1. Menyiapkan Data

```python
import numpy as np
import pandas as pd
import warnings
warnings.filterwarnings('ignore')
```

```python
# Import library
import numpy as np
import pandas as pd
import random
import tensorflow as tf

# Set SEED untuk konsistensi hasil
SEED = 42
np.random.seed(SEED)
random.seed(SEED)
tf.random.set_seed(SEED)  # Untuk konsistensi di TensorFlow
```

```python
# Data
data = pd.read_excel('C:/Users/ASUS/OneDrive - uny.ac.id/SKRIPSI/jpsleman.xlsx')
data.head()
```

	Tahun	Jumlah Penduduk
0	1998	828960
1	1999	838628
2	2000	850176
3	2001	862314
4	2002	874795

```python
data.tail()
```

	Tahun	Jumlah Penduduk
22	2020	1125804
23	2021	1136474
24	2022	1147562
25	2023	1157290
26	2024	1125571

```python
data.describe()
```

	Tahun	Jumlah Penduduk
count	27.000000	2.700000e+01
mean	2011.000000	1.048393e+06
std	7.937254	1.343984e+05
min	1998.000000	8.289600e+05
25%	2004.500000	9.005980e+05
50%	2011.000000	1.107304e+06
75%	2017.500000	1.152426e+06
max	2024.000000	1.231246e+06

```python
data = data.iloc[:, 1].values
data
```

```
array([ 828960,  838628,  850176,  862314,  874795,  884727,  895327,
         905869,  915876, 1041951, 1040220, 1074673, 1093110, 1107304,
        1114833, 1141733, 1163970, 1167481, 1180479, 1193512, 1206714,
        1231246, 1125804, 1136474, 1147562, 1157290, 1125571], dtype=int64)
```

2. Fuzzifikasi Menggunakan Fuzzy C-Means (FCM)

```python
# Parameter
num_clusters = 3   # Jumlah cluster
beta = 2.0         # Parameter fuzziness
max_iter = 100     # Iterasi maksimum
tol = 1e-5         # Toleransi konvergensi
```

```python
# Inisialisasi derajat keanggotaan awal
weight = pd.DataFrame(np.random.dirichlet(np.ones(num_clusters), size=len(data))
weight
```

	0	1	2
0	0.097843	0.627614	0.274543
1	0.729092	0.135465	0.135443
2	0.020012	0.672618	0.307370
3	0.258905	0.004374	0.736721
4	0.802602	0.107237	0.090161
5	0.154749	0.277061	0.568190
6	0.304686	0.185452	0.509862
7	0.157805	0.362926	0.479269
8	0.256977	0.649026	0.093997
9	0.433105	0.538364	0.028531
10	0.786286	0.157169	0.056545
11	0.371867	0.421505	0.206628
12	0.224416	0.063489	0.712095
13	0.416197	0.093380	0.490423
14	0.012795	0.877709	0.109496
15	0.495122	0.170265	0.334613
16	0.176281	0.045537	0.778182
17	0.227841	0.428292	0.343867
18	0.256408	0.717515	0.026077
19	0.331538	0.070343	0.598120
20	0.191249	0.123020	0.685732
21	0.284033	0.212305	0.503662
22	0.082113	0.876005	0.041882
23	0.718148	0.245144	0.036708
24	0.001895	0.578231	0.419875
25	0.456876	0.516205	0.026919
26	0.173696	0.048189	0.778115

```python
# Menyimpan DataFrame ke file Excel
file_path = "weight_data.xlsx"
weight.to_excel(file_path, index=False, engine='openpyxl')

print(f"DataFrame telah disimpan ke file Excel di: {file_path}")
```

DataFrame telah disimpan ke file Excel di: weight_data.xlsx

```python
# Inisialisasi variabel
p0 = 0  # Fungsi objektif awal
max_change = float('inf')  # Awalnya diatur tak terhingga
iteration_count = 0
```

```python
while max_change >= tol and iteration_count < max_iter:
    print(f"\nIteration {iteration_count + 1}")

    # Derajat keanggotaan dipangkatkan dengan indeks fuzziness
    miu = weight ** beta

    # Jumlah setiap kolom dari (derajat keanggotaan dipangkatkan dengan indeks f
    sm = miu.sum(axis=0)

    # Mengalikan setiap elemen baris data dengan baris yang sesuai
    iterasi = miu.multiply(data, axis=0)

    # Jumlah setiap kolom dari (hasil perkalian)
    si = iterasi.sum(axis=0)

    # Menghitung pusat cluster (c)
    c = si / sm

    # Fungsi objektif
    result = pd.DataFrame()
    for i in range(c.shape[0]):
        result[f"Col_{i+1}"] = ((data - c[i]) ** 2) * miu.iloc[:, i]

    # Jumlah setiap baris dari fungsi objektif
    r_n = result.sum(axis=1)

    # Jumlah total fungsi objektif
    p1 = r_n.sum()

    # Menghitung perubahan fungsi objektif
    max_change = abs(p1 - p0)
    print(f"Max Change: {max_change}")
    p0 = p1

    # Cetak pusat cluster
    print("Cluster Centers (C):")
    print(c.map('{:.2f}'.format))

    # Update derajat keanggotaan (weight)
    result1 = pd.DataFrame()
    for i in range(c.shape[0]):
        result1[f"L{i+1}"] = ((data - c[i]) ** (-2 / (beta - 1)))

    r1_n = result1.sum(axis=1)

    # Membagi setiap elemen di result1 dengan elemen di r1_n berdasarkan baris
    weight = result1.div(r1_n, axis=0)

    # Cetak derajat keanggotaan
    print("Membership Degrees (Weight):")
    print(weight)

    # Increment iteration counter
    iteration_count += 1
```

```
Iteration 1
Max Change: 235277433803.1227
Cluster Centers (C):
0    1021033.18
1    1050633.82
2    1068623.59
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.417876   0.313727   0.268397
1    0.422078   0.312444   0.265478
2    0.427675   0.310695   0.261629
3    0.434367   0.308548   0.257085
4    0.442304   0.305924   0.251772
5    0.449561   0.303453   0.246986
6    0.458439   0.300340   0.241221
7    0.468702   0.296624   0.234674
8    0.480105   0.292352   0.227544
9    0.134792   0.782305   0.082903
10   0.206148   0.699785   0.094067
11   0.011820   0.058851   0.929329
12   0.079720   0.229546   0.690733
13   0.120599   0.279487   0.599914
14   0.137833   0.294237   0.567930
15   0.182446   0.320272   0.497281
16   0.206699   0.328768   0.464534
17   0.209846   0.329633   0.460520
18   0.220271   0.332149   0.447580
19   0.229116   0.333883   0.437001
20   0.236781   0.335109   0.428109
21   0.248412   0.336509   0.415079
22   0.158733   0.308359   0.532909
23   0.175336   0.317108   0.507556
24   0.189636   0.323147   0.487217
25   0.200254   0.326834   0.472912
26   0.158333   0.308123   0.533544

Iteration 2
Max Change: 107223611046.43266
Cluster Centers (C):
L1     945759.50
L2    1050351.79
L3    1102581.49
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.684677   0.190566   0.124758
1    0.703846   0.180207   0.115946
2    0.729176   0.166255   0.104568
3    0.758984   0.149468   0.091548
4    0.793364   0.129634   0.077001
5    0.823536   0.111829   0.064636
6    0.858336   0.090840   0.050824
7    0.894976   0.068221   0.036803
8    0.930232   0.045937   0.023831
9    0.007428   0.973875   0.018697
10   0.011085   0.963483   0.025432
11   0.019829   0.557090   0.423081
12   0.003923   0.046589   0.949488
13   0.000848   0.006823   0.992329
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14   0.005042   0.034667   0.960291
15   0.032622   0.150034   0.817345
16   0.057725   0.212920   0.729355
17   0.061520   0.220444   0.718036
18   0.075003   0.244028   0.680970
19   0.087576   0.262288   0.650136
20   0.099352   0.276721   0.623927
21   0.118850   0.296020   0.585130
22   0.014969   0.085235   0.899796
23   0.026619   0.130535   0.842847
24   0.039312   0.169415   0.791273
25   0.050346   0.196990   0.752664
26   0.014730   0.084173   0.901097


Iteration 3
Max Change: 85001177640.88327
Cluster Centers (C):
L1      881479.99
L2     1059526.18
L3     1138780.92
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.925392   0.048016   0.026592
1    0.945167   0.035569   0.019265
2    0.967002   0.021621   0.011377
3    0.985949   0.009312   0.004738
4    0.998053   0.001307   0.000640
5    0.999492   0.000345   0.000163
6    0.989759   0.007039   0.003202
7    0.965104   0.024314   0.010582
8    0.924946   0.053030   0.022024
9    0.011479   0.956993   0.031527
10   0.014045   0.949522   0.036432
11   0.005788   0.941646   0.052566
12   0.016082   0.638605   0.345313
13   0.013367   0.298625   0.688008
14   0.008791   0.156500   0.834709
15   0.000128   0.001288   0.998584
16   0.007458   0.054558   0.937985
17   0.009318   0.065397   0.925285
18   0.017086   0.104410   0.878504
19   0.025689   0.139325   0.834986
20   0.034718   0.169514   0.795768
21   0.051394   0.213221   0.735385
22   0.002710   0.036821   0.960470
23   0.000082   0.000898   0.999020
24   0.001077   0.009840   0.989082
25   0.004329   0.034454   0.961218
26   0.002808   0.038359   0.958833


Iteration 4
Max Change: 19963732226.522995
Cluster Centers (C):
L1      873522.56
L2     1063960.40
L3     1154056.79
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
```

```
0    0.948094   0.034092   0.017814
1    0.965047   0.023143   0.011810
2    0.982484   0.011717   0.005799
3    0.995455   0.003076   0.001469
4    0.999934   0.000045   0.000021
5    0.994393   0.003886   0.001721
6    0.976733   0.016330   0.006937
7    0.944421   0.039537   0.016042
8    0.898133   0.073468   0.028399
9    0.016176   0.947310   0.036513
10   0.019066   0.940049   0.040885
11   0.002778   0.979387   0.017835
12   0.014138   0.802328   0.183534
13   0.018150   0.528024   0.453825
14   0.016300   0.366756   0.616944
15   0.002055   0.024444   0.973501
16   0.001152   0.009718   0.989129
17   0.002047   0.016504   0.981449
18   0.006998   0.048565   0.944438
19   0.013722   0.083715   0.902564
20   0.021512   0.117191   0.861297
21   0.036968   0.169047   0.793984
22   0.010269   0.170895   0.818835
23   0.004205   0.055296   0.940499
24   0.000558   0.005996   0.993446
25   0.000130   0.001199   0.998672
26   0.010414   0.174286   0.815300


Iteration 5
Max Change: 1740303089.3039665
Cluster Centers (C):
L1       872460.09
L2      1068455.42
L3      1160573.47
dtype: object
Membership Degrees (Weight):
          L1          L2          L3
0    0.952202   0.031413   0.016385
1    0.968323   0.020983   0.010693
2    0.984662   0.010262   0.005075
3    0.996433   0.002414   0.001153
4    0.999788   0.000145   0.000067
5    0.993606   0.004429   0.001965
6    0.975726   0.017022   0.007252
7    0.943905   0.039855   0.016240
8    0.898919   0.072782   0.028298
9    0.022761   0.930772   0.046467
10   0.026148   0.923048   0.050804
11   0.000940   0.993854   0.005207
12   0.010894   0.872570   0.116536
13   0.017550   0.641346   0.341103
14   0.017734   0.484340   0.497926
15   0.004571   0.061724   0.933705
16   0.000136   0.001263   0.998602
17   0.000545   0.004840   0.994615
18   0.004032   0.030484   0.965484
19   0.009747   0.064241   0.926012
20   0.016857   0.098523   0.884620
21   0.031615   0.153569   0.814817
22   0.013586   0.265129   0.721285
```

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23   0.007349   0.110713   0.881939
24   0.002173   0.026284   0.971543
25   0.000133   0.001364   0.998503
26   0.013712   0.269284   0.717004


Iteration 6
Max Change: 487279402.1169281
Cluster Centers (C):
L1      872365.63
L2     1072718.18
L3     1163877.35
dtype: object
Membership Degrees (Weight):
                L1          L2          L3
0    9.537391e-01   0.030242   0.016019
1    9.694329e-01   0.020136   0.010431
2    9.852746e-01   0.009796   0.004930
3    9.966182e-01   0.002275   0.001107
4    9.997788e-01   0.000151   0.000071
5    9.937546e-01   0.004297   0.001949
6    9.765006e-01   0.016361   0.007139
7    9.459102e-01   0.038140   0.015950
8    9.027392e-01   0.069474   0.027787
9    3.001605e-02   0.911916   0.058068
10   3.387510e-02   0.903707   0.062417
11   9.331302e-05   0.999427   0.000480
12   7.817771e-03   0.916115   0.076067
13   1.553049e-02   0.716633   0.267836
14   1.706835e-02   0.565755   0.417177
15   6.090117e-03   0.092775   0.901135
16   1.009540e-07   0.000001   0.999999
17   1.488709e-04   0.001444   0.998407
18   2.827902e-03   0.023119   0.974053
19   7.967765e-03   0.056319   0.935713
20   1.467413e-02   0.091363   0.893963
21   2.898294e-02   0.148536   0.822481
22   1.468378e-02   0.334677   0.650640
23   9.005135e-03   0.154531   0.836464
24   3.344182e-03   0.045213   0.951443
25   5.310121e-04   0.006027   0.993442
26   1.478335e-02   0.339299   0.645918


Iteration 7
Max Change: 233630995.99273682
Cluster Centers (C):
L1      872398.59
L2     1076211.27
L3     1165955.30
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.954672   0.029466   0.015862
1    0.970075   0.019600   0.010326
2    0.985592   0.009527   0.004881
3    0.996685   0.002215   0.001099
4    0.999791   0.000142   0.000068
5    0.993970   0.004120   0.001910
6    0.977283   0.015702   0.007015
7    0.947715   0.036589   0.015695
8    0.905997   0.066619   0.027384
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9    0.036547   0.895126   0.068327
10   0.040777   0.886579   0.072644
11   0.000058   0.999658   0.000284
12   0.005532   0.943683   0.050785
13   0.013492   0.770086   0.216422
14   0.015900   0.626517   0.357582
15   0.007065   0.119384   0.873550
16   0.000046   0.000511   0.999442
17   0.000027   0.000279   0.999694
18   0.002175   0.018992   0.978833
19   0.006931   0.051940   0.941129
20   0.013362   0.087687   0.898951
21   0.027348   0.146519   0.826132
22   0.014938   0.390033   0.595029
23   0.009956   0.191189   0.798854
24   0.004172   0.062053   0.933774
25   0.000914   0.011283   0.987803
26   0.015013   0.394959   0.590028

Iteration 8
Max Change: 134280855.8504982
Cluster Centers (C):
L1     872442.09
L2    1078966.83
L3    1167453.24
dtype: object
Membership Degrees (Weight):
              L1            L2          L3
0    9.553372e-01   2.889839e-02   0.015764
1    9.705259e-01   1.921120e-02   0.010263
2    9.858080e-01   9.336903e-03   0.004855
3    9.967237e-01   2.178215e-03   0.001098
4    9.998026e-01   1.327807e-04   0.000065
5    9.941464e-01   3.976656e-03   0.001877
6    9.778975e-01   1.518652e-02   0.006916
7    9.491080e-01   3.539362e-02   0.015498
8    9.084866e-01   6.443434e-02   0.027079
9    4.202598e-02   8.813085e-01   0.076665
10   4.653608e-02   8.725435e-01   0.080920
11   4.496450e-04   9.974141e-01   0.002136
12   3.948724e-03   9.612615e-01   0.034790
13   1.177312e-02   8.087302e-01   0.179497
14   1.472918e-02   6.727308e-01   0.312540
15   7.750238e-03   1.426616e-01   0.849588
16   1.425003e-04   1.676123e-03   0.998181
17   8.853391e-09   9.836546e-08   1.000000
18   1.756082e-03   1.617015e-02   0.982074
19   6.224179e-03   4.890212e-02   0.944874
20   1.244746e-02   8.522716e-02   0.902325
21   2.618688e-02   1.453842e-01   0.828429
22   1.486602e-02   4.350067e-01   0.550127
23   1.055753e-02   2.225517e-01   0.766891
24   4.798724e-03   7.719386e-02   0.918007
25   1.250383e-03   1.653822e-02   0.982211
26   1.491900e-02   4.401225e-01   0.544958

Iteration 9
Max Change: 81935463.11119461
Cluster Centers (C):
L1     872480.83
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L2     1081130.42
L3     1168604.38
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.955836  0.028470  0.015694
1   0.970862  0.018920  0.010218
2   0.985966  0.009196  0.004838
3   0.996750  0.002152  0.001098
4   0.999812  0.000126  0.000062
5   0.994284  0.003866  0.001850
6   0.978370  0.014792  0.006838
7   0.950172  0.034484  0.015344
8   0.910382  0.062777  0.026841
9   0.046511  0.870215  0.083274
10  0.051234  0.861308  0.087458
11  0.001014  0.994287  0.004699
12  0.002868  0.972641  0.024491
13  0.010399  0.837010  0.152592
14  0.013694  0.708122  0.278184
15  0.008255  0.162947  0.828798
16  0.000252  0.003119  0.996629
17  0.000014  0.000169  0.999816
18  0.001463  0.014064  0.984472
19  0.005705  0.046555  0.947740
20  0.011764  0.083331  0.904905
21  0.025308  0.144552  0.830140
22  0.014666  0.471576  0.513758
23  0.010958  0.249324  0.739719
24  0.005290  0.090701  0.904009
25  0.001542  0.021561  0.976898
26  0.014701  0.476803  0.508496


Iteration 10
Max Change: 51283725.04514313
Cluster Centers (C):
L1      872513.52
L2     1082834.28
L3     1169513.22
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.956217  0.028143  0.015640
1   0.971118  0.018698  0.010185
2   0.986085  0.009090  0.004825
3   0.996769  0.002132  0.001099
4   0.999820  0.000120  0.000060
5   0.994392  0.003780  0.001829
6   0.978736  0.014488  0.006776
7   0.950992  0.033786  0.015222
8   0.911841  0.061508  0.026651
9   0.050149  0.861372  0.088479
10  0.055035  0.852370  0.092595
11  0.001615  0.991046  0.007339
12  0.002127  0.980144  0.017729
13  0.009319  0.857940  0.132741
14  0.012823  0.735352  0.251826
15  0.008635  0.180409  0.810957
16  0.000360  0.004644  0.994996
17  0.000047  0.000576  0.999377
```

```
18   0.001251   0.012439   0.986310
19   0.005310   0.044668   0.950022
20   0.011238   0.081790   0.906973
21   0.024624   0.143867   0.831509
22   0.014424   0.501196   0.484380
23   0.011230   0.271953   0.716816
24   0.005680   0.102561   0.891759
25   0.001791   0.026197   0.972013
26   0.014445   0.506481   0.479073


Iteration 11
Max Change: 32488666.86946869
Cluster Centers (C):
L1      872540.71
L2     1084180.98
L3     1170238.63
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.956512   0.027890   0.015598
1    0.971315   0.018527   0.010158
2    0.986177   0.009008   0.004815
3    0.996783   0.002118   0.001099
4    0.999826   0.000116   0.000058
5    0.994476   0.003712   0.001812
6    0.979022   0.014252   0.006726
7    0.951630   0.033246   0.015124
8    0.912974   0.060527   0.026499
9    0.053087   0.854336   0.092577
10   0.058099   0.845269   0.096631
11   0.002186   0.988034   0.009780
12   0.001614   0.985182   0.013204
13   0.008475   0.873596   0.117929
14   0.012106   0.756391   0.231503
15   0.008924   0.195238   0.795838
16   0.000460   0.006132   0.993409
17   0.000087   0.001095   0.998818
18   0.001092   0.011170   0.987738
19   0.005004   0.043133   0.951863
20   0.010826   0.080518   0.908656
21   0.024085   0.143284   0.832631
22   0.014182   0.525082   0.460735
23   0.011418   0.290876   0.697705
24   0.005991   0.112802   0.881207
25   0.002001   0.030354   0.967645
26   0.014192   0.530395   0.455413


Iteration 12
Max Change: 20696531.321022034
Cluster Centers (C):
L1      872563.16
L2     1085248.28
L3     1170820.00
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.956742   0.027693   0.015564
1    0.971468   0.018394   0.010138
2    0.986247   0.008945   0.004808
3    0.996793   0.002107   0.001100
```

```
4    0.999831   0.000112   0.000057
5    0.994542   0.003660   0.001798
6    0.979246   0.014068   0.006686
7    0.952130   0.032824   0.015045
8    0.913861   0.059762   0.026377
9    0.055454   0.848739   0.095807
10   0.060564   0.839627   0.099809
11   0.002698   0.985381   0.011921
12   0.001256   0.988625   0.010118
13   0.007817   0.885419   0.106764
14   0.011523   0.772713   0.215764
15   0.009145   0.207680   0.783175
16   0.000548   0.007511   0.991941
17   0.000128   0.001646   0.998226
18   0.000973   0.010173   0.988854
19   0.004766   0.041883   0.953352
20   0.010501   0.079468   0.910031
21   0.023657   0.142787   0.833555
22   0.013959   0.544277   0.441764
23   0.011549   0.306548   0.681903
24   0.006239   0.121512   0.872249
25   0.002176   0.033996   0.963828
26   0.013960   0.549598   0.436442


Iteration 13
Max Change: 13212620.852153778
Cluster Centers (C):
L1      872581.59
L2     1086095.64
L3     1171286.42
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.956922   0.027539   0.015538
1    0.971588   0.018290   0.010122
2    0.986302   0.008896   0.004802
3    0.996801   0.002098   0.001101
4    0.999835   0.000110   0.000056
5    0.994595   0.003618   0.001787
6    0.979423   0.013923   0.006654
7    0.952524   0.032494   0.014982
8    0.914558   0.059164   0.026278
9    0.057356   0.844286   0.098358
10   0.062543   0.835142   0.102316
11   0.003141   0.983117   0.013742
12   0.001003   0.991019   0.007978
13   0.007302   0.894424   0.098274
14   0.011053   0.785423   0.203525
15   0.009316   0.218011   0.772673
16   0.000625   0.008744   0.990631
17   0.000166   0.002181   0.997653
18   0.000882   0.009389   0.989729
19   0.004578   0.040866   0.954555
20   0.010243   0.078604   0.911152
21   0.023317   0.142368   0.834315
22   0.013762   0.559659   0.426579
23   0.011641   0.319422   0.668936
24   0.006437   0.128825   0.864738
25   0.002321   0.037125   0.960554
26   0.013756   0.564977   0.421267
```

```
Iteration 14
Max Change: 8437731.06470871
Cluster Centers (C):
L1     872596.64
L2    1086769.11
L3    1171660.53
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957064   0.027419   0.015517
1    0.971682   0.018209   0.010109
2    0.986345   0.008858   0.004797
3    0.996807   0.002092   0.001101
4    0.999838   0.000108   0.000055
5    0.994637   0.003585   0.001778
6    0.979563   0.013809   0.006628
7    0.952835   0.032233   0.014931
8    0.915108   0.058693   0.026199
9    0.058881   0.840743   0.100375
10   0.064129   0.831575   0.104296
11   0.003516   0.981222   0.015263
12   0.000821   0.992710   0.006469
13   0.006899   0.901334   0.091767
14   0.010675   0.795353   0.193972
15   0.009447   0.226517   0.764036
16   0.000689   0.009819   0.989491
17   0.000200   0.002674   0.997126
18   0.000813   0.008771   0.990417
19   0.004430   0.040043   0.955527
20   0.010039   0.077898   0.912064
21   0.023046   0.142016   0.834938
22   0.013593   0.571960   0.414447
23   0.011706   0.329929   0.658364
24   0.006594   0.134902   0.858504
25   0.002440   0.039772   0.957787
26   0.013581   0.577271   0.409148

Iteration 15
Max Change: 5385408.033756256
Cluster Centers (C):
L1     872608.88
L2    1087304.69
L3    1171960.36
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957176   0.027324   0.015501
1    0.971756   0.018145   0.010099
2    0.986378   0.008828   0.004794
3    0.996811   0.002087   0.001102
4    0.999840   0.000106   0.000054
5    0.994670   0.003559   0.001770
6    0.979674   0.013719   0.006607
7    0.953081   0.032028   0.014891
8    0.915543   0.058321   0.026135
9    0.060104   0.837924   0.101972
10   0.065399   0.828739   0.105862
11   0.003828   0.979656   0.016515
12   0.000689   0.993923   0.005388
```

```
13  0.006584  0.906669  0.086747
14  0.010373  0.803135  0.186492
15  0.009549  0.233472  0.756979
16  0.000743  0.010738  0.988519
17  0.000230  0.003111  0.996659
18  0.000759  0.008283  0.990958
19  0.004313  0.039378  0.956309
20  0.009877  0.077322  0.912802
21  0.022830  0.141725  0.835445
22  0.013451  0.581783  0.404766
23  0.011753  0.338459  0.649788
24  0.006720  0.139907  0.853373
25  0.002537  0.041984  0.955478
26  0.013435  0.587084  0.399482


Iteration 16
Max Change: 3433971.401397705
Cluster Centers (C):
L1     872618.79
L2    1087730.75
L3    1172200.41
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957264  0.027249  0.015487
1   0.971815  0.018095  0.010091
2   0.986405  0.008804  0.004791
3   0.996815  0.002083  0.001102
4   0.999842  0.000104  0.000054
5   0.994697  0.003539  0.001765
6   0.979762  0.013648  0.006591
7   0.953276  0.031866  0.014858
8   0.915888  0.058028  0.026084
9   0.061081  0.835682  0.103237
10  0.066415  0.826483  0.107102
11  0.004086  0.978376  0.017538
12  0.000592  0.994806  0.004602
13  0.006336  0.910811  0.082854
14  0.010132  0.809249  0.180619
15  0.009629  0.239127  0.751244
16  0.000788  0.011511  0.987701
17  0.000255  0.003489  0.996256
18  0.000717  0.007898  0.991385
19  0.004221  0.038842  0.956938
20  0.009748  0.076854  0.913398
21  0.022658  0.141485  0.835857
22  0.013333  0.589619  0.397048
23  0.011786  0.345355  0.642859
24  0.006819  0.144002  0.849179
25  0.002616  0.043815  0.953569
26  0.013313  0.594910  0.391777


Iteration 17
Max Change: 2187297.8169517517
Cluster Centers (C):
L1     872626.79
L2    1088069.73
L3    1172392.42
dtype: object
Membership Degrees (Weight):
```

```
            L1          L2          L3
0     0.957334    0.027189    0.015477
1     0.971861    0.018055    0.010084
2     0.986426    0.008785    0.004789
3     0.996817    0.002080    0.001103
4     0.999844    0.000103    0.000053
5     0.994718    0.003522    0.001760
6     0.979832    0.013591    0.006577
7     0.953431    0.031737    0.014832
8     0.916161    0.057795    0.026043
9     0.061863    0.833897    0.104240
10    0.067226    0.824689    0.108085
11    0.004297    0.977335    0.018369
12    0.000520    0.995457    0.004023
13    0.006140    0.914040    0.079820
14    0.009940    0.814064    0.175996
15    0.009691    0.243705    0.746604
16    0.000825    0.012154    0.987021
17    0.000276    0.003810    0.995914
18    0.000684    0.007594    0.991721
19    0.004147    0.038411    0.957442
20    0.009645    0.076477    0.913878
21    0.022521    0.141289    0.836190
22    0.013236    0.595865    0.390898
23    0.011810    0.350911    0.637279
24    0.006899    0.147333    0.845769
25    0.002680    0.045317    0.952003
26    0.013214    0.601146    0.385640

Iteration 18
Max Change: 1391754.8759155273
Cluster Centers (C):
L1      872633.23
L2     1088339.45
L3     1172545.86
dtype: object
Membership Degrees (Weight):
            L1          L2          L3
0     0.957389    0.027142    0.015469
1     0.971897    0.018023    0.010079
2     0.986442    0.008771    0.004787
3     0.996819    0.002078    0.001103
4     0.999845    0.000102    0.000053
5     0.994734    0.003509    0.001756
6     0.979887    0.013546    0.006567
7     0.953554    0.031635    0.014811
8     0.916378    0.057611    0.026011
9     0.062487    0.832477    0.105036
10    0.067873    0.823261    0.108865
11    0.004468    0.976493    0.019040
12    0.000466    0.995942    0.003592
13    0.005986    0.916568    0.077446
14    0.009786    0.817862    0.172352
15    0.009740    0.247397    0.742863
16    0.000855    0.012684    0.986462
17    0.000294    0.004078    0.995628
18    0.000659    0.007354    0.991988
19    0.004089    0.038065    0.957846
20    0.009563    0.076172    0.914264
21    0.022412    0.141130    0.836459
```

```
22  0.013158  0.600841  0.386001
23  0.011828  0.355375  0.632796
24  0.006962  0.150030  0.843009
25  0.002731  0.046543  0.950726
26  0.013133  0.606113  0.380754


Iteration 19
Max Change: 884711.006729126
Cluster Centers (C):
L1     872638.40
L2    1088554.06
L3    1172668.38
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0   0.957433  0.027105  0.015462
1   0.971926  0.017998  0.010075
2   0.986455  0.008759  0.004786
3   0.996821  0.002076  0.001103
4   0.999846  0.000102  0.000052
5   0.994748  0.003499  0.001753
6   0.979931  0.013511  0.006558
7   0.953651  0.031554  0.014794
8   0.916550  0.057465  0.025985
9   0.062984  0.831347  0.105668
10  0.068390  0.822126  0.109484
11  0.004606  0.975814  0.019579
12  0.000425  0.996307  0.003267
13  0.005864  0.918553  0.075583
14  0.009664  0.820863  0.169473
15  0.009778  0.250367  0.739855
16  0.000879  0.013117  0.986004
17  0.000308  0.004300  0.995392
18  0.000639  0.007163  0.992198
19  0.004043  0.037788  0.958169
20  0.009498  0.075928  0.914574
21  0.022324  0.141001  0.836675
22  0.013094  0.604804  0.382103
23  0.011841  0.358955  0.629203
24  0.007012  0.152206  0.840783
25  0.002772  0.047537  0.949691
26  0.013067  0.610068  0.376865


Iteration 20
Max Change: 561921.7685470581
Cluster Centers (C):
L1     872642.55
L2    1088724.82
L3    1172766.13
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0   0.957468  0.027076  0.015457
1   0.971949  0.017979  0.010072
2   0.986465  0.008750  0.004785
3   0.996822  0.002074  0.001103
4   0.999847  0.000101  0.000052
5   0.994758  0.003491  0.001751
6   0.979966  0.013482  0.006551
7   0.953729  0.031490  0.014781
```

```
8    0.916687   0.057349   0.025964
9    0.063381   0.830449   0.106170
10   0.068802   0.821223   0.109976
11   0.004718   0.975269   0.020013
12   0.000394   0.996585   0.003020
13   0.005768   0.920116   0.074117
14   0.009567   0.823238   0.167196
15   0.009808   0.252751   0.737441
16   0.000899   0.013469   0.985632
17   0.000320   0.004482   0.995198
18   0.000623   0.007012   0.992365
19   0.004007   0.037567   0.958427
20   0.009447   0.075732   0.914822
21   0.022255   0.140897   0.836848
22   0.013042   0.607959   0.379000
23   0.011851   0.361821   0.626327
24   0.007052   0.153956   0.838992
25   0.002805   0.048341   0.948854
26   0.013014   0.613216   0.373770


Iteration 21
Max Change: 356647.93019485474
Cluster Centers (C):
L1      872645.86
L2     1088860.67
L3     1172844.08
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957495   0.027052   0.015452
1    0.971967   0.017963   0.010070
2    0.986474   0.008743   0.004784
3    0.996823   0.002073   0.001103
4    0.999847   0.000101   0.000052
5    0.994767   0.003484   0.001749
6    0.979994   0.013460   0.006546
7    0.953790   0.031439   0.014770
8    0.916796   0.057257   0.025947
9    0.063698   0.829734   0.106569
10   0.069130   0.820504   0.110366
11   0.004808   0.974832   0.020360
12   0.000370   0.996799   0.002831
13   0.005692   0.921348   0.072961
14   0.009489   0.825118   0.165393
15   0.009832   0.254660   0.735508
16   0.000914   0.013754   0.985331
17   0.000329   0.004630   0.995041
18   0.000611   0.006892   0.992497
19   0.003977   0.037390   0.958633
20   0.009406   0.075574   0.915020
21   0.022200   0.140813   0.836987
22   0.013000   0.610470   0.376530
23   0.011859   0.364113   0.624028
24   0.007083   0.155361   0.837555
25   0.002831   0.048989   0.948180
26   0.012971   0.615722   0.371307


Iteration 22
Max Change: 226226.4758644104
Cluster Centers (C):
```

```
L1      872648.51
L2     1088968.76
L3     1172906.22
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957517  0.027034  0.015449
1   0.971982  0.017951  0.010068
2   0.986480  0.008737  0.004783
3   0.996824  0.002072  0.001104
4   0.999848  0.000100  0.000052
5   0.994773  0.003479  0.001748
6   0.980016  0.013442  0.006542
7   0.953839  0.031399  0.014762
8   0.916882  0.057184  0.025934
9   0.063950  0.829165  0.106886
10  0.069391  0.819933  0.110676
11  0.004880  0.974482  0.020638
12  0.000352  0.996963  0.002685
13  0.005631  0.922321  0.072047
14  0.009428  0.826609  0.163964
15  0.009851  0.256187  0.733962
16  0.000927  0.013984  0.985089
17  0.000337  0.004751  0.994913
18  0.000601  0.006797  0.992602
19  0.003954  0.037249  0.958797
20  0.009373  0.075449  0.915178
21  0.022156  0.140746  0.837098
22  0.012967  0.612468  0.374565
23  0.011865  0.365943  0.622193
24  0.007109  0.156487  0.836404
25  0.002852  0.049509  0.947639
26  0.012937  0.617716  0.369348

Iteration 23
Max Change: 143427.36054229736
Cluster Centers (C):
L1      872650.63
L2     1089054.75
L3     1172955.72
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957535  0.027019  0.015446
1   0.971993  0.017941  0.010066
2   0.986485  0.008732  0.004783
3   0.996825  0.002072  0.001104
4   0.999848  0.000100  0.000052
5   0.994779  0.003475  0.001746
6   0.980034  0.013428  0.006538
7   0.953878  0.031367  0.014755
8   0.916951  0.057126  0.025923
9   0.064150  0.828712  0.107137
10  0.069599  0.819478  0.110922
11  0.004937  0.974203  0.020860
12  0.000337  0.997091  0.002572
13  0.005583  0.923092  0.071325
14  0.009379  0.827791  0.162830
15  0.009865  0.257407  0.732727
16  0.000937  0.014170  0.984893
```

```
17   0.000343   0.004848   0.994809
18   0.000593   0.006722   0.992685
19   0.003936   0.037136   0.958928
20   0.009347   0.075348   0.915305
21   0.022121   0.140692   0.837187
22   0.012940   0.614058   0.373002
23   0.011869   0.367403   0.620728
24   0.007129   0.157388   0.835484
25   0.002869   0.049926   0.947205
26   0.012909   0.619302   0.367789


Iteration 24
Max Change: 90895.89407730103
Cluster Centers (C):
L1      872652.32
L2     1089123.16
L3     1172995.15
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957549   0.027007   0.015444
1    0.972003   0.017933   0.010065
2    0.986489   0.008728   0.004782
3    0.996825   0.002071   0.001104
4    0.999848   0.000100   0.000052
5    0.994783   0.003472   0.001745
6    0.980048   0.013417   0.006535
7    0.953909   0.031341   0.014750
8    0.917005   0.057080   0.025915
9    0.064310   0.828352   0.107337
10   0.069765   0.819116   0.111118
11   0.004983   0.973979   0.021037
12   0.000326   0.997190   0.002484
13   0.005545   0.923702   0.070753
14   0.009340   0.828729   0.161931
15   0.009877   0.258381   0.731741
16   0.000945   0.014318   0.984737
17   0.000348   0.004926   0.994726
18   0.000587   0.006662   0.992751
19   0.003921   0.037046   0.959032
20   0.009326   0.075268   0.915405
21   0.022093   0.140649   0.837258
22   0.012919   0.615323   0.371758
23   0.011873   0.368567   0.619560
24   0.007145   0.158107   0.834748
25   0.002883   0.050260   0.946857
26   0.012887   0.620564   0.366548


Iteration 25
Max Change: 57585.482734680176
Cluster Centers (C):
L1      872653.67
L2     1089177.58
L3     1173026.54
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957560   0.026998   0.015443
1    0.972010   0.017927   0.010064
2    0.986493   0.008726   0.004782
```

```
3    0.996826   0.002071   0.001104
4    0.999849   0.000100   0.000052
5    0.994786   0.003469   0.001745
6    0.980059   0.013408   0.006533
7    0.953934   0.031321   0.014746
8    0.917049   0.057043   0.025908
9    0.064437   0.828066   0.107497
10   0.069897   0.818829   0.111274
11   0.005020   0.973801   0.021179
12   0.000317   0.997268   0.002415
13   0.005515   0.924185   0.070300
14   0.009309   0.829474   0.161217
15   0.009886   0.259158   0.730955
16   0.000952   0.014437   0.984611
17   0.000352   0.004989   0.994659
18   0.000582   0.006615   0.992803
19   0.003910   0.036975   0.959115
20   0.009310   0.075204   0.915486
21   0.022071   0.140614   0.837315
22   0.012902   0.616330   0.370769
23   0.011875   0.369495   0.618629
24   0.007157   0.158682   0.834161
25   0.002893   0.050527   0.946580
26   0.012870   0.621568   0.365562

Iteration 26
Max Change: 36472.50085449219
Cluster Centers (C):
L1      872654.74
L2     1089220.87
L3     1173051.54
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957568   0.026990   0.015441
1    0.972016   0.017922   0.010063
2    0.986495   0.008723   0.004782
3    0.996826   0.002070   0.001104
4    0.999849   0.000100   0.000051
5    0.994789   0.003467   0.001744
6    0.980068   0.013400   0.006532
7    0.953953   0.031304   0.014742
8    0.917083   0.057014   0.025903
9    0.064539   0.827838   0.107623
10   0.070002   0.818600   0.111398
11   0.005049   0.973659   0.021291
12   0.000310   0.997329   0.002360
13   0.005491   0.924569   0.069940
14   0.009284   0.830066   0.160650
15   0.009894   0.259778   0.730328
16   0.000957   0.014532   0.984511
17   0.000355   0.005039   0.994606
18   0.000578   0.006577   0.992845
19   0.003900   0.036918   0.959182
20   0.009297   0.075153   0.915550
21   0.022053   0.140587   0.837360
22   0.012888   0.617130   0.369982
23   0.011878   0.370235   0.617888
24   0.007167   0.159140   0.833692
25   0.002902   0.050740   0.946358
```

```
26  0.012856  0.622367  0.364777

Iteration 27
Max Change: 23095.33863067627
Cluster Centers (C):
L1     872655.60
L2    1089255.31
L3    1173071.43
dtype: object
Membership Degrees (Weight):
         L1         L2         L3
0   0.957575  0.026985  0.015440
1   0.972020  0.017918  0.010062
2   0.986497  0.008721  0.004781
3   0.996826  0.002070  0.001104
4   0.999849  0.000100  0.000051
5   0.994791  0.003465  0.001744
6   0.980075  0.013395  0.006530
7   0.953969  0.031292  0.014739
8   0.917111  0.056991  0.025898
9   0.064619  0.827657  0.107724
10  0.070086  0.818418  0.111496
11  0.005073  0.973546  0.021381
12  0.000305  0.997377  0.002318
13  0.005472  0.924873  0.069655
14  0.009264  0.830536  0.160200
15  0.009900  0.260271  0.729829
16  0.000961  0.014608  0.984431
17  0.000358  0.005080  0.994563
18  0.000575  0.006547  0.992878
19  0.003893  0.036873  0.959234
20  0.009286  0.075113  0.915601
21  0.022039  0.140565  0.837396
22  0.012877  0.617767  0.369356
23  0.011879  0.370824  0.617297
24  0.007175  0.159506  0.833319
25  0.002909  0.050910  0.946181
26  0.012845  0.623003  0.364153

Iteration 28
Max Change: 14622.032398223877
Cluster Centers (C):
L1     872656.28
L2    1089282.70
L3    1173087.26
dtype: object
Membership Degrees (Weight):
         L1         L2         L3
0   0.957581  0.026980  0.015439
1   0.972024  0.017915  0.010062
2   0.986499  0.008720  0.004781
3   0.996826  0.002070  0.001104
4   0.999849  0.000099  0.000051
5   0.994793  0.003464  0.001743
6   0.980081  0.013390  0.006529
7   0.953981  0.031281  0.014737
8   0.917133  0.056972  0.025895
9   0.064683  0.827513  0.107804
10  0.070152  0.818273  0.111575
11  0.005091  0.973456  0.021453
```

```
12  0.000301  0.997415  0.002284
13  0.005457  0.925115  0.069428
14  0.009249  0.830910  0.159842
15  0.009904  0.260664  0.729431
16  0.000964  0.014669  0.984367
17  0.000360  0.005112  0.994529
18  0.000573  0.006523  0.992904
19  0.003887  0.036836  0.959276
20  0.009278  0.075081  0.915642
21  0.022028  0.140548  0.837424
22  0.012868  0.618274  0.368857
23  0.011880  0.371293  0.616827
24  0.007182  0.159797  0.833021
25  0.002914  0.051046  0.946040
26  0.012836  0.623508  0.363656


Iteration 29
Max Change: 9256.156074523926
Cluster Centers (C):
L1     872656.82
L2    1089304.49
L3    1173099.86
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957585  0.026976  0.015439
1   0.972027  0.017912  0.010061
2   0.986500  0.008719  0.004781
3   0.996826  0.002070  0.001104
4   0.999849  0.000099  0.000051
5   0.994794  0.003463  0.001743
6   0.980085  0.013387  0.006528
7   0.953991  0.031273  0.014736
8   0.917150  0.056958  0.025892
9   0.064734  0.827398  0.107867
10  0.070205  0.818158  0.111637
11  0.005106  0.973384  0.021510
12  0.000297  0.997445  0.002258
13  0.005445  0.925307  0.069248
14  0.009236  0.831206  0.159557
15  0.009908  0.260977  0.729115
16  0.000967  0.014717  0.984316
17  0.000361  0.005137  0.994501
18  0.000571  0.006504  0.992925
19  0.003883  0.036808  0.959310
20  0.009271  0.075055  0.915674
21  0.022019  0.140534  0.837447
22  0.012862  0.618677  0.368461
23  0.011881  0.371666  0.616453
24  0.007187  0.160029  0.832784
25  0.002918  0.051154  0.945927
26  0.012829  0.623910  0.363261


Iteration 30
Max Change: 5858.752624511719
Cluster Centers (C):
L1     872657.25
L2    1089321.82
L3    1173109.89
dtype: object
```

```
Membership Degrees (Weight):
          L1        L2        L3
0    0.957589  0.026973  0.015438
1    0.972029  0.017910  0.010061
2    0.986501  0.008718  0.004781
3    0.996827  0.002069  0.001104
4    0.999849  0.000099  0.000051
5    0.994795  0.003462  0.001743
6    0.980089  0.013384  0.006528
7    0.953999  0.031267  0.014734
8    0.917164  0.056946  0.025890
9    0.064775  0.827307  0.107918
10   0.070247  0.818066  0.111686
11   0.005118  0.973327  0.021555
12   0.000295  0.997469  0.002237
13   0.005435  0.925459  0.069105
14   0.009226  0.831443  0.159331
15   0.009911  0.261227  0.728862
16   0.000969  0.014756  0.984275
17   0.000363  0.005158  0.994479
18   0.000569  0.006489  0.992942
19   0.003879  0.036785  0.959336
20   0.009266  0.075034  0.915700
21   0.022012  0.140523  0.837465
22   0.012856  0.618998  0.368146
23   0.011882  0.371963  0.616155
24   0.007191  0.160213  0.832596
25   0.002922  0.051240  0.945838
26   0.012823  0.624230  0.362947

Iteration 31
Max Change: 3708.0102043151855
Cluster Centers (C):
L1      872657.60
L2     1089335.61
L3     1173117.86
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0    0.957592  0.026971  0.015438
1    0.972031  0.017908  0.010061
2    0.986502  0.008717  0.004781
3    0.996827  0.002069  0.001104
4    0.999849  0.000099  0.000051
5    0.994796  0.003461  0.001742
6    0.980092  0.013381  0.006527
7    0.954005  0.031262  0.014733
8    0.917175  0.056937  0.025888
9    0.064807  0.827235  0.107958
10   0.070281  0.817994  0.111726
11   0.005127  0.973282  0.021591
12   0.000292  0.997488  0.002220
13   0.005428  0.925581  0.068992
14   0.009219  0.831630  0.159151
15   0.009913  0.261425  0.728662
16   0.000971  0.014786  0.984243
17   0.000364  0.005174  0.994462
18   0.000568  0.006477  0.992955
19   0.003876  0.036767  0.959358
20   0.009262  0.075018  0.915720
```

```
21   0.022007   0.140514   0.837480
22   0.012852   0.619253   0.367895
23   0.011883   0.372199   0.615918
24   0.007194   0.160360   0.832446
25   0.002925   0.051309   0.945766
26   0.012819   0.624484   0.362697


Iteration 32
Max Change: 2346.636054992676
Cluster Centers (C):
L1      872657.87
L2     1089346.58
L3     1173124.21
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957594   0.026969   0.015437
1    0.972032   0.017907   0.010060
2    0.986503   0.008717   0.004781
3    0.996827   0.002069   0.001104
4    0.999849   0.000099   0.000051
5    0.994797   0.003461   0.001742
6    0.980094   0.013380   0.006527
7    0.954010   0.031258   0.014732
8    0.917184   0.056929   0.025887
9    0.064833   0.827177   0.107990
10   0.070307   0.817936   0.111757
11   0.005135   0.973245   0.021620
12   0.000291   0.997503   0.002207
13   0.005422   0.925677   0.068902
14   0.009212   0.831779   0.159008
15   0.009915   0.261583   0.728502
16   0.000972   0.014811   0.984217
17   0.000364   0.005187   0.994448
18   0.000567   0.006467   0.992966
19   0.003874   0.036752   0.959374
20   0.009259   0.075005   0.915736
21   0.022002   0.140507   0.837491
22   0.012848   0.619456   0.367696
23   0.011883   0.372388   0.615729
24   0.007197   0.160477   0.832326
25   0.002927   0.051364   0.945710
26   0.012815   0.624687   0.362498


Iteration 33
Max Change: 1484.997989654541
Cluster Centers (C):
L1      872658.09
L2     1089355.30
L3     1173129.26
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957596   0.026968   0.015437
1    0.972033   0.017906   0.010060
2    0.986503   0.008716   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994797   0.003461   0.001742
6    0.980096   0.013378   0.006526
```

```
7   0.954014  0.031254  0.014732
8   0.917190  0.056924  0.025886
9   0.064853  0.827131  0.108016
10  0.070328  0.817890  0.111782
11  0.005141  0.973217  0.021643
12  0.000289  0.997514  0.002196
13  0.005417  0.925754  0.068830
14  0.009207  0.831898  0.158895
15  0.009917  0.261709  0.728375
16  0.000973  0.014830  0.984197
17  0.000365  0.005198  0.994437
18  0.000566  0.006460  0.992974
19  0.003872  0.036740  0.959388
20  0.009256  0.074995  0.915749
21  0.021999  0.140501  0.837500
22  0.012845  0.619617  0.367537
23  0.011884  0.372537  0.615579
24  0.007199  0.160571  0.832231
25  0.002928  0.051407  0.945664
26  0.012812  0.624848  0.362340

Iteration 34
Max Change: 939.6936683654785
Cluster Centers (C):
L1     872658.26
L2    1089362.24
L3    1173133.27
dtype: object
Membership Degrees (Weight):
         L1        L2        L3
0   0.957597  0.026966  0.015437
1   0.972034  0.017905  0.010060
2   0.986504  0.008716  0.004781
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994798  0.003460  0.001742
6   0.980097  0.013377  0.006526
7   0.954017  0.031252  0.014731
8   0.917196  0.056919  0.025885
9   0.064870  0.827095  0.108036
10  0.070345  0.817853  0.111802
11  0.005146  0.973194  0.021661
12  0.000288  0.997524  0.002188
13  0.005413  0.925814  0.068773
14  0.009203  0.831992  0.158804
15  0.009918  0.261808  0.728274
16  0.000974  0.014846  0.984180
17  0.000366  0.005206  0.994428
18  0.000565  0.006454  0.992981
19  0.003870  0.036731  0.959398
20  0.009254  0.074986  0.915760
21  0.021996  0.140497  0.837508
22  0.012843  0.619746  0.367411
23  0.011884  0.372656  0.615460
24  0.007200  0.160645  0.832155
25  0.002930  0.051442  0.945628
26  0.012810  0.624976  0.362214

Iteration 35
Max Change: 594.6083946228027
```

```
Cluster Centers (C):
L1      872658.40
L2     1089367.76
L3     1173136.47
dtype: object
Membership Degrees (Weight):
           L1        L2        L3
0    0.957598  0.026965  0.015437
1    0.972035  0.017905  0.010060
2    0.986504  0.008715  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994798  0.003460  0.001742
6    0.980098  0.013376  0.006526
7    0.954020  0.031250  0.014731
8    0.917200  0.056915  0.025884
9    0.064883  0.827066  0.108052
10   0.070359  0.817824  0.111817
11   0.005149  0.973175  0.021675
12   0.000287  0.997531  0.002181
13   0.005410  0.925863  0.068727
14   0.009200  0.832067  0.158732
15   0.009919  0.261888  0.728193
16   0.000974  0.014858  0.984167
17   0.000366  0.005213  0.994421
18   0.000565  0.006449  0.992986
19   0.003869  0.036724  0.959407
20   0.009252  0.074980  0.915768
21   0.021994  0.140493  0.837513
22   0.012841  0.619848  0.367311
23   0.011884  0.372751  0.615365
24   0.007202  0.160704  0.832095
25   0.002931  0.051469  0.945600
26   0.012808  0.625078  0.362114

Iteration 36
Max Change: 376.238525390625
Cluster Centers (C):
L1      872658.51
L2     1089372.15
L3     1173139.01
dtype: object
Membership Degrees (Weight):
           L1        L2        L3
0    0.957599  0.026965  0.015436
1    0.972036  0.017904  0.010060
2    0.986504  0.008715  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994798  0.003460  0.001742
6    0.980099  0.013375  0.006525
7    0.954022  0.031248  0.014730
8    0.917204  0.056912  0.025884
9    0.064893  0.827043  0.108065
10   0.070369  0.817801  0.111830
11   0.005152  0.973161  0.021687
12   0.000287  0.997537  0.002176
13   0.005407  0.925901  0.068691
14   0.009198  0.832127  0.158675
15   0.009919  0.261951  0.728129
```

```
16  0.000975  0.014868  0.984157
17  0.000366  0.005218  0.994416
18  0.000565  0.006445  0.992990
19  0.003868  0.036718  0.959414
20  0.009251  0.074975  0.915774
21  0.021992  0.140490  0.837518
22  0.012840  0.619929  0.367231
23  0.011885  0.372827  0.615289
24  0.007203  0.160751  0.832047
25  0.002932  0.051491  0.945577
26  0.012807  0.625159  0.362034


Iteration 37
Max Change: 238.05950927734375
Cluster Centers (C):
L1     872658.60
L2    1089375.64
L3    1173141.03
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957600  0.026964  0.015436
1   0.972036  0.017904  0.010060
2   0.986504  0.008715  0.004781
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003460  0.001742
6   0.980100  0.013375  0.006525
7   0.954023  0.031247  0.014730
8   0.917207  0.056910  0.025884
9   0.064901  0.827024  0.108075
10  0.070378  0.817782  0.111840
11  0.005155  0.973149  0.021696
12  0.000286  0.997542  0.002172
13  0.005406  0.925932  0.068663
14  0.009196  0.832175  0.158630
15  0.009920  0.262002  0.728078
16  0.000975  0.014876  0.984149
17  0.000367  0.005222  0.994411
18  0.000564  0.006442  0.992994
19  0.003867  0.036714  0.959419
20  0.009250  0.074971  0.915780
21  0.021990  0.140488  0.837522
22  0.012839  0.619994  0.367168
23  0.011885  0.372886  0.615229
24  0.007203  0.160788  0.832009
25  0.002932  0.051509  0.945559
26  0.012806  0.625223  0.361971


Iteration 38
Max Change: 150.62597274780273
Cluster Centers (C):
L1     872658.67
L2    1089378.42
L3    1173142.64
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957600  0.026964  0.015436
1   0.972037  0.017904  0.010060
```

```
2    0.986505   0.008715   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980100   0.013374   0.006525
7    0.954025   0.031246   0.014730
8    0.917209   0.056908   0.025883
9    0.064908   0.827010   0.108083
10   0.070385   0.817767   0.111848
11   0.005157   0.973140   0.021703
12   0.000286   0.997546   0.002169
13   0.005404   0.925956   0.068640
14   0.009194   0.832212   0.158593
15   0.009921   0.262042   0.728038
16   0.000976   0.014882   0.984142
17   0.000367   0.005225   0.994408
18   0.000564   0.006440   0.992996
19   0.003867   0.036710   0.959423
20   0.009249   0.074967   0.915784
21   0.021989   0.140486   0.837525
22   0.012838   0.620045   0.367117
23   0.011885   0.372934   0.615181
24   0.007204   0.160818   0.831978
25   0.002933   0.051523   0.945544
26   0.012805   0.625274   0.361921


Iteration 39
Max Change: 95.30329132080078
Cluster Centers (C):
L1      872658.72
L2     1089380.63
L3     1173143.92
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957601   0.026963   0.015436
1    0.972037   0.017903   0.010060
2    0.986505   0.008715   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980101   0.013374   0.006525
7    0.954026   0.031245   0.014730
8    0.917211   0.056906   0.025883
9    0.064913   0.826998   0.108089
10   0.070390   0.817756   0.111854
11   0.005158   0.973133   0.021709
12   0.000285   0.997549   0.002166
13   0.005403   0.925976   0.068622
14   0.009193   0.832242   0.158565
15   0.009921   0.262074   0.728006
16   0.000976   0.014887   0.984137
17   0.000367   0.005228   0.994405
18   0.000564   0.006438   0.992998
19   0.003866   0.036707   0.959427
20   0.009248   0.074965   0.915787
21   0.021988   0.140485   0.837527
22   0.012837   0.620086   0.367077
23   0.011885   0.372972   0.615143
24   0.007205   0.160841   0.831954
```

```
25  0.002933  0.051534  0.945533
26  0.012804  0.625315  0.361881


Iteration 40
Max Change: 60.29911422729492
Cluster Centers (C):
L1     872658.76
L2    1089382.39
L3    1173144.94
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957601  0.026963  0.015436
1    0.972037  0.017903  0.010060
2    0.986505  0.008715  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980101  0.013374  0.006525
7    0.954026  0.031244  0.014729
8    0.917212  0.056905  0.025883
9    0.064917  0.826989  0.108095
10   0.070394  0.817747  0.111859
11   0.005159  0.973127  0.021714
12   0.000285  0.997551  0.002164
13   0.005402  0.925991  0.068607
14   0.009192  0.832266  0.158542
15   0.009921  0.262099  0.727980
16   0.000976  0.014891  0.984133
17   0.000367  0.005230  0.994403
18   0.000564  0.006436  0.993000
19   0.003866  0.036705  0.959429
20   0.009248  0.074963  0.915790
21   0.021988  0.140484  0.837529
22   0.012837  0.620118  0.367045
23   0.011885  0.373002  0.615113
24   0.007205  0.160860  0.831935
25   0.002934  0.051542  0.945524
26   0.012803  0.625348  0.361849


Iteration 41
Max Change: 38.151336669921875
Cluster Centers (C):
L1     872658.80
L2    1089383.78
L3    1173145.74
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957601  0.026963  0.015436
1    0.972037  0.017903  0.010060
2    0.986505  0.008715  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980101  0.013374  0.006525
7    0.954027  0.031244  0.014729
8    0.917213  0.056904  0.025882
9    0.064920  0.826981  0.108099
10   0.070398  0.817739  0.111863
```

```
11  0.005160  0.973122  0.021717
12  0.000285  0.997553  0.002162
13  0.005401  0.926003  0.068596
14  0.009191  0.832285  0.158524
15  0.009921  0.262119  0.727959
16  0.000976  0.014894  0.984129
17  0.000367  0.005232  0.994401
18  0.000564  0.006435  0.993001
19  0.003866  0.036703  0.959432
20  0.009247  0.074961  0.915792
21  0.021987  0.140483  0.837530
22  0.012836  0.620144  0.367020
23  0.011885  0.373026  0.615089
24  0.007205  0.160875  0.831920
25  0.002934  0.051549  0.945517
26  0.012803  0.625373  0.361824


Iteration 42
Max Change: 24.138248443603516
Cluster Centers (C):
L1      872658.83
L2     1089384.90
L3     1173146.39
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0    0.957601  0.026962  0.015436
1    0.972037  0.017903  0.010060
2    0.986505  0.008715  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980102  0.013373  0.006525
7    0.954028  0.031243  0.014729
8    0.917214  0.056904  0.025882
9    0.064923  0.826975  0.108102
10   0.070400  0.817733  0.111866
11   0.005161  0.973119  0.021720
12   0.000285  0.997554  0.002161
13   0.005400  0.926013  0.068586
14   0.009190  0.832300  0.158509
15   0.009922  0.262135  0.727943
16   0.000977  0.014897  0.984127
17   0.000367  0.005233  0.994400
18   0.000563  0.006434  0.993002
19   0.003865  0.036701  0.959433
20   0.009247  0.074960  0.915793
21   0.021987  0.140482  0.837531
22   0.012836  0.620165  0.366999
23   0.011885  0.373045  0.615069
24   0.007206  0.160887  0.831907
25   0.002934  0.051555  0.945511
26   0.012803  0.625394  0.361803


Iteration 43
Max Change: 15.272109985351562
Cluster Centers (C):
L1      872658.85
L2     1089385.78
L3     1173146.90
```

dtype: object
Membership Degrees (Weight):
```
            L1         L2         L3
0     0.957602   0.026962   0.015436
1     0.972037   0.017903   0.010060
2     0.986505   0.008715   0.004781
3     0.996827   0.002069   0.001104
4     0.999850   0.000099   0.000051
5     0.994799   0.003459   0.001742
6     0.980102   0.013373   0.006525
7     0.954028   0.031243   0.014729
8     0.917215   0.056903   0.025882
9     0.064925   0.826971   0.108104
10    0.070403   0.817729   0.111869
11    0.005162   0.973116   0.021723
12    0.000285   0.997555   0.002160
13    0.005400   0.926021   0.068579
14    0.009190   0.832312   0.158498
15    0.009922   0.262148   0.727930
16    0.000977   0.014899   0.984125
17    0.000367   0.005234   0.994399
18    0.000563   0.006433   0.993003
19    0.003865   0.036700   0.959435
20    0.009247   0.074958   0.915795
21    0.021986   0.140481   0.837532
22    0.012836   0.620181   0.366983
23    0.011885   0.373061   0.615054
24    0.007206   0.160896   0.831898
25    0.002935   0.051559   0.945506
26    0.012802   0.625410   0.361787
```

Iteration 44
Max Change: 9.662517547607422
Cluster Centers (C):
```
L1      872658.87
L2     1089386.48
L3     1173147.31
```
dtype: object
Membership Degrees (Weight):
```
            L1         L2         L3
0     0.957602   0.026962   0.015436
1     0.972038   0.017903   0.010060
2     0.986505   0.008714   0.004781
3     0.996827   0.002069   0.001104
4     0.999850   0.000099   0.000051
5     0.994799   0.003459   0.001742
6     0.980102   0.013373   0.006525
7     0.954028   0.031243   0.014729
8     0.917215   0.056903   0.025882
9     0.064926   0.826967   0.108106
10    0.070404   0.817725   0.111871
11    0.005162   0.973113   0.021724
12    0.000285   0.997556   0.002159
13    0.005400   0.926027   0.068573
14    0.009190   0.832322   0.158489
15    0.009922   0.262158   0.727920
16    0.000977   0.014900   0.984123
17    0.000367   0.005235   0.994398
18    0.000563   0.006433   0.993004
19    0.003865   0.036699   0.959436
```

```
20  0.009247  0.074958  0.915796
21  0.021986  0.140481  0.837533
22  0.012835  0.620194  0.366970
23  0.011885  0.373073  0.615042
24  0.007206  0.160904  0.831890
25  0.002935  0.051563  0.945502
26  0.012802  0.625423  0.361775

Iteration 45
Max Change: 6.1133575439453125
Cluster Centers (C):
L1     872658.88
L2    1089387.04
L3    1173147.63
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017903  0.010060
2   0.986505  0.008714  0.004781
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980102  0.013373  0.006525
7   0.954029  0.031242  0.014729
8   0.917216  0.056902  0.025882
9   0.064928  0.826964  0.108108
10  0.070406  0.817722  0.111872
11  0.005163  0.973112  0.021726
12  0.000285  0.997557  0.002158
13  0.005399  0.926032  0.068569
14  0.009189  0.832330  0.158481
15  0.009922  0.262166  0.727912
16  0.000977  0.014902  0.984122
17  0.000367  0.005236  0.994397
18  0.000563  0.006432  0.993004
19  0.003865  0.036699  0.959437
20  0.009246  0.074957  0.915797
21  0.021986  0.140481  0.837534
22  0.012835  0.620204  0.366960
23  0.011885  0.373082  0.615032
24  0.007206  0.160910  0.831884
25  0.002935  0.051566  0.945500
26  0.012802  0.625434  0.361764

Iteration 46
Max Change: 3.8678359985351562
Cluster Centers (C):
L1     872658.89
L2    1089387.49
L3    1173147.89
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017903  0.010060
2   0.986505  0.008714  0.004781
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
```

```
6    0.980102   0.013373   0.006525
7    0.954029   0.031242   0.014729
8    0.917216   0.056902   0.025882
9    0.064929   0.826962   0.108109
10   0.070407   0.817720   0.111874
11   0.005163   0.973110   0.021727
12   0.000284   0.997558   0.002158
13   0.005399   0.926036   0.068565
14   0.009189   0.832336   0.158475
15   0.009922   0.262172   0.727905
16   0.000977   0.014903   0.984121
17   0.000367   0.005236   0.994396
18   0.000563   0.006432   0.993005
19   0.003865   0.036698   0.959437
20   0.009246   0.074956   0.915797
21   0.021986   0.140480   0.837534
22   0.012835   0.620213   0.366952
23   0.011885   0.373090   0.615025
24   0.007206   0.160915   0.831879
25   0.002935   0.051568   0.945497
26   0.012802   0.625442   0.361756


Iteration 47
Max Change: 2.4471168518066406
Cluster Centers (C):
L1      872658.90
L2     1089387.84
L3     1173148.09
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017903   0.010060
2    0.986505   0.008714   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980102   0.013373   0.006525
7    0.954029   0.031242   0.014729
8    0.917216   0.056902   0.025882
9    0.064930   0.826960   0.108110
10   0.070408   0.817718   0.111875
11   0.005163   0.973109   0.021728
12   0.000284   0.997558   0.002157
13   0.005399   0.926039   0.068562
14   0.009189   0.832340   0.158471
15   0.009922   0.262178   0.727900
16   0.000977   0.014903   0.984120
17   0.000367   0.005237   0.994396
18   0.000563   0.006432   0.993005
19   0.003865   0.036697   0.959438
20   0.009246   0.074956   0.915798
21   0.021985   0.140480   0.837534
22   0.012835   0.620219   0.366946
23   0.011885   0.373096   0.615019
24   0.007206   0.160919   0.831875
25   0.002935   0.051570   0.945495
26   0.012802   0.625448   0.361750


Iteration 48
```

```
Max Change: 1.5482597351074219
Cluster Centers (C):
L1      872658.91
L2     1089388.12
L3     1173148.26
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0    0.957602  0.026962  0.015436
1    0.972038  0.017902  0.010060
2    0.986505  0.008714  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980102  0.013373  0.006525
7    0.954029  0.031242  0.014729
8    0.917217  0.056901  0.025882
9    0.064930  0.826958  0.108111
10   0.070408  0.817716  0.111876
11   0.005163  0.973108  0.021729
12   0.000284  0.997559  0.002157
13   0.005399  0.926041  0.068560
14   0.009189  0.832344  0.158467
15   0.009922  0.262182  0.727896
16   0.000977  0.014904  0.984119
17   0.000367  0.005237  0.994396
18   0.000563  0.006431  0.993006
19   0.003865  0.036697  0.959438
20   0.009246  0.074956  0.915798
21   0.021985  0.140480  0.837535
22   0.012835  0.620224  0.366941
23   0.011885  0.373101  0.615014
24   0.007206  0.160922  0.831872
25   0.002935  0.051571  0.945494
26   0.012802  0.625454  0.361745


Iteration 49
Max Change: 0.9795570373535156
Cluster Centers (C):
L1      872658.91
L2     1089388.35
L3     1173148.39
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0    0.957602  0.026962  0.015436
1    0.972038  0.017902  0.010060
2    0.986505  0.008714  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980102  0.013373  0.006525
7    0.954029  0.031242  0.014729
8    0.917217  0.056901  0.025882
9    0.064931  0.826957  0.108112
10   0.070409  0.817715  0.111876
11   0.005163  0.973107  0.021729
12   0.000284  0.997559  0.002157
13   0.005399  0.926043  0.068558
14   0.009188  0.832347  0.158464
```

```
15  0.009922  0.262185  0.727893
16  0.000977  0.014904  0.984119
17  0.000367  0.005237  0.994395
18  0.000563  0.006431  0.993006
19  0.003865  0.036697  0.959439
20  0.009246  0.074955  0.915799
21  0.021985  0.140480  0.837535
22  0.012835  0.620229  0.366937
23  0.011885  0.373105  0.615010
24  0.007206  0.160924  0.831870
25  0.002935  0.051572  0.945493
26  0.012801  0.625458  0.361741


Iteration 50
Max Change: 0.6197433471679688
Cluster Centers (C):
L1      872658.92
L2     1089388.53
L3     1173148.49
dtype: object
Membership Degrees (Weight):
           L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004781
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980102  0.013373  0.006525
7   0.954029  0.031242  0.014729
8   0.917217  0.056901  0.025882
9   0.064931  0.826956  0.108112
10  0.070409  0.817714  0.111877
11  0.005164  0.973107  0.021730
12  0.000284  0.997559  0.002157
13  0.005398  0.926045  0.068557
14  0.009188  0.832350  0.158462
15  0.009922  0.262187  0.727890
16  0.000977  0.014905  0.984118
17  0.000367  0.005237  0.994395
18  0.000563  0.006431  0.993006
19  0.003865  0.036697  0.959439
20  0.009246  0.074955  0.915799
21  0.021985  0.140480  0.837535
22  0.012835  0.620232  0.366933
23  0.011885  0.373108  0.615007
24  0.007206  0.160926  0.831868
25  0.002935  0.051573  0.945492
26  0.012801  0.625461  0.361738


Iteration 51
Max Change: 0.3921012878417969
Cluster Centers (C):
L1      872658.92
L2     1089388.67
L3     1173148.57
dtype: object
Membership Degrees (Weight):
           L1        L2        L3
0   0.957602  0.026962  0.015436
```

```
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980102   0.013373   0.006525
7    0.954029   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064932   0.826956   0.108113
10   0.070410   0.817713   0.111877
11   0.005164   0.973106   0.021730
12   0.000284   0.997559   0.002156
13   0.005398   0.926046   0.068556
14   0.009188   0.832352   0.158460
15   0.009922   0.262190   0.727888
16   0.000977   0.014905   0.984118
17   0.000367   0.005238   0.994395
18   0.000563   0.006431   0.993006
19   0.003865   0.036696   0.959439
20   0.009246   0.074955   0.915799
21   0.021985   0.140480   0.837535
22   0.012835   0.620235   0.366931
23   0.011885   0.373110   0.615005
24   0.007206   0.160927   0.831866
25   0.002935   0.051574   0.945491
26   0.012801   0.625464   0.361735


Iteration 52
Max Change: 0.24807357788085938
Cluster Centers (C):
L1      872658.92
L2     1089388.78
L3     1173148.64
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980102   0.013373   0.006525
7    0.954029   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064932   0.826955   0.108113
10   0.070410   0.817713   0.111877
11   0.005164   0.973106   0.021730
12   0.000284   0.997559   0.002156
13   0.005398   0.926047   0.068555
14   0.009188   0.832353   0.158459
15   0.009922   0.262191   0.727887
16   0.000977   0.014905   0.984118
17   0.000367   0.005238   0.994395
18   0.000563   0.006431   0.993006
19   0.003865   0.036696   0.959439
20   0.009246   0.074955   0.915799
21   0.021985   0.140480   0.837535
22   0.012835   0.620237   0.366929
23   0.011885   0.373112   0.615003
```

```
24  0.007206  0.160929  0.831865
25  0.002935  0.051574  0.945491
26  0.012801  0.625466  0.361733

Iteration 53
Max Change: 0.15695571899414062
Cluster Centers (C):
L1      872658.93
L2     1089388.87
L3     1173148.69
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957602  0.026962  0.015436
1    0.972038  0.017902  0.010060
2    0.986505  0.008714  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980102  0.013373  0.006525
7    0.954029  0.031242  0.014729
8    0.917217  0.056901  0.025882
9    0.064932  0.826955  0.108113
10   0.070410  0.817712  0.111878
11   0.005164  0.973106  0.021731
12   0.000284  0.997560  0.002156
13   0.005398  0.926048  0.068554
14   0.009188  0.832354  0.158457
15   0.009922  0.262192  0.727885
16   0.000977  0.014906  0.984117
17   0.000367  0.005238  0.994395
18   0.000563  0.006431  0.993006
19   0.003865  0.036696  0.959439
20   0.009246  0.074955  0.915799
21   0.021985  0.140479  0.837536
22   0.012835  0.620238  0.366927
23   0.011885  0.373114  0.615001
24   0.007206  0.160930  0.831864
25   0.002935  0.051575  0.945490
26   0.012801  0.625467  0.361731

Iteration 54
Max Change: 0.09930038452148438
Cluster Centers (C):
L1      872658.93
L2     1089388.94
L3     1173148.73
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957602  0.026962  0.015436
1    0.972038  0.017902  0.010060
2    0.986505  0.008714  0.004781
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980102  0.013373  0.006525
7    0.954029  0.031242  0.014729
8    0.917217  0.056901  0.025882
9    0.064932  0.826954  0.108114
```

```
10   0.070410   0.817712   0.111878
11   0.005164   0.973105   0.021731
12   0.000284   0.997560   0.002156
13   0.005398   0.926049   0.068553
14   0.009188   0.832355   0.158457
15   0.009922   0.262193   0.727884
16   0.000977   0.014906   0.984117
17   0.000367   0.005238   0.994395
18   0.000563   0.006431   0.993006
19   0.003865   0.036696   0.959439
20   0.009246   0.074955   0.915799
21   0.021985   0.140479   0.837536
22   0.012835   0.620240   0.366926
23   0.011885   0.373115   0.615000
24   0.007206   0.160930   0.831863
25   0.002935   0.051575   0.945490
26   0.012801   0.625469   0.361730


Iteration 55
Max Change: 0.06282806396484375
Cluster Centers (C):
L1      872658.93
L2     1089389.00
L3     1173148.76
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980102   0.013373   0.006525
7    0.954029   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064932   0.826954   0.108114
10   0.070410   0.817712   0.111878
11   0.005164   0.973105   0.021731
12   0.000284   0.997560   0.002156
13   0.005398   0.926049   0.068553
14   0.009188   0.832356   0.158456
15   0.009922   0.262194   0.727883
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006431   0.993006
19   0.003865   0.036696   0.959440
20   0.009246   0.074955   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620241   0.366925
23   0.011885   0.373116   0.614999
24   0.007206   0.160931   0.831863
25   0.002935   0.051575   0.945489
26   0.012801   0.625470   0.361729


Iteration 56
Max Change: 0.039745330810546875
Cluster Centers (C):
L1      872658.93
L2     1089389.04
```

```
L3     1173148.79
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004781
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980102   0.013373   0.006525
7    0.954029   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064932   0.826954   0.108114
10   0.070410   0.817711   0.111878
11   0.005164   0.973105   0.021731
12   0.000284   0.997560   0.002156
13   0.005398   0.926049   0.068552
14   0.009188   0.832357   0.158455
15   0.009922   0.262195   0.727883
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993006
19   0.003865   0.036696   0.959440
20   0.009246   0.074955   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620241   0.366924
23   0.011885   0.373117   0.614998
24   0.007206   0.160931   0.831862
25   0.002935   0.051576   0.945489
26   0.012801   0.625471   0.361728


Iteration 57
Max Change: 0.025146484375
Cluster Centers (C):
L1      872658.93
L2     1089389.08
L3     1173148.81
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004780
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980102   0.013373   0.006525
7    0.954029   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064932   0.826953   0.108114
10   0.070411   0.817711   0.111878
11   0.005164   0.973105   0.021731
12   0.000284   0.997560   0.002156
13   0.005398   0.926050   0.068552
14   0.009188   0.832357   0.158455
15   0.009922   0.262195   0.727882
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993006
```

```
19  0.003865   0.036696   0.959440
20  0.009246   0.074955   0.915800
21  0.021985   0.140479   0.837536
22  0.012835   0.620242   0.366923
23  0.011885   0.373117   0.614997
24  0.007206   0.160932   0.831862
25  0.002935   0.051576   0.945489
26  0.012801   0.625471   0.361728


Iteration 58
Max Change: 0.015911102294921875
Cluster Centers (C):
L1      872658.93
L2     1089389.11
L3     1173148.83
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0   0.957602   0.026962   0.015436
1   0.972038   0.017902   0.010060
2   0.986505   0.008714   0.004780
3   0.996827   0.002069   0.001104
4   0.999850   0.000099   0.000051
5   0.994799   0.003459   0.001742
6   0.980102   0.013373   0.006525
7   0.954029   0.031242   0.014729
8   0.917217   0.056901   0.025882
9   0.064933   0.826953   0.108114
10  0.070411   0.817711   0.111878
11  0.005164   0.973105   0.021731
12  0.000284   0.997560   0.002156
13  0.005398   0.926050   0.068552
14  0.009188   0.832358   0.158454
15  0.009922   0.262196   0.727882
16  0.000977   0.014906   0.984117
17  0.000368   0.005238   0.994394
18  0.000563   0.006430   0.993006
19  0.003865   0.036696   0.959440
20  0.009246   0.074955   0.915800
21  0.021985   0.140479   0.837536
22  0.012835   0.620243   0.366923
23  0.011885   0.373118   0.614997
24  0.007207   0.160932   0.831861
25  0.002935   0.051576   0.945489
26  0.012801   0.625472   0.361727


Iteration 59
Max Change: 0.010066986083984375
Cluster Centers (C):
L1      872658.93
L2     1089389.13
L3     1173148.84
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0   0.957602   0.026962   0.015436
1   0.972038   0.017902   0.010060
2   0.986505   0.008714   0.004780
3   0.996827   0.002069   0.001104
4   0.999850   0.000099   0.000051
```

```
5    0.994799   0.003459   0.001742
6    0.980102   0.013373   0.006525
7    0.954030   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064933   0.826953   0.108114
10   0.070411   0.817711   0.111878
11   0.005164   0.973105   0.021731
12   0.000284   0.997560   0.002156
13   0.005398   0.926050   0.068552
14   0.009188   0.832358   0.158454
15   0.009922   0.262196   0.727881
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993006
19   0.003865   0.036696   0.959440
20   0.009246   0.074955   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620243   0.366922
23   0.011885   0.373118   0.614997
24   0.007207   0.160932   0.831861
25   0.002935   0.051576   0.945489
26   0.012801   0.625472   0.361727


Iteration 60
Max Change: 0.006366729736328125
Cluster Centers (C):
L1     872658.93
L2    1089389.15
L3    1173148.85
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004780
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980103   0.013373   0.006525
7    0.954030   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064933   0.826953   0.108114
10   0.070411   0.817711   0.111878
11   0.005164   0.973105   0.021731
12   0.000284   0.997560   0.002156
13   0.005398   0.926050   0.068552
14   0.009188   0.832358   0.158454
15   0.009922   0.262196   0.727881
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993007
19   0.003865   0.036696   0.959440
20   0.009246   0.074954   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620243   0.366922
23   0.011885   0.373118   0.614996
24   0.007207   0.160932   0.831861
25   0.002935   0.051576   0.945489
26   0.012801   0.625472   0.361726
```

```
Iteration 61
Max Change: 0.004032135009765625
Cluster Centers (C):
L1      872658.93
L2     1089389.16
L3     1173148.86
dtype: object
Membership Degrees (Weight):
            L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004780
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980103   0.013373   0.006525
7    0.954030   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064933   0.826953   0.108114
10   0.070411   0.817711   0.111879
11   0.005164   0.973105   0.021731
12   0.000284   0.997560   0.002156
13   0.005398   0.926050   0.068551
14   0.009188   0.832358   0.158454
15   0.009922   0.262197   0.727881
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993007
19   0.003865   0.036696   0.959440
20   0.009246   0.074954   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620244   0.366922
23   0.011885   0.373119   0.614996
24   0.007207   0.160933   0.831861
25   0.002935   0.051576   0.945489
26   0.012801   0.625473   0.361726

Iteration 62
Max Change: 0.0025482177734375
Cluster Centers (C):
L1      872658.93
L2     1089389.17
L3     1173148.87
dtype: object
Membership Degrees (Weight):
            L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004780
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980103   0.013373   0.006525
7    0.954030   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064933   0.826953   0.108114
10   0.070411   0.817711   0.111879
11   0.005164   0.973105   0.021732
12   0.000284   0.997560   0.002156
13   0.005398   0.926051   0.068551
```

```
14   0.009188   0.832359   0.158453
15   0.009922   0.262197   0.727881
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993007
19   0.003865   0.036696   0.959440
20   0.009246   0.074954   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620244   0.366922
23   0.011885   0.373119   0.614996
24   0.007207   0.160933   0.831861
25   0.002935   0.051576   0.945488
26   0.012801   0.625473   0.361726


Iteration 63
Max Change: 0.001617431640625
Cluster Centers (C):
L1      872658.93
L2     1089389.18
L3     1173148.87
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004780
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980103   0.013373   0.006525
7    0.954030   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064933   0.826953   0.108114
10   0.070411   0.817711   0.111879
11   0.005164   0.973104   0.021732
12   0.000284   0.997560   0.002156
13   0.005398   0.926051   0.068551
14   0.009188   0.832359   0.158453
15   0.009922   0.262197   0.727881
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993007
19   0.003865   0.036696   0.959440
20   0.009246   0.074954   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620244   0.366921
23   0.011885   0.373119   0.614996
24   0.007207   0.160933   0.831861
25   0.002935   0.051576   0.945488
26   0.012801   0.625473   0.361726


Iteration 64
Max Change: 0.00101470947265625
Cluster Centers (C):
L1      872658.93
L2     1089389.19
L3     1173148.88
dtype: object
Membership Degrees (Weight):
           L1         L2         L3
```

```
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004780
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980103   0.013373   0.006525
7    0.954030   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064933   0.826953   0.108114
10   0.070411   0.817711   0.111879
11   0.005164   0.973104   0.021732
12   0.000284   0.997560   0.002156
13   0.005398   0.926051   0.068551
14   0.009188   0.832359   0.158453
15   0.009922   0.262197   0.727881
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993007
19   0.003865   0.036696   0.959440
20   0.009246   0.074954   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620244   0.366921
23   0.011885   0.373119   0.614996
24   0.007207   0.160933   0.831861
25   0.002935   0.051576   0.945488
26   0.012801   0.625473   0.361726


Iteration 65
Max Change: 0.000644683837890625
Cluster Centers (C):
L1      872658.93
L2     1089389.20
L3     1173148.88
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0    0.957602   0.026962   0.015436
1    0.972038   0.017902   0.010060
2    0.986505   0.008714   0.004780
3    0.996827   0.002069   0.001104
4    0.999850   0.000099   0.000051
5    0.994799   0.003459   0.001742
6    0.980103   0.013373   0.006525
7    0.954030   0.031242   0.014729
8    0.917217   0.056901   0.025882
9    0.064933   0.826953   0.108114
10   0.070411   0.817711   0.111879
11   0.005164   0.973104   0.021732
12   0.000284   0.997560   0.002156
13   0.005398   0.926051   0.068551
14   0.009188   0.832359   0.158453
15   0.009922   0.262197   0.727881
16   0.000977   0.014906   0.984117
17   0.000368   0.005238   0.994394
18   0.000563   0.006430   0.993007
19   0.003865   0.036696   0.959440
20   0.009246   0.074954   0.915800
21   0.021985   0.140479   0.837536
22   0.012835   0.620244   0.366921
```

```
23  0.011885  0.373119  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051576  0.945488
26  0.012801  0.625473  0.361725

Iteration 66
Max Change: 0.00040435791015625
Cluster Centers (C):
L1      872658.93
L2     1089389.20
L3     1173148.88
dtype: object
Membership Degrees (Weight):
           L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004780
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980103  0.013373  0.006525
7   0.954030  0.031242  0.014729
8   0.917217  0.056901  0.025882
9   0.064933  0.826953  0.108114
10  0.070411  0.817711  0.111879
11  0.005164  0.973104  0.021732
12  0.000284  0.997560  0.002156
13  0.005398  0.926051  0.068551
14  0.009188  0.832359  0.158453
15  0.009922  0.262197  0.727880
16  0.000977  0.014906  0.984117
17  0.000368  0.005238  0.994394
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620244  0.366921
23  0.011885  0.373119  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051576  0.945488
26  0.012801  0.625473  0.361725

Iteration 67
Max Change: 0.0002593994140625
Cluster Centers (C):
L1      872658.94
L2     1089389.20
L3     1173148.88
dtype: object
Membership Degrees (Weight):
           L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004780
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980103  0.013373  0.006525
7   0.954030  0.031242  0.014729
8   0.917217  0.056901  0.025882
```

```
9   0.064933  0.826953  0.108114
10  0.070411  0.817710  0.111879
11  0.005164  0.973104  0.021732
12  0.000284  0.997560  0.002156
13  0.005398  0.926051  0.068551
14  0.009188  0.832359  0.158453
15  0.009922  0.262197  0.727880
16  0.000977  0.014906  0.984117
17  0.000368  0.005238  0.994394
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620244  0.366921
23  0.011885  0.373119  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051576  0.945488
26  0.012801  0.625473  0.361725


Iteration 68
Max Change: 0.0001678466796875
Cluster Centers (C):
L1     872658.94
L2    1089389.21
L3    1173148.88
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004780
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980103  0.013373  0.006525
7   0.954030  0.031242  0.014729
8   0.917217  0.056901  0.025882
9   0.064933  0.826953  0.108114
10  0.070411  0.817710  0.111879
11  0.005164  0.973104  0.021732
12  0.000284  0.997560  0.002156
13  0.005398  0.926051  0.068551
14  0.009188  0.832359  0.158453
15  0.009922  0.262197  0.727880
16  0.000977  0.014906  0.984117
17  0.000368  0.005238  0.994394
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620245  0.366921
23  0.011885  0.373119  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051576  0.945488
26  0.012801  0.625474  0.361725


Iteration 69
Max Change: 0.000110626220703125
Cluster Centers (C):
L1     872658.94
```

```
L2     1089389.21
L3     1173148.89
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0    0.957602  0.026962  0.015436
1    0.972038  0.017902  0.010060
2    0.986505  0.008714  0.004780
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980103  0.013373  0.006525
7    0.954030  0.031242  0.014729
8    0.917217  0.056901  0.025882
9    0.064933  0.826953  0.108114
10   0.070411  0.817710  0.111879
11   0.005164  0.973104  0.021732
12   0.000284  0.997560  0.002156
13   0.005398  0.926051  0.068551
14   0.009188  0.832359  0.158453
15   0.009922  0.262197  0.727880
16   0.000977  0.014906  0.984117
17   0.000368  0.005238  0.994394
18   0.000563  0.006430  0.993007
19   0.003865  0.036696  0.959440
20   0.009246  0.074954  0.915800
21   0.021985  0.140479  0.837536
22   0.012835  0.620245  0.366921
23   0.011885  0.373120  0.614995
24   0.007207  0.160933  0.831860
25   0.002935  0.051577  0.945488
26   0.012801  0.625474  0.361725


Iteration 70
Max Change: 5.7220458984375e-05
Cluster Centers (C):
L1      872658.94
L2     1089389.21
L3     1173148.89
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0    0.957602  0.026962  0.015436
1    0.972038  0.017902  0.010060
2    0.986505  0.008714  0.004780
3    0.996827  0.002069  0.001104
4    0.999850  0.000099  0.000051
5    0.994799  0.003459  0.001742
6    0.980103  0.013373  0.006525
7    0.954030  0.031242  0.014729
8    0.917217  0.056901  0.025882
9    0.064933  0.826953  0.108114
10   0.070411  0.817710  0.111879
11   0.005164  0.973104  0.021732
12   0.000284  0.997560  0.002156
13   0.005398  0.926051  0.068551
14   0.009188  0.832359  0.158453
15   0.009922  0.262197  0.727880
16   0.000977  0.014906  0.984117
17   0.000368  0.005238  0.994394
```

```
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620245  0.366921
23  0.011885  0.373120  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051577  0.945488
26  0.012801  0.625474  0.361725


Iteration 71
Max Change: 4.57763671875e-05
Cluster Centers (C):
L1     872658.94
L2    1089389.21
L3    1173148.89
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004780
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980103  0.013373  0.006525
7   0.954030  0.031242  0.014729
8   0.917217  0.056901  0.025882
9   0.064933  0.826953  0.108114
10  0.070411  0.817710  0.111879
11  0.005164  0.973104  0.021732
12  0.000284  0.997560  0.002156
13  0.005398  0.926051  0.068551
14  0.009188  0.832359  0.158453
15  0.009922  0.262197  0.727880
16  0.000977  0.014906  0.984117
17  0.000368  0.005238  0.994394
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620245  0.366921
23  0.011885  0.373120  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051577  0.945488
26  0.012801  0.625474  0.361725


Iteration 72
Max Change: 2.288818359375e-05
Cluster Centers (C):
L1     872658.94
L2    1089389.21
L3    1173148.89
dtype: object
Membership Degrees (Weight):
          L1         L2         L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004780
3   0.996827  0.002069  0.001104
```

```
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980103  0.013373  0.006525
7   0.954030  0.031242  0.014729
8   0.917217  0.056901  0.025882
9   0.064933  0.826953  0.108114
10  0.070411  0.817710  0.111879
11  0.005164  0.973104  0.021732
12  0.000284  0.997560  0.002156
13  0.005398  0.926051  0.068551
14  0.009188  0.832359  0.158453
15  0.009922  0.262197  0.727880
16  0.000977  0.014906  0.984117
17  0.000368  0.005238  0.994394
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620245  0.366921
23  0.011885  0.373120  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051577  0.945488
26  0.012801  0.625474  0.361725


Iteration 73
Max Change: 1.9073486328125e-05
Cluster Centers (C):
L1      872658.94
L2     1089389.22
L3     1173148.89
dtype: object
Membership Degrees (Weight):
         L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004780
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980103  0.013373  0.006525
7   0.954030  0.031242  0.014729
8   0.917217  0.056901  0.025882
9   0.064933  0.826953  0.108114
10  0.070411  0.817710  0.111879
11  0.005164  0.973104  0.021732
12  0.000284  0.997560  0.002156
13  0.005398  0.926051  0.068551
14  0.009188  0.832359  0.158453
15  0.009922  0.262197  0.727880
16  0.000977  0.014906  0.984117
17  0.000368  0.005238  0.994394
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620245  0.366921
23  0.011885  0.373120  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051577  0.945488
26  0.012801  0.625474  0.361725
```

```
Iteration 74
Max Change: 7.62939453125e-06
Cluster Centers (C):
L1      872658.94
L2     1089389.22
L3     1173148.89
dtype: object
Membership Degrees (Weight):
          L1        L2        L3
0   0.957602  0.026962  0.015436
1   0.972038  0.017902  0.010060
2   0.986505  0.008714  0.004780
3   0.996827  0.002069  0.001104
4   0.999850  0.000099  0.000051
5   0.994799  0.003459  0.001742
6   0.980103  0.013373  0.006525
7   0.954030  0.031242  0.014729
8   0.917217  0.056901  0.025882
9   0.064933  0.826953  0.108114
10  0.070411  0.817710  0.111879
11  0.005164  0.973104  0.021732
12  0.000284  0.997560  0.002156
13  0.005398  0.926051  0.068551
14  0.009188  0.832359  0.158453
15  0.009922  0.262197  0.727880
16  0.000977  0.014906  0.984117
17  0.000368  0.005238  0.994394
18  0.000563  0.006430  0.993007
19  0.003865  0.036696  0.959440
20  0.009246  0.074954  0.915800
21  0.021985  0.140479  0.837536
22  0.012835  0.620245  0.366921
23  0.011885  0.373120  0.614995
24  0.007207  0.160933  0.831860
25  0.002935  0.051577  0.945488
26  0.012801  0.625474  0.361725
```

In [210…
```python
# Hasil akhir
final_weight_n = pd.DataFrame(weight)
final_c = c
```

In [211…
```python
# Cetak hasil akhir
print("\nFinal Membership Degrees (Weight):")
pd.DataFrame(final_weight_n)
```

```
Final Membership Degrees (Weight):
```

	L1	L2	L3
0	0.957602	0.026962	0.015436
1	0.972038	0.017902	0.010060
2	0.986505	0.008714	0.004780
3	0.996827	0.002069	0.001104
4	0.999850	0.000099	0.000051
5	0.994799	0.003459	0.001742
6	0.980103	0.013373	0.006525
7	0.954030	0.031242	0.014729
8	0.917217	0.056901	0.025882
9	0.064933	0.826953	0.108114
10	0.070411	0.817710	0.111879
11	0.005164	0.973104	0.021732
12	0.000284	0.997560	0.002156
13	0.005398	0.926051	0.068551
14	0.009188	0.832359	0.158453
15	0.009922	0.262197	0.727880
16	0.000977	0.014906	0.984117
17	0.000368	0.005238	0.994394
18	0.000563	0.006430	0.993007
19	0.003865	0.036696	0.959440
20	0.009246	0.074954	0.915800
21	0.021985	0.140479	0.837536
22	0.012835	0.620245	0.366921
23	0.011885	0.373120	0.614995
24	0.007207	0.160933	0.831860
25	0.002935	0.051577	0.945488
26	0.012801	0.625474	0.361725

```python
# Menyimpan DataFrame ke file Excel
file_path = "final_weight_n.xlsx"
final_weight_n.to_excel(file_path, index=False, engine='openpyxl')

print(f"DataFrame telah disimpan ke file Excel di: {file_path}")
```

DataFrame telah disimpan ke file Excel di: final_weight_n.xlsx

```
In [213...    print("\nFinal Cluster Centers (C):")
              print(pd.DataFrame(final_c).map('{:.2f}'.format))

         Final Cluster Centers (C):
                      0
         L1     872658.94
         L2    1089389.22
         L3    1173148.89

In [214...    import matplotlib.pyplot as plt

              # Fungsi untuk menghitung fungsi objektif (sum of squared errors)
              def calculate_objective_function(data, weight, c, beta):
                  miu = weight ** beta
                  result = pd.DataFrame()
                  for i in range(c.shape[0]):
                      result[f"Col_{i+1}"] = ((data - c[i]) ** 2) * miu.iloc[:, i]
                  r_n = result.sum(axis=1)
                  return r_n.sum()

              # Menyimpan fungsi objektif untuk berbagai jumlah kluster
              num_clusters_list = range(2, 11)  # Menguji jumlah kluster dari 2 hingga 10
              objective_values = []

              for num_clusters in num_clusters_list:
                  print(f"\nEvaluating for {num_clusters} clusters")

                  # Inisialisasi derajat keanggotaan awal
                  weight = pd.DataFrame(np.random.dirichlet(np.ones(num_clusters), size=len(da

                  p0 = 0  # Fungsi objektif awal
                  iteration_count = 0
                  max_change = float('inf')

                  # Fuzzy c-means clustering untuk jumlah kluster yang berbeda
                  while max_change >= tol and iteration_count < max_iter:
                      # Derajat keanggotaan dipangkatkan dengan indeks fuzziness
                      miu = weight ** beta

                      # Jumlah setiap kolom dari (derajat keanggotaan dipangkatkan dengan inde
                      sm = miu.sum(axis=0)

                      # Mengalikan setiap elemen baris data dengan baris yang sesuai
                      iterasi = miu.multiply(data, axis=0)

                      # Jumlah setiap kolom dari (hasil perkalian)
                      si = iterasi.sum(axis=0)

                      # Menghitung pusat cluster (c)
                      c = si / sm

                      # Fungsi objektif
                      p1 = calculate_objective_function(data, weight, c, beta)

                      # Menghitung perubahan fungsi objektif
                      max_change = abs(p1 - p0)
                      p0 = p1

                      # Update derajat keanggotaan (weight)
                      result1 = pd.DataFrame()
```

```python
        for i in range(c.shape[0]):
            result1[f"L{i+1}"] = ((data - c[i]) ** (-2 / (beta - 1)))

        r1_n = result1.sum(axis=1)

        # Membagi setiap elemen di result1 dengan elemen di r1_n berdasarkan bar
        weight = result1.div(r1_n, axis=0)

        # Increment iteration counter
        iteration_count += 1

    # Menyimpan nilai fungsi objektif untuk jumlah kluster ini
    objective_values.append(p1)

# Plotting fungsi objektif vs jumlah kluster
plt.plot(num_clusters_list, objective_values, marker='o')
plt.xlabel('Number of Clusters')
plt.ylabel('Objective Function Value')
plt.title('Elbow Method for Optimal Number of Clusters')
plt.show()
```

```
Evaluating for 2 clusters

Evaluating for 3 clusters

Evaluating for 4 clusters

Evaluating for 5 clusters

Evaluating for 6 clusters

Evaluating for 7 clusters

Evaluating for 8 clusters

Evaluating for 9 clusters

Evaluating for 10 clusters
```

Elbow Method for Optimal Number of Clusters
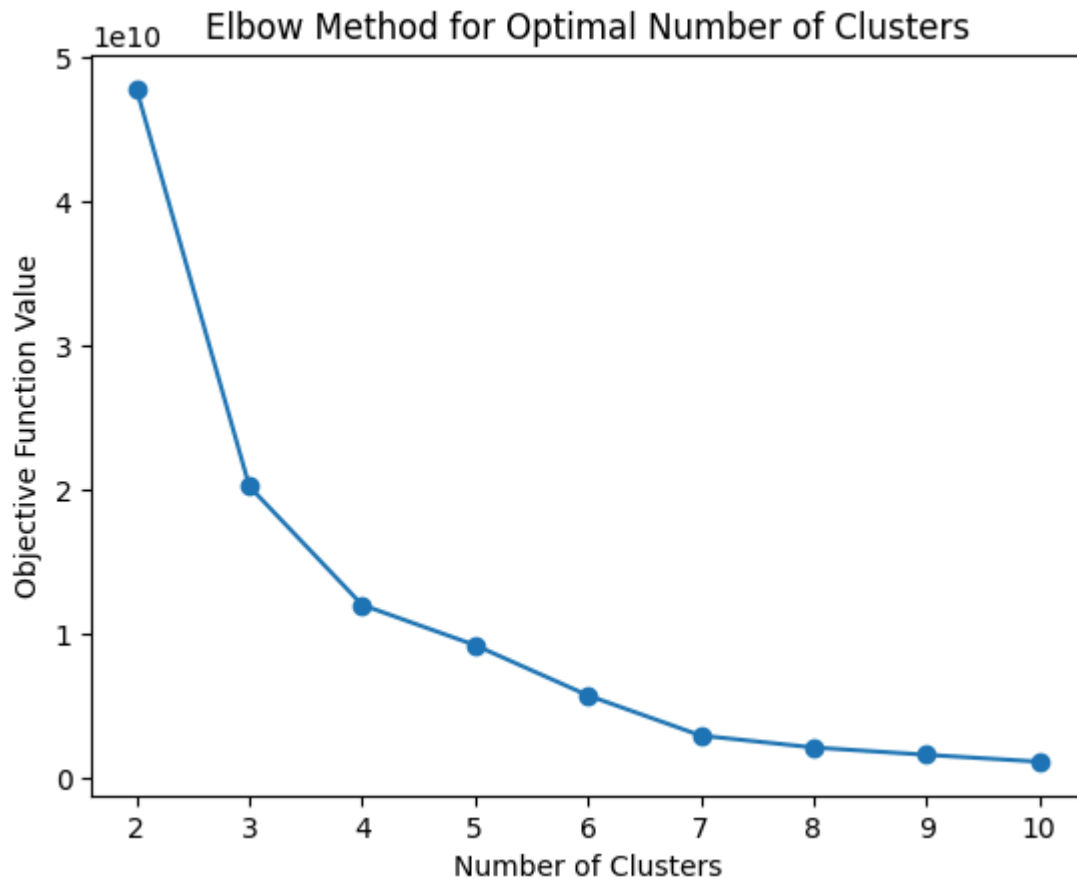
```
# Menghitung PCI
def compute_pci(final_weight_n, num_data, num_clusters):
    pci = (1 / num_data) * np.sum(np.sum(final_weight_n**2, axis=1))
    return pci

# Menghitung PCI
num_data = len(data)
pci_value = compute_pci(final_weight_n, num_data, num_clusters)
print(f"Partition Coefficient Index (PCI): {pci_value}")
```

Partition Coefficient Index (PCI): 0.8388825256637759

```
# Data observasi keanggotaan
df = pd.DataFrame({
    't': range(1, len(data) + 1),  # Waktu dari 1 hingga 26
    'X_t': data,  # Kolom kedua sebagai X_t
    'L1' : final_weight_n.iloc[:, 0].values,
    'L2' : final_weight_n.iloc[:, 1].values,
    'L3' : final_weight_n.iloc[:, 2].values,
})
df
```

	t	X_t	L1	L2	L3
0	1	828960	0.957602	0.026962	0.015436
1	2	838628	0.972038	0.017902	0.010060
2	3	850176	0.986505	0.008714	0.004780
3	4	862314	0.996827	0.002069	0.001104
4	5	874795	0.999850	0.000099	0.000051
5	6	884727	0.994799	0.003459	0.001742
6	7	895327	0.980103	0.013373	0.006525
7	8	905869	0.954030	0.031242	0.014729
8	9	915876	0.917217	0.056901	0.025882
9	10	1041951	0.064933	0.826953	0.108114
10	11	1040220	0.070411	0.817710	0.111879
11	12	1074673	0.005164	0.973104	0.021732
12	13	1093110	0.000284	0.997560	0.002156
13	14	1107304	0.005398	0.926051	0.068551
14	15	1114833	0.009188	0.832359	0.158453
15	16	1141733	0.009922	0.262197	0.727880
16	17	1163970	0.000977	0.014906	0.984117
17	18	1167481	0.000368	0.005238	0.994394
18	19	1180479	0.000563	0.006430	0.993007
19	20	1193512	0.003865	0.036696	0.959440
20	21	1206714	0.009246	0.074954	0.915800
21	22	1231246	0.021985	0.140479	0.837536
22	23	1125804	0.012835	0.620245	0.366921
23	24	1136474	0.011885	0.373120	0.614995
24	25	1147562	0.007207	0.160933	0.831860
25	26	1157290	0.002935	0.051577	0.945488
26	27	1125571	0.012801	0.625474	0.361725

```python
# Menyimpan DataFrame ke file Excel
file_path = "df.xlsx"
df.to_excel(file_path, index=False, engine='openpyxl')

print(f"DataFrame telah disimpan ke file Excel di: {file_path}")
```

DataFrame telah disimpan ke file Excel di: df.xlsx

```python
# List untuk menyimpan hasil
training_samples = []

# Loop untuk membuat pasangan input-target dengan operasi irisan (lag 6)
for i in range(5, len(df) - 1):  # Mulai dari indeks ke-5 untuk mempertimbangkan
    # Ambil derajat keanggotaan dari lag 6 (t-5, ..., t)
    input_row = [min(df.loc[j, f"L{k}"] for j in range(i - 5, i + 1)) for k in r

    # Ambil target dari waktu t+1
    target_row = df.loc[i + 1, [f"L{k}" for k in range(1, 4)]].values

    # Simpan ke dalam list hasil
    training_samples.append({
        "t": df.loc[i + 1, "t"],
        **{f"Input {k}": input_row[k - 1] for k in range(1, 4)},
        **{f"Target {k}": target_row[k - 1] for k in range(1, 4)}
    })

# Konversi hasil ke DataFrame
training_df = pd.DataFrame(training_samples)
training_df
```

	t	Input 1	Input 2	Input 3	Target 1	Target 2	Target 3
0	7	0.957602	0.000099	0.000051	0.980103	0.013373	0.006525
1	8	0.972038	0.000099	0.000051	0.954030	0.031242	0.014729
2	9	0.954030	0.000099	0.000051	0.917217	0.056901	0.025882
3	10	0.917217	0.000099	0.000051	0.064933	0.826953	0.108114
4	11	0.064933	0.000099	0.000051	0.070411	0.817710	0.111879
5	12	0.064933	0.003459	0.001742	0.005164	0.973104	0.021732
6	13	0.005164	0.013373	0.006525	0.000284	0.997560	0.002156
7	14	0.000284	0.031242	0.002156	0.005398	0.926051	0.068551
8	15	0.000284	0.056901	0.002156	0.009188	0.832359	0.158453
9	16	0.000284	0.817710	0.002156	0.009922	0.262197	0.727880
10	17	0.000284	0.262197	0.002156	0.000977	0.014906	0.984117
11	18	0.000284	0.014906	0.002156	0.000368	0.005238	0.994394
12	19	0.000284	0.005238	0.002156	0.000563	0.006430	0.993007
13	20	0.000368	0.005238	0.068551	0.003865	0.036696	0.959440
14	21	0.000368	0.005238	0.158453	0.009246	0.074954	0.915800
15	22	0.000368	0.005238	0.727880	0.021985	0.140479	0.837536
16	23	0.000368	0.005238	0.837536	0.012835	0.620245	0.366921
17	24	0.000368	0.005238	0.366921	0.011885	0.373120	0.614995
18	25	0.000563	0.006430	0.366921	0.007207	0.160933	0.831860
19	26	0.003865	0.036696	0.366921	0.002935	0.051577	0.945488
20	27	0.002935	0.051577	0.366921	0.012801	0.625474	0.361725

```python
# Menyimpan DataFrame ke file Excel
file_path = "training_df.xlsx"
training_df.to_excel(file_path, index=False, engine='openpyxl')

print(f"DataFrame telah disimpan ke file Excel di: {file_path}")
```

DataFrame telah disimpan ke file Excel di: training_df.xlsx

3. Mendefinisikan hubungan samar dengan Feedforward Artificial Neural Network (FFANN)

```
pip install tf-levenberg-marquardt
```

Requirement already satisfied: tf-levenberg-marquardt in c:\users\asus\appdata\lo
cal\programs\python\python312\lib\site-packages (1.0.2)Note: you may need to rest
art the kernel to use updated packages.

[notice] A new release of pip is available: 24.3.1 -> 25.1.1
[notice] To update, run: python.exe -m pip install --upgrade pip

```
Requirement already satisfied: numpy>=1.22 in c:\users\asus\appdata\local\program
s\python\python312\lib\site-packages (from tf-levenberg-marquardt) (1.26.4)
Requirement already satisfied: tensorflow>=2.15.0 in c:\users\asus\appdata\local
\programs\python\python312\lib\site-packages (from tf-levenberg-marquardt) (2.16.
1)
Requirement already satisfied: tensorflow-intel==2.16.1 in c:\users\asus\appdata
\local\programs\python\python312\lib\site-packages (from tensorflow>=2.15.0->tf-l
evenberg-marquardt) (2.16.1)
Requirement already satisfied: absl-py>=1.0.0 in c:\users\asus\appdata\local\prog
rams\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflo
w>=2.15.0->tf-levenberg-marquardt) (2.1.0)
Requirement already satisfied: astunparse>=1.6.0 in c:\users\asus\appdata\local\p
rograms\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensor
flow>=2.15.0->tf-levenberg-marquardt) (1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in c:\users\asus\appdata\loca
l\programs\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->ten
sorflow>=2.15.0->tf-levenberg-marquardt) (24.3.25)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in c:\users\as
us\appdata\local\programs\python\python312\lib\site-packages (from tensorflow-int
el==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (0.5.4)
Requirement already satisfied: google-pasta>=0.1.1 in c:\users\asus\appdata\local
\programs\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tens
orflow>=2.15.0->tf-levenberg-marquardt) (0.2.0)
Requirement already satisfied: h5py>=3.10.0 in c:\users\asus\appdata\local\progra
ms\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow>
=2.15.0->tf-levenberg-marquardt) (3.11.0)
Requirement already satisfied: libclang>=13.0.0 in c:\users\asus\appdata\local\pr
ograms\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorf
low>=2.15.0->tf-levenberg-marquardt) (18.1.1)
Requirement already satisfied: ml-dtypes~=0.3.1 in c:\users\asus\appdata\local\pr
ograms\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorf
low>=2.15.0->tf-levenberg-marquardt) (0.3.2)
Requirement already satisfied: opt-einsum>=2.3.2 in c:\users\asus\appdata\local\p
rograms\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensor
flow>=2.15.0->tf-levenberg-marquardt) (3.3.0)
Requirement already satisfied: packaging in c:\users\asus\appdata\local\programs
\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow>=
2.15.0->tf-levenberg-marquardt) (24.0)
Requirement already satisfied: protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.2
1.4,!=4.21.5,<5.0.0dev,>=3.20.3 in c:\users\asus\appdata\local\programs\python\py
thon312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow>=2.15.0->tf-
levenberg-marquardt) (4.25.3)
Requirement already satisfied: requests<3,>=2.21.0 in c:\users\asus\appdata\local
\programs\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tens
orflow>=2.15.0->tf-levenberg-marquardt) (2.31.0)
Requirement already satisfied: setuptools in c:\users\asus\appdata\local\programs
\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow>=
2.15.0->tf-levenberg-marquardt) (69.2.0)
Requirement already satisfied: six>=1.12.0 in c:\users\asus\appdata\local\program
s\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow>=
2.15.0->tf-levenberg-marquardt) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in c:\users\asus\appdata\local\pr
ograms\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorf
low>=2.15.0->tf-levenberg-marquardt) (2.4.0)
Requirement already satisfied: typing-extensions>=3.6.6 in c:\users\asus\appdata
\local\programs\python\python312\lib\site-packages (from tensorflow-intel==2.16.1
->tensorflow>=2.15.0->tf-levenberg-marquardt) (4.12.2)
Requirement already satisfied: wrapt>=1.11.0 in c:\users\asus\appdata\local\progr
ams\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow
>=2.15.0->tf-levenberg-marquardt) (1.16.0)
```

```
Requirement already satisfied: grpcio<2.0,>=1.24.3 in c:\users\asus\appdata\local
\programs\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tens
orflow>=2.15.0->tf-levenberg-marquardt) (1.64.1)
Requirement already satisfied: tensorboard<2.17,>=2.16 in c:\users\asus\appdata\l
ocal\programs\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->
tensorflow>=2.15.0->tf-levenberg-marquardt) (2.16.2)
Requirement already satisfied: keras>=3.0.0 in c:\users\asus\appdata\local\progra
ms\python\python312\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow>
=2.15.0->tf-levenberg-marquardt) (3.3.3)
Requirement already satisfied: wheel<1.0,>=0.23.0 in c:\users\asus\appdata\local
\programs\python\python312\lib\site-packages (from astunparse>=1.6.0->tensorflow-
intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (0.43.0)
Requirement already satisfied: rich in c:\users\asus\appdata\local\programs\pytho
n\python312\lib\site-packages (from keras>=3.0.0->tensorflow-intel==2.16.1->tenso
rflow>=2.15.0->tf-levenberg-marquardt) (13.7.1)
Requirement already satisfied: namex in c:\users\asus\appdata\local\programs\pyth
on\python312\lib\site-packages (from keras>=3.0.0->tensorflow-intel==2.16.1->tens
orflow>=2.15.0->tf-levenberg-marquardt) (0.0.8)
Requirement already satisfied: optree in c:\users\asus\appdata\local\programs\pyt
hon\python312\lib\site-packages (from keras>=3.0.0->tensorflow-intel==2.16.1->ten
sorflow>=2.15.0->tf-levenberg-marquardt) (0.11.0)
Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\asus\appdata
\local\programs\python\python312\lib\site-packages (from requests<3,>=2.21.0->ten
sorflow-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in c:\users\asus\appdata\local\progra
ms\python\python312\lib\site-packages (from requests<3,>=2.21.0->tensorflow-intel
==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (3.6)
Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\asus\appdata\local
\programs\python\python312\lib\site-packages (from requests<3,>=2.21.0->tensorflo
w-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (2.2.1)
Requirement already satisfied: certifi>=2017.4.17 in c:\users\asus\appdata\local
\programs\python\python312\lib\site-packages (from requests<3,>=2.21.0->tensorflo
w-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (2024.2.2)
Requirement already satisfied: markdown>=2.6.8 in c:\users\asus\appdata\local\pro
grams\python\python312\lib\site-packages (from tensorboard<2.17,>=2.16->tensorflo
w-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (3.6)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in c:\users
\asus\appdata\local\programs\python\python312\lib\site-packages (from tensorboard
<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquard
t) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in c:\users\asus\appdata\local\pro
grams\python\python312\lib\site-packages (from tensorboard<2.17,>=2.16->tensorflo
w-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (3.0.3)
Requirement already satisfied: MarkupSafe>=2.1.1 in c:\users\asus\appdata\local\p
rograms\python\python312\lib\site-packages (from werkzeug>=1.0.1->tensorboard<2.1
7,>=2.16->tensorflow-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt)
(2.1.5)
Requirement already satisfied: markdown-it-py>=2.2.0 in c:\users\asus\appdata\loc
al\programs\python\python312\lib\site-packages (from rich->keras>=3.0.0->tensorfl
ow-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in c:\users\asus\appdata\r
oaming\python\python312\site-packages (from rich->keras>=3.0.0->tensorflow-intel=
=2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (2.17.2)
Requirement already satisfied: mdurl~=0.1 in c:\users\asus\appdata\local\programs
\python\python312\lib\site-packages (from markdown-it-py>=2.2.0->rich->keras>=3.
0.0->tensorflow-intel==2.16.1->tensorflow>=2.15.0->tf-levenberg-marquardt) (0.1.
2)
```

In [221...
```python
# Mengambil dataframe input dan target dari training_df
X = training_df[["Input 1", "Input 2", "Input 3"]].values
```

```
y = training_df[["Target 1", "Target 2", "Target 3"]].values
```

In [222...
```
import time
import keras
import matplotlib.pyplot as plt
import numpy as np
import tensorflow as tf
import tf_levenberg_marquardt as lm
from sklearn.model_selection import train_test_split
import pandas as pd
```

In [223...
```
# Split data menjadi training dan testing set (80% training, 20% testing)
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_
```

In [224...
```
# Konversi ke format TensorFlow
X_train = tf.cast(X_train, tf.float32)
X_test = tf.cast(X_test, tf.float32)
y_train = tf.cast(y_train, tf.float32)
y_test = tf.cast(y_test, tf.float32)

# Dataset TensorFlow untuk training
batch_size = 16
train_dataset = tf.data.Dataset.from_tensor_slices((X_train, y_train))
train_dataset = train_dataset.shuffle(len(X_train))
train_dataset = train_dataset.batch(batch_size).repeat(10).cache()
train_dataset = train_dataset.prefetch(tf.data.AUTOTUNE)
```

In [225...
```
#Model ANN
model = keras.Sequential([
    keras.layers.Input(shape=(X.shape[1],)),    # Input layer
    keras.layers.Dense(8, activation='sigmoid'), # Hidden layer
    keras.layers.Dense(y.shape[1], activation='sigmoid') # Output layer
])

model.summary()
```

Model: "sequential_191"

Layer (type)	Output Shape	Param #
dense_568 (Dense)	(None, 8)	32
dense_569 (Dense)	(None, 3)	27

◀ ▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬ ▶

Total params: 59 (236.00 B)

Trainable params: 59 (236.00 B)

Non-trainable params: 0 (0.00 B)

In [226...
```
# Wrapper untuk Levenberg-Marquardt
model_wrapper = lm.model.ModelWrapper(keras.models.clone_model(model))
model_wrapper.compile(
    optimizer=keras.optimizers.SGD(learning_rate=0.01),
    loss=lm.loss.MeanSquaredError(),
)
```

```python
print('\nTraining menggunakan Levenberg-Marquardt')
t2_start = time.perf_counter()
history = model_wrapper.fit(
    train_dataset,
    epochs=100
)
t2_stop = time.perf_counter()
print('Waktu yang dibutuhkan: ', t2_stop - t2_start)
```

```
Training menggunakan Levenberg-Marquardt
Epoch 1/100
10/10 ──────────────── 1s 43ms/step - attempts: 1.3636 - damping_factor: 1.01
37e-05 - loss: 0.2219
Epoch 2/100
10/10 ──────────────── 1s 49ms/step - attempts: 2.0909 - damping_factor: 2.63
64e-08 - loss: 0.1753
Epoch 3/100
10/10 ──────────────── 1s 52ms/step - attempts: 1.9091 - damping_factor: 5.82
73e-09 - loss: 0.1493
Epoch 4/100
10/10 ──────────────── 1s 58ms/step - attempts: 1.8182 - damping_factor: 5.74
55e-09 - loss: 0.1269
Epoch 5/100
10/10 ──────────────── 0s 36ms/step - attempts: 1.0000 - damping_factor: 1.00
00e-10 - loss: 0.1031
Epoch 6/100
10/10 ──────────────── 0s 48ms/step - attempts: 1.3636 - damping_factor: 1.00
00e-10 - loss: 0.0779
Epoch 7/100
10/10 ──────────────── 0s 45ms/step - attempts: 1.3636 - damping_factor: 1.00
00e-10 - loss: 0.0578
Epoch 8/100
10/10 ──────────────── 1s 58ms/step - attempts: 1.8182 - damping_factor: 1.00
00e-10 - loss: 0.0481
Epoch 9/100
10/10 ──────────────── 1s 54ms/step - attempts: 1.5455 - damping_factor: 3.45
45e-10 - loss: 0.0420
Epoch 10/100
10/10 ──────────────── 1s 67ms/step - attempts: 1.4545 - damping_factor: 1.00
00e-10 - loss: 0.0341
Epoch 11/100
10/10 ──────────────── 1s 55ms/step - attempts: 1.6364 - damping_factor: 1.00
00e-10 - loss: 0.0275
Epoch 12/100
10/10 ──────────────── 1s 53ms/step - attempts: 1.6364 - damping_factor: 1.00
00e-10 - loss: 0.0228
Epoch 13/100
10/10 ──────────────── 1s 49ms/step - attempts: 1.5455 - damping_factor: 1.81
82e-10 - loss: 0.0186
Epoch 14/100
10/10 ──────────────── 0s 48ms/step - attempts: 1.3636 - damping_factor: 1.00
00e-10 - loss: 0.0149
Epoch 15/100
10/10 ──────────────── 1s 49ms/step - attempts: 1.7273 - damping_factor: 2.63
64e-10 - loss: 0.0113
Epoch 16/100
10/10 ──────────────── 1s 52ms/step - attempts: 1.7273 - damping_factor: 1.81
82e-10 - loss: 0.0092
Epoch 17/100
10/10 ──────────────── 1s 47ms/step - attempts: 1.5455 - damping_factor: 1.00
00e-10 - loss: 0.0080
Epoch 18/100
10/10 ──────────────── 1s 48ms/step - attempts: 1.5455 - damping_factor: 1.00
00e-10 - loss: 0.0068
Epoch 19/100
10/10 ──────────────── 1s 57ms/step - attempts: 2.0000 - damping_factor: 1.49
09e-09 - loss: 0.0058
Epoch 20/100
10/10 ──────────────── 0s 48ms/step - attempts: 1.6364 - damping_factor: 2.63
```

```
64e-10 - loss: 0.0050
Epoch 21/100
10/10 ──────────────────── 0s 42ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 0.0041
Epoch 22/100
10/10 ──────────────────── 0s 45ms/step - attempts: 1.3636 - damping_factor: 1.81
82e-10 - loss: 0.0033
Epoch 23/100
10/10 ──────────────────── 0s 48ms/step - attempts: 1.5455 - damping_factor: 1.81
82e-10 - loss: 0.0027
Epoch 24/100
10/10 ──────────────────── 1s 52ms/step - attempts: 1.6364 - damping_factor: 3.45
45e-10 - loss: 0.0023
Epoch 25/100
10/10 ──────────────────── 0s 35ms/step - attempts: 1.0000 - damping_factor: 1.00
00e-10 - loss: 0.0019
Epoch 26/100
10/10 ──────────────────── 0s 42ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 0.0016
Epoch 27/100
10/10 ──────────────────── 0s 40ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 0.0014
Epoch 28/100
10/10 ──────────────────── 0s 46ms/step - attempts: 1.3636 - damping_factor: 1.81
82e-10 - loss: 0.0011
Epoch 29/100
10/10 ──────────────────── 0s 37ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 8.9394e-04
Epoch 30/100
10/10 ──────────────────── 1s 52ms/step - attempts: 1.0000 - damping_factor: 1.00
00e-10 - loss: 7.4613e-04
Epoch 31/100
10/10 ──────────────────── 0s 46ms/step - attempts: 1.4545 - damping_factor: 1.00
00e-10 - loss: 6.3133e-04
Epoch 32/100
10/10 ──────────────────── 0s 39ms/step - attempts: 1.0909 - damping_factor: 1.00
00e-10 - loss: 5.4776e-04
Epoch 33/100
10/10 ──────────────────── 0s 36ms/step - attempts: 1.0909 - damping_factor: 1.00
00e-10 - loss: 4.6359e-04
Epoch 34/100
10/10 ──────────────────── 0s 47ms/step - attempts: 1.4545 - damping_factor: 2.63
64e-10 - loss: 3.8400e-04
Epoch 35/100
10/10 ──────────────────── 0s 41ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 3.2854e-04
Epoch 36/100
10/10 ──────────────────── 1s 51ms/step - attempts: 1.5455 - damping_factor: 3.45
45e-10 - loss: 2.7708e-04
Epoch 37/100
10/10 ──────────────────── 0s 43ms/step - attempts: 1.2727 - damping_factor: 1.81
82e-10 - loss: 2.2664e-04
Epoch 38/100
10/10 ──────────────────── 0s 41ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 1.9223e-04
Epoch 39/100
10/10 ──────────────────── 0s 41ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 1.6312e-04
Epoch 40/100
10/10 ──────────────────── 0s 43ms/step - attempts: 1.4545 - damping_factor: 2.63
```

```
64e-10 - loss: 1.3736e-04
Epoch 41/100
10/10 ───────────────────── 0s 41ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 1.1469e-04
Epoch 42/100
10/10 ───────────────────── 0s 49ms/step - attempts: 1.4545 - damping_factor: 2.63
64e-10 - loss: 9.5459e-05
Epoch 43/100
10/10 ───────────────────── 0s 47ms/step - attempts: 1.3636 - damping_factor: 1.81
82e-10 - loss: 7.9428e-05
Epoch 44/100
10/10 ───────────────────── 0s 45ms/step - attempts: 1.5455 - damping_factor: 2.63
64e-10 - loss: 6.6460e-05
Epoch 45/100
10/10 ───────────────────── 0s 41ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 5.5554e-05
Epoch 46/100
10/10 ───────────────────── 1s 58ms/step - attempts: 1.9091 - damping_factor: 1.00
00e-10 - loss: 4.4948e-05
Epoch 47/100
10/10 ───────────────────── 0s 41ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 3.6862e-05
Epoch 48/100
10/10 ───────────────────── 0s 40ms/step - attempts: 1.2727 - damping_factor: 1.81
82e-10 - loss: 2.9887e-05
Epoch 49/100
10/10 ───────────────────── 1s 49ms/step - attempts: 1.0909 - damping_factor: 1.00
00e-10 - loss: 2.4569e-05
Epoch 50/100
10/10 ───────────────────── 0s 48ms/step - attempts: 1.5455 - damping_factor: 1.00
00e-10 - loss: 2.0615e-05
Epoch 51/100
10/10 ───────────────────── 0s 45ms/step - attempts: 1.5455 - damping_factor: 1.81
82e-10 - loss: 1.7433e-05
Epoch 52/100
10/10 ───────────────────── 0s 48ms/step - attempts: 1.4545 - damping_factor: 2.63
64e-10 - loss: 1.4798e-05
Epoch 53/100
10/10 ───────────────────── 0s 44ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 1.2456e-05
Epoch 54/100
10/10 ───────────────────── 0s 42ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 1.0461e-05
Epoch 55/100
10/10 ───────────────────── 1s 48ms/step - attempts: 1.5455 - damping_factor: 1.81
82e-10 - loss: 8.8716e-06
Epoch 56/100
10/10 ───────────────────── 0s 39ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 7.4745e-06
Epoch 57/100
10/10 ───────────────────── 0s 45ms/step - attempts: 1.3636 - damping_factor: 2.63
64e-10 - loss: 6.1844e-06
Epoch 58/100
10/10 ───────────────────── 0s 44ms/step - attempts: 1.2727 - damping_factor: 1.81
82e-10 - loss: 4.9271e-06
Epoch 59/100
10/10 ───────────────────── 0s 43ms/step - attempts: 1.2727 - damping_factor: 1.81
82e-10 - loss: 3.9788e-06
Epoch 60/100
10/10 ───────────────────── 0s 49ms/step - attempts: 1.5455 - damping_factor: 1.00
```

```
00e-10 - loss: 3.2075e-06
Epoch 61/100
10/10 ───────────────────── 1s 57ms/step - attempts: 1.4545 - damping_factor: 1.00
00e-10 - loss: 2.6914e-06
Epoch 62/100
10/10 ───────────────────── 0s 43ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 2.2551e-06
Epoch 63/100
10/10 ───────────────────── 0s 44ms/step - attempts: 1.4545 - damping_factor: 1.81
82e-10 - loss: 1.8555e-06
Epoch 64/100
10/10 ───────────────────── 1s 51ms/step - attempts: 1.3636 - damping_factor: 1.00
00e-10 - loss: 1.5085e-06
Epoch 65/100
10/10 ───────────────────── 1s 45ms/step - attempts: 1.4545 - damping_factor: 2.63
64e-10 - loss: 1.2888e-06
Epoch 66/100
10/10 ───────────────────── 1s 51ms/step - attempts: 1.8182 - damping_factor: 2.63
64e-10 - loss: 1.0895e-06
Epoch 67/100
10/10 ───────────────────── 0s 44ms/step - attempts: 1.2727 - damping_factor: 1.00
00e-10 - loss: 9.2904e-07
Epoch 68/100
10/10 ───────────────────── 0s 42ms/step - attempts: 1.1818 - damping_factor: 1.00
00e-10 - loss: 7.6423e-07
Epoch 69/100
10/10 ───────────────────── 1s 55ms/step - attempts: 1.6364 - damping_factor: 3.45
45e-10 - loss: 6.4033e-07
Epoch 70/100
10/10 ───────────────────── 0s 46ms/step - attempts: 1.4545 - damping_factor: 1.81
82e-10 - loss: 5.3656e-07
Epoch 71/100
10/10 ───────────────────── 1s 57ms/step - attempts: 1.8182 - damping_factor: 2.63
64e-10 - loss: 4.4607e-07
Epoch 72/100
10/10 ───────────────────── 1s 56ms/step - attempts: 1.5455 - damping_factor: 1.00
00e-10 - loss: 3.6137e-07
Epoch 73/100
10/10 ───────────────────── 0s 44ms/step - attempts: 1.4545 - damping_factor: 1.81
82e-10 - loss: 3.0921e-07
Epoch 74/100
10/10 ───────────────────── 1s 56ms/step - attempts: 1.7273 - damping_factor: 3.45
45e-10 - loss: 2.6618e-07
Epoch 75/100
10/10 ───────────────────── 1s 59ms/step - attempts: 1.9091 - damping_factor: 6.72
73e-10 - loss: 2.2545e-07
Epoch 76/100
10/10 ───────────────────── 1s 53ms/step - attempts: 1.8182 - damping_factor: 4.27
27e-10 - loss: 1.9793e-07
Epoch 77/100
10/10 ───────────────────── 1s 79ms/step - attempts: 2.0000 - damping_factor: 6.72
73e-10 - loss: 1.7234e-07
Epoch 78/100
10/10 ───────────────────── 1s 54ms/step - attempts: 1.6364 - damping_factor: 4.27
27e-10 - loss: 1.4233e-07
Epoch 79/100
10/10 ───────────────────── 1s 63ms/step - attempts: 2.2727 - damping_factor: 2.63
64e-09 - loss: 1.2488e-07
Epoch 80/100
10/10 ───────────────────── 1s 54ms/step - attempts: 1.6364 - damping_factor: 4.27
```

```
27e-10 - loss: 1.1026e-07
Epoch 81/100
10/10 ──────────────────── 1s 63ms/step - attempts: 2.0909 - damping_factor: 2.22
73e-09 - loss: 9.6380e-08
Epoch 82/100
10/10 ──────────────────── 1s 59ms/step - attempts: 2.0000 - damping_factor: 1.65
45e-09 - loss: 8.6466e-08
Epoch 83/100
10/10 ──────────────────── 1s 62ms/step - attempts: 2.2727 - damping_factor: 2.47
27e-09 - loss: 7.8393e-08
Epoch 84/100
10/10 ──────────────────── 1s 57ms/step - attempts: 1.8182 - damping_factor: 1.57
27e-09 - loss: 7.1334e-08
Epoch 85/100
10/10 ──────────────────── 1s 51ms/step - attempts: 1.7273 - damping_factor: 4.27
27e-10 - loss: 6.5877e-08
Epoch 86/100
10/10 ──────────────────── 1s 59ms/step - attempts: 2.0909 - damping_factor: 5.09
09e-10 - loss: 6.1026e-08
Epoch 87/100
10/10 ──────────────────── 1s 63ms/step - attempts: 2.0000 - damping_factor: 1.65
45e-09 - loss: 5.5858e-08
Epoch 88/100
10/10 ──────────────────── 1s 55ms/step - attempts: 1.8182 - damping_factor: 2.47
27e-09 - loss: 5.2073e-08
Epoch 89/100
10/10 ──────────────────── 1s 57ms/step - attempts: 2.0909 - damping_factor: 2.63
64e-09 - loss: 4.8262e-08
Epoch 90/100
10/10 ──────────────────── 1s 61ms/step - attempts: 2.0000 - damping_factor: 9.18
18e-10 - loss: 4.5383e-08
Epoch 91/100
10/10 ──────────────────── 1s 54ms/step - attempts: 1.8182 - damping_factor: 1.65
45e-09 - loss: 4.3349e-08
Epoch 92/100
10/10 ──────────────────── 1s 59ms/step - attempts: 2.0000 - damping_factor: 2.63
64e-09 - loss: 4.1220e-08
Epoch 93/100
10/10 ──────────────────── 1s 61ms/step - attempts: 2.2727 - damping_factor: 2.47
27e-09 - loss: 3.9365e-08
Epoch 94/100
10/10 ──────────────────── 1s 59ms/step - attempts: 1.9091 - damping_factor: 3.37
27e-09 - loss: 3.8041e-08
Epoch 95/100
10/10 ──────────────────── 1s 57ms/step - attempts: 1.9091 - damping_factor: 4.19
09e-09 - loss: 3.6907e-08
Epoch 96/100
10/10 ──────────────────── 1s 60ms/step - attempts: 2.0000 - damping_factor: 2.63
64e-09 - loss: 3.5747e-08
Epoch 97/100
10/10 ──────────────────── 1s 57ms/step - attempts: 1.9091 - damping_factor: 1.57
27e-09 - loss: 3.4561e-08
Epoch 98/100
10/10 ──────────────────── 1s 59ms/step - attempts: 1.9091 - damping_factor: 4.27
27e-09 - loss: 3.3581e-08
Epoch 99/100
10/10 ──────────────────── 1s 66ms/step - attempts: 2.0000 - damping_factor: 4.92
73e-09 - loss: 3.2925e-08
Epoch 100/100
10/10 ──────────────────── 1s 61ms/step - attempts: 2.0909 - damping_factor: 4.10
```

```
91e-09 - loss: 3.2157e-08
Waktu yang dibutuhkan:   52.799264700035565
```

In [228…
```python
# Plot loss
plt.plot(history.history['loss'], label='Training Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```
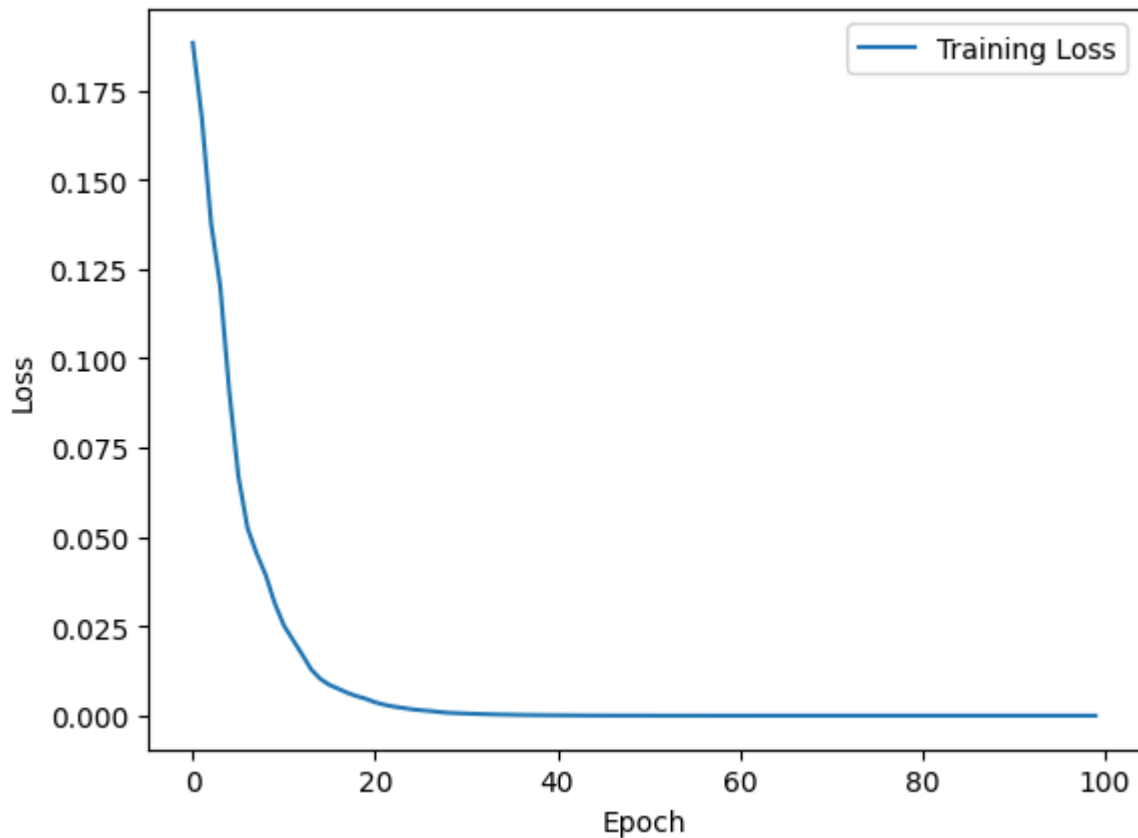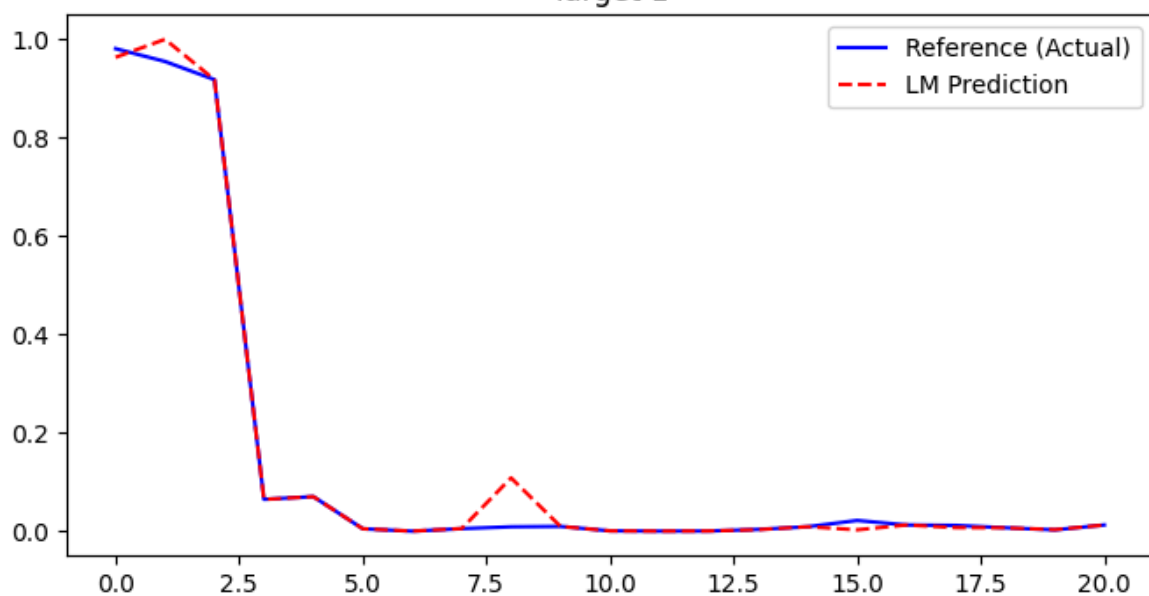

In [229…
```python
# Visualisasi hasil
print('\nPlot hasil prediksi')
y_pred_lm = model_wrapper.predict(X)
y_pred_lm


# Hasil visualisasi
for i in range(y.shape[1]):
    plt.figure(figsize=(8, 4))
    plt.plot(range(len(y)), y[:, i], 'b-', label='Reference (Actual)')
    plt.plot(range(len(y_pred_lm)), y_pred_lm[:, i], 'r--', label='LM Prediction
    plt.title(f"Target {i+1}")
    plt.legend()
    plt.show()
```

```
Plot hasil prediksi
1/1 ─────────────────── 0s 54ms/step
```

Target 1

Target 2
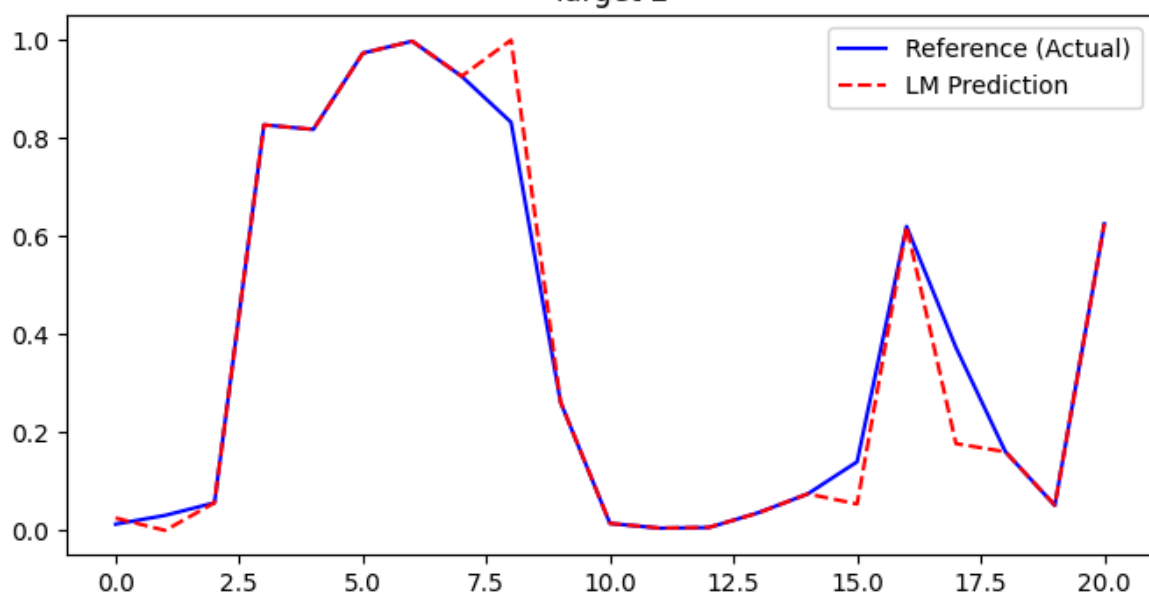
Target 3
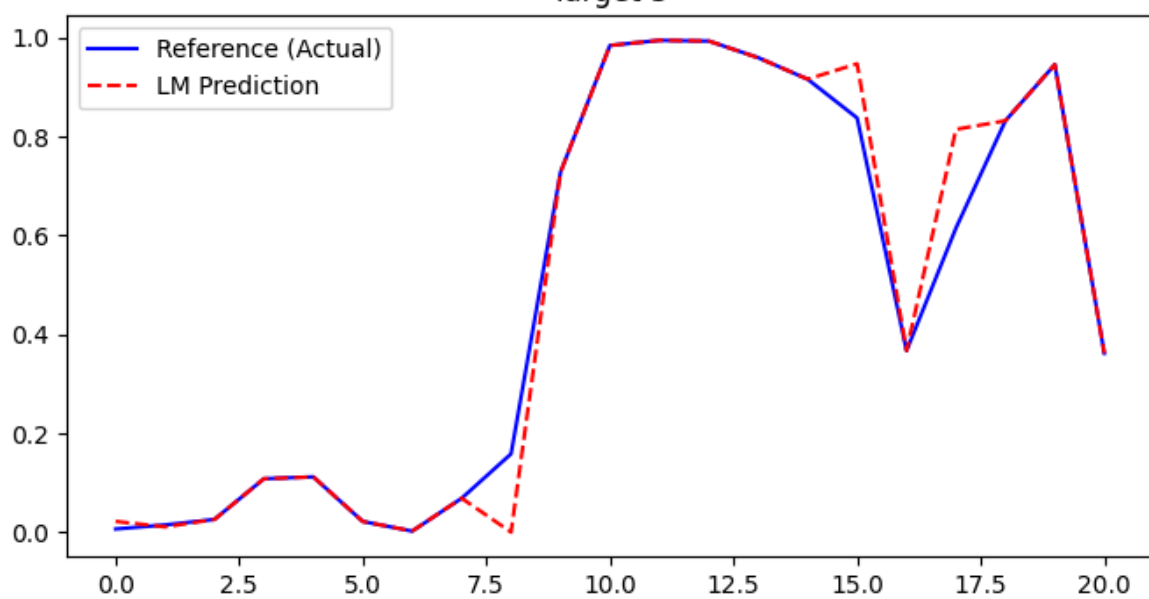
```python
In [230... # Cetak hasil prediksi
         print("Hasil Prediksi dengan Levenberg-Marquardt:")
         print(pd.DataFrame(y_pred_lm))
```

Hasil Prediksi dengan Levenberg-Marquardt:
```
            0         1         2
0    0.962521  0.025902  0.021864
1    0.999115  0.000626  0.010774
2    0.917184  0.056915  0.025845
3    0.064854  0.826999  0.108067
4    0.070329  0.817780  0.111826
5    0.005153  0.972998  0.021598
6    0.000370  0.997624  0.002418
7    0.005571  0.926162  0.068650
8    0.108473  0.999871  0.000099
9    0.009896  0.262186  0.727845
10   0.000866  0.014851  0.984059
11   0.000337  0.005503  0.994541
12   0.000651  0.006845  0.993146
13   0.003405  0.036151  0.959039
14   0.009355  0.075100  0.915966
15   0.003004  0.054525  0.947076
16   0.012883  0.620172  0.366875
17   0.007461  0.177455  0.814506
18   0.007122  0.160820  0.831891
19   0.003368  0.051746  0.945680
20   0.012704  0.625416  0.361720
```

```python
In [231... # Menyimpan DataFrame ke file Excel
         file_path = "y_pred_lm.xlsx"
         pd.DataFrame(y_pred_lm).to_excel(file_path, index=False, engine='openpyxl')

         print(f"DataFrame telah disimpan ke file Excel di: {file_path}")
```

DataFrame telah disimpan ke file Excel di: y_pred_lm.xlsx

4. Defuzzifikasi Hasil Peramalan

```python
In [232... def defuzzify_fuzzy_forecast(y_pred_lm, final_c):
             """
             Perform defuzzification using the weighted average method.

             Parameters:
                 predictions (np.ndarray): Matrix of fuzzy membership values.
                 centroids (list or np.ndarray): Centroids (representative values) of the

             Returns:
                 np.ndarray: Crisp forecast values.
             """
             y_pred_lm = np.array(y_pred_lm)
             final_c= np.array(final_c)

             # Validate shapes
             if y_pred_lm.shape[1] != len(final_c):
                 raise ValueError("The number of centroids must match the number of fuzzy

             # Normalize fuzzy membership values
             weights = y_pred_lm / y_pred_lm.sum(axis=1, keepdims=True)
```

```python
    # Compute crisp forecast as a weighted sum of centroids
    crisp_values = np.dot(weights, final_c)
    return crisp_values

# Perform defuzzification
crisp_forecast_values = defuzzify_fuzzy_forecast(y_pred_lm, final_c)

# Display results
print("Crisp Forecast Values:")
print(pd.DataFrame(crisp_forecast_values, columns=["Crisp Value"]).map('{:.2f}'.
```

```
Crisp Forecast Values:
    Crisp Value
0      884718.61
1      875996.90
2      892761.30
3     1084384.67
4     1083512.74
5     1090081.62
6     1089511.44
7     1093930.21
8     1068187.31
9     1148212.71
10    1171644.47
11    1172586.90
12    1172380.39
13    1169092.04
14    1164051.21
15    1167704.39
16    1117328.23
17    1156033.37
18    1157536.04
19    1167806.90
20    1116937.80
```

In [233…
```python
# Menyimpan DataFrame ke file Excel
file_path = "crisp.xlsx"
pd.DataFrame(crisp_forecast_values, columns=["Crisp Value"]).map('{:.2f}'.format

print(f"DataFrame telah disimpan ke file Excel di: {file_path}")
```

```
DataFrame telah disimpan ke file Excel di: crisp.xlsx
```

5. Perhitungan Nilai MAPE

In [234…
```python
import numpy as np

def calculate_mape(actual, predicted):
    """
    Menghitung Mean Absolute Percentage Error (MAPE).

    Parameters:
    - actual: Array data asli (numpy array).
    - predicted: Array prediksi (numpy array).

    Returns:
    - mape: Nilai MAPE dalam persen.
    """

    actual, predicted = np.array(actual), np.array(predicted)
```

```python
        # Pastikan panjang prediksi dan data asli sesuai
        if len(predicted) != len(actual):
            raise ValueError("Panjang prediksi tidak sesuai dengan data asli.")

        # Hitung MAPE
        mape = np.mean(np.abs((actual - predicted) / actual)) * 100
        return mape

# Data asli setelah baris ke-7
data_actual = np.array(data[6:])  # Konversi ke numpy array

# Prediksi setelah defuzzifikasi
predicted = np.array(crisp_forecast_values.flatten())

# Pisahkan kembali data sesuai pembagian train-test (80% training, 20% testing)
split_index = int(len(data_actual) * 0.8)  # 80% training, 20% testing

y_train_actual = data_actual[:split_index]
y_train_pred = predicted[:split_index]

y_test_actual = data_actual[split_index:]
y_test_pred = predicted[split_index:]

# Hitung MAPE untuk data training dan testing
mape_train = calculate_mape(y_train_actual, y_train_pred)
mape_test = calculate_mape(y_test_actual, y_test_pred)

print(f"MAPE Data Training: {mape_train:.2f}%")
print(f"MAPE Data Testing: {mape_test:.2f}%")
```

```
MAPE Data Training: 2.22%
MAPE Data Testing: 1.00%
```

```python
def calculate_mape(data, crisp_forecast):
    """
    Menghitung Mean Absolute Percentage Error (MAPE) dengan data asli dimulai da

    Parameters:
    - data: Array data asli (1D).
    - crisp_forecast: Array prediksi (1D).

    Returns:
    - mape: Nilai MAPE dalam persen.
    """
    # Data asli dimulai dari baris ke-7
    actual = data[6:]  # Mengambil data dari indeks 6 hingga akhir

    # Pastikan panjang prediksi dan data asli sesuai
    if len(crisp_forecast_values) != len(actual):
        raise ValueError("Panjang prediksi tidak sesuai dengan data asli dimulai

    # Hitung MAPE
    mape = np.mean(np.abs((actual - crisp_forecast_values) / actual)) * 100
    return mape

# Prediksi (hasil fuzzy forecast setelah defuzzifikasi)
predicted = crisp_forecast_values.flatten()

# Hitung MAPE
mape = calculate_mape(data, predicted)
```

```python
# Tampilkan hasil MAPE
print("\nMean Absolute Percentage Error (MAPE): {:.2f}%".format(mape))
```

```
Mean Absolute Percentage Error (MAPE): 1.93%
```

```python
# Hyperparameter tuning menggunakan LM wrapper dengan tf_levenberg_marquardt
import time
import keras
import matplotlib.pyplot as plt
import numpy as np
import tensorflow as tf
import tf_levenberg_marquardt as lm
from sklearn.model_selection import train_test_split
import pandas as pd

# Fungsi membuat dan membungkus model dengan LM
def create_model(units, learning_rate):
    base_model = keras.Sequential([
        keras.layers.Dense(units, input_dim=3, activation='sigmoid'),
        keras.layers.Dense(units, activation='sigmoid'),
        keras.layers.Dense(3, activation='sigmoid')
    ])

    # Bungkus model dengan LM wrapper
    model_wrapper = lm.model.ModelWrapper(keras.models.clone_model(base_model))
    model_wrapper.compile(
        optimizer=keras.optimizers.SGD(learning_rate=learning_rate),
        loss=lm.loss.MeanSquaredError()
    )
    return model_wrapper

# Grid parameter
param_grid = {
    'units': [7,8],
    'learning_rate': [0.001, 0.01],
    'batch_size': [16, 32],
    'epochs': [50, 100]
}

best_params = None
best_score = float('inf')

# Lakukan tuning hyperparameter secara manual
for units in param_grid['units']:
    for learning_rate in param_grid['learning_rate']:
        for batch_size in param_grid['batch_size']:
            for epochs in param_grid['epochs']:
                print(f"\nTraining: units={units}, lr={learning_rate}, bs={batch

                # Buat model & dataset
                model = create_model(units, learning_rate)
                train_dataset = tf.data.Dataset.from_tensor_slices((X_train, y_t

                # Training
                t_start = time.perf_counter()
                model.fit(train_dataset, epochs=epochs, verbose=0)
                t_stop = time.perf_counter()
                print(f"Waktu training: {t_stop - t_start:.2f} detik")
```

```python
                # Evaluasi
                predictions = model.predict(X_test)
                predictions = np.array(predictions, dtype=np.float32)
                y_test_np = np.array(y_test, dtype=np.float32)

                if y_test_np.shape != predictions.shape:
                    predictions = predictions.reshape(y_test_np.shape)

                # Evaluasi pakai MSE
                score = np.mean((y_test_np - predictions) ** 2)
                print(f"MSE: {score}")

                if score < best_score:
                    best_score = score
                    best_params = {
                        'units': units,
                        'learning_rate': learning_rate,
                        'batch_size': batch_size,
                        'epochs': epochs
                    }

print("\nBest Parameters:", best_params)
print("Best Score (MSE):", best_score)
```

Training: units=7, lr=0.001, bs=16, epochs=50

```
Waktu training: 4.72 detik
1/1 ──────────────────── 0s 196ms/step
MSE: 0.15844954550266266

Training: units=7, lr=0.001, bs=16, epochs=100
Waktu training: 9.25 detik
1/1 ──────────────────── 0s 66ms/step
MSE: 0.1255486160516739

Training: units=7, lr=0.001, bs=32, epochs=50
Waktu training: 4.64 detik
1/1 ──────────────────── 0s 63ms/step
MSE: 0.11899123340845108

Training: units=7, lr=0.001, bs=32, epochs=100
Waktu training: 7.42 detik
1/1 ──────────────────── 0s 55ms/step
MSE: 0.11494702845811844

Training: units=7, lr=0.01, bs=16, epochs=50
Waktu training: 4.29 detik
1/1 ──────────────────── 0s 47ms/step
MSE: 0.0315060056746006

Training: units=7, lr=0.01, bs=16, epochs=100
Waktu training: 7.80 detik
1/1 ──────────────────── 0s 47ms/step
MSE: 0.025923246517777443

Training: units=7, lr=0.01, bs=32, epochs=50
Waktu training: 4.23 detik
1/1 ──────────────────── 0s 47ms/step
MSE: 0.08479031920433044

Training: units=7, lr=0.01, bs=32, epochs=100
Waktu training: 8.01 detik
1/1 ──────────────────── 0s 63ms/step
MSE: 0.041891831904649734

Training: units=8, lr=0.001, bs=16, epochs=50
Waktu training: 5.17 detik
1/1 ──────────────────── 0s 47ms/step
MSE: 0.07645101845264435

Training: units=8, lr=0.001, bs=16, epochs=100
Waktu training: 8.19 detik
1/1 ──────────────────── 0s 56ms/step
MSE: 0.10602226108312607

Training: units=8, lr=0.001, bs=32, epochs=50
Waktu training: 4.28 detik
1/1 ──────────────────── 0s 55ms/step
MSE: 0.22408059239387512

Training: units=8, lr=0.001, bs=32, epochs=100
Waktu training: 7.94 detik
1/1 ──────────────────── 0s 63ms/step
MSE: 0.14871737360954285

Training: units=8, lr=0.01, bs=16, epochs=50
```

```
Waktu training: 4.51 detik
1/1 ───────────────── 0s 47ms/step
MSE: 0.054990772157907486

Training: units=8, lr=0.01, bs=16, epochs=100
Waktu training: 8.37 detik
1/1 ───────────────── 0s 71ms/step
MSE: 0.019251303747296333

Training: units=8, lr=0.01, bs=32, epochs=50
Waktu training: 4.37 detik
1/1 ───────────────── 0s 47ms/step
MSE: 0.06595417112112045

Training: units=8, lr=0.01, bs=32, epochs=100
Waktu training: 8.40 detik
1/1 ───────────────── 0s 63ms/step
MSE: 0.03167447820305824

Best Parameters: {'units': 8, 'learning_rate': 0.01, 'batch_size': 16, 'epochs':
100}
Best Score (MSE): 0.019251304
```

In [237…
```python
# Membuat input untuk peramalan 1 periode ke depan
last_six_data = df.tail(6)
last_six_input = [min(last_six_data[f"L{k}"].iloc[j] for j in range(len(last_six

# Membuat DataFrame untuk input
input_df = pd.DataFrame([last_six_input], columns=["Input 1", "Input 2", "Input

# Melakukan prediksi menggunakan model
next_period_prediction = model_wrapper.predict(input_df)

# Defuzzifikasi hasil prediksi
next_period_crisp = defuzzify_fuzzy_forecast(next_period_prediction, final_c)

# Menampilkan hasil prediksi crisp untuk periode berikutnya

print("Prediksi Crisp untuk Periode Berikutnya:")
print(pd.DataFrame(next_period_crisp, columns=["Crisp Value"]).map('{:.2f}'.form
```

```
1/1 ───────────────── 0s 52ms/step
1/1 ───────────────── 0s 52ms/step
Prediksi Crisp untuk Periode Berikutnya:
  Crisp Value
0  1110478.42
```