Data Import

In[2]:=
```
SetDirectory[
  "C:/Users/serha/OneDrive/Masaüstü/MyRepo/master_thesis_MMT003/210210_impacts_in_time
    _windows"];
```

In[3]:=
```
datafull = Import["../data/ccm1_data_modified.csv", HeaderLines → 1];
datafullwithheading = Import["../data/ccm1_data_modified.csv"];
```

In[5]:=
```
Get["../algoritm_packages/SingleNetworks-algorithm-package.wl"]
(* ?SingleNetworks`* *)
```

In[6]:=
```
Print["Dataset Length: ", Dimensions@datafull[[All, 9]]]
```

```
Dataset Length: {459 203}
```

In[10]:=
```
Magnify[TableView[datafullwithheading], 0.6]
```

Out[10]=

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		SEQUENCE_ID	R_OS _ID	PRODUCTION_LINE _NAME	REFERENCE_DATE	PIECE_ID	MATERIAL_ID	MOLD_WIDTH	WIDTH	THICKNESS	WEIGHT	LENGTH	HEAT_ID	STEEL_GRADE	EXIT_TEMP	SLAB_TRANSITIO
2	1	122	115 686	CCM1	14.12.16	16 000 181	148 956	#NAME?	1.24×10^{6}	87.	2.74×10^{9}	3.35×10^{9}	16 000 181	26	0	0
3	2	122	115 686	CCM1	14.12.16	16 000 181	148 958	#NAME?	1.24×10^{6}	87.	2.74×10^{9}	3.35×10^{9}	16 000 181	26	0	0
4	3	122	115 686	CCM1	14.12.16	16 000 181	148 959	#NAME?	1.24×10^{6}	87.	2.74×10^{9}	3.35×10^{9}	16 000 181	26	0	0
5	4	122	115 686	CCM1	14.12.16	16 000 181	148 957	#NAME?	1.24×10^{6}	87.	2.74×10^{9}	3.35×10^{9}	16 000 181	26	0	0
6	5	122	115 686	CCM1	14.12.16	16 000 181	000 000-1	#NAME?	1.24×10^{6}	87.	2.74×10^{9}	3.35×10^{9}	16 000 181	26	0	0
7	6	122	115 686	CCM1	14.12.16	16 000 181	148 954	#NAME?	1.24×10^{6}	87.	2.74×10^{9}	3.35×10^{9}	16 000 181	26	0	0
8	7	122	115 686	CCM1	14.12.16	16 000 181	148 955	#NAME?	1.24×10^{6}	87.	2.74×10^{9}	3.35×10^{9}	16 000 181	26	0	0
9	8	173	117 744	CCM1	03.01.17	17 000 341	150 353	#NAME?	1.23×10^{6}	65.	1.97×10^{9}	3.23×10^{9}	17 000 341	30	0	0
10	9	173	117 744	CCM1	03.01.17	17 000 341	150 351	#NAME?	1.23×10^{6}	65.	1.97×10^{9}	3.23×10^{9}	17 000 341	30	0	0
11	10	173	117 744	CCM1	03.01.17	17 000 341	150 352	#NAME?	1.23×10^{6}	65.	1.97×10^{9}	3.23×10^{9}	17 000 341	30	0	0
12	11	173	117 744	CCM1	03.01.17	17 000 341	150 354	#NAME?	1.23×10^{6}	65.	1.97×10^{9}	3.23×10^{9}	17 000 341	30	0	0
13	12	173	117 744	CCM1	03.01.17	17 000 341	150 355	#NAME?	1.23×10^{6}	65.	1.97×10^{9}	3.23×10^{9}	17 000 341	30	0	0
14	13	173	117 744	CCM1	03.01.17	17 000 341	150 356	#NAME?	1.23×10^{6}	65.	1.97×10^{9}	3.23×10^{9}	17 000 341	30	0	0
15	14	173	117 744	CCM1	03.01.17	17 000 341	150 357	#NAME?	1.23×10^{6}	65.	1.97×10^{9}	3.23×10^{9}	17 000 341	30	0	0
16	15	169	117 701	CCM1	03.01.17	17 000 281	150 467	#NAME?	1.22×10^{6}	65.	2.07×10^{5}	3.42×10^{9}	17 000 281	30	0	4
17	16	169	117 701	CCM1	03.01.17	17 000 281	150 469	#NAME?	1.22×10^{6}	65.	2.07×10^{5}	3.42×10^{9}	17 000 281	30	0	4
18	17	169	117 701	CCM1	03.01.17	17 000 281	150 470	#NAME?	1.22×10^{6}	65.	2.07×10^{5}	3.42×10^{9}	17 000 281	30	0	4

In[•]:=
```
Print["Width Feature Data Summary: ", Counts@(Head /@ datafull[[All, 9]])]
Print["Thickness Feature Data Summary: ", Counts@(Head /@ datafull[[All, 10]])]
```

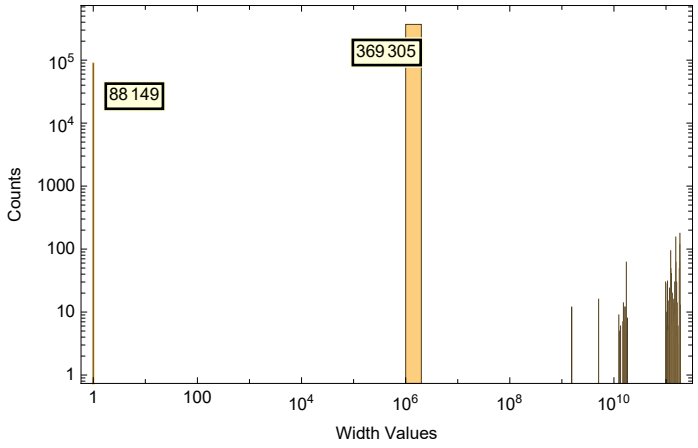
```
Width Feature Data Summary: ⟨|Real → 397 873, Integer → 61 183, String → 147|⟩

Thickness Feature Data Summary: ⟨|Real → 397 860, Integer → 61 199, String → 144|⟩
```

Modifications in the Dataset

Width Feature

In[•]:=
```
Histogram[datafull[[All, 9]], {10^6}, ScalingFunctions → {"Log", "Log"},
 PlotRange → Full, Frame → True, ChartLabels → Placed[{88 149, 369 305},
   {{0.07, 0.8}, Top}, Framed[#, FrameMargins → 1, Background → LightYellow] &],
 FrameLabel → {"Width Values", "Counts"}]
```

Out[•]=



In[•]:=
```
widthmodified = Table[
  If[StringQ@i, i, If[(RealDigits@i)[[2]] > 4, i / 10^((RealDigits@i)[[2]] - 4), i, i]],
  {i, datafull[[All, 9]]}]
Counts@(Head /@ widthmodified)
```

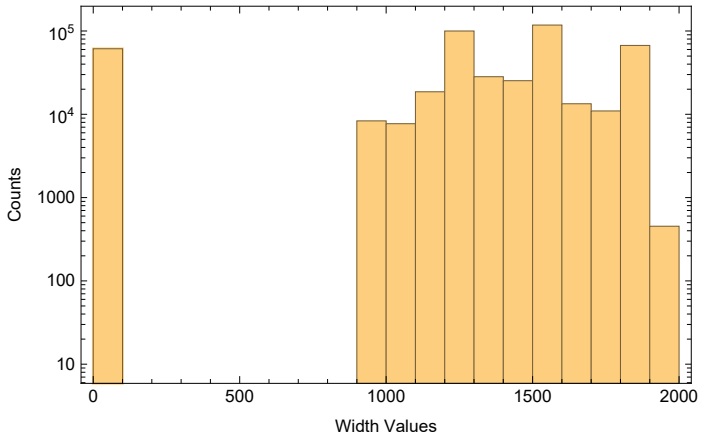
Out[•]=
```
{1240., 1240., 1240., 1240., 1240., 1240., 1240., 1230., 1230., 1230., 1230., 1230.,
 1230., 1230., 1220., 1220., 1220., 1220., 1220., 1220., 1220., 1230., 1230.,
 1230., 1230., 1230., 1230., 1230., 1530., 1530., 1530., 1530., 1530., 1530., 1530.,
 1520., 1520., 1520., 1520., 1520., 1520., 1520., 1520., 0, 0, 0, 0, 1240., 1240.,
 ··· 459 103 ···, 0, 0, 0, 0, 0, 0, 1350., 1350., 1350., 1350., 1350., 1350., 1350.,
 1350., 1350., 1350., 1350., 1350., 1360., 1360., 1360., 1360., 0, 0, 0, 0, 1360.,
 1360., 1360., 1360., 1360., 1360., 1360., 1360., 1360., 1360., 1360., 1360.,
 1360., 1360., 1360., 1360., 1360., 1360., 1350., 1350., 1350., 1350., NA, NA}
```

large output | show less | show more | show all | set size limit...

Out[•]=
```
⟨|Real → 397 873, Integer → 61 183, String → 147|⟩
```

In[•]:=
```
Histogram[widthmodified, ScalingFunctions → "Log",
 PlotRange → {{0, 2000}, All}, Frame → True, FrameLabel → {"Width Values", "Counts"}]
```

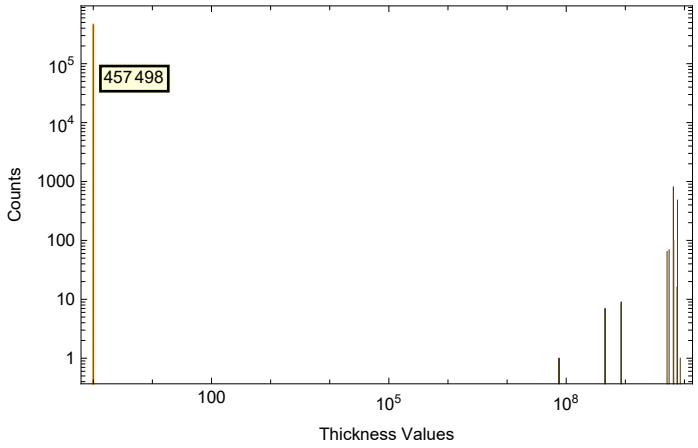
Out[•]=



Thickness Feature

In[ ]:=
```
Histogram[datafull[[All, 10]], {10^6},
 ScalingFunctions → {"Log", "Log"}, PlotRange → Full, Frame → True, ChartLabels →
  Placed[457498, {0.07, 0.85}, Framed[#, FrameMargins → 1, Background → LightYellow] &],
 FrameLabel → {"Thickness Values", "Counts"}]
```

Out[ ]=



In[ ]:=
```
thicknessmodified = Table[
  If[StringQ@i, i, If[(RealDigits@i)[[2]] > 2, i / 10^((RealDigits@i)[[2]] - 2), i, i]],
  {i, datafull[[All, 10]]}]
Counts@(Head /@ thicknessmodified)
```

Out[ ]=

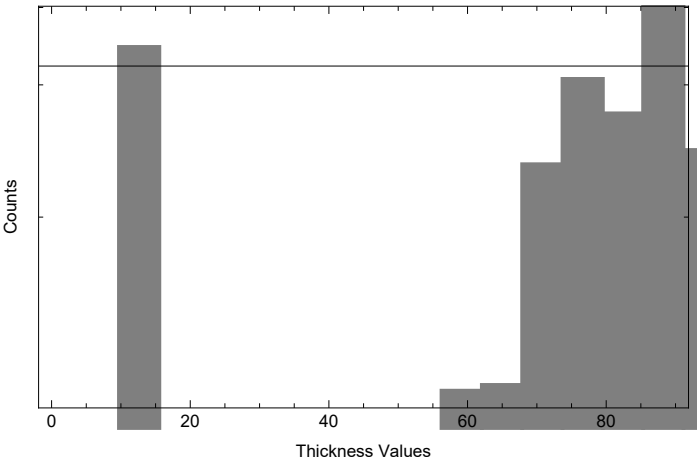
```
{87., 87., 87., 87., 87., 87., 87., 65., 65., 65., 65., 65., 65., 65., 65., 65., 65.,
 65., 65., 65., 65., 65., 65., 65., 65., 65., 65., 65., 66., 66., 66., 66., 66.,
 66., 66., 66., 66., 66., 66., 66., 66., 66., 66., 0, 0, 0, 0, 67., 67., 67., 67.,
 67., 67., 65., 65., 65., 65., 65., 65., 65., 65., 65., 0, 0, 0, 0, 0, 0, 0, ··· 459065 ···,
 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67.,
 67., 67., 67., 0, 0, 0, 0, 0, 0, 67., 67., 67., 67., 67., 67., 66., 66., 66., 66.,
 66., 66., 67., 67., 67., 67., 0, 0, 0, 0, 67., 67., 67., 67., 67., 67., 67., 67.,
 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., 67., NA, NA}
```

large output | show less | show more | show all | set size limit...

Out[ ]=
```
⟨|Real → 397860, Integer → 61199, String → 144|⟩
```

In[ ]:=
```
Histogram[thicknessmodified, ScalingFunctions → "Log",
 PlotRange → Full, Frame → True, FrameLabel → {"Thickness Values", "Counts"}]
```

Out[•]=



Time Windows Generation by Data Partitioning

In[•]:=
```
datafull[[All, 9]] = widthmodified;
datafull[[All, 10]] = thicknessmodified;
data = Table[Take[datafull, UpTo@i],
   {i, {46 497, 91 690, 138 440, 183 584, 230 005, 275 844, 320 350, 367 179, 413 106, 459 203}}];

(* Export["data_with_time_windows.mx",data] *)
```

Investigation of Constraints Impact in Time Windows

Simple Association Networks

Width Feature

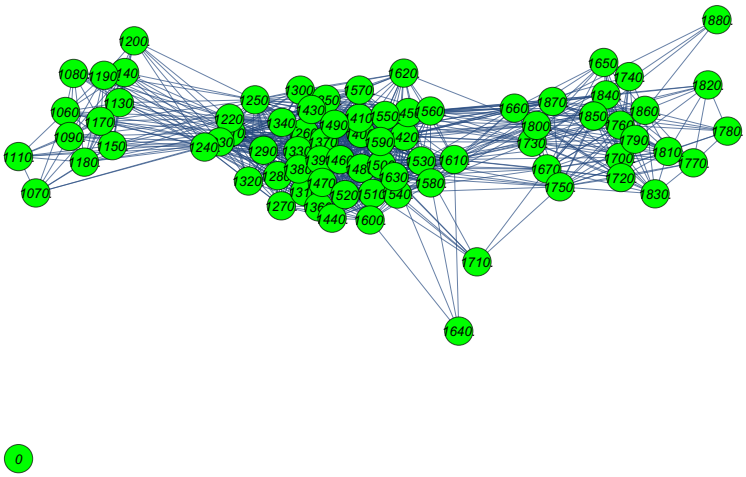
In[•]:=
```
AbsoluteTiming[widthdataintimewindows = snetworkdatasingleintimewindows[9, 10];]
```

Out[•]=
```
{3.9276, Null}
```

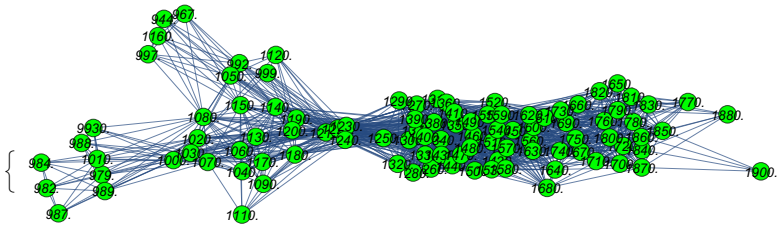
In[•]:=
```
graphsandnodenumbers = Table[snetworkgraphsinglenodes[widthdataintimewindows[[1]][[i]],
     widthdataintimewindows[[2]][[i]], 2, 7, 400, Green], {i, Range@10}];
```

In[•]:=
```
graphsandnodenumbers
```

Out[•]=

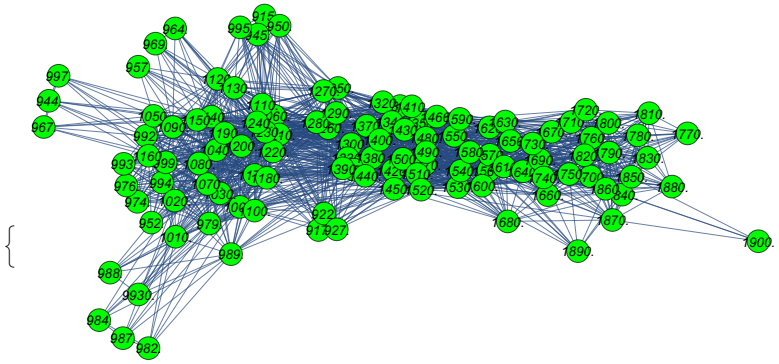


{{ , 79},



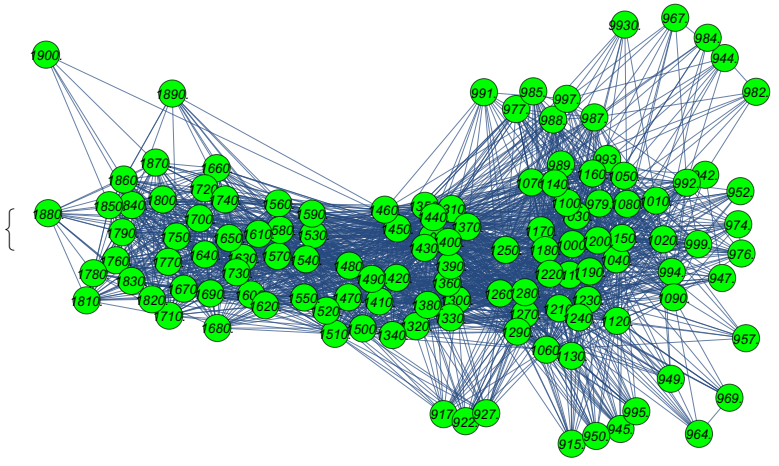
, 102},

0

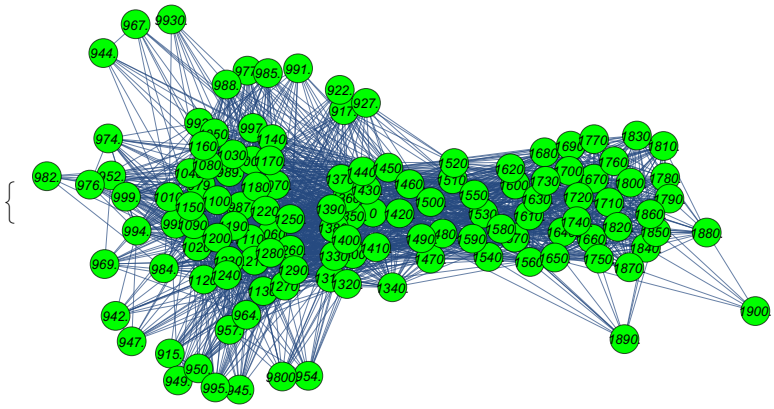


, 119},

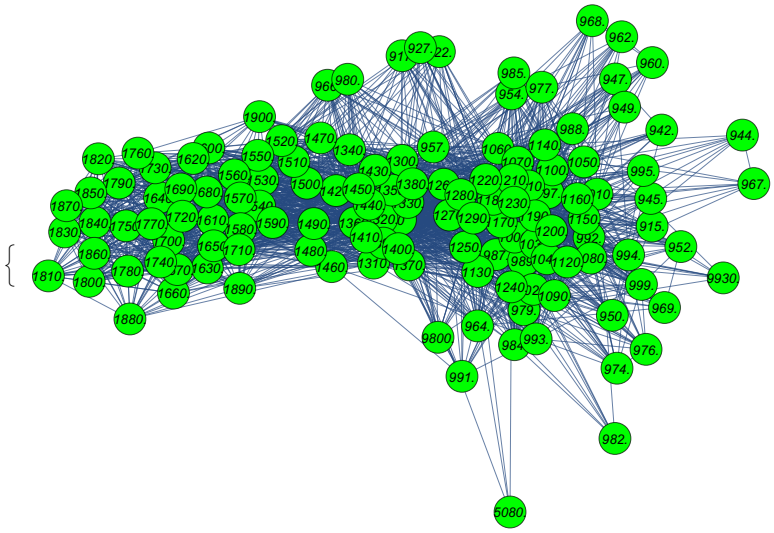
0



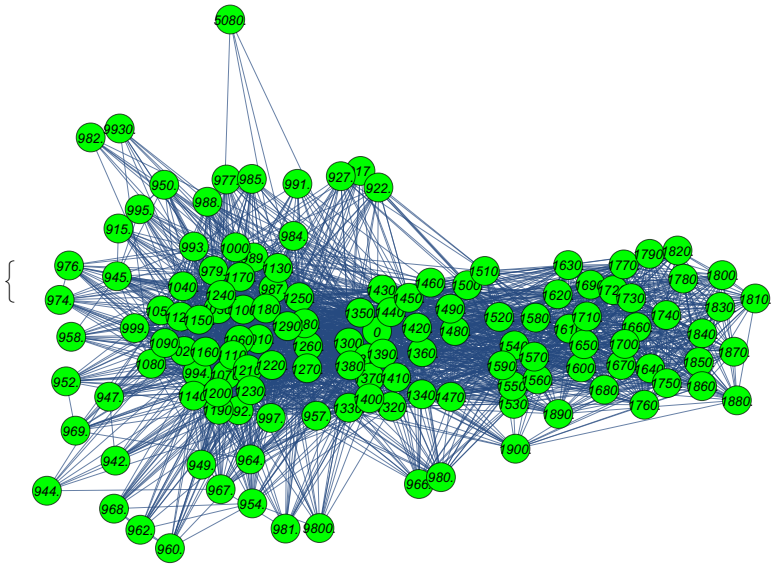
, 125},



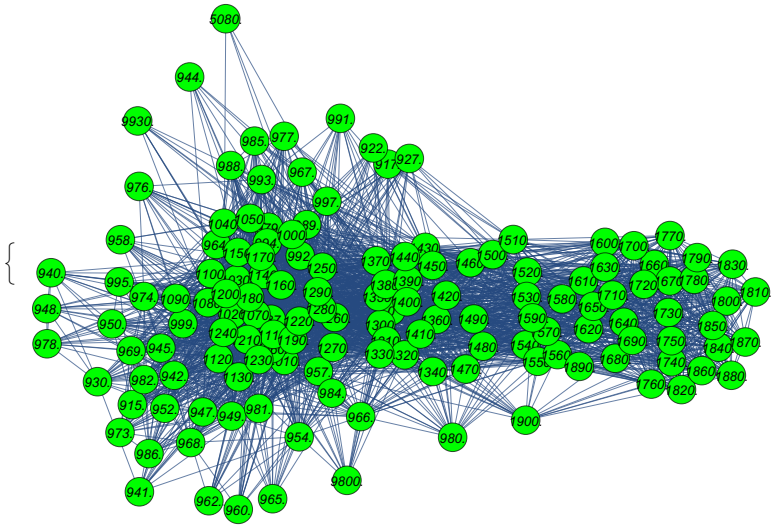
, 127},



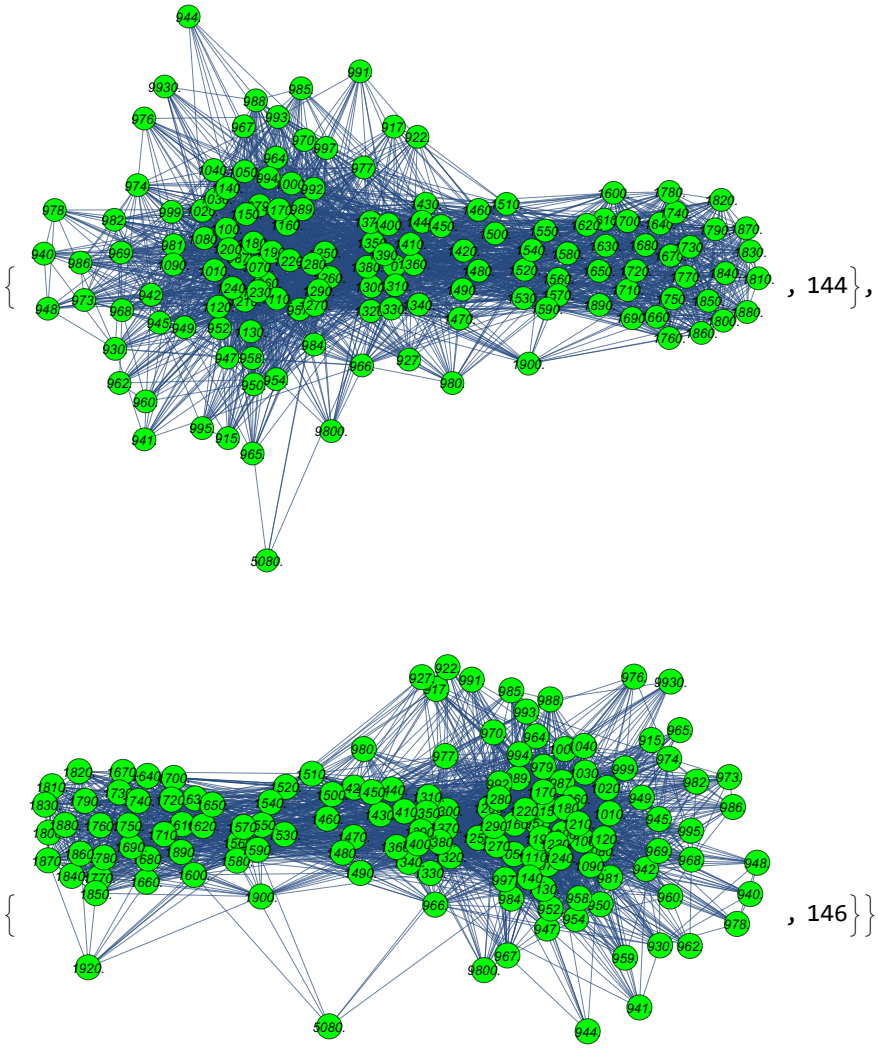
, 133},



, 135},



, 143},



In[•]:=
```
correlationvaluesthroughwindowsspearman =
  Table[correlationfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}];
correlationvaluesthroughwindowspearson =
  Table[correlationfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}];
```

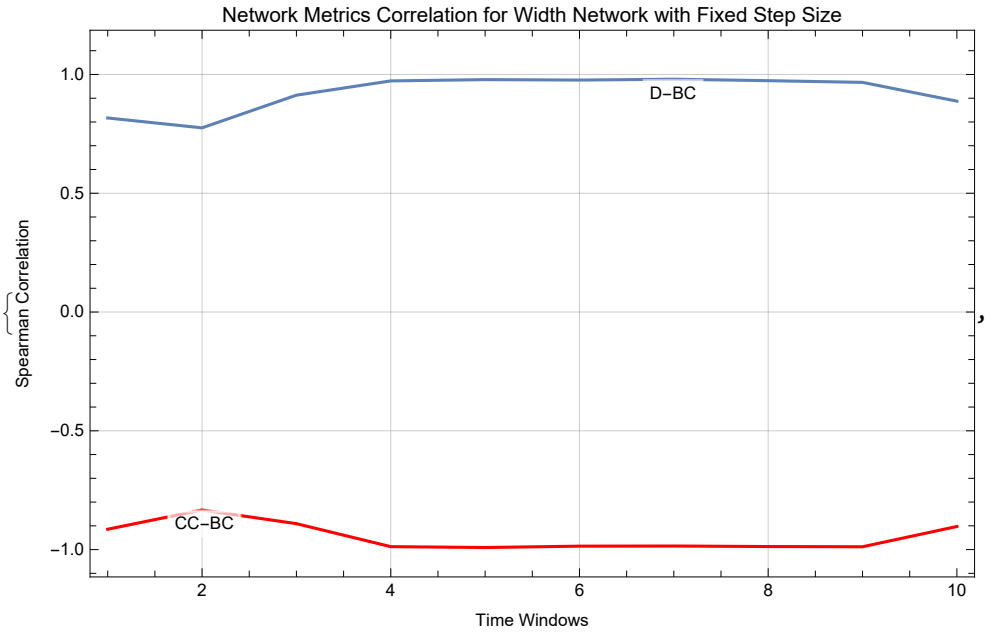
In[•]:=
```
correlationvaluesthroughwindowsspearman
correlationvaluesthroughwindowspearson
```

Out[•]=
```
{{0.816837, -0.914287}, {0.775318, -0.833272}, {0.912826, -0.890899}, {0.9729, -0.987608},
 {0.978297, -0.991312}, {0.976393, -0.985596}, {0.979992, -0.984999},
 {0.973833, -0.987195}, {0.966704, -0.988102}, {0.887562, -0.902762}}
```

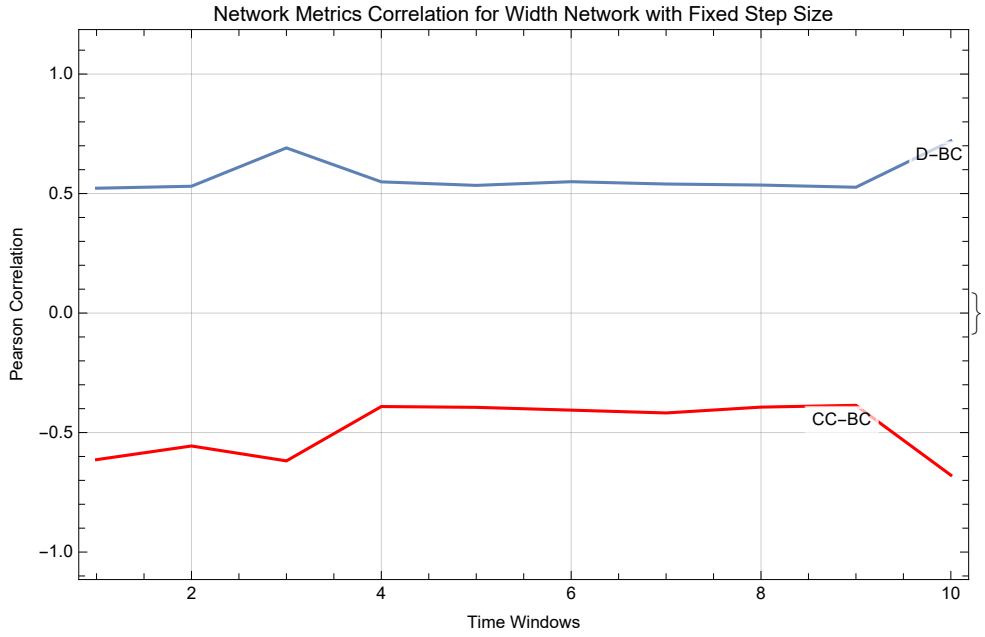
Out[•]= {{0.522385, −0.613315}, {0.530661, −0.556155}, {0.691093, −0.618492}, {0.549054, −0.3911},
{0.534222, −0.394403}, {0.549708, −0.406185}, {0.539973, −0.417934},
{0.535635, −0.393469}, {0.526522, −0.386032}, {0.720341, −0.678254}}

In[•]:=
```
{Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 1]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Spearman Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 2]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Spearman Correlation"}],
  PlotRange -> {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Width Network with Fixed Step Size"],
 Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 1]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Pearson Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 2]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Pearson Correlation"}],
  PlotRange → {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Width Network with Fixed Step Size"]}
```

Out[•]=



,



In[•]:=
```
ZscoreDeBCspearman = Transpose[{Range[1, 10],
    Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
```

Out[•]=
```
{{1, -15.3086}, {2, -27.6464}, {3, -10.1391}, {4, -0.619594}, {5, 0.370311},
 {6, -0.281378}, {7, 0.426047}, {8, -1.50236}, {9, -3.50008}, {10, -24.4219}}
```

In[•]:=
```
ZscoreCCBCspearman = Transpose[{Range[1, 10],
    Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
```

Out[•]=
```
{{1, -5.60894}, {2, -5.8892}, {3, -6.9099}, {4, -7.9931}, {5, -7.9275},
 {6, -7.91104}, {7, -8.34481}, {8, -8.37427}, {9, -7.98517}, {10, -7.71136}}
```

```
In[•]:= ZscoreDeBCpearson = Transpose[{Range[1, 10],
           Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
```

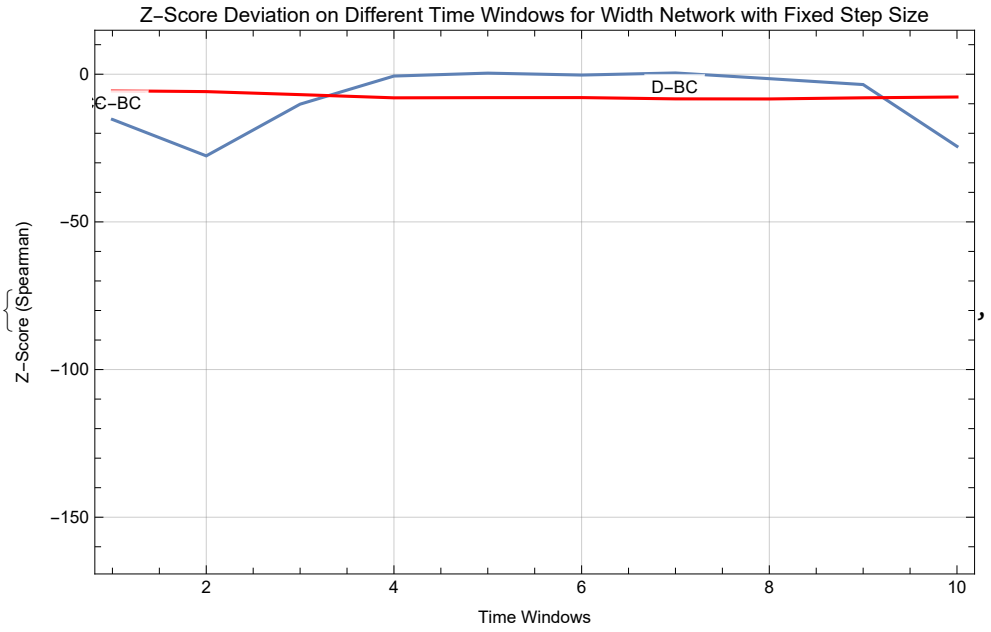
```
Out[•]= {{1, -57.9931}, {2, -74.5995}, {3, -58.4635}, {4, -113.126}, {5, -126.63},
         {6, -128.182}, {7, -131.784}, {8, -156.037}, {9, -158.978}, {10, -86.3946}}
```

```
In[•]:= ZscoreCCBCpearson = Transpose[{Range[1, 10],
           Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
```

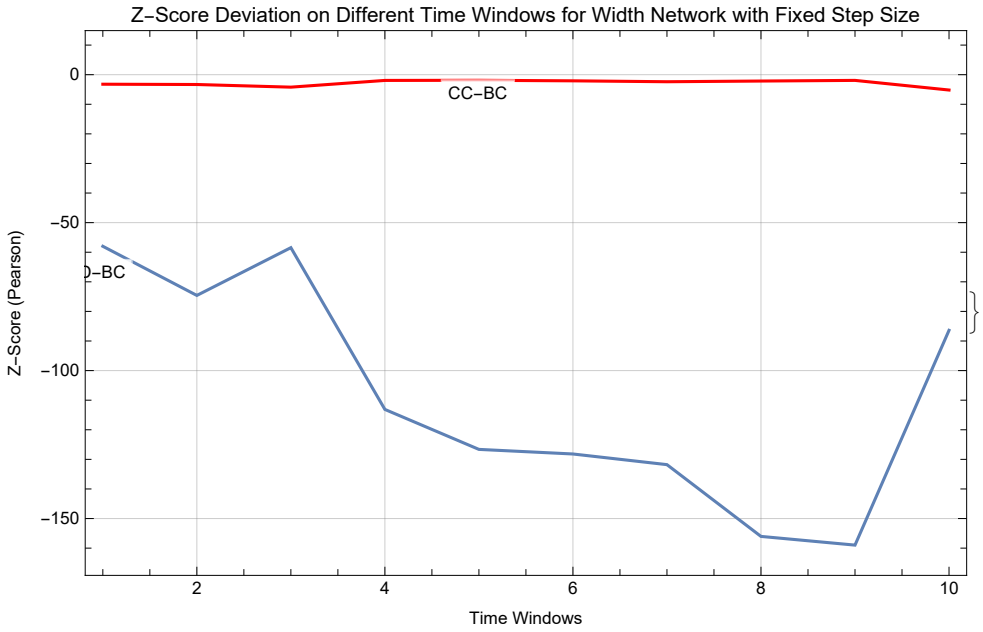
```
Out[•]= {{1, -3.22148}, {2, -3.32278}, {3, -4.21425}, {4, -1.94097}, {5, -1.89757},
         {6, -2.08029}, {7, -2.38328}, {8, -2.14969}, {9, -1.93196}, {10, -5.18526}}
```

```
In[•]:= {Show[ListPlot[ZscoreDeBCspearman, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
           Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         ListPlot[ZscoreCCBCspearman, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         PlotRange → {All, {-160, 0}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel →
          "Z-Score Deviation on Different Time Windows for Width Network with Fixed Step Size"],
        Show[ListPlot[ZscoreDeBCpearson, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
          Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         ListPlot[ZscoreCCBCpearson, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         PlotRange -> {All, {-160, 0}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel →
          "Z-Score Deviation on Different Time Windows for Width Network with Fixed Step Size"]}
```

Out[•]=



,



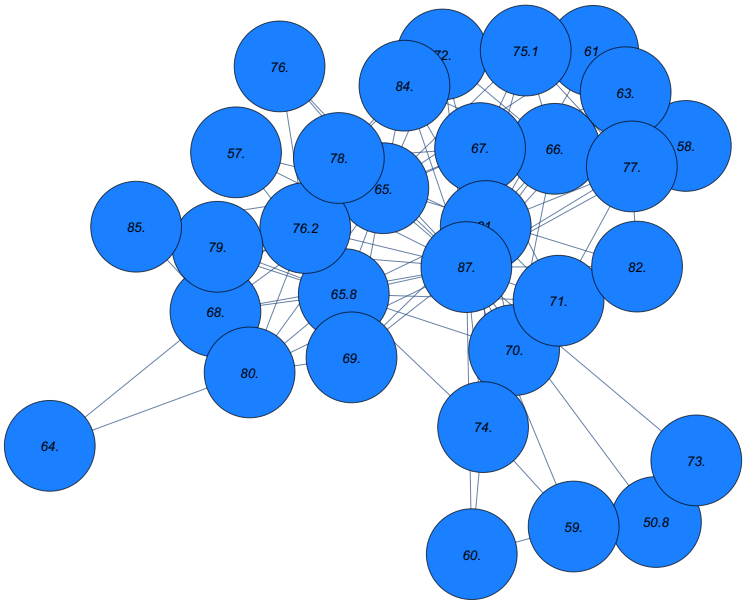
Thickness Feature

In[•]:=
```
AbsoluteTiming[thicknessdataintimewindows = snetworkdatasingleintimewindows[10, 10];]
```

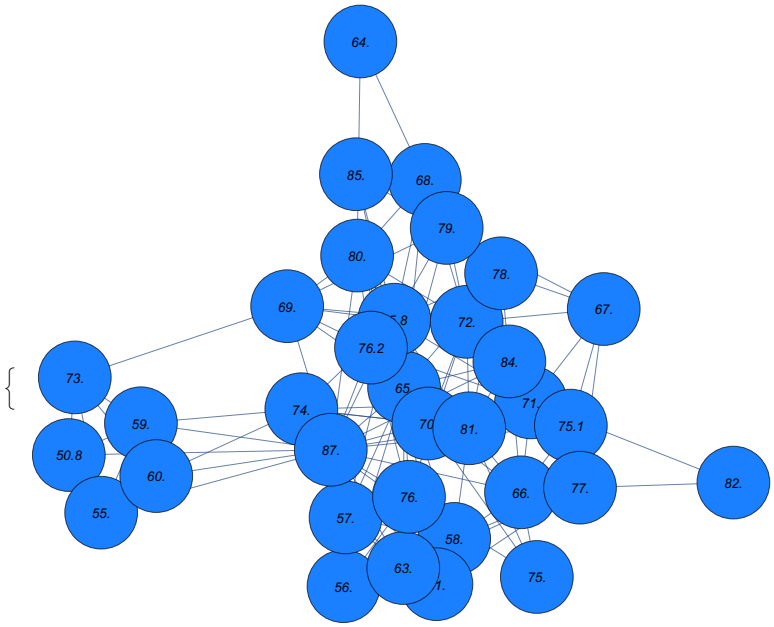
Out[•]=
```
{4.35942, Null}
```

In[•]:=
```
graphsandnodenumbers = Table[snetworkgraphsinglenodes[
    thicknessdataintimewindows[[1]][[i]], thicknessdataintimewindows[[2]][[i]],
    2, 7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@10}];
```

In[•]:=
```
graphsandnodenumbers
```

Out[ ]= {{ 
76.
84.
75.1
61.
63.
57.
78.
67.
66.
58.
77.
65.
85.
79.
76.2
87.
82.
65.8
71.
68.
70.
80.
69.
74.
64.
73.
59.
50.8
60.
, 32},


0

{ 
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68.
79.
80.
78.
69.
67.
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76.2
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73.
59.
74.
81.
75.1
50.8
87.
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76.
66.
77.
82.
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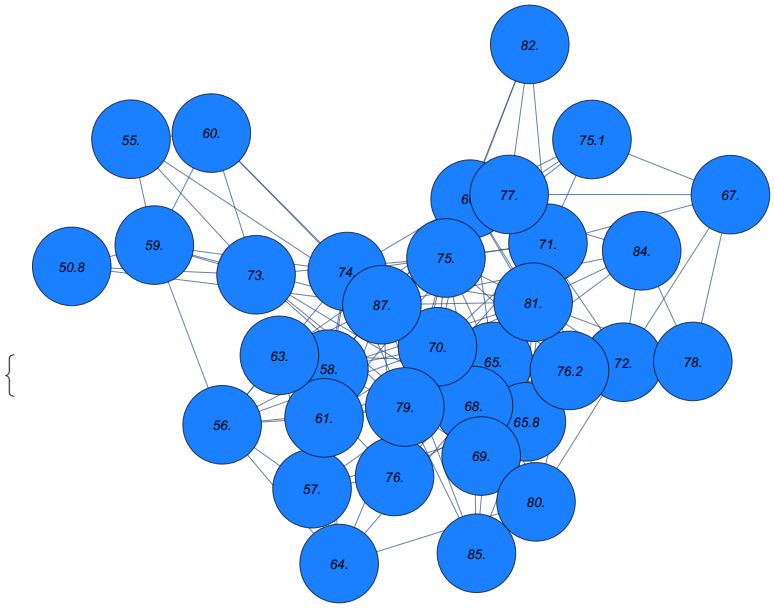
57.
58.
63.
56.
75.
, 35},


0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50.8
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75.
87.
81.
63.
70.
58.
65.
76.2
72.
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79.
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65.8
69.
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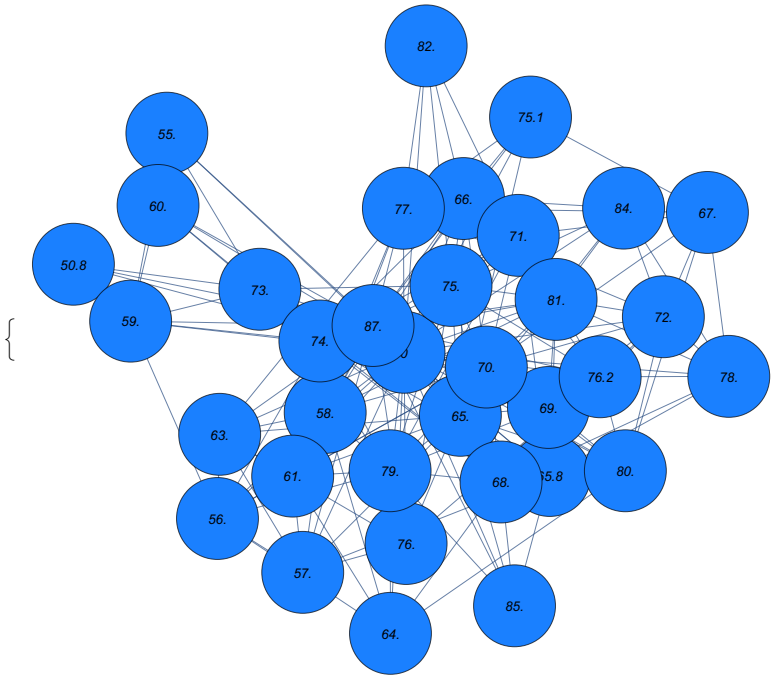
76.
80.
64.
85.

, 35},

0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67.
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81.
72.
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74.
87.
70.
76.2
78.
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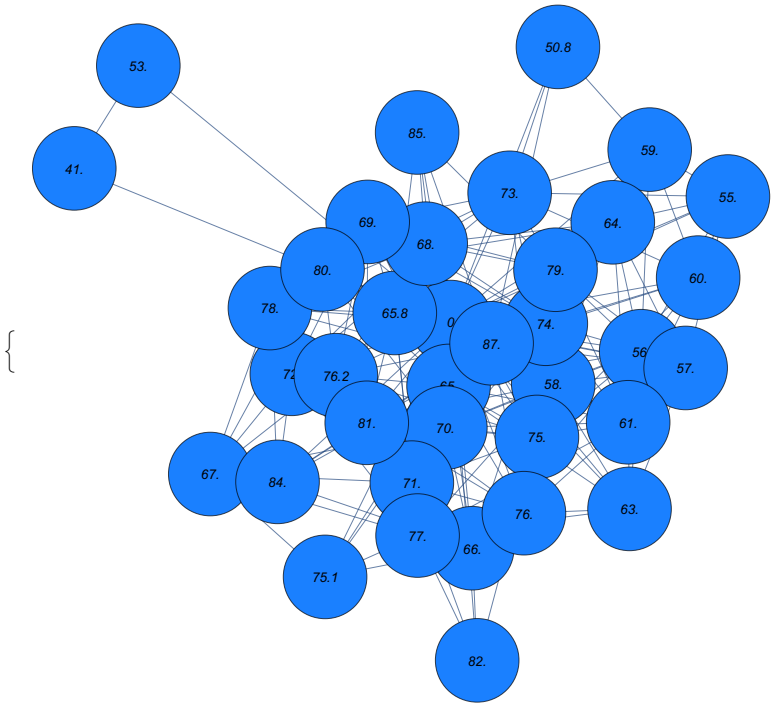
63.
61.
79.
68.
80.
56.
76.
57.
85.
64.

, 35},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41.
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69.
64.
68.
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79.
60.
78.
65.8
74.
87.
56
57.
76.2
58.
81.
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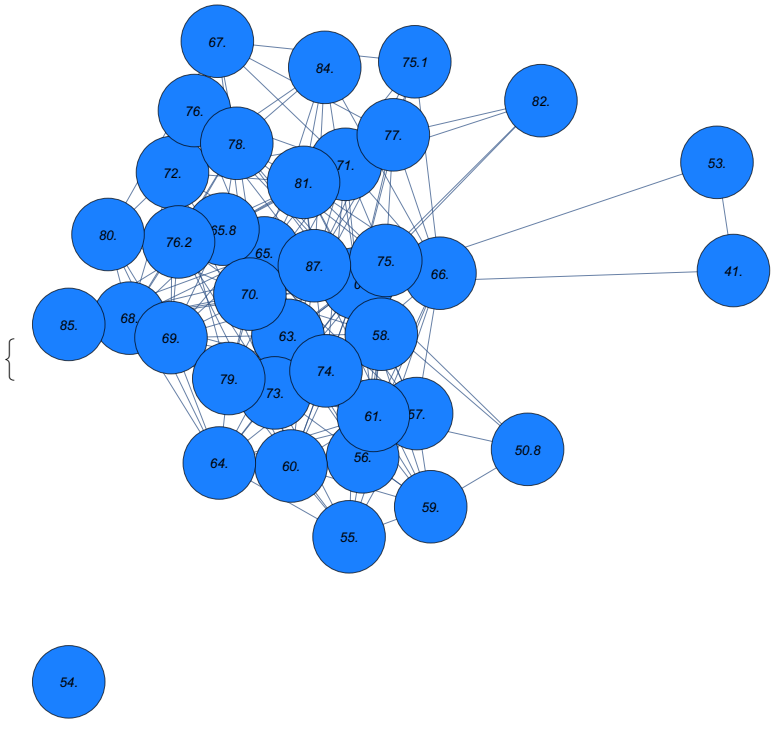
63.
77.
66.
75.1
82.

{ , 37},


67.
84.
75.1
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76.
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77.
72.
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53.
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76.2
65.8
65.
87.
75.
66.
41.
70.
85.
68.
69.
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73.
61.
57.
50.8
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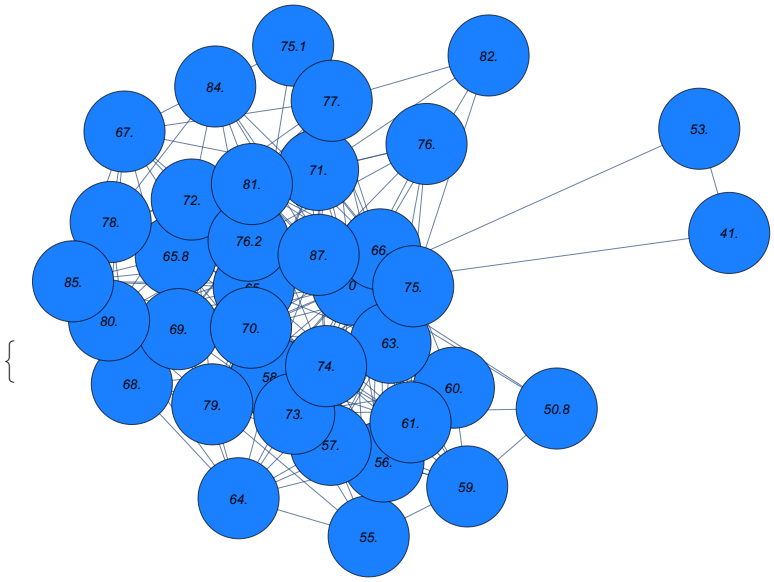
60.
56.
59.
55.
54.

{ , 38},


75.1
82.
84.
77.
67.
76.
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71.
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72.
41.
78.
76.2
65.8
87.
66.
85.
75.
80.
69.
70.
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50.8
61.
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64.
59.
55.
54.

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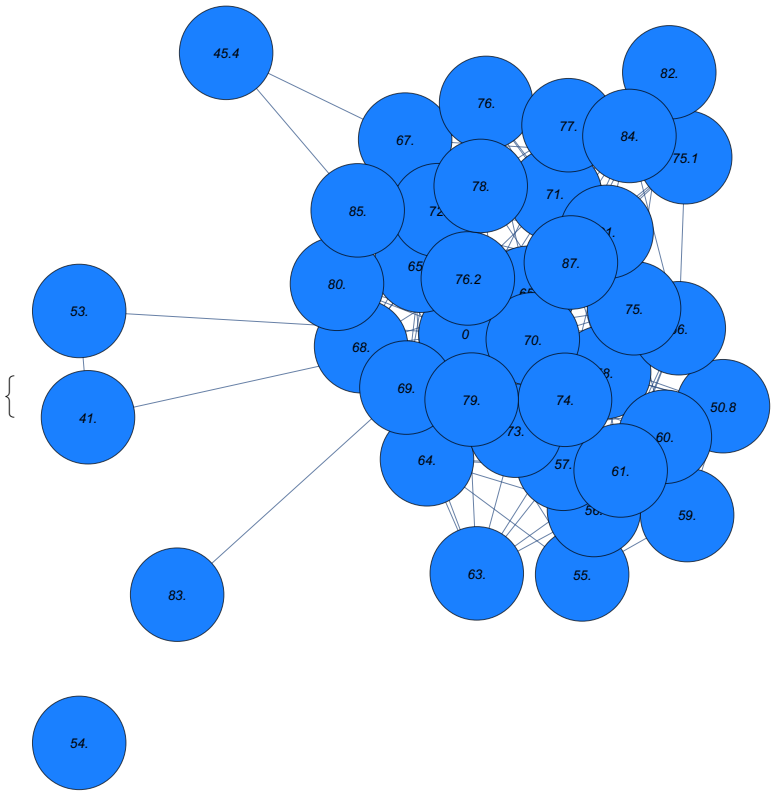
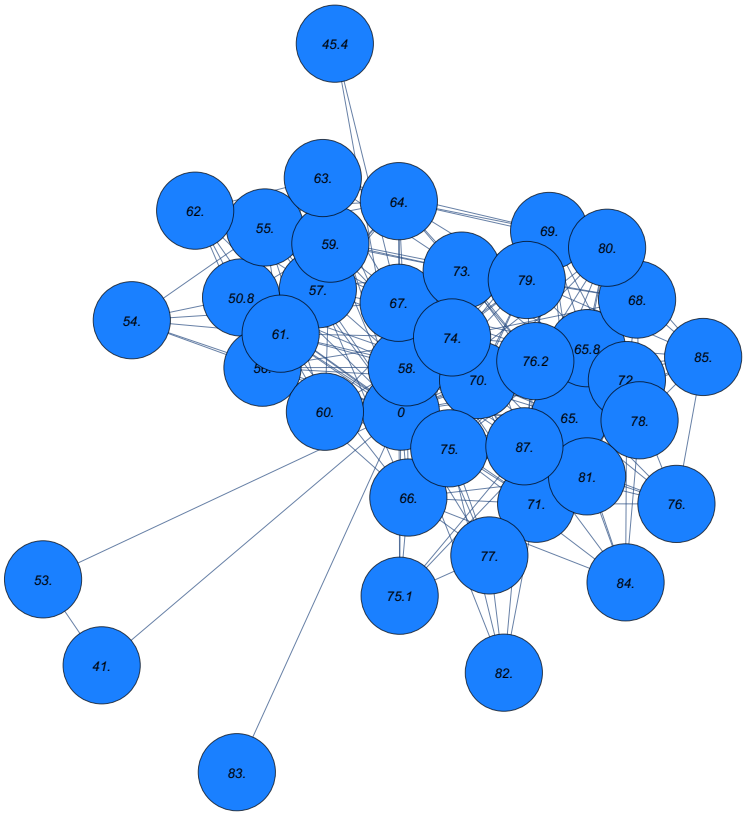
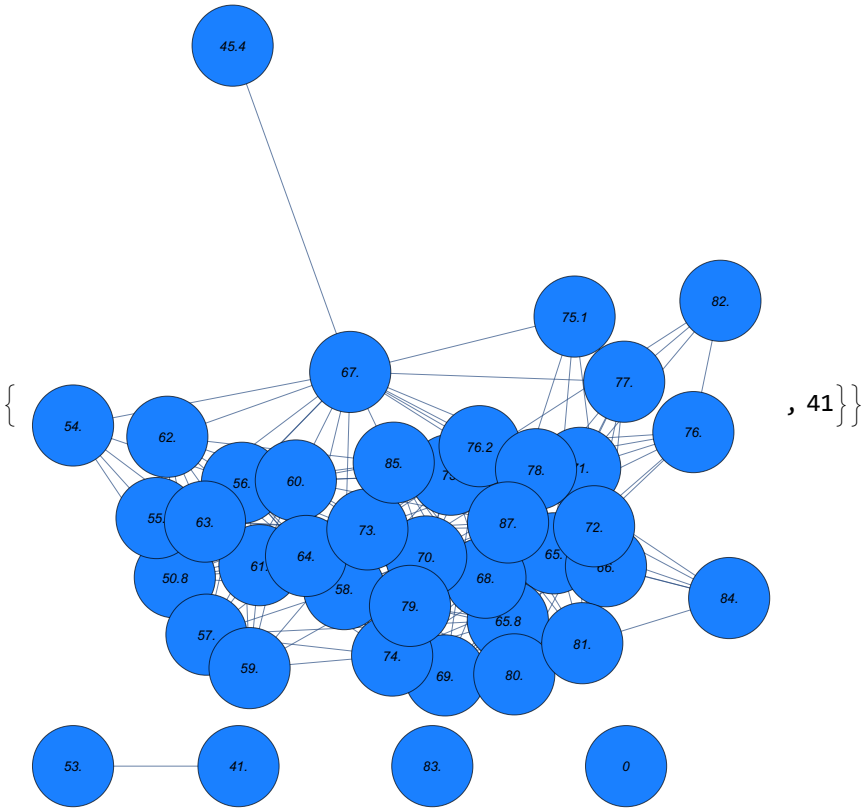

45.4
82.
76.
67.
77.
84.
75.1
78.
71.
85.
87.
80.
76.2
53.
75.
70.
68.
69.
79.
74.
50.8
41.
60.
64.
57.
61.
59.
63.
55.
83.
54.

, 40},

{ 
45.4
63.
64.
62.
55.
59.
69.
80.
73.
79.
50.8
57.
67.
68.
54.
61.
74.
65.8
85.
58.
76.2
72
70.
60.
0
65.
78.
75.
87.
81.
66.
71.
76.
53.
77.
84.
75.1
41.
82.
83.
, 41},



In[ ]:=
```
correlationvaluesthroughwindowsspearman =
  Table[correlationfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}];
correlationvaluesthroughwindowspearson =
  Table[correlationfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}];
```

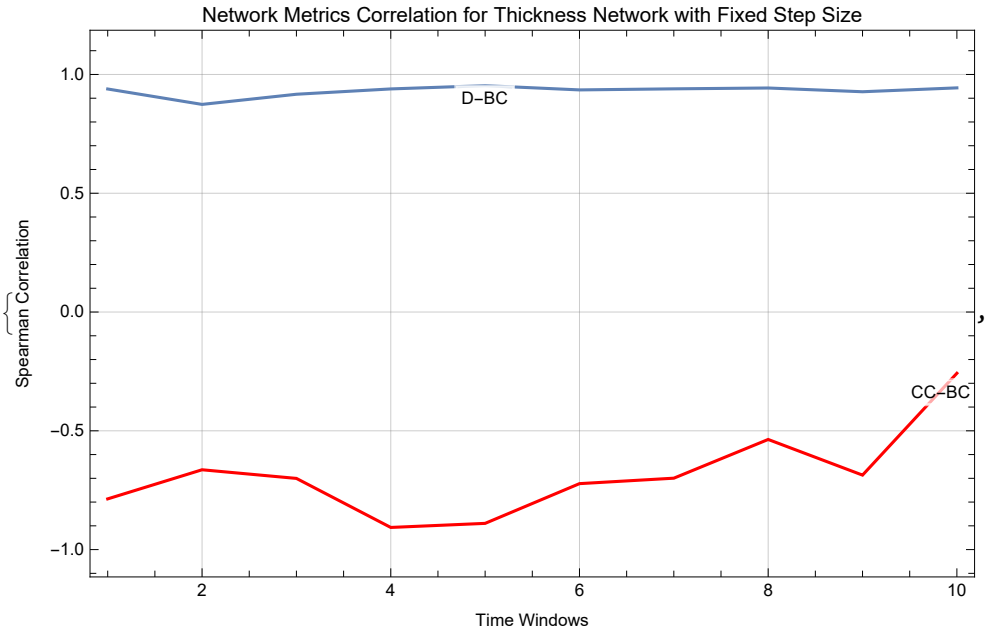
In[ ]:=
```
correlationvaluesthroughwindowsspearman
correlationvaluesthroughwindowspearson
```

Out[ ]=
```
{{0.938808, -0.78658}, {0.873987, -0.663998}, {0.916719, -0.7004}, {0.93912, -0.906811},
 {0.95285, -0.889666}, {0.935017, -0.722435}, {0.939483, -0.699436},
 {0.943043, -0.53645}, {0.927237, -0.686511}, {0.94354, -0.25778}}
```

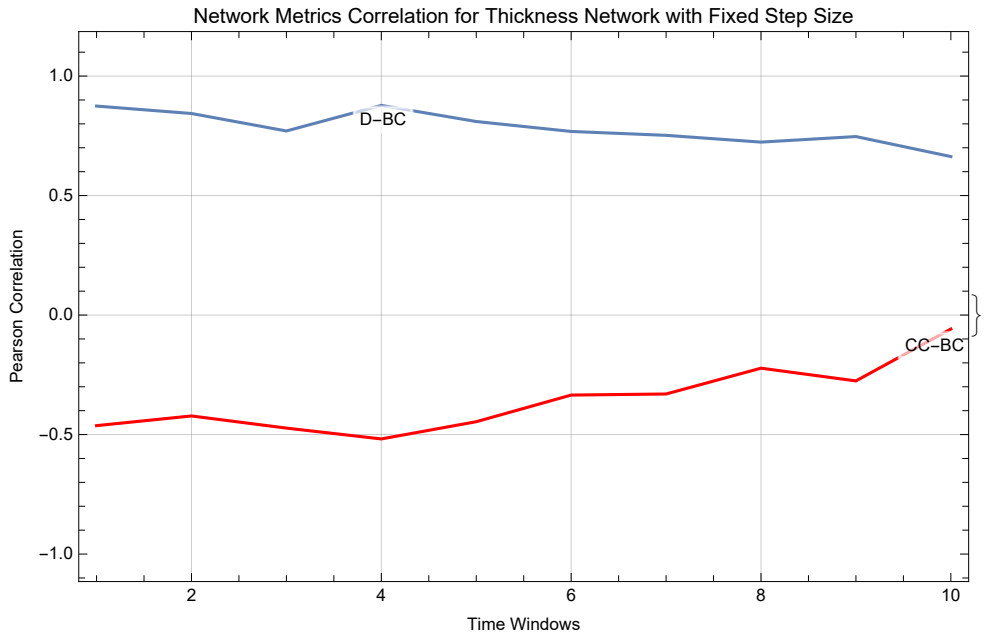
Out[ ]=
```
{{0.874484, -0.462631}, {0.843387, -0.422115},
 {0.770286, -0.472945}, {0.877292, -0.518271}, {0.809918, -0.446188},
 {0.768257, -0.334724}, {0.752032, -0.330238}, {0.723693, -0.22225},
 {0.746908, -0.275495}, {0.663251, -0.0583977}}
```

In[•]:=
```
{Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 1]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Spearman Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 2]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Spearman Correlation"}],
  PlotRange -> {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Thickness Network with Fixed Step Size"],
 Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 1]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Pearson Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 2]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Pearson Correlation"}],
  PlotRange → {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Thickness Network with Fixed Step Size"]}
```

Out[•]=



,



In[•]:=
```
ZscoreDeBCspearman = Transpose[{Range[1, 10],
    Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
```

Out[•]=
```
{{1, 0.616193}, {2, -1.28733}, {3, -0.104282}, {4, 0.565508}, {5, 1.07189},
 {6, 0.367045}, {7, 0.478779}, {8, 0.559077}, {9, -0.0694945}, {10, 0.590463}}
```

In[•]:=
```
ZscoreCCBCspearman = Transpose[{Range[1, 10],
    Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
```

Out[•]=
```
{{1, -2.93182}, {2, -2.53266}, {3, -2.40751}, {4, -3.46177}, {5, -3.3986},
 {6, -2.49543}, {7, -2.42854}, {8, -1.50394}, {9, -2.47674}, {10, 0.109912}}
```

```
In[•]:= ZscoreDeBCpearson = Transpose[{Range[1, 10],
          Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
```

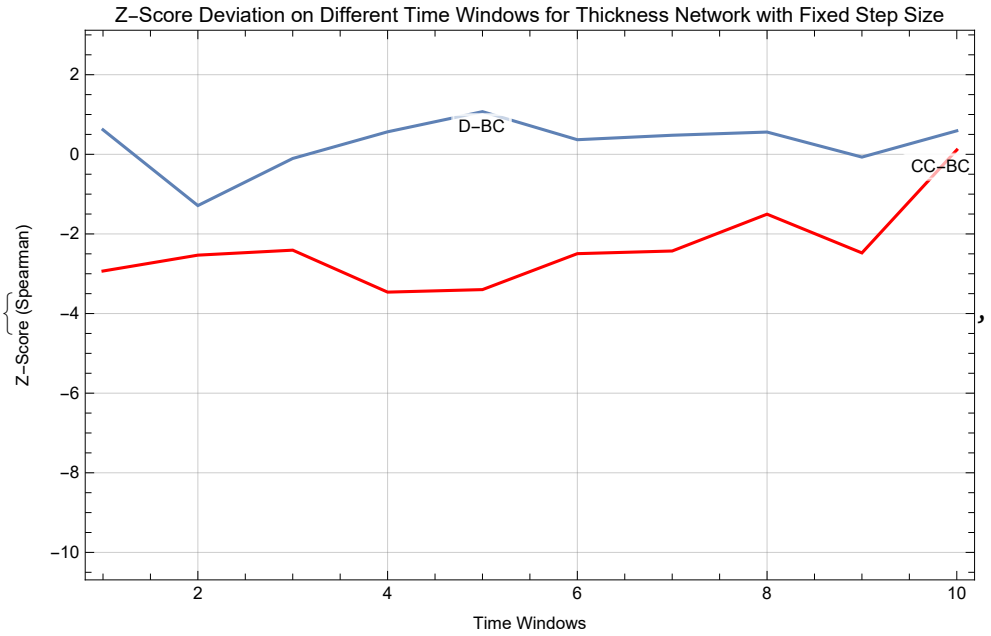
```
Out[•]= {{1, -0.510046}, {2, -1.66848}, {3, -4.13987}, {4, -1.43423}, {5, -4.2623},
         {6, -5.6921}, {7, -6.62055}, {8, -8.47877}, {9, -7.56998}, {10, -9.23535}}
```

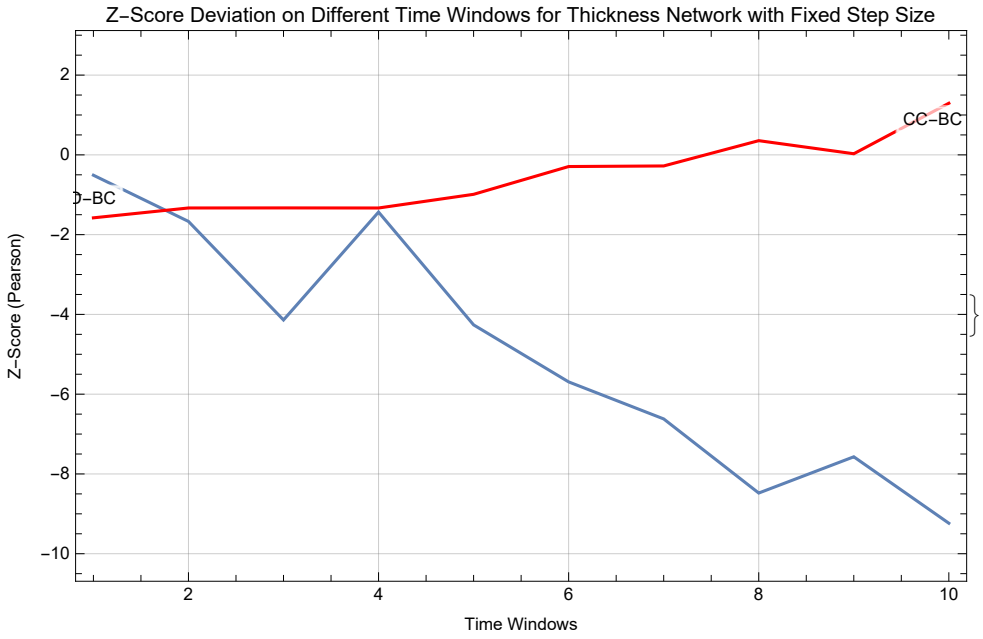
```
In[•]:= ZscoreCCBCpearson = Transpose[{Range[1, 10],
          Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
```

```
Out[•]= {{1, -1.57851}, {2, -1.33152}, {3, -1.32984}, {4, -1.33201}, {5, -0.9891},
         {6, -0.2925}, {7, -0.278031}, {8, 0.356254}, {9, 0.0282377}, {10, 1.29413}}
```

```
In[•]:= {Show[ListPlot[ZscoreDeBCspearman, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
          Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         ListPlot[ZscoreCCBCspearman, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         PlotRange → {All, {-10, 2}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel → "Z-Score Deviation on Different
            Time Windows for Thickness Network with Fixed Step Size"],
        Show[ListPlot[ZscoreDeBCpearson, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
          Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         ListPlot[ZscoreCCBCpearson, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         PlotRange -> {All, {-10, 2}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel → "Z-Score Deviation on Different
            Time Windows for Thickness Network with Fixed Step Size"]}
```

Out[•]=





Fixed Step Size Networks

Width Feature

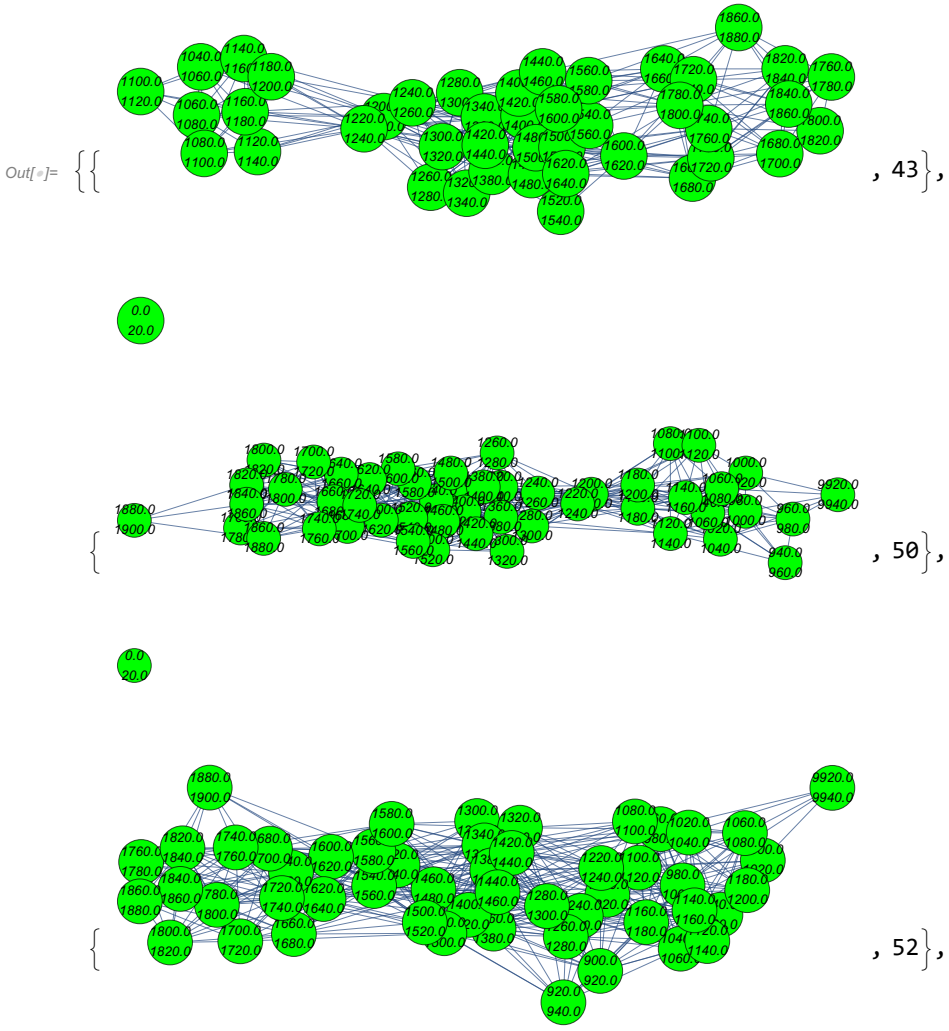
In[•]:=
```
AbsoluteTiming[
 widthdataintimewindowsFixedstep = snetworkdatabinnedintimewindows[9, 20, 10];]
```

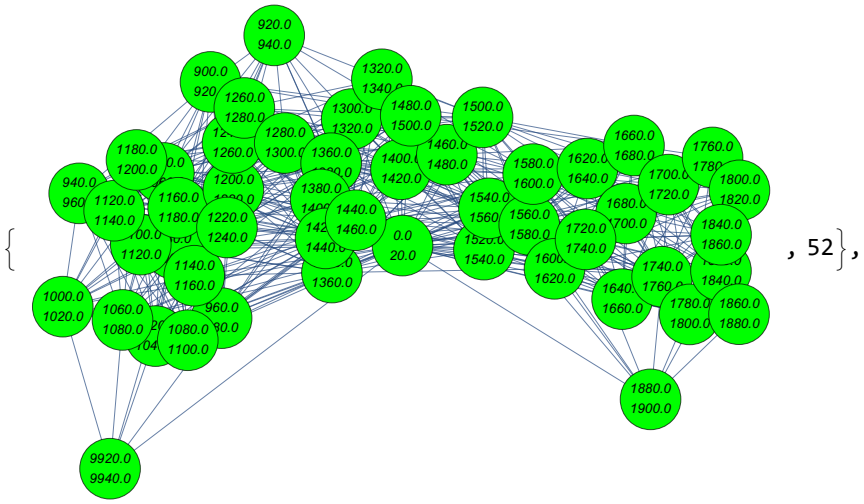
Out[•]= {939.348, Null}

In[•]:=
```
graphsandnodenumbers = Table[snetworkgraph[widthdataintimewindowsFixedstep[[1]][[i]],
    widthdataintimewindowsFixedstep[[2]][[i]], 2, 7, 400, Green], {i, Range@10}];
```

In[ ]:= **graphsandnodenumbers**

Out[ ]=

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940.0
900.0
920.0
1320.0
1340.0
1260.0
1280.0
1480.0
1500.0
1500.0
1520.0
1660.0
1680.0
1760.0
1780.0
1180.0
1200.0
1460.0
1480.0
1580.0
1600.0
1620.0
1640.0
1700.0
1720.0
1800.0
1820.0
940.0
960.0
1120.0
1140.0
1160.0
1180.0
1200.0
1220.0
1240.0
1380.0
1440.0
1460.0
1540.0
1560.0
1560.0
1580.0
1680.0
1720.0
1740.0
1840.0
1860.0
0.0
20.0
1000.0
1020.0
1060.0
1080.0
1080.0
1100.0
1140.0
1160.0
1360.0
1540.0
1600.0
1620.0
1640.0
1660.0
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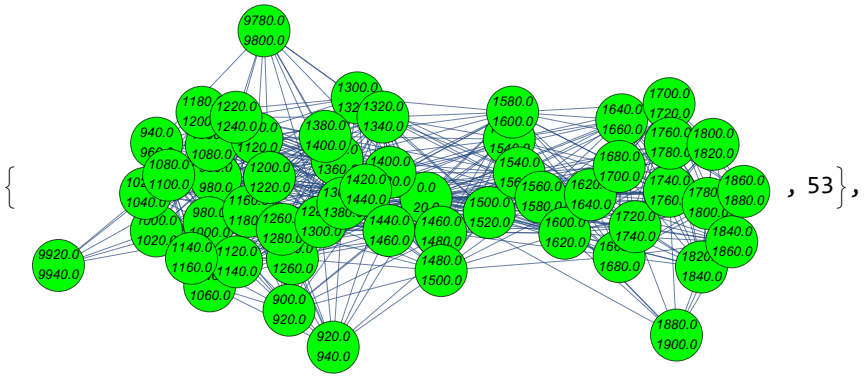
1880.0
1900.0
9920.0
9940.0

, 52},


9780.0
9800.0
1300.0
1320.0
1340.0
1580.0
1600.0
1700.0
1720.0
1640.0
1660.0
1760.0
1780.0
1800.0
1820.0
1180.0
1200.0
1220.0
1240.0
1380.0
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1420.0
1440.0
1540.0
1560.0
1620.0
1640.0
1680.0
1700.0
1740.0
1760.0
1780.0
1800.0
1860.0
1880.0
940.0
960.0
1080.0
1100.0
1120.0
1200.0
1220.0
1360.0
0.0
20.0
1040.0
1000.0
1020.0
980.0
1160.0
1180.0
1260.0
1280.0
1300.0
1380.0
1400.0
1440.0
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1500.0
1520.0
1600.0
1620.0
1720.0
1740.0
1760.0
1820.0
1840.0
1860.0
9920.0
9940.0
1140.0
1160.0
1120.0
1140.0
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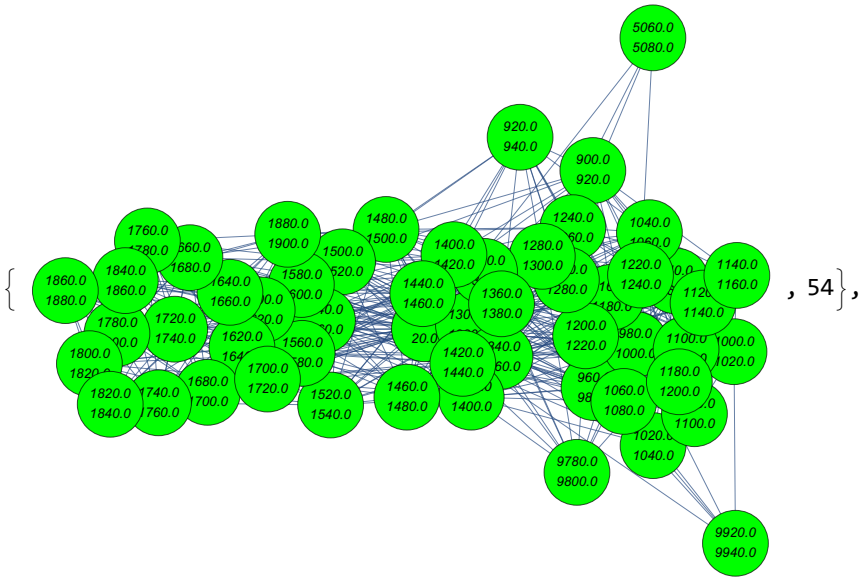
920.0
940.0
1880.0
1900.0

, 53},


5060.0
5080.0
920.0
940.0
900.0
920.0
1760.0
1880.0
1900.0
1480.0
1500.0
1240.0
1040.0
1860.0
1880.0
1840.0
1860.0
1500.0
1400.0
1420.0
1280.0
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1460.0
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1800.0
1700.0
1720.0
1420.0
1440.0
1180.0
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1820.0
1740.0
1760.0
1680.0
1700.0
1520.0
1540.0
1460.0
1480.0
1400.0
1060.0
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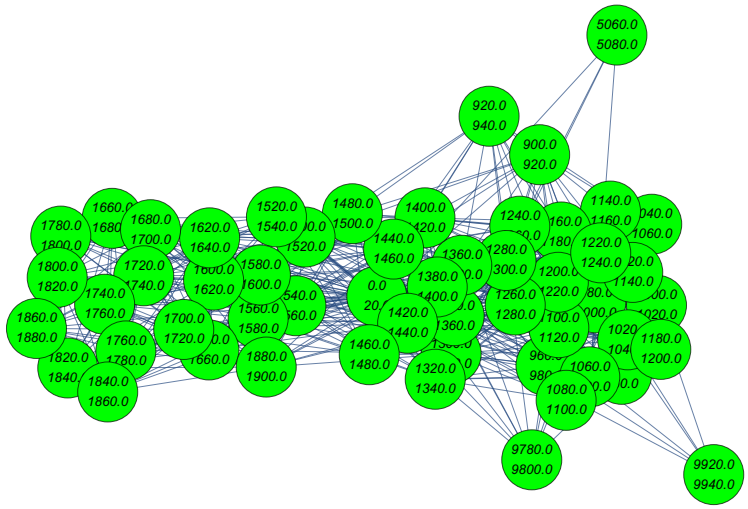
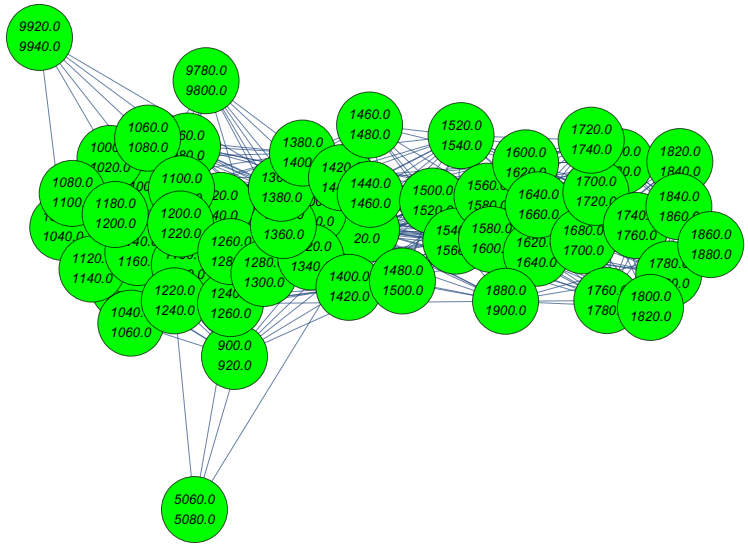
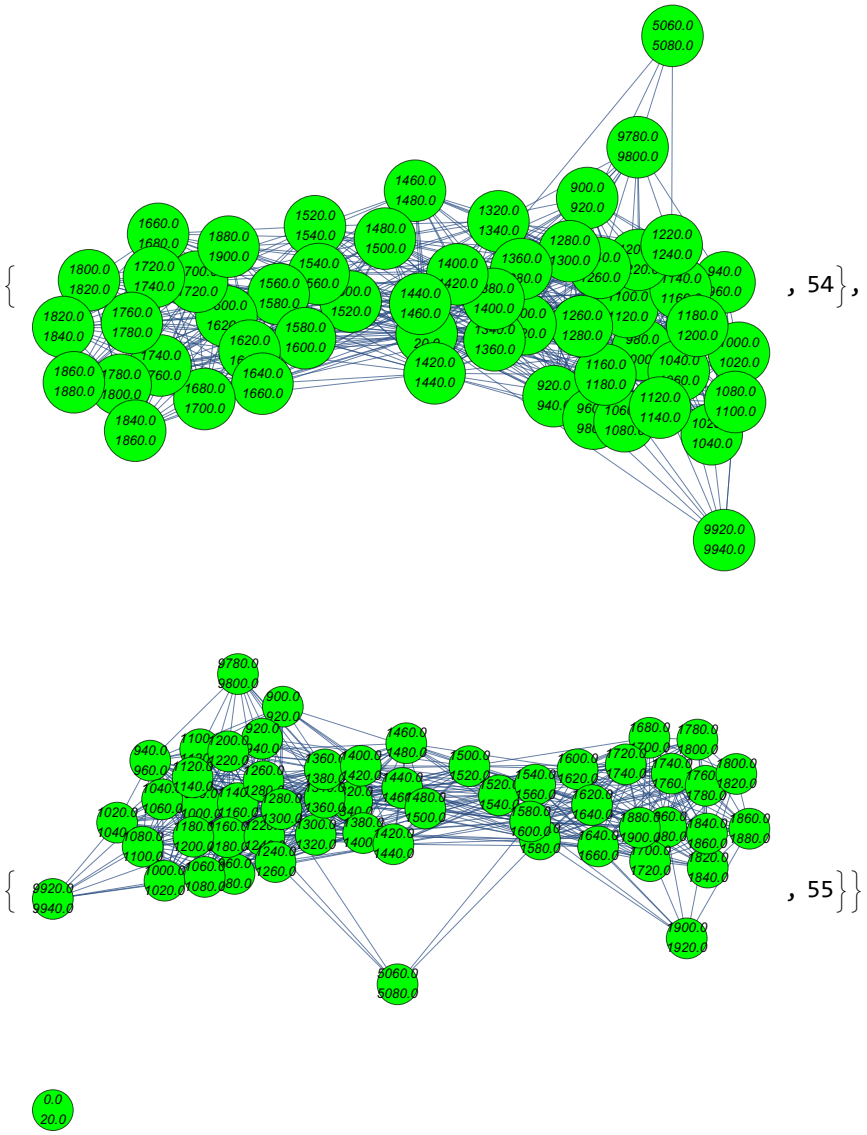
1100.0
1020.0
1040.0
9780.0
9800.0
9920.0
9940.0

, 54},

{  , 54},

{  , 54},



In[•]:=
```
correlationvaluesthroughwindowsspearman =
  Table[correlationfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}];
correlationvaluesthroughwindowspearson =
  Table[correlationfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}];
```

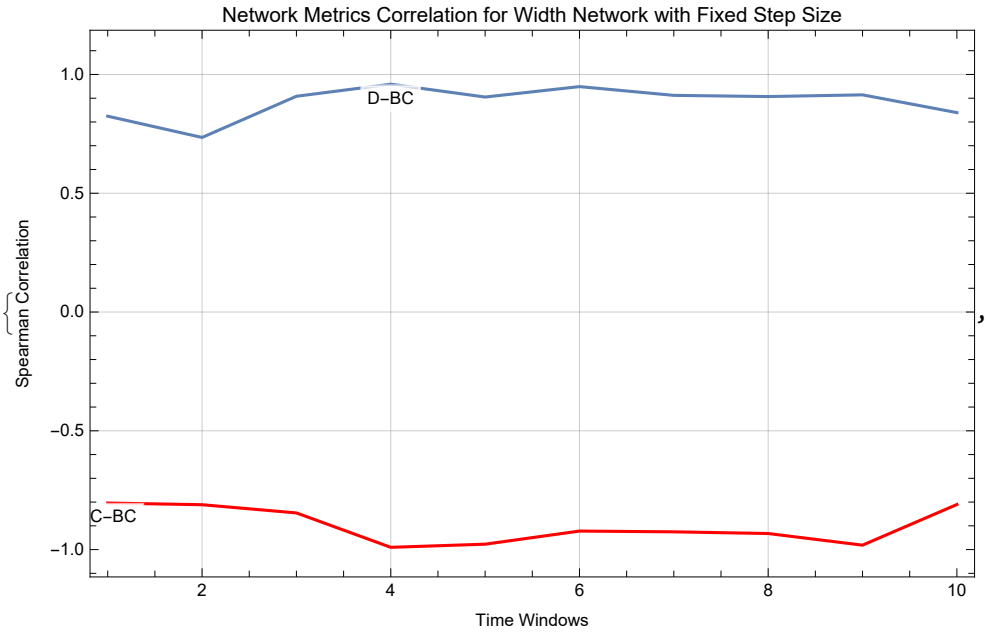
In[•]:=
```
correlationvaluesthroughwindowsspearman
correlationvaluesthroughwindowspearson
```

Out[•]=
```
{{0.82433, -0.804068}, {0.734855, -0.811107}, {0.908269, -0.845656},
 {0.959018, -0.990457}, {0.904981, -0.977276}, {0.948857, -0.922007},
 {0.912036, -0.92532}, {0.906995, -0.932347}, {0.914195, -0.981357}, {0.839404, -0.81029}}
```

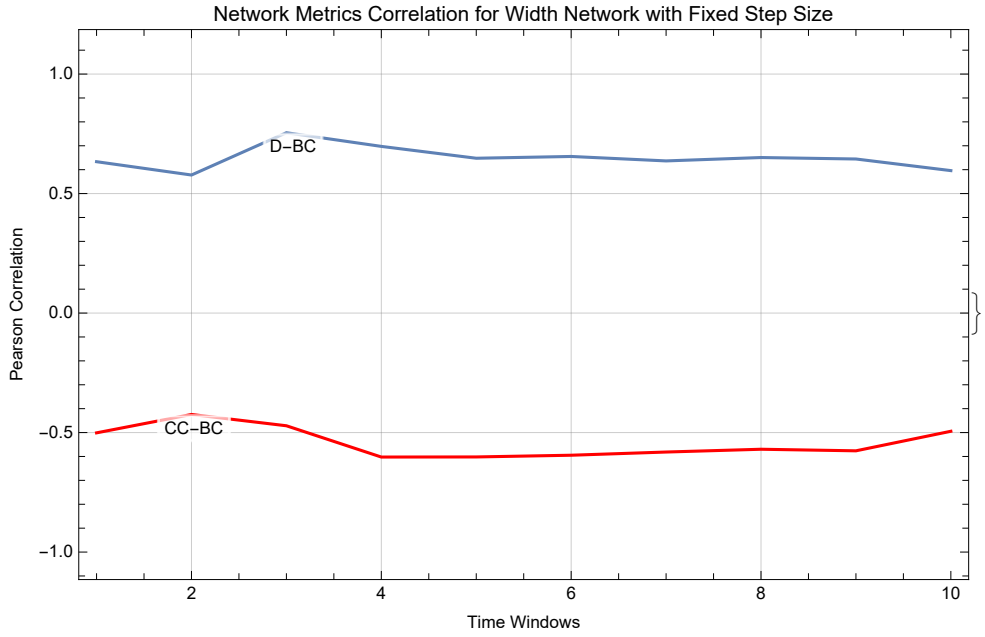
Out[•]=
```
{{0.633363, -0.501172}, {0.577619, -0.424247},
 {0.754601, -0.471542}, {0.697417, -0.602426},
 {0.647809, -0.601992}, {0.655278, -0.594798}, {0.636646, -0.581435},
 {0.650767, -0.56981}, {0.644673, -0.576368}, {0.596069, -0.494557}}
```

In[•]:=
```
{Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 1]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Spearman Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 2]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Spearman Correlation"}],
  PlotRange -> {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Width Network with Fixed Step Size"],
 Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 1]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Pearson Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 2]], {j, 1, 10}]}],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Pearson Correlation"}],
  PlotRange → {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Width Network with Fixed Step Size"]}
```

Out[•]=



,



In[•]:=
```
ZscoreDeBCspearman = Transpose[{Range[1, 10],
    Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
```

Out[•]=
```
{{1, -5.1755}, {2, -11.6583}, {3, -2.47415}, {4, 0.543807}, {5, -3.0229},
 {6, -0.266199}, {7, -2.79112}, {8, -3.14454}, {9, -2.76298}, {10, -7.74058}}
```

In[•]:=
```
ZscoreCCBCspearman = Transpose[{Range[1, 10],
    Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
```

Out[•]=
```
{{1, -3.10541}, {2, -3.49844}, {3, -3.74481}, {4, -4.40348}, {5, -4.34677},
 {6, -4.13687}, {7, -4.03405}, {8, -4.18468}, {9, -4.52992}, {10, -3.36863}}
```

```
In[•]:= ZscoreDeBCpearson = Transpose[{Range[1, 10],
          Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
```

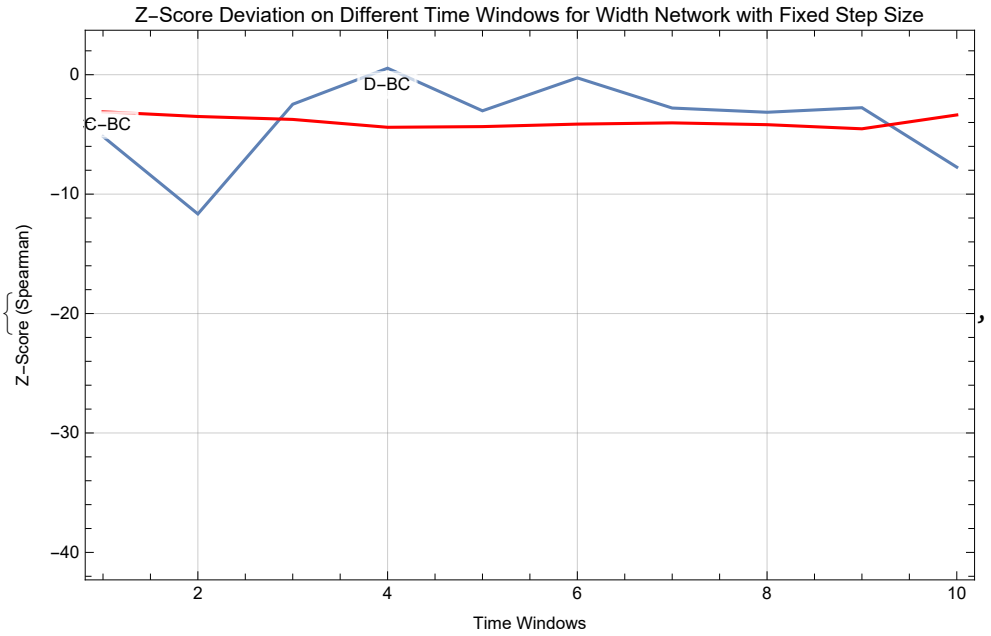
```
Out[•]= {{1, -16.9464}, {2, -23.8082}, {3, -14.4413}, {4, -21.4366}, {5, -25.8088},
         {6, -27.1513}, {7, -29.5267}, {8, -27.1861}, {9, -29.4036}, {10, -31.3332}}
```

```
In[•]:= ZscoreCCBCpearson = Transpose[{Range[1, 10],
          Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
```

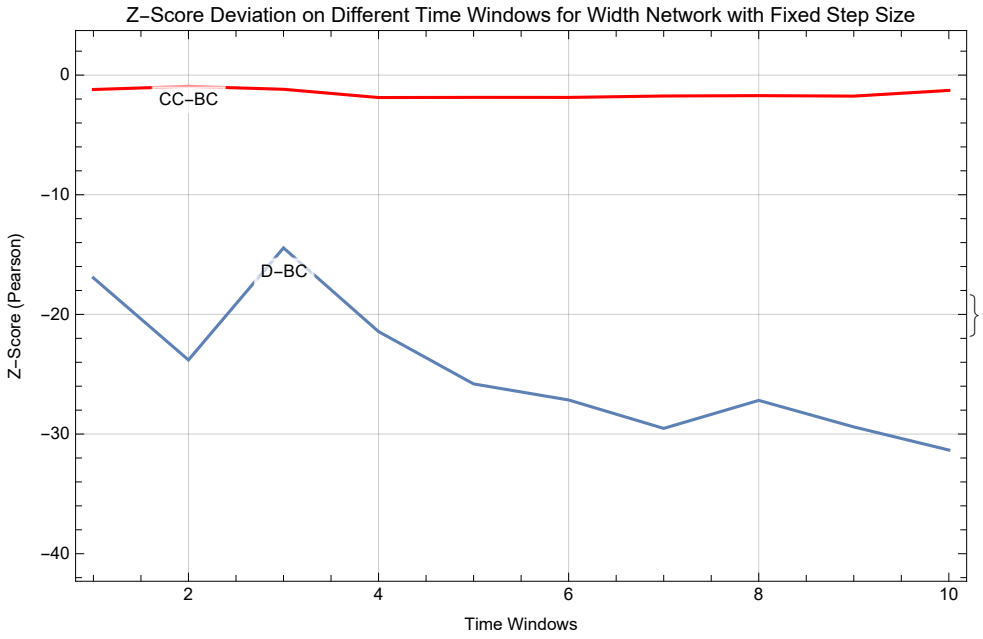
```
Out[•]= {{1, -1.20444}, {2, -0.944433}, {3, -1.1856}, {4, -1.87577}, {5, -1.86207},
         {6, -1.86466}, {7, -1.74752}, {8, -1.71597}, {9, -1.75729}, {10, -1.28099}}
```

```
In[•]:= {Show[ListPlot[ZscoreDeBCspearman, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
          Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         ListPlot[ZscoreCCBCspearman, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         PlotRange → {All, {-40, 0}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel →
          "Z-Score Deviation on Different Time Windows for Width Network with Fixed Step Size"],
        Show[ListPlot[ZscoreDeBCpearson, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
          Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         ListPlot[ZscoreCCBCpearson, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         PlotRange -> {All, {-40, 0}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel →
          "Z-Score Deviation on Different Time Windows for Width Network with Fixed Step Size"]}
```

Out[•]=



,



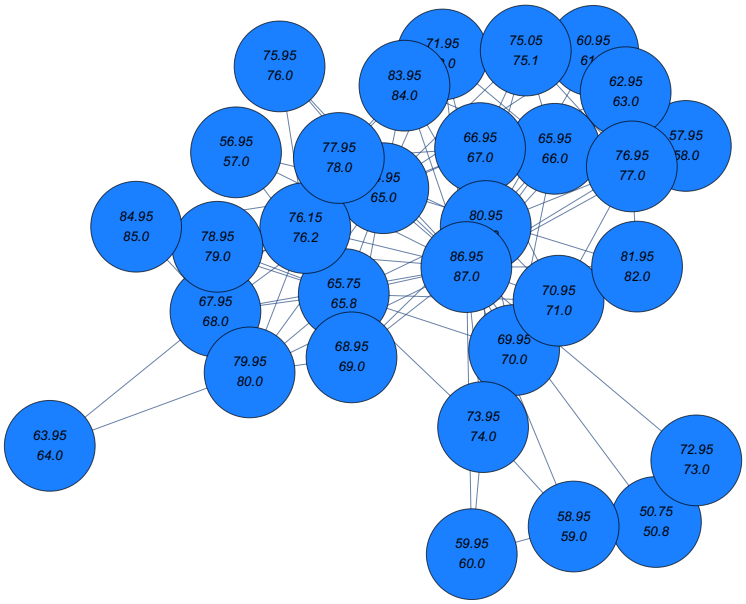
Thickness Feature

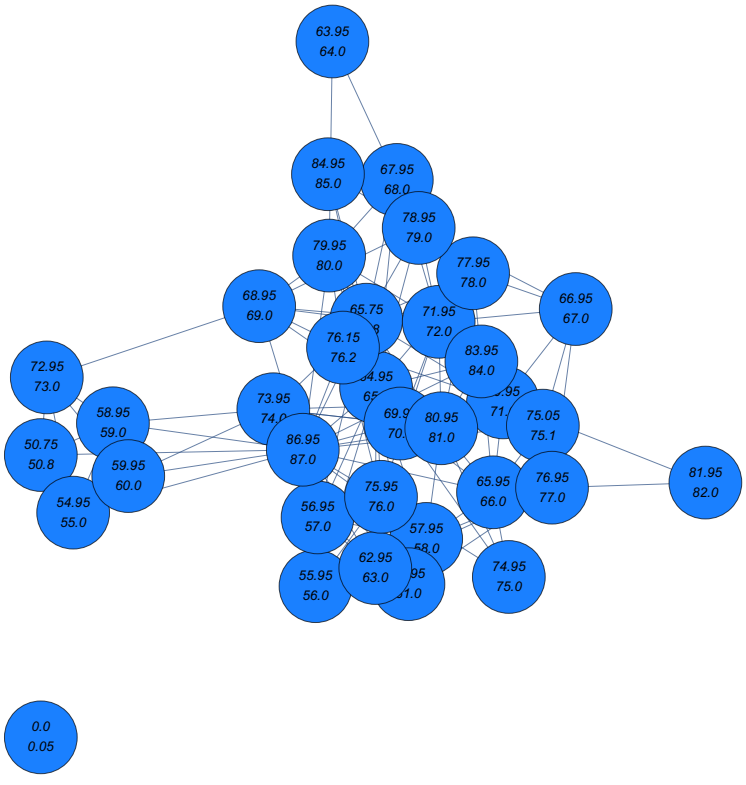
In[•]:=
```
AbsoluteTiming[
 thicknessdataintimewindowsFixedstep = snetworkdatabinnedintimewindows[10, 0.05, 10];]
```

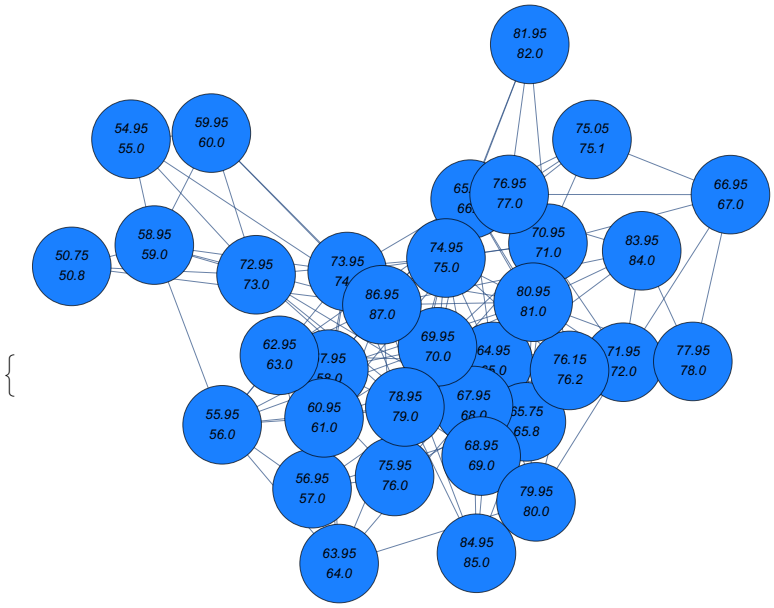
Out[•]= $Aborted

In[•]:=
```
graphsandnodenumbers = Table[snetworkgraph[thicknessdataintimewindowsFixedstep[[1]][[i]],
    thicknessdataintimewindowsFixedstep[[2]][[i]],
    2, 7, 400, RGBColor[0.1, 0.5, 1.]], {i, Range@10}];
```

In[•]:=
```
graphsandnodenumbers
```

Out[ ]= {{ 
75.95
76.0
83.95
84.0
75.05
75.1
60.95
62.95
63.0
56.95
57.0
77.95
78.0
66.95
67.0
65.95
66.0
76.95
77.0
57.95
84.95
85.0
78.95
79.0
76.15
76.2
80.95
86.95
87.0
81.95
82.0
65.75
65.8
67.95
68.0
70.95
71.0
69.95
70.0
79.95
80.0
68.95
69.0
63.95
64.0
73.95
74.0
72.95
73.0
58.95
59.0
50.75
50.8
59.95
60.0
0.0
0.05
, 32}},

{ 
63.95
64.0
84.95
85.0
67.95
68.0
78.95
79.0
79.95
80.0
77.95
78.0
68.95
69.0
65.75
71.95
72.0
66.95
67.0
76.15
76.2
83.95
84.0
72.95
73.0
58.95
59.0
73.95
69.9
80.95
81.0
75.05
75.1
50.75
50.8
86.95
87.0
59.95
60.0
75.95
76.0
65.95
66.0
76.95
77.0
81.95
82.0
54.95
55.0
56.95
57.0
57.95
62.95
63.0
55.95
56.0
74.95
75.0
0.0
0.05
, 35},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82.0
54.95
55.0
59.95
60.0
75.05
75.1
76.95
77.0
66.95
67.0
58.95
59.0
50.75
50.8
72.95
73.0
74.95
75.0
70.95
71.0
83.95
84.0
86.95
87.0
80.95
81.0
62.95
63.0
69.95
70.0
76.15
76.2
71.95
72.0
77.95
78.0
55.95
56.0
60.95
61.0
78.95
79.0
68.95
69.0
56.95
57.0
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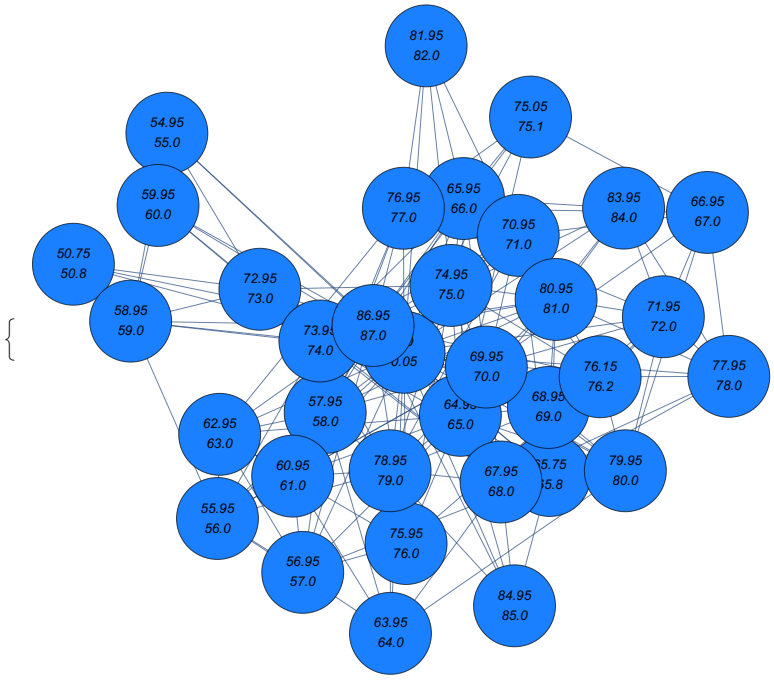
79.95
80.0
63.95
64.0
84.95
85.0

, 35},


0.0
0.05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82.0
54.95
55.0
75.05
75.1
59.95
60.0
76.95
77.0
65.95
66.0
83.95
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66.95
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70.95
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84.95
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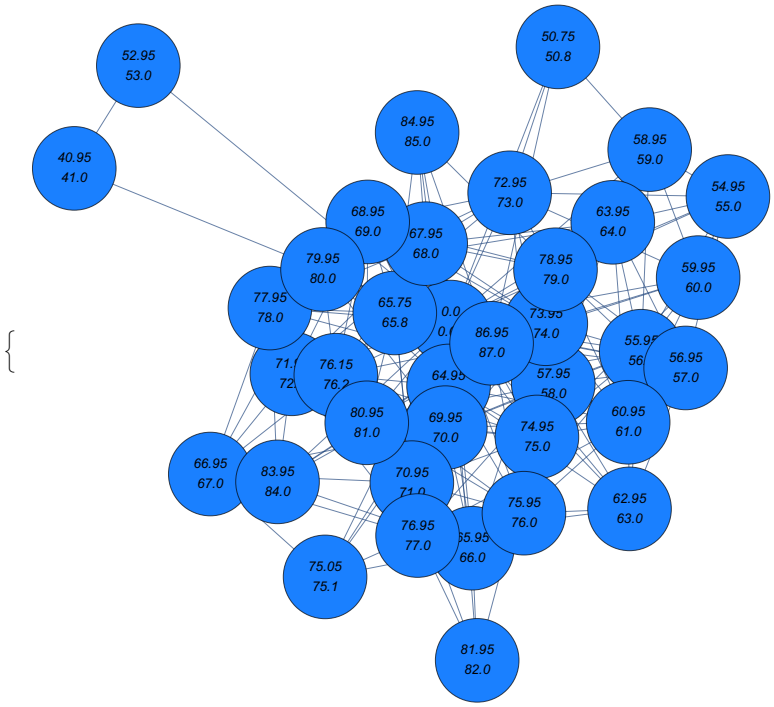
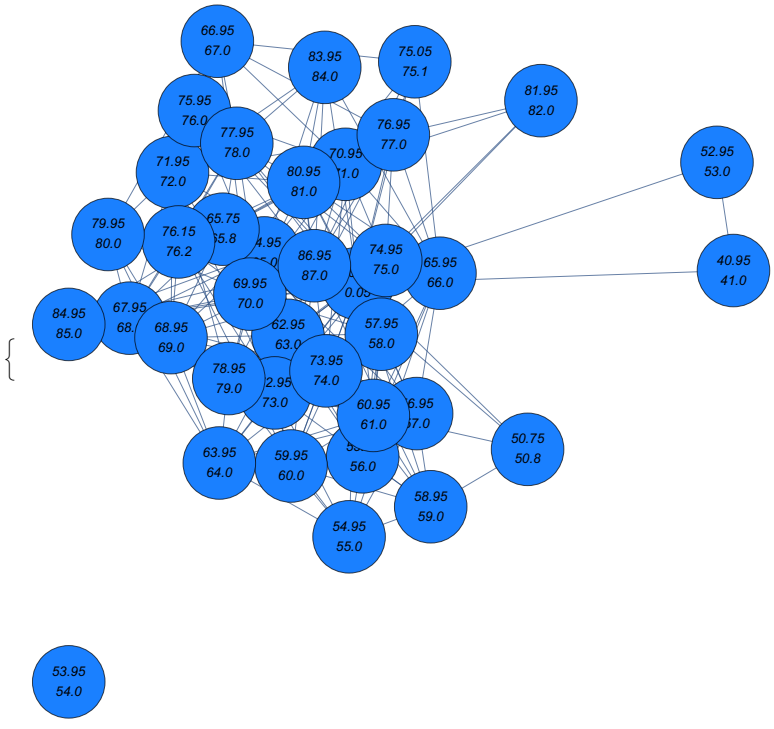
63.95
64.0

, 35},


52.95
53.0
50.75
50.8
40.95
41.0
84.95
85.0
58.95
59.0
72.95
73.0
54.95
55.0
68.95
69.0
67.95
68.0
63.95
64.0
79.95
80.0
78.95
79.0
59.95
60.0
77.95
78.0
65.75
65.8
86.95
87.0
56.95
57.0
80.95
81.0
69.95
70.0
74.95
75.0
60.95
61.0
66.95
67.0
83.95
84.0
70.95
75.95
76.0
62.95
63.0
76.95
77.0
75.05
75.1
81.95
82.0

{ , 37},


66.95
67.0
83.95
84.0
75.05
75.1
81.95
82.0
75.95
76.0
77.95
78.0
76.95
77.0
71.95
72.0
80.95
81.0
52.95
53.0
79.95
80.0
76.15
76.2
74.95
75.0
65.95
66.0
40.95
41.0
86.95
87.0
69.95
70.0
84.95
85.0
68.95
69.0
62.95
63.0
57.95
58.0
78.95
79.0
73.95
74.0
60.95
61.0
50.75
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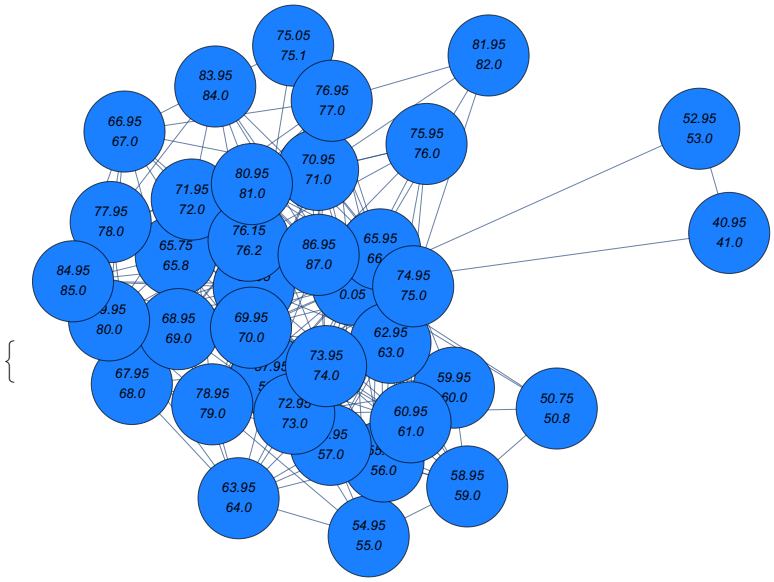
54.95
55.0
53.95
54.0

{ , 38},


75.05
75.1
81.95
82.0
83.95
84.0
76.95
77.0
66.95
67.0
75.95
76.0
52.95
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81.0
71.95
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40.95
41.0
77.95
78.0
76.15
76.2
65.75
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86.95
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65.95
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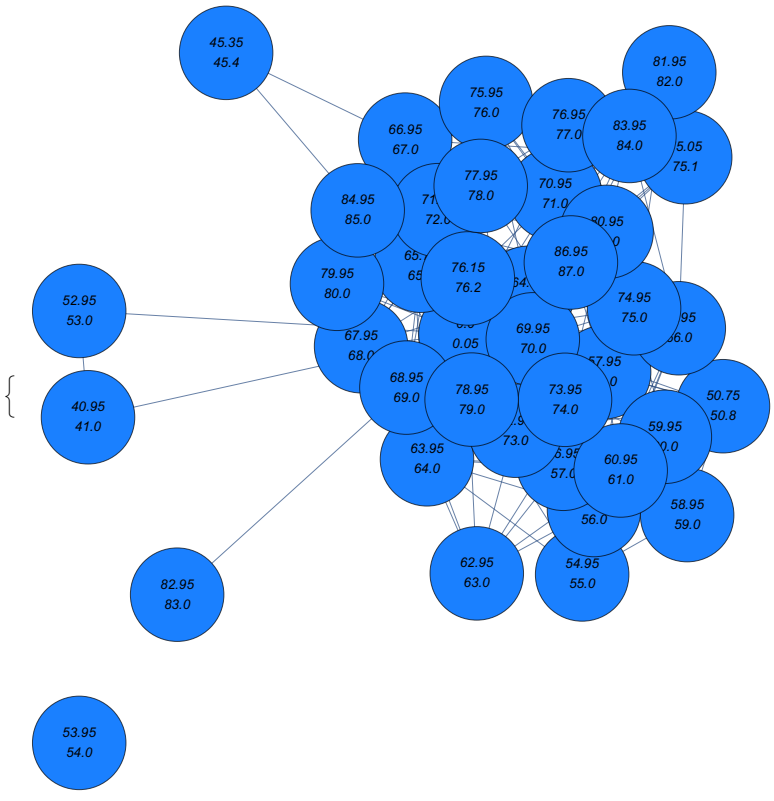
64.0
54.95
55.0
53.95
54.0

, 38},


45.35
45.4
81.95
82.0
75.95
76.0
66.95
67.0
76.95
77.0
83.95
84.0
77.95
78.0
70.95
71.0
84.95
85.0
86.95
87.0
79.95
80.0
76.15
76.2
74.95
75.0
52.95
53.0
67.95
68.0
69.95
70.0
0.05
68.95
69.0
78.95
79.0
73.95
74.0
50.75
50.8
40.95
41.0
59.95
63.95
64.0
60.95
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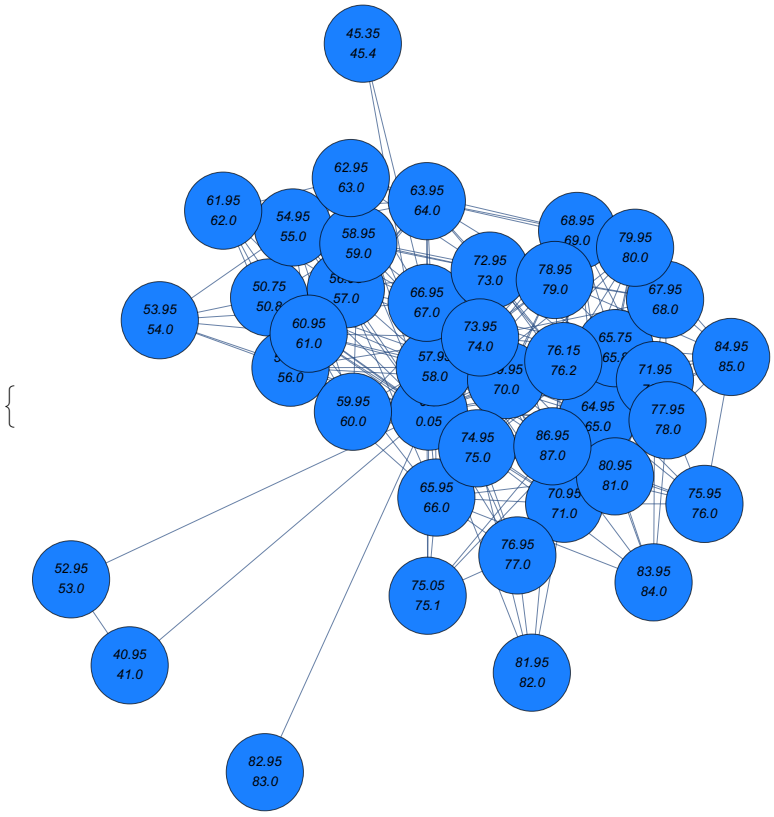
55.0
82.95
83.0
53.95
54.0

, 40},


45.35
45.4
62.95
63.0
63.95
64.0
61.95
62.0
54.95
55.0
58.95
59.0
68.95
69.0
79.95
80.0
72.95
73.0
78.95
79.0
50.75
50.8
57.0
66.95
67.0
67.95
68.0
53.95
54.0
60.95
61.0
73.95
74.0
76.15
76.2
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64.95
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87.0
80.95
81.0
65.95
66.0
70.95
71.0
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76.95
77.0
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40.95
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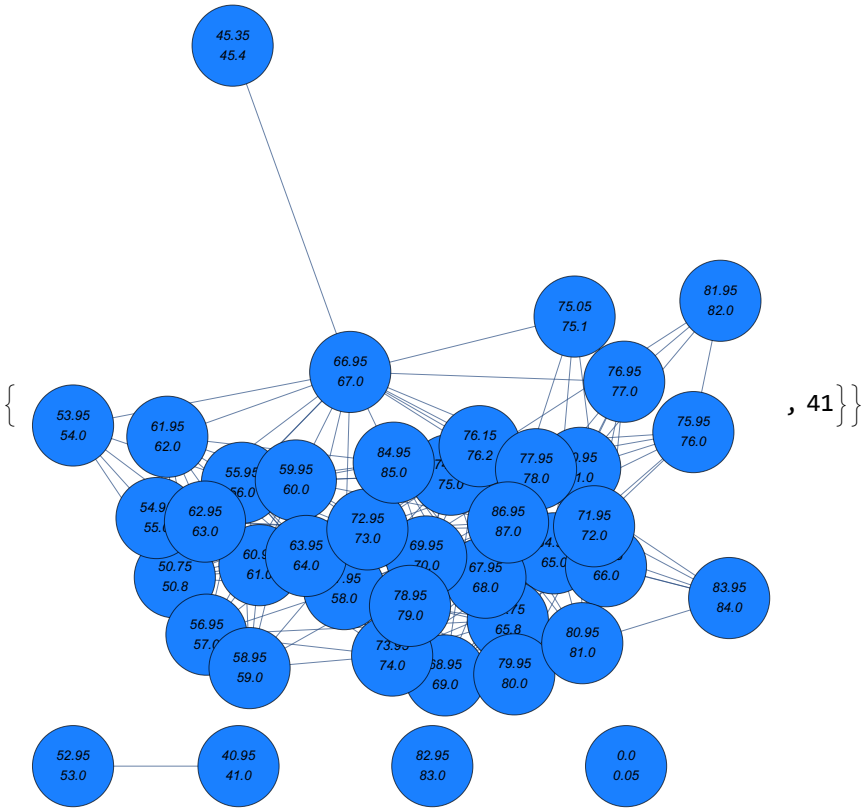
82.95
83.0

{ , 41},



In[ ]:=
```
correlationvaluesthroughwindowsspearman =
  Table[correlationfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}];
correlationvaluesthroughwindowspearson =
  Table[correlationfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}];
```

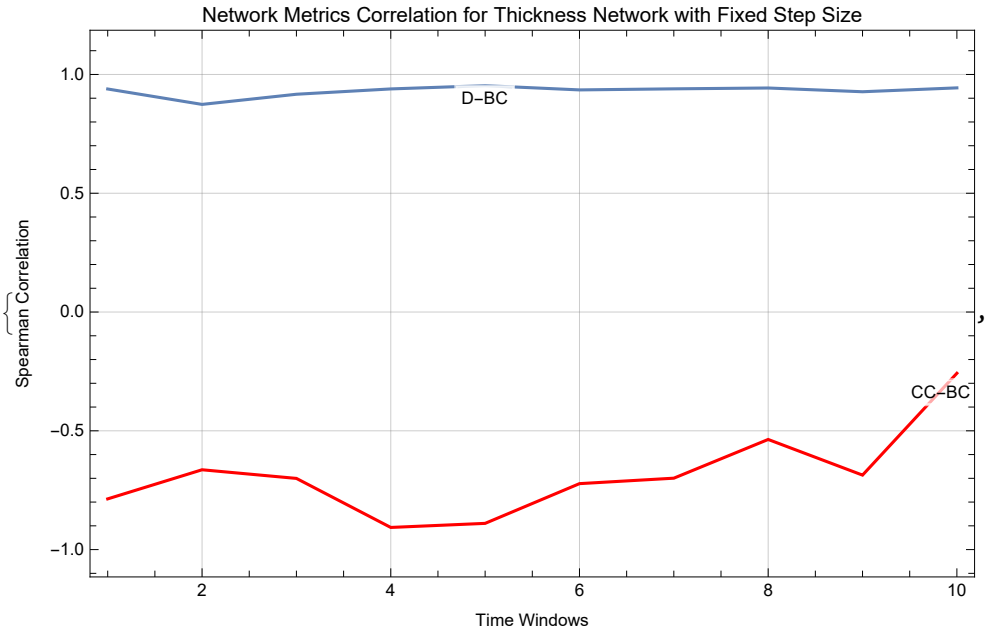
In[ ]:=
```
correlationvaluesthroughwindowsspearman
correlationvaluesthroughwindowspearson
```

Out[ ]=
```
{{0.938808, -0.78658}, {0.873987, -0.663998}, {0.916719, -0.7004}, {0.93912, -0.906811},
 {0.95285, -0.889666}, {0.935017, -0.722435}, {0.939483, -0.699436},
 {0.943043, -0.53645}, {0.927237, -0.686511}, {0.94354, -0.25778}}
```

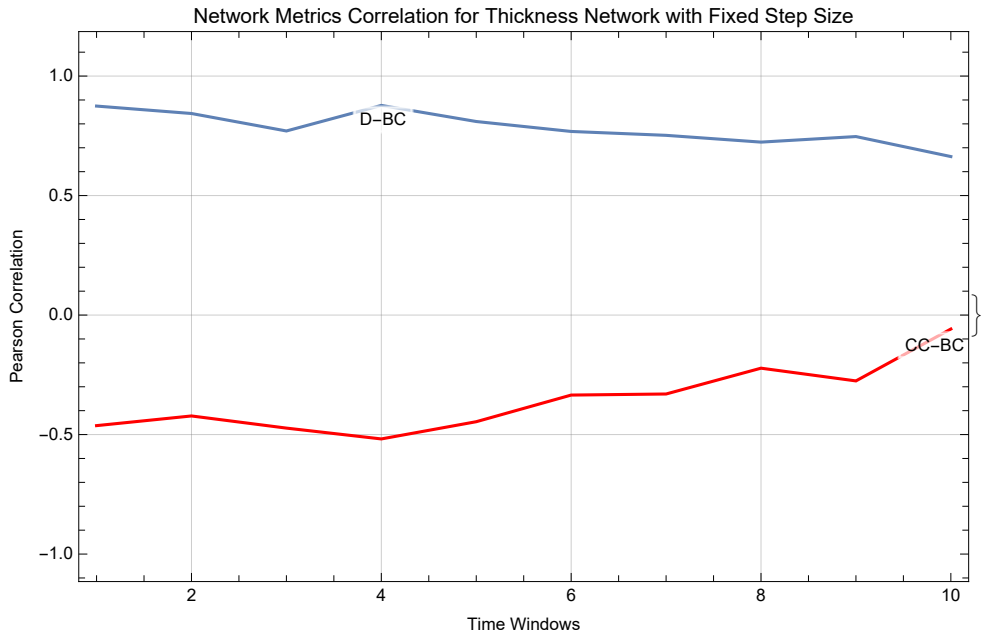
Out[ ]=
```
{{0.874484, -0.462631}, {0.843387, -0.422115},
 {0.770286, -0.472945}, {0.877292, -0.518271}, {0.809918, -0.446188},
 {0.768257, -0.334724}, {0.752032, -0.330238}, {0.723693, -0.22225},
 {0.746908, -0.275495}, {0.663251, -0.0583977}}
```

In[•]:=
```
{Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 1]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Spearman Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowsspearman[[j, 2]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Spearman Correlation"}],
  PlotRange -> {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Thickness Network with Fixed Step Size"],
 Show[ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 1]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"D-BC"}, Top], Frame → True,
   FrameLabel → {"Time Windows", "Pearson Correlation"}], ListPlot[Transpose[
    {Range@10, Table[correlationvaluesthroughwindowspearson[[j, 2]], {j, 1, 10}]}]],
   Joined → True, PlotLabels → Placed[{"CC-BC"}, Top], PlotStyle → Red,
   Frame → True, FrameLabel → {"Time Windows", "Pearson Correlation"}],
  PlotRange → {All, {-1, 1}}, Axes -> False, ImageSize → 500, GridLines -> Automatic,
  PlotLabel → "Network Metrics Correlation for Thickness Network with Fixed Step Size"]}
```

Out[•]=



,



In[•]:=
```
ZscoreDeBCspearman = Transpose[{Range[1, 10],
   Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
```

Out[•]=
```
{{1, 0.616193}, {2, -1.28733}, {3, -0.104282}, {4, 0.565508}, {5, 1.07189},
 {6, 0.367045}, {7, 0.478779}, {8, 0.559077}, {9, -0.0694945}, {10, 0.590463}}
```

In[•]:=
```
ZscoreCCBCspearman = Transpose[{Range[1, 10],
   Table[randomnessfunction[i, 1], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
```

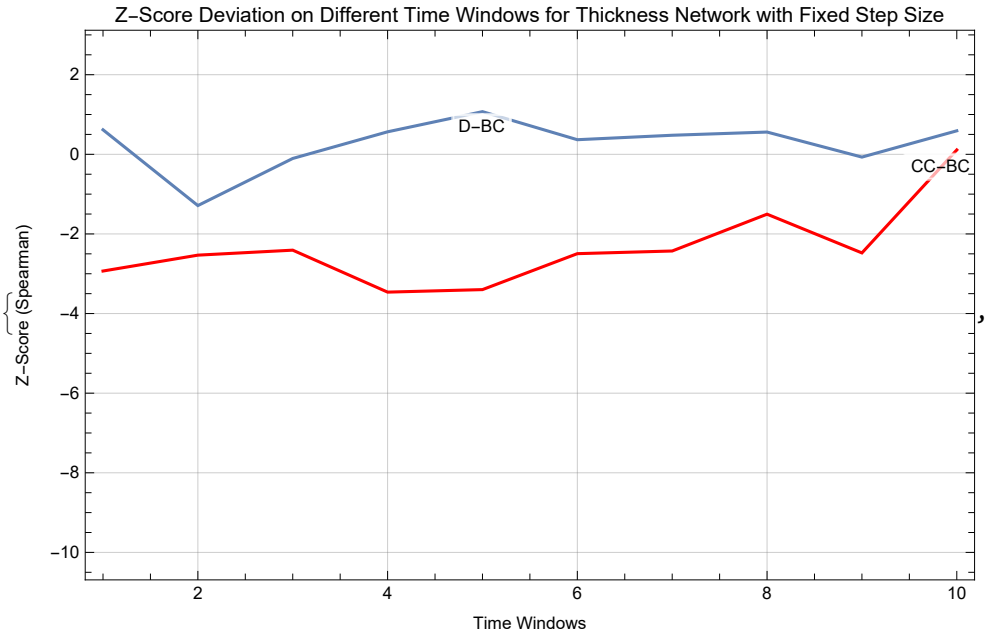
Out[•]=
```
{{1, -2.93182}, {2, -2.53266}, {3, -2.40751}, {4, -3.46177}, {5, -3.3986},
 {6, -2.49543}, {7, -2.42854}, {8, -1.50394}, {9, -2.47674}, {10, 0.109912}}
```

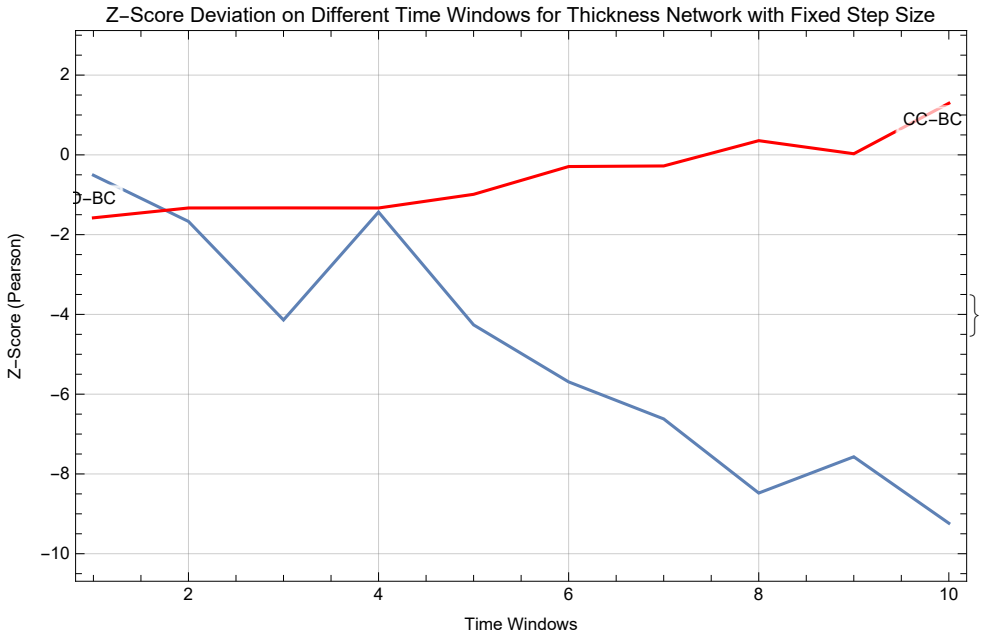
```
In[•]:= ZscoreDeBCpearson = Transpose[{Range[1, 10],
          Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 1]]}]
Out[•]= {{1, -0.510046}, {2, -1.66848}, {3, -4.13987}, {4, -1.43423}, {5, -4.2623},
         {6, -5.6921}, {7, -6.62055}, {8, -8.47877}, {9, -7.56998}, {10, -9.23535}}

In[•]:= ZscoreCCBCpearson = Transpose[{Range[1, 10],
          Table[randomnessfunction[i, 2], {i, graphsandnodenumbers[[All, 1]]}][[All, 2]]}]
Out[•]= {{1, -1.57851}, {2, -1.33152}, {3, -1.32984}, {4, -1.33201}, {5, -0.9891},
         {6, -0.2925}, {7, -0.278031}, {8, 0.356254}, {9, 0.0282377}, {10, 1.29413}}

In[•]:= {Show[ListPlot[ZscoreDeBCspearman, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
           Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         ListPlot[ZscoreCCBCspearman, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Spearman)"}],
         PlotRange → {All, {-10, 2}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel → "Z-Score Deviation on Different
            Time Windows for Thickness Network with Fixed Step Size"],
        Show[ListPlot[ZscoreDeBCpearson, Joined → True, PlotLabels → Placed[{"D-BC"}, Top],
          Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         ListPlot[ZscoreCCBCpearson, Joined → True, PlotLabels → Placed[{"CC-BC"}, Top],
          PlotStyle → Red, Frame → True, FrameLabel → {"Time Windows", "Z-Score (Pearson)"}],
         PlotRange -> {All, {-10, 2}}, Axes -> False, ImageSize → 500,
         GridLines -> Automatic, PlotLabel → "Z-Score Deviation on Different
            Time Windows for Thickness Network with Fixed Step Size"]}
```

Out[•]=





Fixed Bucket Size Networks

Width Feature

Thickness Feature