THE UNIVERSITY OF WESTERN ONTARIO
DEPARTMENT OF GEOGRAPHY
Geography 270a

Air Transport and the Canadian Urban System

One of the processes that binds cities into a system is spatial interaction. However, the interaction between centres is not equal for all pairs of cities. Some cities are more important in the city system than others. This exercise is designed to enable you to determine those cities in the Canadian urban system which are the dominate cities. You are provided with air passage flows between eighteen Canadian cities (Table 2).

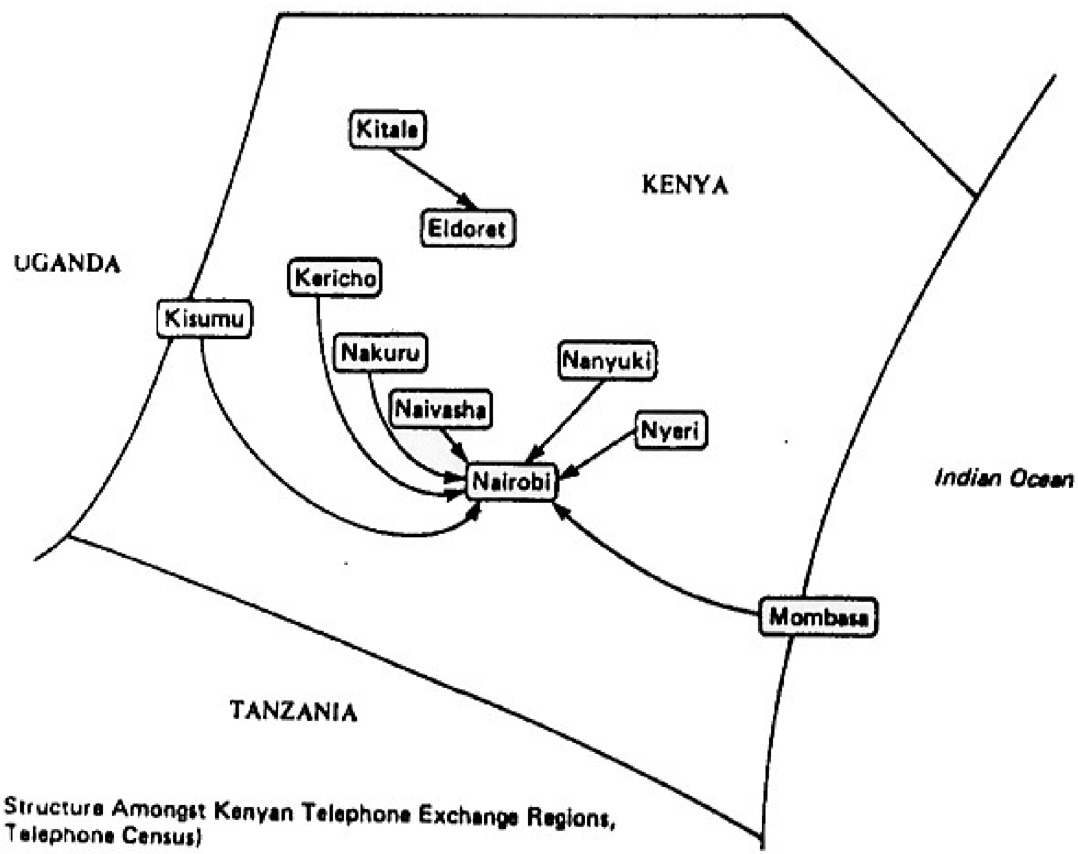
To find these dominant cities you will use a method called nodal analysis. This method may be applied to any interaction matrix to identify nodal flows. A nodal flow occurs if a given city's largest flow is to a city higher in the urban hierarchy than itself. Usually the hierarchical position of a city is measured by the total flows incoming to the city. In this exercise these are the column totals

A city is a dominant city if its largest flow is to a city lower in the hierarchy than itself. The first step in the analysis is to find the largest value in each row. If the sum of the column in which the largest row value is found is larger than the column sum for the city identified by the row a 1 is entered in a nodal graph matrix. A nodal flow matrix is made up of 0's and 1's. The size and labels for the rows and columns are the same as the original data matrix. Therefore, the nodal flow matrix for this exercise is 17 x 17.

An example of the analyses is found in Table 1 using telephone traffic in Kenya. The largest flows in each row are underlined. For a one to be entered in the nodal flow matrix, the column sum of the column containing the underlined value must be greater than the column sum of the city identified by the row. For example, the largest value in row 1 is 189 for the flow between Eldoret and Kitale. The column sum for the column containing 189 is 414. The column sum for the column for Eldoret is 826. Since 414 is not greater than 826 we do not have a nodal flow.

The next step is to draw a map of the nodal flows as found in Figure 1. The arrows should go from the lower centers to the more dominant centers.

FIGURE 1



Nodal Structure Amongst Kenyan Telephone Exchange Regions,
(1967 Telephone Census)

TABLE 1

Example

TELEPHONE TRUNK CENSUS JULY 1967 (5 Days Total 30 hrs.)
KENYA

	Eldoret	Kericho	Kisumu	Kitale	Mombasa	Nairobi	Naivasha	Nakuru	Nanyuki	Nyeri	Nodal ?	If yes, to where?
Eldoret	0	14	79	189	1	172	10	166	-	6	No	-
Kericho	33	0	222	8	8	396	14	270	1	-	Yes	Nairobi
Kisumu	121	148	0	32	35	757	3	188	2	5	Yes	Nairobi
Kitale	265	3	56	0	7	233	-	88	-	5	Yes	Eldoret
Mombasa	-	3	-	2	0	1315	1	33	-	2	Yes	Nairobi
Nairobi	284	230	633	110	1747	0	386	1153	334	577	No	-
Naivasha	6	7	1	2	2	420	0	272	-	1	Yes	Nairobi
Nakuru	109	190	191	69	30	1800	209	-	21	16	Yes	Nairobi
Nanyuki	4	-	2	1	2	410	1	76	0	221	Yes	Nairobi
Nyeri	4	1	2	1	10	805	1	37	183	0	Yes	Nairobi
Column Totals (Basis for the hierarchy of cities.)	826	596	1186	414	1842	6308	625	2278	541	833		

The highest entry in each row, the potential nodal flow, is underlined. Note that Nairobi to Mombosa is not a nodal flow, nor is Eldoret to Kitale.

We get a nodal flow matrix :

$$\begin{pmatrix} 0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&0&0&0 \\ 0&0&0&0&0&1&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&0&0&0 \\ &&&&&0&&&& \\ &&&&&1&&&& \\ &&0&&&1&&0&& \\ &&&&&1&&&& \\ &&&&&1&&&& \end{pmatrix}$$

From: Tinkler, K.J., "An Introduction to Graph Theoretic Methods in Geography", Concepts and Techniques in Modern Geography, No. 14, London, U.K., 1977.

Use of Spearman's Rank-Correlation Coefficient

The Spearman rank-correlation coefficient is probably the best known and most used of all nonparametric correlation techniques. The nonparametric technique does not require the calculation of means, variances, and standard deviations. This technique requires that the data only be in rank measurement.

The value of the coefficient varies from -1 (perfect negative correlation), 0 (no correlation), and +1 (perfect positive correlation). Correlation is the degree to which one phenomenon varies with respect to another phenomenon.

The formula for the coefficient is:

$$r_s = 1 - \frac{6 \sum_{i=1}^{N} d^2}{N^3 - N}$$

where d^2 = squared differences in ranks of the subject for a pair of different variables

N = number of subjects

An example problem is found below.

Country	population in millions	average annual percent growth in GDP 1990-2001
China	1272	10.0
India	1032	5.9
Russia	145	-3.7
USA	285	3.4
Canada	31	3.1
Niger	11	2.5
Togo	5	2.2

from: http://www.worldbank.org/

Step 1: Rank the countries on each variable and calculate the difference and square the difference

Country	population in millions (rank)	average annual percent growth in GDP 1990-2001 (rank)	d	d^2
China	1	1	0	0
India	2	2	0	0
Russia	4	7	3	9
USA	3	3	0	0
Canada	5	4	1	1
Niger	6	5	1	1
Togo	7	6	1	1

Step 2: Sum up the ds (∑ sigma means sum up)

0 + 0 + 9 + 0 +1 + 1 + 1 = 11 then substitute into the formula

$r_s = 1 - (6(12)/(343-7)) = 1 -(72/336) = 1 - .214 = .786$

We conclude that the relationship between population and average GDP growth is positive and a strong one at that, for this very small sample.

Questions for Canadian Data

1. What city is at the top of the urban hierarchy according to the results of this exercise? This city has no outgoing arrows.

Remove that city from the table and redo the nodal analysis.

2. What cities are in the second level of the hierarchy? These are cities that have both in and outgoing arrows. Remember that the most important city you found at this level feeds into the highest order city you found in Question 1.

3. Does the pattern in the hierarchy reflect what you would anticipate? If not, what explanation can you offer for the discrepancies.

4. Calculate the Spearman rank correlation coefficient between the flow of passenger traffic and population, use column totals (Table 2 and City population, Table 3). Use all 17 cities. What does this tell you about the relationship between population size and importance of a city in air traffic?

5. If we extended this analysis to a global scale what sort of map of flows would you expect to see?

Be sure to include in your answer sheets:

1) the nodal flow matrixes
2) the maps of flows
3) the work on the Spearman rank coefficient

Table 2

n - to	Calgary	Edmonton	Halifax	London	Montreal	Ottawa-	Quebec	Regina	St.Johns	Saint.John	Saskatoon	Sudbury	Toronto	Vancouver	Victoria	Windsor	Winnipeg
Calgary		114	41	10	81	75	7	46	13	3	39	3	292	269	49	6	91
Edmonton	113		19	6	34	39	5	13	8	2	12	2	154	146	25	3	42
Halifax	41	19		6	59	58	5	3	54	2	3	2	166	32	6	4	13
London	11	6	6		17	19	1	2	1	1	2	1	20	13	2	0	8
Montreal	81	34	58	18		9	25	8	20	9	8	4	630	121	9	11	41
Ottawa-Hull	75	39	59	20	7		15	14	21	5	13	3	361	102	19	9	58
Quebec	7	5	5	2	25	15		2	1	1	2	0	58	10	1	1	5
Regina	45	13	3	1	8	13	2		1	0	1	0	45	30	6	1	15
St. Johns	14	8	53	2	20	21	1	1		4	1	0	69	8	2	1	3
Saint John	3	2	2	1	9	5	1	0	4		0	0	28	3	0	0	1
Saskatoon	39	11	3	2	8	13	2	1	1	0		1	43	34	7	0	1
Sudbury	3	2	2	1	4	3	0	0	0	0	1		35	3	0	1	2
Toronto	292	152	167	23	631	364	58	44	67	28	43	35		471	52	57	185
Vancouver	262	146	32	13	122	102	10	29	8	3	33	3	476		52	8	93
Victoria	49	25	6	2	9	19	1	6	2	0	7	0	53	46		1	16
Windsor	6	3	4	0	11	9	1	1	1	0	0	1	56	8	1		3
Winnipeg	92	40	13	8	40	58	5	15	3	1	1	2	185	92	16	3	
Total	1133	505	473	115	1085	822	139	185	205	59	166	57	2671	1388	247	106	577

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Total																	

Table 2a

From - to	Calgary	Edmonton	Halifax	London	Montreal	Ottawa-	Quebec	Regina	St. Johns	Saint John	Saskatoon	Sudbury	Vancouver	Victoria	Windsor	Winnipeg
Calgary		114	41	10	81	75	7	46	13	3	39	3	269	49	6	91
Edmonton	113		19	6	34	39	5	13	8	2	12	2	146	25	3	42
Halifax	41	19		6	59	58	5	3	54	2	3	2	32	6	4	13
London	11	6	6		17	19	1	2	1	1	2	1	13	2	0	8
Montreal	81	34	58	18		9	25	8	20	9	8	4	121	9	11	41
Ottawa-Hull	75	39	59	20	7		15	14	21	5	13	3	102	19	9	58
Quebec	7	5	5	2	25	15		2	1	1	2	0	10	1	1	5
Regina	45	13	3	1	8	13	2		1	0	1	0	30	6	1	15
St. Johns	14	8	53	2	20	21	1	1		4	1	0	8	2	1	3
Saint John	3	2	2	1	9	5	1	0	4		0	0	3	0	0	1
Saskatoon	39	11	3	2	8	13	2	1	1	0		1	34	7	0	1
Sudbury	3	2	2	1	4	3	0	0	0	0	1		3	0	1	2
Vancouver	262	146	32	13	122	102	10	29	8	3	33	3		52	8	93
Victoria	49	25	6	2	9	19	1	6	2	0	7	0	46		1	16
Windsor	6	3	4	0	11	9	1	1	1	0	0	1	8	1		3
Winnipeg	92	40	13	8	40	58	5	15	3	1	1	2	92	16	3	
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Table 3: Census Metropolitan Areas Populations

City	Population (in millions) 2002
Calgary	.99
Edmonton	.97
Halifax	.36
London	.43
Montreal	3.55
Ottawa-Hull	1.13
Quebec	.70
Regina	.20
St. Johns	.18
Saint John	.13
Saskatoon	.23
Sudbury	.16
Toronto	5.03
Vancouver	2.12
Victoria	.319
Windsor	.320
Winnipeg	.69

http://www.statcan.ca/english/Pgdb/demo05.htm