SYSEN 6000: Foundations of Complex Systems

Networks & Matrices

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Washington I-5 Corridor Interstate Highway System

This is a basic network analysis of the Washington I-5 corridor interstate highway system containing the following four parts: 1) Geographic Map, 2) Graph Network, 3) Adjacency Matrix, 4) Histogram of Connected Edges

Geographic Map

The following is a geographic map of Washington State identifying 10 major population centers along the I-5 corridor (north-south), as well as the broader interstate highway system connecting them (bold lines).

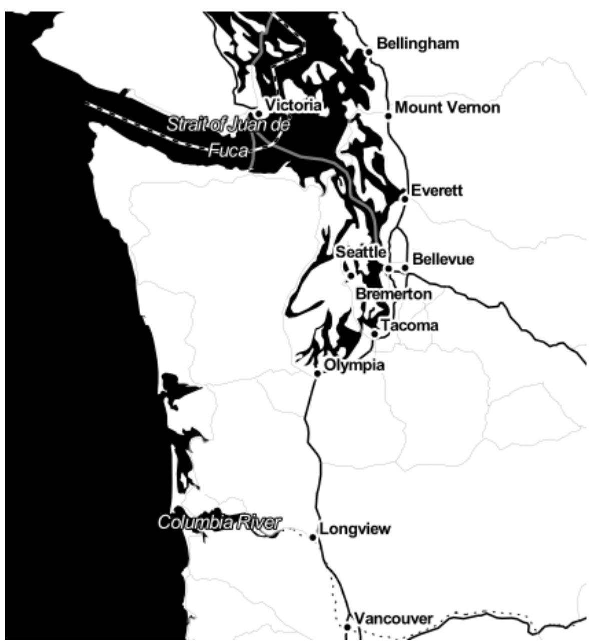

Figure 1: Washington I-5 Corridor Geographic Map (1)

Graph Network

The following is a graph network representing the interstate highway system in the geographic map (Figure 1). All other road systems, such as state and local highways, were beyond the scope of this analysis and not included here.

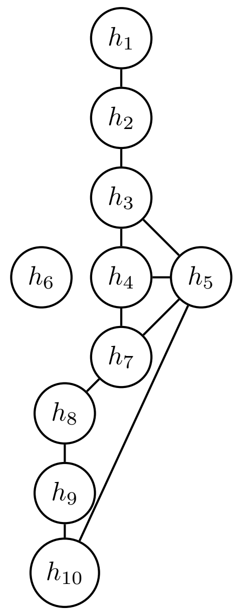

Figure 2: Washington I-5 Corridor Graph Network

Adjacency Matrix

The following is a matrix representation of the graph network (Figure 2). Notice that h_6 is included. However, not connected to the broader interstate system, and that h_5 and h_{10} are connected, but not exhibited within the bounds of the geographic map (Figure 1).

$$A_h = \begin{array}{c} \\ h_1 \\ h_2 \\ h_3 \\ h_4 \\ h_5 \\ h_6 \\ h_7 \\ h_8 \\ h_9 \\ h_{10} \end{array} \begin{array}{c} \begin{array}{cccccccccc} h_1 & h_2 & h_3 & h_4 & h_5 & h_6 & h_7 & h_8 & h_9 & h_{10} \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \end{pmatrix} \end{array} \tag{1}$$

Figure 3: Washington I-5 Corridor Adjacency Matrix

where:

$$
\begin{aligned}
h_1 &= \text{Bellingham} \\
h_2 &= \text{Mount Vernon} \\
h_3 &= \text{Everett} \\
h_4 &= \text{Seattle} \\
h_5 &= \text{Bellevue} \\
h_6 &= \text{Bremerton} \\
h_7 &= \text{Tacoma} \\
h_8 &= \text{Olympia} \\
h_9 &= \text{Longview} \\
h_{10} &= \text{Vancouver}
\end{aligned}
$$

Histogram of Connected Edges

The following exhibit illustrates the ten major population centers ordered by the number of edges connecting them. Notice that h_5 (Bellevue) has the highest number of edges (four), and that h_6 (Bremerton) has the lowest number of edges (zero).

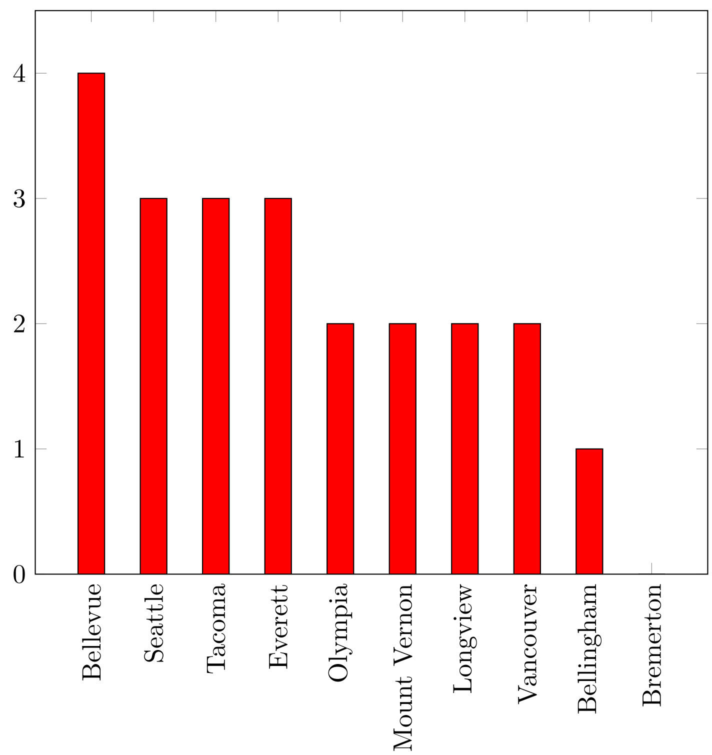

Figure 4: Washington I-5 Corridor Connected Edges

Japanese Shinkansen High Speed Rail System

This is a basic network analysis of the Japanese Shinkansen high speed rail system containing the following four parts: 1) Geographic Map, 2) Graph Network, 3) Adjacency Matrix, 4) Histogram of Connected Edges

Geographic Map

The following is a geographic map of the Japanese Shinkansen high speed rail system throughout broader Japan. This analysis is focused on only those cities which are northeast of Tokyo.

Figure 5: Japanese Shinkansen Geographic Map (2)

Graph Network

The following is a graph network representing the high speed rail system northeast of Tokyo in the geographic map (Figure 5). All other transportation systems, such as roads, were beyond the scope of this analysis and not included here.

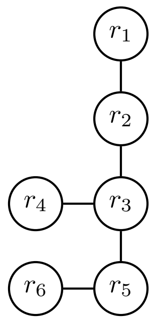

Figure 6: Japanese Shinkansen Graph Network (Northeast of Tokyo)

Adjacency Matrix

The following is a matrix representation of the graph network (Figure 6). Notice that r_5 is the truncated node to the broader high speed rail system, and that r_5 is connected to Tokyo, but is not exhibited within the bounds of graph network (Figure 6).

$$A_r = \begin{array}{c} \\ r_1 \\ r_2 \\ r_3 \\ r_4 \\ r_5 \\ r_6 \end{array} \begin{array}{c} \begin{array}{cccccc} r_1 & r_2 & r_3 & r_4 & r_5 & r_6 \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix} \end{array} \tag{2}$$

Figure 7: Japanese Shinkansen Adjacency Matrix (Northeast of Tokyo)

where:

$$\begin{aligned} r_1 &= \text{Hakodate} \\ r_2 &= \text{Aomori} \\ r_3 &= \text{Morioka} \\ r_4 &= \text{Akita} \\ r_5 &= \text{Sendai} \\ r_6 &= \text{Yamagata} \end{aligned}$$

Histogram of Connected Edges

The following exhibit illustrates the six major population centers ordered by the number of edges connecting them. Notice that r_3 (Morioka) has the highest number of edges (three), while r_1 (Hakodate), r_2 (Aomori), and r_6 (Yamagata) have the lowest number of edges (one).

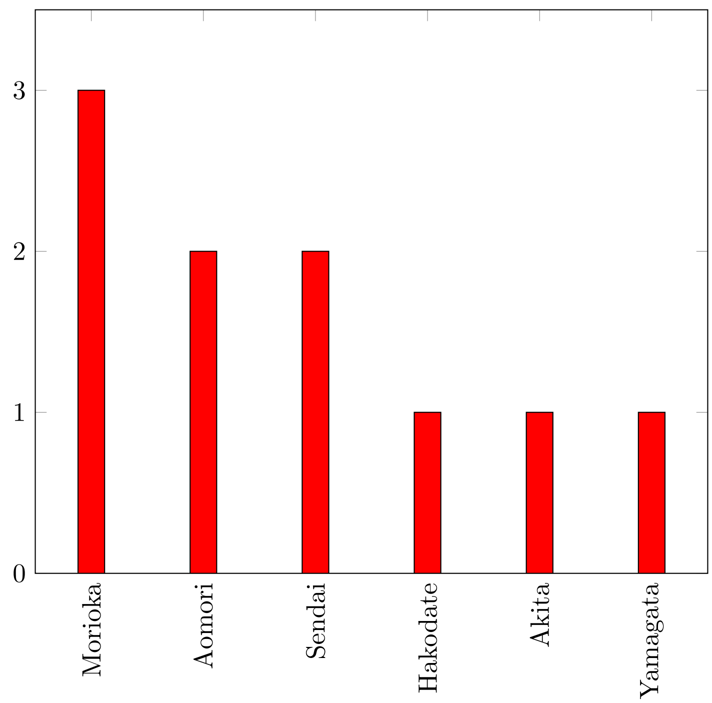

Figure 8: Japanese Shinkansen Connected Edges (Northeast of Tokyo)

German Intercity-Express High Speed Rail System

This is a basic network analysis of the German Intercity-Express (ICE) high speed rail system containing the following four parts: 1) Geographic Map, 2) Graph Network, 3) Adjacency Matrix, 4) Histogram of Connected Edges

Geographic Map

The following is a geographic map of the German Intercity-Express high speed rail system throughout broader Germany. This analysis is focused on only those cities in the east south-east portion of the country.

Figure 9: Germany Intercity-Express Geographic Map (3)

Graph Network

The following is a graph network representing the high speed rail system in the east south-east portion of the geographic map (Figure 9). All other transportation systems, such as roads, were beyond the scope of this analysis and not included here.

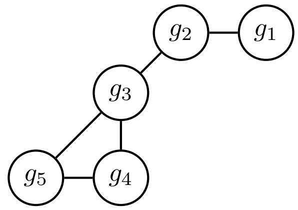

Figure 10: Germany Intercity-Express Graph Network (East South-East Cities)

Adjacency Matrix

The following is a matrix representation of the graph network (Figure 10). Notice that g_2, g_3, and g_5 are truncated nodes connected to the broader high speed rail system, but are not exhibited within the bounds of graph network (Figure

$$A_g = \begin{array}{c} \\ g_1 \\ g_2 \\ g_3 \\ g_4 \\ g_5 \end{array} \begin{array}{c} \begin{array}{ccccc} g_1 & g_2 & g_3 & g_4 & g_5 \end{array} \\ \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{pmatrix} \end{array} \tag{3}$$

Figure 11: Germany Intercity-Express Adjacency Matrix (East South-East Cities)

where:

$$\begin{aligned} g_1 &= \text{Dresden} \\ g_2 &= \text{Leipzig} \\ g_3 &= \text{Nurnberg} \\ g_4 &= \text{Munchen} \\ g_5 &= \text{Stuttgart} \end{aligned}$$

Histogram of Connected Edges

The following exhibit illustrates the five major population centers ordered by the number of edges connecting them. Notice that g_3 (Nurnberg) has the highest number of edges (three), while g_1 (Dresden) has the lowest number of edges (one).

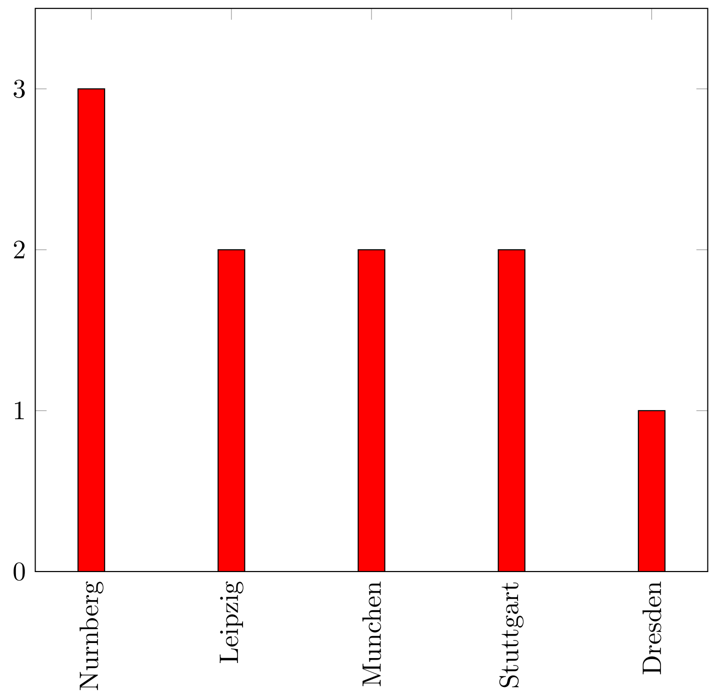

Figure 12: Germany Intercity-Express Connected Edges (East South-East Cities)

References

[1] Folium, “Basemap data.”

[2] JRPass, “Shinkansen: Japanese bullet trains.”

[3] DeutscheBahn, “Ice - travel on board a high-speed train.”