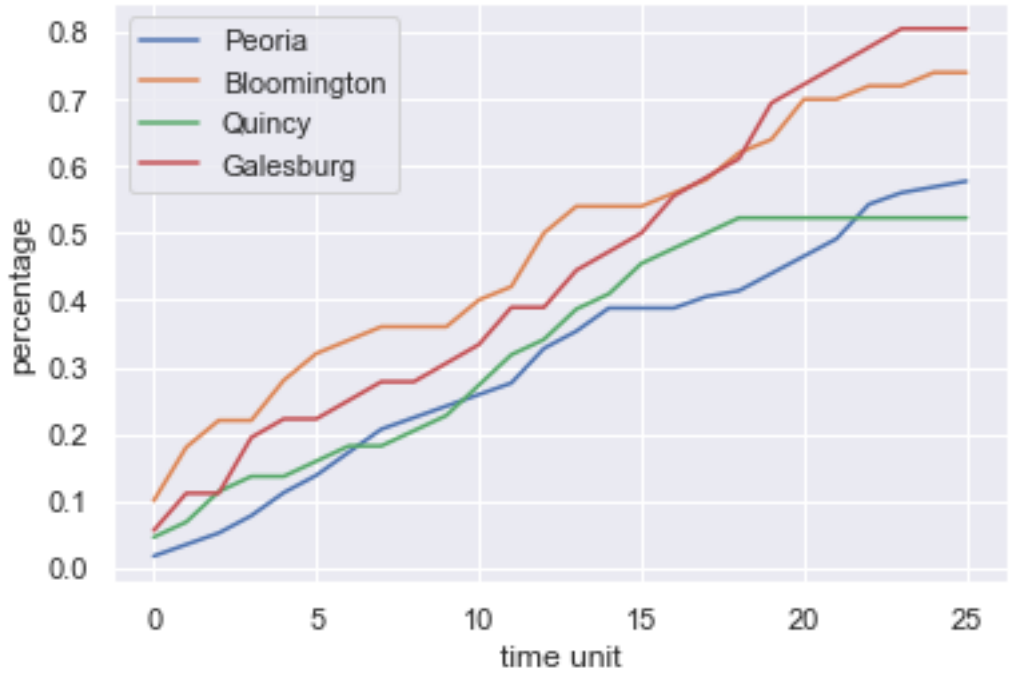
7	7	0.36
8	8	0.36
9	9	0.36
10	10	0.40
11	11	0.42
12	12	0.50
13	13	0.54
14	14	0.54
15	15	0.54
16	16	0.56
17	17	0.58
18	18	0.62
19	19	0.64
20	20	0.70
21	21	0.70
22	22	0.72
23	23	0.72
24	24	0.74

cluster 2

	time unit	percentage
0	0	0.045455
1	1	0.068182
2	2	0.113636
3	3	0.136364
4	4	0.136364
5	5	0.159091
6	6	0.181818
7	7	0.181818
8	8	0.204545
9	9	0.227273
10	10	0.272727
11	11	0.318182
12	12	0.340909
13	13	0.386364
14	14	0.409091
15	15	0.454545
16	16	0.477273
17	17	0.500000
18	18	0.522727
19	19	0.522727
20	20	0.522727
21	21	0.522727
22	22	0.522727
23	23	0.522727
24	24	0.522727

cluster 3

	time unit	percentage
0	0	0.055556
1	1	0.111111
2	2	0.111111
3	3	0.194444
4	4	0.222222
5	5	0.222222
6	6	0.250000
7	7	0.277778
8	8	0.277778
9	9	0.305556
10	10	0.333333
11	11	0.388889
12	12	0.388889
13	13	0.444444
14	14	0.472222
15	15	0.500000
16	16	0.555556
17	17	0.583333
18	18	0.611111
19	19	0.694444
20	20	0.722222
21	21	0.750000
22	22	0.777778
23	23	0.805556
24	24	0.805556



15 train Bloomington, get parameters, predicte other clusters

[89]:
```
run_simulation(1, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 930.11it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1410.24it/s]
simulation step :   8%|         | 2/25 [00:00<00:01, 18.57it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1122.79it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1134.33it/s]
simulation step :  16%|        | 4/25 [00:00<00:01, 19.06it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1375.60it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None
None
training model …: 100%|     | 50/50 [00:00<00:00, 1403.90it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1521.84it/s]
simulation step :  28%|        | 7/25 [00:00<00:00, 21.55it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1492.76it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1525.36it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1558.69it/s]
simulation step :  40%|        | 10/25 [00:00<00:00, 23.18it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1556.07it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

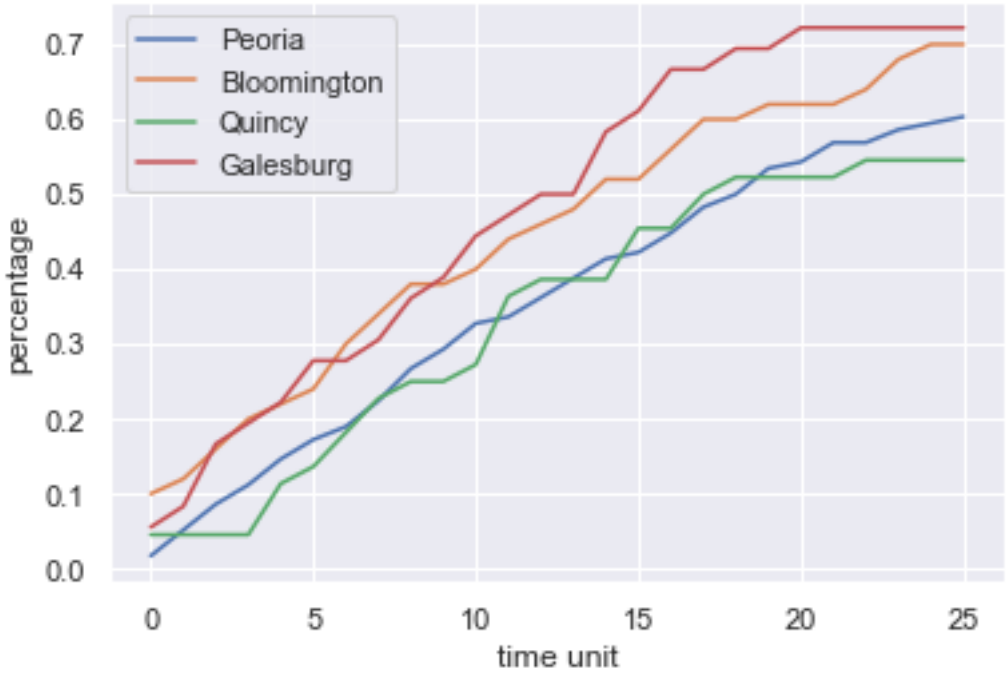
```
None
None
None
None
None
None
training model …: 100%|      | 50/50 [00:00<00:00, 1516.03it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1611.93it/s]
simulation step :  52%|        | 13/25 [00:00<00:00, 24.34it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1566.71it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1616.83it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1574.80it/s]
simulation step :  64%|       | 16/25 [00:00<00:00, 25.14it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1555.74it/s]

training model …:   0%|           | 0/50 [00:00<?, ?it/s]
None
None
None
None
None
None
training model …: 100%|      | 50/50 [00:00<00:00, 1488.19it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1518.70it/s]
simulation step :  76%|      | 19/25 [00:00<00:00, 25.33it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1527.03it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1548.80it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1569.67it/s]
simulation step :  88%|      | 22/25 [00:00<00:00, 25.72it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1566.41it/s]

training model …:   0%|           | 0/50 [00:00<?, ?it/s]
None
None
None
None
None
None
training model …: 100%|      | 50/50 [00:00<00:00, 1560.56it/s]
```

```
training model …: 100%|      | 50/50 [00:00<00:00, 1563.09it/s]
simulation step : 100%|      | 25/25 [00:01<00:00, 24.50it/s]
```

```
None
None
cluster  0
    time unit  percentage
0           0    0.017241
1           1    0.051724
2           2    0.086207
3           3    0.112069
4           4    0.146552
5           5    0.172414
6           6    0.189655
7           7    0.224138
8           8    0.267241
9           9    0.293103
10         10    0.327586
11         11    0.336207
12         12    0.362069
13         13    0.387931
14         14    0.413793
15         15    0.422414
16         16    0.448276
17         17    0.482759
18         18    0.500000
19         19    0.534483
20         20    0.543103
21         21    0.568966
22         22    0.568966
23         23    0.586207
24         24    0.594828

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.12
2           2        0.16
3           3        0.20
4           4        0.22
5           5        0.24
6           6        0.30
7           7        0.34
8           8        0.38
9           9        0.38
10         10        0.40
11         11        0.44
```

```
12          12        0.46
13          13        0.48
14          14        0.52
15          15        0.52
16          16        0.56
17          17        0.60
18          18        0.60
19          19        0.62
20          20        0.62
21          21        0.62
22          22        0.64
23          23        0.68
24          24        0.70

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.045455
2           2    0.045455
3           3    0.045455
4           4    0.113636
5           5    0.136364
6           6    0.181818
7           7    0.227273
8           8    0.250000
9           9    0.250000
10         10    0.272727
11         11    0.363636
12         12    0.386364
13         13    0.386364
14         14    0.386364
15         15    0.454545
16         16    0.454545
17         17    0.500000
18         18    0.522727
19         19    0.522727
20         20    0.522727
21         21    0.522727
22         22    0.545455
23         23    0.545455
24         24    0.545455

cluster  3
    time unit  percentage
0           0    0.055556
1           1    0.083333
2           2    0.166667
3           3    0.194444
```

4	4	0.222222
5	5	0.277778
6	6	0.277778
7	7	0.305556
8	8	0.361111
9	9	0.388889
10	10	0.444444
11	11	0.472222
12	12	0.500000
13	13	0.500000
14	14	0.583333
15	15	0.611111
16	16	0.666667
17	17	0.666667
18	18	0.694444
19	19	0.694444
20	20	0.722222
21	21	0.722222
22	22	0.722222
23	23	0.722222
24	24	0.722222



16 train Quincy, get parameters, predicte other clusters

[90]:
```
run_simulation(2, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 939.00it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1444.13it/s]
simulation step :   8%|         | 2/25 [00:00<00:01, 18.86it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1360.35it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1201.92it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1577.78it/s]
simulation step :  20%|        | 5/25 [00:00<00:00, 21.68it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None
None

training model …: 100%|     | 50/50 [00:00<00:00, 1395.56it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1675.50it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1587.61it/s]
simulation step :  32%|       | 8/25 [00:00<00:00, 23.83it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1784.13it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1724.96it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1805.26it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None
```

```
None
None

training model …: 100%|      | 50/50 [00:00<00:00, 1751.63it/s]
simulation step :  48%|        | 12/25 [00:00<00:00, 26.58it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1754.40it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1778.91it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1786.47it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1789.50it/s]
simulation step :  64%|       | 16/25 [00:00<00:00, 27.94it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1751.55it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1737.85it/s]

None
None
None
None
None
None
None


training model …: 100%|      | 50/50 [00:00<00:00, 1724.92it/s]
simulation step :  76%|      | 19/25 [00:00<00:00, 28.41it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1725.70it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1754.76it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1738.17it/s]
simulation step :  88%|      | 22/25 [00:00<00:00, 28.74it/s]
training model …: 100%|      | 50/50 [00:00<00:00, 1721.64it/s]

training model …: 100%|      | 50/50 [00:00<00:00, 1699.59it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]

None
None
None
None
None
None

training model …: 100%|      | 50/50 [00:00<00:00, 1661.74it/s]
simulation step : 100%|      | 25/25 [00:00<00:00, 27.11it/s]

None
```

cluster 0

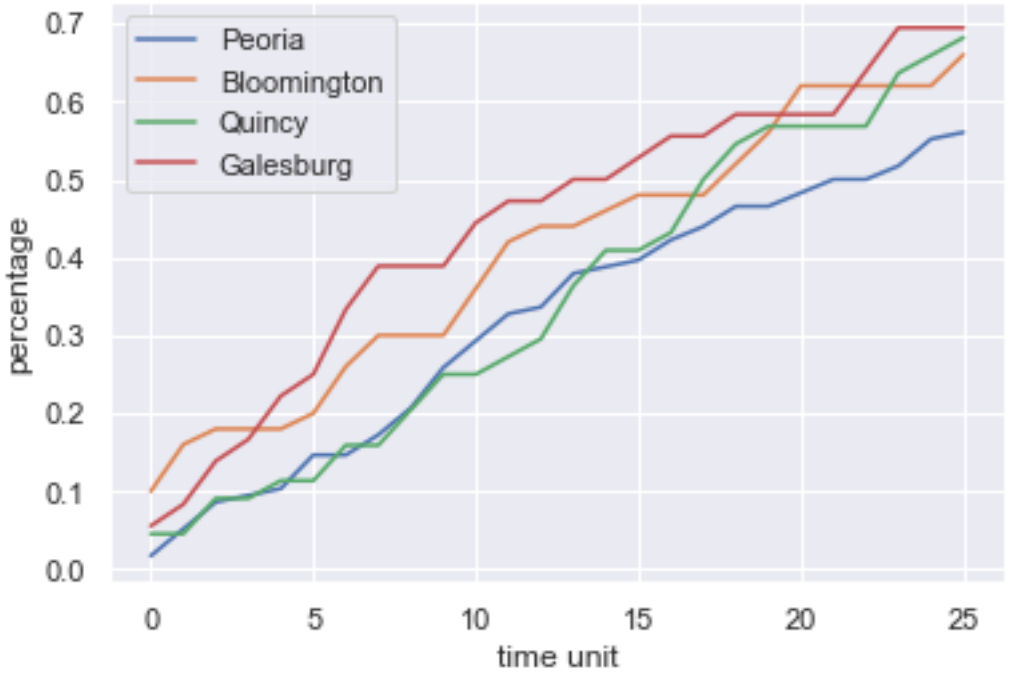
	time unit	percentage
0	0	0.017241
1	1	0.051724
2	2	0.086207
3	3	0.094828
4	4	0.103448
5	5	0.146552
6	6	0.146552
7	7	0.172414
8	8	0.206897
9	9	0.258621
10	10	0.293103
11	11	0.327586
12	12	0.336207
13	13	0.379310
14	14	0.387931
15	15	0.396552
16	16	0.422414
17	17	0.439655
18	18	0.465517
19	19	0.465517
20	20	0.482759
21	21	0.500000
22	22	0.500000
23	23	0.517241
24	24	0.551724

cluster 1

	time unit	percentage
0	0	0.10
1	1	0.16
2	2	0.18
3	3	0.18
4	4	0.18
5	5	0.20
6	6	0.26
7	7	0.30
8	8	0.30
9	9	0.30
10	10	0.36
11	11	0.42
12	12	0.44
13	13	0.44
14	14	0.46
15	15	0.48
16	16	0.48
17	17	0.48

```
18          18         0.52
19          19         0.56
20          20         0.62
21          21         0.62
22          22         0.62
23          23         0.62
24          24         0.62

cluster  2
    time unit  percentage
0           0    0.045455
1           1    0.045455
2           2    0.090909
3           3    0.090909
4           4    0.113636
5           5    0.113636
6           6    0.159091
7           7    0.159091
8           8    0.204545
9           9    0.250000
10         10    0.250000
11         11    0.272727
12         12    0.295455
13         13    0.363636
14         14    0.409091
15         15    0.409091
16         16    0.431818
17         17    0.500000
18         18    0.545455
19         19    0.568182
20         20    0.568182
21         21    0.568182
22         22    0.568182
23         23    0.636364
24         24    0.659091

cluster  3
    time unit  percentage
0           0    0.055556
1           1    0.083333
2           2    0.138889
3           3    0.166667
4           4    0.222222
5           5    0.250000
6           6    0.333333
7           7    0.388889
8           8    0.388889
9           9    0.388889
```

10	10	0.444444
11	11	0.472222
12	12	0.472222
13	13	0.500000
14	14	0.500000
15	15	0.527778
16	16	0.555556
17	17	0.555556
18	18	0.583333
19	19	0.583333
20	20	0.583333
21	21	0.583333
22	22	0.638889
23	23	0.694444
24	24	0.694444



17 train Galesburg, get parameters, predicte other clusters

[91]:
```
run_simulation(3, parameters_to_fit)
get_change_simulated(0, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(1, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
get_change_simulated(2, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
get_change_simulated(3, parameters_to_fit[0], parameters_to_fit[1],␣
 ↪parameters_to_fit[2], parameters_to_fit[3])
```

```
simulation step :   0%|          | 0/25 [00:00<?, ?it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1039.47it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1621.95it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1297.72it/s]
simulation step :  12%|         | 3/25 [00:00<00:01, 21.20it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1488.41it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1697.38it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1759.02it/s]
simulation step :  24%|        | 6/25 [00:00<00:00, 24.62it/s]
training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
None
None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 1840.14it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1925.88it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2081.35it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2044.39it/s]
simulation step :  40%|        | 10/25 [00:00<00:00, 28.59it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 2055.25it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2050.02it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2035.50it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
None
None
```

```
None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 2054.42it/s]
simulation step :  56%|       | 14/25 [00:00<00:00, 30.95it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 2044.47it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2077.01it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2095.98it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2112.66it/s]
simulation step :  72%|      | 18/25 [00:00<00:00, 32.38it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 1992.58it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 1937.07it/s]

training model …:   0%|          | 0/50 [00:00<?, ?it/s]
```

```
None
None
None
None
None
None
None
```

```
training model …: 100%|     | 50/50 [00:00<00:00, 1911.11it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2087.61it/s]
simulation step :  88%|      | 22/25 [00:00<00:00, 32.81it/s]
training model …: 100%|     | 50/50 [00:00<00:00, 2035.93it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2021.02it/s]

training model …: 100%|     | 50/50 [00:00<00:00, 2042.42it/s]
simulation step : 100%|     | 25/25 [00:00<00:00, 31.07it/s]
```

```
None
None
None
None
None
cluster  0
    time unit  percentage
0           0    0.017241
1           1    0.068966
2           2    0.103448
3           3    0.137931
4           4    0.163793
5           5    0.206897
```

```
6           6    0.215517
7           7    0.232759
8           8    0.241379
9           9    0.258621
10         10    0.301724
11         11    0.327586
12         12    0.327586
13         13    0.353448
14         14    0.362069
15         15    0.370690
16         16    0.396552
17         17    0.422414
18         18    0.439655
19         19    0.474138
20         20    0.482759
21         21    0.491379
22         22    0.500000
23         23    0.534483
24         24    0.534483

cluster  1
    time unit  percentage
0           0        0.10
1           1        0.12
2           2        0.18
3           3        0.28
4           4        0.30
5           5        0.34
6           6        0.34
7           7        0.40
8           8        0.46
9           9        0.52
10         10        0.54
11         11        0.60
12         12        0.62
13         13        0.64
14         14        0.66
15         15        0.68
16         16        0.70
17         17        0.70
18         18        0.70
19         19        0.70
20         20        0.72
21         21        0.74
22         22        0.74
23         23        0.74
24         24        0.74
```

cluster 2

	time unit	percentage
0	0	0.045455
1	1	0.136364
2	2	0.181818
3	3	0.250000
4	4	0.295455
5	5	0.340909
6	6	0.340909
7	7	0.386364
8	8	0.454545
9	9	0.454545
10	10	0.477273
11	11	0.500000
12	12	0.500000
13	13	0.500000
14	14	0.568182
15	15	0.590909
16	16	0.590909
17	17	0.613636
18	18	0.636364
19	19	0.636364
20	20	0.636364
21	21	0.636364
22	22	0.636364
23	23	0.659091
24	24	0.659091

cluster 3

	time unit	percentage
0	0	0.055556
1	1	0.083333
2	2	0.194444
3	3	0.250000
4	4	0.277778
5	5	0.305556
6	6	0.305556
7	7	0.333333
8	8	0.361111
9	9	0.472222
10	10	0.472222
11	11	0.472222
12	12	0.500000
13	13	0.500000
14	14	0.527778
15	15	0.583333
16	16	0.611111
17	17	0.638889

18	18	0.638889
19	19	0.638889
20	20	0.638889
21	21	0.638889
22	22	0.638889
23	23	0.666667
24	24	0.666667