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# Climatic Effects on Bus Durability

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ABSTRACT

The purpose of this paper is to provide climate peer groups that may be used in combination with any set of Section 15 indicators as a guide to understanding the impact of climate on participating transit authorities. The method of deriving these climate peer groups involves applying three climatic indicators to partition 203 transit authorities into "harsh," "intermediate," and "benign" climate peer groups. The results are mapped and are displayed in tabular form. The simple numerical procedure is checked using elementary linear algebra, and the resulting climate peer groups are again mapped and displayed in tabular form. The hypothesis that bus durability is adversely affected in harsh climates is then tested, using data from Section 15 indicators, to illustrate the method of employing these climate peer groups. Section 15 indicators on "age distribution," "distance between road calls," and "vehicle miles per maintenance dollar," partitioned by climate class, provide support for this hypothesis. Implications resulting from the testing of this hypothesis suggest which climate peer groups might benefit from additional evaluation of their maintenance strategy and which climate peer groups might serve as maintenance models for others.

Cars and buses heavily scarred from rusty sores are a familiar sight to residents of the Great Lakes Basin as well as to those in other regions that experience heavy concentrations of snow and road salt, or heat and airborne salt, near urban surface routes. Other environmental stresses that contribute to the aging of a bus fleet might involve the steepness of the underlying terrain and the density of traffic congestion. Steep grades produce extra strain on the motor and power-train, and frequent stopping and starting wear the brakes, the engine, and the drive train. However, major "surgery" often fixes component breakdowns, via brake transplant or electrical bypass, resulting from the various strains on the visceral bus system. Distintegration of the bus skin, however, is irreparable and often forces vehicle replacement; one response to this problem is to build rust-proof buses of stainless steel that resist corrosion from road and airborne salt. This change in material could extend bus life, thereby presenting transit authorities, in adversely affected climatic regions, with an opportunity to build healthier, more efficient bus fleets.

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The major contribution of this work is to derive measures of climatic conditions that can be used in the analysis of several factors related to vehicle performance. This exploits the "Potential Data Applications" suggested in the Fourth Annual Section 15 Report of National Urban Mass Transportation Statistics that "Peer groups could be formed based on mode, fleet size, annual operating expenses, and/or such other factors not contained in this report as climate and collective bargaining agreements. Comparisons can be made to the individual transit systems in the group, or to overall group averages" (1). These climate peer groups are then used to show how an increased understanding of other factors, such as age profile and performance data on bus fleets, might result.

## CLIMATE PEER GROUPS

The mechanics of constructing climate peer groups involves incorporating material from climatic atlases into the Section 15 data and using the resulting climatic indicators to sort transit authorities into "harsh," "intermediate," or "benign" climatic peer groups. These peer groups are determined first according to a simple numerical procedure based only on climatic indicators above, below, or equal to a mean value, and are checked with an approach using linear algebra to associate a climate vector with each transit authority. The latter approach also generates a rank-ordering of transit authorities in each climate peer group. It does so using the lengths of climate vectors (vector norms) measured in a coordinate system with the national average as the origin.

### Peer Groups Formed by a Simple Numerical Procedure

It is assumed that when road salt is used as an aid in snow removal, it speeds bus body corrosion; it is not assumed that all corrosion is caused by road salt, however, nor is it assumed that all communities employ road salt in snow removal. Thus, the measures that follow include transit authorities in which airborne salt in warm, humid climates promotes corrosion of buses that travel coastal routes, as well as transit authorities in agricultural states that do not use road salt in snow removal. Inclusion of these transit authorities provides a broad spectrum of positions for data points to partition into peer groups on relatively unchanging, purely climatic, bases. Changes in policy, involving decisions to salt, or changes in bus route position, involving nearness to salt water, are more closely spaced in time than are changes in climate. Although these are issues that could be superimposed on the results of this study, they are beyond its scope as they do not contribute, at the fundamental level, to sorting transit authorities by climatic type; it is the typology that is dominant here.

The following climatic indicators will be used to link snow to road salt. First, the "total amount of annual snowfall" is significant as a rough measure of total volume of road salt to which bus bodies are subjected in a single winter. Second, the "mean number of days of one inch or more of snow and sleet" uses frequency of snow events to measure the extent to which bus bodies are exposed to road salt on a continuing basis. Third, the "average number of times per year of an alternation of freezing and thawing" gives a general indication of the number of days that are optimal for applying salt to melt snow and accumulated ice. These factors are assumed to have roughly the same weight in describing winter adversity at the national scale, as suggested by groupings of variables of this sort to describe national climate patterns in climate atlases; however, individual transit authorities may see one factor as more significant than another. Further, these climatic indicators measure trends over time and may thus differ from local weather patterns in any single year. Therefore, individual transit authorities should exercise caution in using current weather statistics. To understand the range of possible weather patterns, it is necessary to supplement current weather observations with a longer view of the climatic history of the region.

Data for the first two climatic indicators is available on a city-by-city basis in the tables of "Normals, Means, and Extremes" in Climates of the States (2). These tables report data only from locations with complete weather stations. Only data from those weather stations in cities with bus systems were included. Cities with bus systems, but not with reporting weather stations, were grouped with the weather station in their climatic zone as shown in maps of "Climatic Zones" in Climates of the States. Data for the third variable come from the maps in Figures 1A, B, and C, which appeared originally in Stephen Visher's Climatic Atlas of the United States (3). To form the isolines in this map, Figure 1A, Visher used the differences found by subtracting "Normal annual number of days with temperature continuously below freezing" (Figure 1B) from "Normal annual number of nights with frost (minimum of 32°F or lower)" (Figure 1C). For example, Detroit, Michigan, has about 135 nights with frost in a year. Of those, about 45 are associated with days where the temperature is already below freezing; on these days, little benefit comes from applying salt to the roads. That leaves 135 - 45 = 90 times per year with frost at night when the day temperature is not continuously below freezing; hence, an alternation occurs across the freeze line. Locations between isolines were assigned the value of the lower of the two isolines. Interpolation was not employed because these climate values generally do not vary linearly between isolines. Numerical values for this climatic indicator range from 0 to 130 days. High values of this Visher index should be expected in alpine areas, due to daily temperature fluctuation. Low values should appear in southern cities, and these values will increase more rapidly away from large bodies of water because the land temperature responds more quickly than does the water temperature to changes in the surrounding air temperature.

The three climatic indicators were calculated for each of 193 cities associated with 203 transit authorities of more than 25 buses that filed Section 15 reports for at least two of the four years under study. The national mean for these indicators, rounded to the nearest integer and expressed as an ordered triple (number of inches of snow per year, number of snow events per year, and number of alternations of freeze-thaw per year), was (23, 7, 50). An ordered triple that represents the climatic indicators for a particular city has entries of positive sign to represent deviation above the mean, of negative sign to represent deviation below the mean, or of 0 to represent no deviation from the mean. The following list classifies the 193 cities according to the signs of their ordered triples. No city received a score of (0, 0, 0), the national mean. Cities in which all three climatic indicators are above the mean are represented by triples with sign (+, +, +). These cities are grouped in the "harsh" climate class in the list (ordered by longitude). Similarly, cities in which all three climatic indicators are below the mean are represented by ordered triples with sign (-, -, -). These are grouped as the "benign" climate class of entries in the list (ordered by longitude). The cities associated with the remaining sign possibilities are grouped in the "intermediate" climate class of the list (ordered by longitude).

Class

Harsh

Portland, Maine
Haverhill, Mass.
Boston, Mass.
Lowell, Mass.
Manchester, N.H.
Worcester, Mass.
Springfield, Mass.
Hartford, Conn.
New Haven, Conn.
White Plains, N.Y.
Albany, N.Y.
Yonkers, N.Y.
Newark, N.J.
Utica, N.Y.
Allentown, Pa.
Scranton, Pa.
Kingston, Pa.
Binghamton, N.Y.
Syracuse, N.Y.
Harrisburg, Pa.
Rochester, N.Y.
Altoona, Pa.
Johnstown, Pa.
Buffalo, N.Y.
Pittsburgh, Pa.
Erie, Pa.
Youngstown, Ohio
Kent, Ohio
Canton, Ohio
Akron, Ohio
Cleveland, Ohio
Detroit, Mich.
Toledo, Ohio
Saginaw, Mich.
Ann Arbor, Mich.
Flint, Mich.
Bay City, Mich.
Jackson, Mich.
Fort Wayne, Ind.
Kalamazoo, Mich.
South Bend, Ind.
Gary, Ind.
Chicago, Ill.
Racine, Wis.
Kenosha, Wis.
Waukegan, Ill.
Des Plaines, Ill.
Milwaukee, Wis.
Joliet, Ill.
Elgin, Ill.
Aurora, Ill.
Appleton, Wis.
Oshkosh, Wis.
Rockford, Ill.
Madison, Wis.
Rock Island, Ill.
Davenport, Iowa
Dubuque, Iowa
La Crosse, Wis.
Cedar Rapids, Iowa
Duluth, Minn.
Waterloo, Iowa
St. Paul, Minn.
Des Moines, Iowa
St. Cloud, Minn.
Sioux City, Iowa
Lincoln, Nebr.
Fargo, N.Dak.
Omaha, Nebr.
Colorado Springs, Colo.
Denver, Colo.
Salt Lake City, Utah
Spokane, Wash.

Benign

Norfolk, Va.
Hampton, Va.
Raleigh, N.C.
Fayetteville, N.C.
West Palm Beach, Fla.
Fort Lauderdale, Fla.
Miami, Fla.
South Daytona, Fla.
Savannah, Ga.
Orlando, Fla.
Jacksonville, Fla.
Augusta, Ga.
Gainesville, Fla.
Tampa, Fla.
St. Petersburg, Fla.
Bradenton, Fla.
Clearwater, Fla.
Tallahassee, Fla.
Columbus, Ga.
Montgomery, Ala.
Pensacola, Fla.
Mobile, Ala.
Harahan, La.
Gretna, La.
New Orleans, La.
Jackson, Miss.
Baton Rouge, La.
Shreveport, La.
Houston, Tex.
Dallas, Tex.
San Antonio, Tex.
Fort Worth, Tex.
Corpus Christi, Tex.
Austin, Tex.
Laredo, Tex.
El Paso, Tex.
Tucson, Ariz.
Phoenix, Ariz.
San Diego, Calif.
San Bernardino, Calif.
Riverside, Calif.
Oceanside, Calif.
Garden Grove, Calif.
Norwalk, Calif.
Montebello, Calif.
Long Beach, Calif.
Los Angeles, Calif.
Santa Monica, Calif.
Gardena, Calif.
Torrance, Calif.
Bakersfield, Calif.
Ventura, Calif.
Santa Barbara, Calif.
Fresno, Calif.
Stockton, Calif.
Sacramento, Calif.
Monterey, Calif.
San Jose, Calif.
Santa Cruz, Calif.
Oakland, Calif.
Seattle, Wash.
San Mateo, Calif.
San Francisco, Calif.
Tacoma, Wash.
Salem, Oreg.
Eugene, Oreg.
Portland, Oreg.

Intermediate

Class (-, -, +)

Philadelphia, Pa.
Wilmington, Del.
Lancaster, Pa.
Washington, D.C.
Lynchburg, Va.
Columbus, Ohio

Knoxville, Tenn.
Chattanooga, Tenn.
Kansas City, Mo.
Topeka, Kans.
Tulsa, Okla.
Wichita, Kans.
Oklahoma City, Okla.
Amarillo, Tex.
Lubbock, Tex.
Albuquerque, N.M.

Class (-, -, 0)
Richmond, Va.
Winston-Salem, N.C.
Charlotte, N.C.
Dayton, Ohio
Atlanta, Ga.
Cincinnati, Ohio
Newport, Ky.
Lexington, Ky.
Nashville, Tenn.
Birmingham, Ala.
Memphis, Tenn.
St. Louis, Mo.
Little Rock, Ark.

Class (+, +, 0)
New Bedford, Mass.
Brockton, Mass.
Providence, R.I.
Flushing, N.Y.
Jamaica, N.Y.
Jackson Heights, N.Y.
New York, N.Y.
East Meadow, N.Y.
Brooklyn, N.Y.
West Coxsackie, N.Y.
Louisville, Ky.

Class (-, 0, 0)
Indianapolis, Ind.
Urbana, Ill.
Decatur, Ill.
Peoria, Ill.
Springfield, Ill.

Class (+, -, +)
Bridgeport, Conn.
Stamford, Conn.
Asheville, N.C.

Class (-, 0, +)
Huntington, W.Va.
Charleston, W.Va.

Class (0, -, +)
Baltimore, Md.

Class (+, 0, +)
Roanoke, Va.

Class (-, +, +)
Boise, Idaho

Note that some cities may have more than one transit authority associated with them. Also note that the cities with the harshest climates are as follows (ordered by longitude): Portland, Maine; Manchester, New Hampshire; Springfield, Massachusetts; Albany, Utica, Binghamton, Syracuse, Rochester, and Buffalo, New York; Erie, Pennsylvania; Duluth, Minnesota; Colorado Springs and Denver, Colorado; Salt Lake City, Utah; and Spokane, Washington. The cities whose climate was closest to the average were as follows (ordered by longitude): Indianapolis, Indiana; Urbana, Peoria, Springfield, and Decatur, Illinois; Baltimore, Maryland; and Charleston and Huntington, West Virginia.

Figure 1 partitions the continental United States into harsh, benign, and intermediate climate peer groups of transit authorities. Peer group boundaries were drawn to separate transit authorities in, or near, cities of harsh climate (see the preceding list) from transit authorities in, or near, cities of intermediate climate (see the preceding list). The latter were separated, in turn, from transit authorities in, or near, cities of benign climate (see the preceding list). As is evident from the underlying scatter of dots in Figure 2, the accuracy with which these climate peer group boundaries were placed is greater in the east than in the west. In much of the western mountainous region, the boundary follows topographic features such as mountain ranges and river basins. Because the climatic indicators that formed the basis for delineating climate peer groups were chosen for their capability to link road salt to snow, Figure 2 also shows the position of the Salina Basin, a major subsurface rock salt deposit near many of the transit authorities in the Great Lakes portion of the harsh climate peer group.

## The Distribution of Climate Vectors

The three climate peer groups shown in Figure 2 exhibit a great deal of variation within each group; this section shows how to determine the peers most closely related, in both climate and geographic position, to an arbitrarily chosen transit authority. The map in Figure 3 displays the grid generally employed for the polar case of an azimuthal equidistant map projection (on which distances measured from the center are true). In maps of this sort, the radials generally represent longitude and the arcs represent latitude. Because latitude and climate are related, climate is substituted for latitude; the column "climate vector norms" in Table 1 gives single climate values, based on all three climatic indicators, used in place of latitude in the map of Figure 3. Then, dots on that map that are close have both climate and longitude (geographic position) that are close. Hence, the nearest neighbors within a semi-circular band of a given point are its geographically proximate climate peers. Table 2 gives the names of each transit authority represented in Figure 2 and its nearest climate peers. For example, there is no transit authority with winters as severe as those in Duluth, Minnesota, nearer than Springfield, Massachusetts, on the east, or than Denver, Colorado, on the west. Thus, Springfield and Denver are Duluth's geographically nearest climate peers.

The detail of constructing this map and these tables rests in viewing the ordered triples of climate indicators as vectors in three-dimensional space. The components of the vectors are numerical measures of different ranges, but are of equal weight in describing severity of winter (as previously explained). Thus, to compare vectors, adjustment is required of the set of values over which individual components may range. A variety of strategies is available for this purpose, and each could lead to the means for determining climate peer groups based on the climate vectors associated with individual transit authorities.

Suppose that the ordered triples are referenced to three mutually orthogonal axes. The x-axis measures the number of inches of snow, and values along it range from -23 in. below to 86 in. above the national mean; the y-axis measures the number of events, and values on it range from -7 events below to 25 events above the national mean, and the z-axis measures the Visher index, and values on it range from -50 alternations below to 80 alternations above the national mean. The origin (0, 0, 0) represents the national mean. To standardize the units, any arbitrary scale, including those already on the axes, might have been used. Because the Visher scale has the finest mesh of the three scales already present, the authors chose, for ease in matching units, to convert each of the scales on the x and y axes to

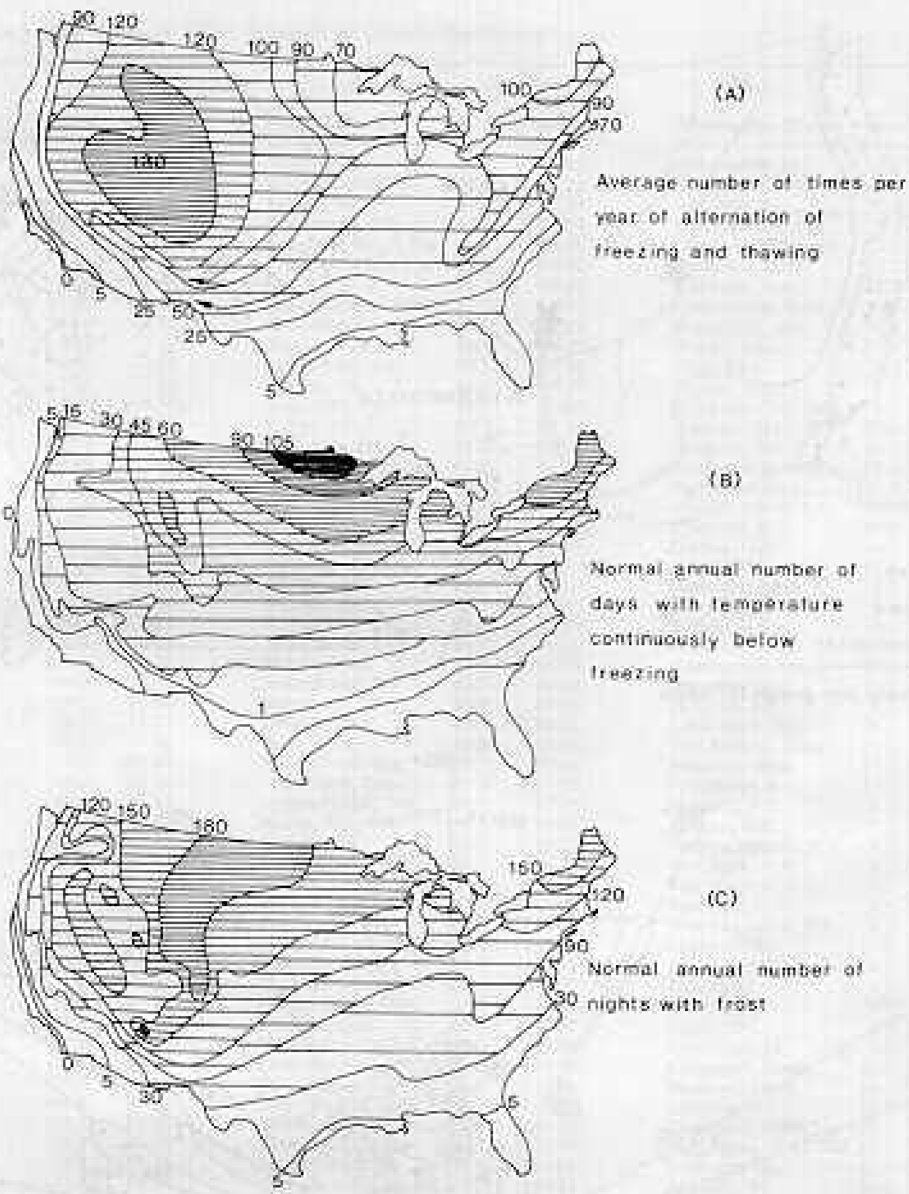


FIGURE 1 Visher maps.

the 130-part Visher scale of the z-axis. Thus, the unit vector on the x-axis becomes (1.1926606, 0, 0) because x/130 = 1/109; the unit vector on the y-axis stretches to (0, 4.0625, 0) because y/130 = 1/32; and the unit vector on the z-axis remains fixed. Then, a climate vector may be associated with each transit authority by multiplying the number of inches of snow for that authority by 1.1926606, and the number of events by 4.0625. Table 1 gives the lengths (norms) of the climate vectors measured from (0, 0, 0) for each transit authority for which both climatic and Section 15 data were available.

Figure 3 employs an azimuthal equidistant projection centered at the national mean of (0, 0, 0) to show, using climate vectors, how much each transit authority lies above or below the average vector of (0, 0, 0). On this projection, distances measured from the center are true. The horizontal line, as a base line in Figure 3, represents a meridian of 65 degrees west longitude to the right of the map center and a meridian of 125 degrees west longitude to the left of the map center. These choices of longitude correspond roughly to the east-west longitudinal extremes in the United States. The meridians that interrupt the projection, at 69 degrees and 118 degrees in the above average zone, and at 75 degrees and 124 degrees in the below average zone, show more precise positions for the transit authorities that are farthest east and west in each of the above and below average zones (i.e., Portland, Maine, and Spokane, Washington, in the above average zone, and Norfolk, Virginia, and Portland, Oregon, in the below average zone). A set of five evenly spaced lines concurrent with the base line at (0, 0, 0) partitions the map into wedges. These radials are assigned values of 75, 85, 95, 105, and 115 to represent longitude, and are followed by a "+" symbol when they lie above the origin and by a "-" symbol when they lie below it. The evenly spaced set of concentric circles, which might generally suggest latitude on a projection of this sort, represents instead the length of the climate vector--the interval measuring the spacing is 10 units of climate vector length. Climate vectors all have positive length measured from the map center. Vector heads associated with triples containing only positive or zero entries

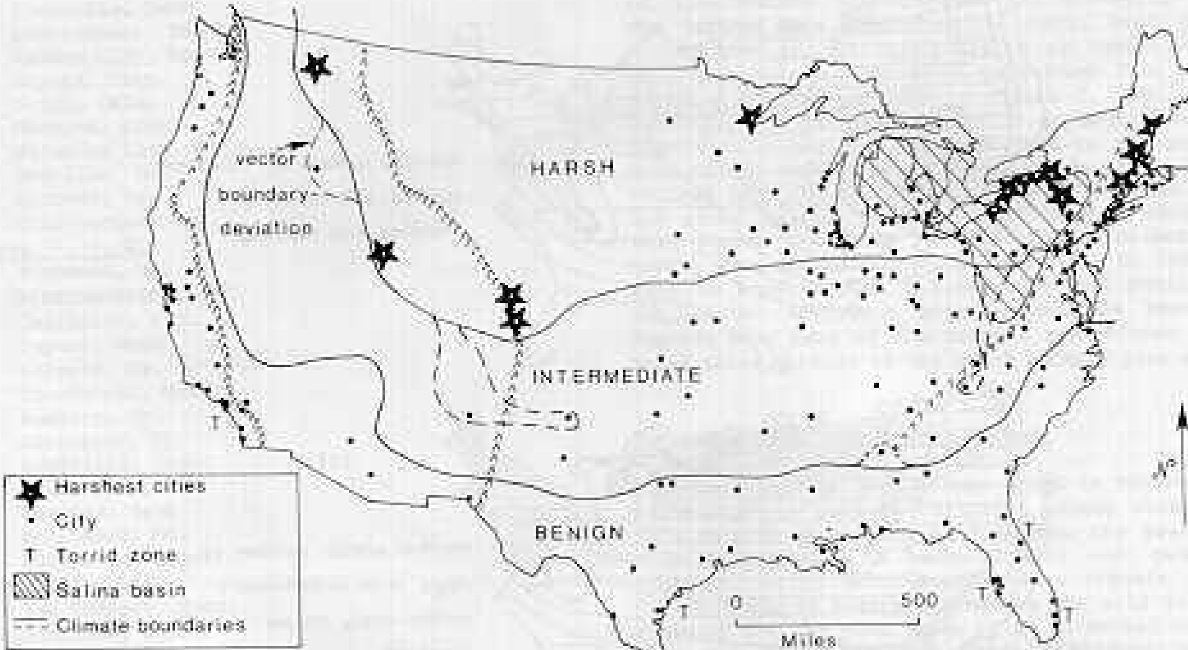


FIGURE 2 Climate peer groups for buses.

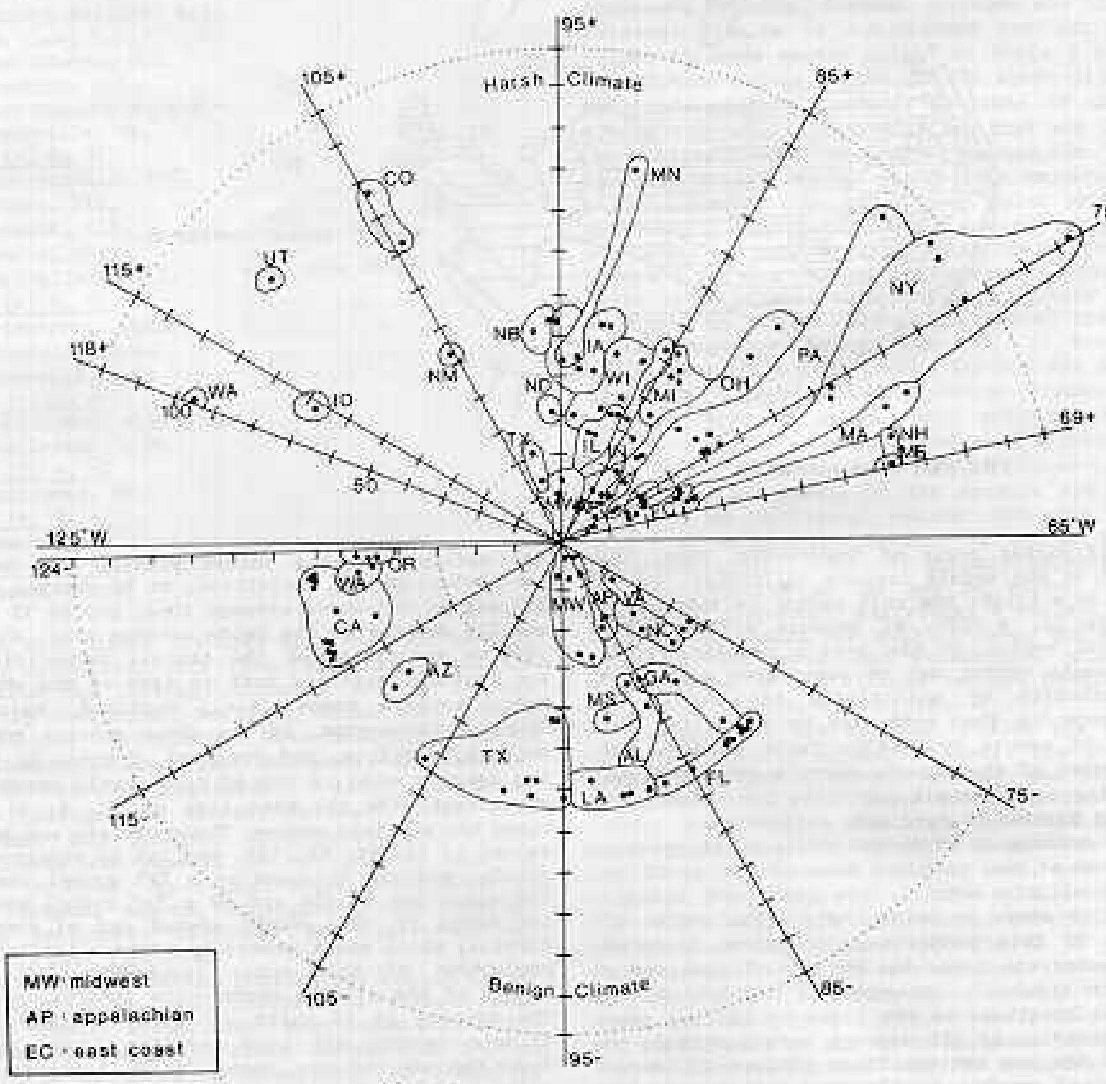


FIGURE 3 Bus climate vectors grouped by state.

TABLE 1 Climate Vector Norms of Cities Arranged by Climate Peer Group[a]

| Harsh Climate | Norm | Longitude (degrees and minutes) | Benign Climate | Norm | Longitude (degrees and minutes) | Intermediate Climate | Norm | Longitude (degrees and minutes) |
|---|---|---|---|---|---|---|---|---|
| Portland, Maine | 82.4 | 70 16 | Norfolk, Va. | 37.4 | 76 15 | Philadelphia, Pa. | 15.7 ↑ | 75 13 |
| Haverhill, Mass. | 33.6 | 71 05 | Hampton, Va. | 37.4 | 76 21 | Wilmington, Del. | 9.9 ↑ | 75 33 |
| Boston, Mass. | 33.6 | 71 07 | Raleigh, N.C. | 37.4 | 78 39 | Lancaster, Pa. | 15.7 ↑ | 76 20 |
| Lowell, Mass. | 33.6 | 71 18 | Fayetteville, N.C. | 37.4 | 78 54 | Washington, D.C. | 9.9 ↑ | 77 00 |
| Manchester, N.H. | 85.3 | 71 30 | West Palm Beach, Fla. | 63.7 | 80 04 | Lynchburg, Va. | 13.7 ↑ | 79 08 |
| Worcester, Mass. | 85.1 | 71 49 | Fort Lauderdale, Fla. | 63.7 | 80 09 | Columbus, Ohio | 15.7 ↑ | 83 00 |
| Springfield, Mass. | 91.9 | 72 35 | Miami, Fla. | 63.7 | 80 11 | Knoxville, Tenn. | 3.3 ↓ | 83 55 |
| Hartford, Conn. | 31.0 | 72 40 | South Daytona, Fla. | 63.7 | 81 02 | Chattanooga, Tenn. | 1.9 ↓ | 85 15 |
| New Haven, Conn. | 31.0 | 72 55 | Savannah, Ga. | 60.0 | 81 07 | Kansas City, Mo. | 14.5 ↑ | 94 35 |
| White Plains, N.Y. | 22.0 | 73 47 | Orlando, Fla. | 63.7 | 81 22 | Topeka, Kans. | 12.7 ↑ | 95 41 |
| Albany, N.Y. | 74.6 | 73 50 | Jacksonville, Fla. | 63.7 | 81 40 | Tulsa, Okla. | 0.3 ↓ | 95 58 |
| Yonkers, N.Y. | 22.0 | 73 54 | Augusta, Ga. | 46.0 | 82 00 | Wichita, Kans. | 7.1 ↓ | 97 21 |
| Newark, N.J. | 22.0 | 74 10 | Gainesville, Fla. | 63.7 | 82 20 | Oklahoma City, Okla. | 3.3 ↑ | 97 32 |
| Utica, N.Y. | 74.7 | 75 30 | Tampa, Fla. | 63.7 | 82 25 | Amarillo, Tex. | 23.0 ↑ | 101 49 |
| Allentown, Pa. | 42.9 | 75 30 | Bradenton, Fla. | 63.7 | 82 35 | Lubbock, Tex. | 16.7 ↑ | 101 50 |
| Scranton, Pa. | 60.0 | 75 45 | Saint Petersburg, Fla. | 63.7 | 82 38 | Albuquerque, N.Mex. | 50.3 ↑ | 106 40 |
| Kingston, Pa. | 42.9 | 75 50 | Clearwater, Fla. | 63.7 | 82 45 | Richmond, Va. | 15.5 | 77 30 |
| Binghamton, N.Y. | 113.8 | 75 55 | Tallahassee, Fla. | 63.7 | 84 17 | Winston-Salem, N.C. | 26.3 | 80 15 |
| Syracuse, N.Y. | 149.9 | 76 10 | Columbus, Ga. | 39.5 | 84 56 | Charlotte, N.C. | 29.6 | 80 50 |
| Harrisburg, Pa. | 45.0 | 76 50 | Montgomery, Ala. | 46.0 | 86 17 | Dayton, Ohio | 4.8 | 84 15 |
| Rochester, N.Y. | 114.1 | 77 35 | Pensacola, Fla. | 63.7 | 87 13 | Atlanta, Ga. | 21.8 | 84 23 |
| Altoona, Pa. | 45.0 | 78 25 | Mobile, Ala. | 63.7 | 88 03 | Cincinnati, Ohio | 8.3 | 84 30 |
| Johnstown, Pa. | 42.0 | 78 50 | Harahan, La. | 63.7 | 90 00 | Newport, Ky. | 8.3 | 84 30 |
| Buffalo, N.Y. | 116.5 | 78 51 | Gretna, La. | 63.7 | 90 00 | Lexington, Ky. | 6.3 | 84 30 |
| Pittsburgh, Pa. | 41.9 | 80 01 | New Orleans, La. | 63.7 | 90 05 | Nashville, Tenn. | 24.2 | 86 48 |
| Erie, Pa. | 111.9 | 80 05 | Jackson, Miss. | 45.3 | 90 10 | Birmingham, Ala. | 38.0 | 86 49 |
| Youngstown, Ohio | 64.3 | 80 40 | Baton Rouge, La. | 63.7 | 91 10 | Memphis, Tenn. | 29.6 | 90 03 |
| Kent, Ohio | 28.1 | 81 20 | Shreveport, La. | 60.0 | 93 46 | St. Louis, Mo. | 8.3 | 90 15 |
| Canton, Ohio | 28.1 | 81 25 | Houston, Tex. | 63.7 | 95 21 | Little Rock, Ark. | 28.7 | 92 16 |
| Akron, Ohio | 28.1 | 81 30 | Dallas, Tex. | 43.0 | 96 48 | New Bedford, Mass. | 17.0 | 70 55 |
| Cleveland, Ohio | 75.3 | 81 42 | San Antonio, Tex. | 59.9 | 97 08 | Brockton, Mass. | 17.0 | 71 01 |
| Detroit, Mich. | 49.6 | 83 10 | Fort Worth, Tex. | 42.3 | 97 20 | Providence, R.I. | 17.0 | 71 23 |
| Toledo, Ohio | 31.0 | 83 35 | Corpus Christi, Tex. | 63.7 | 97 24 | Flushing, N.Y. | 8.3 | 73 50 |
| Saginaw, Mich. | 38.2 | 83 40 | Austin, Tex. | 59.3 | 97 42 | Jamaica, N.Y. | 8.3 | 73 50 |
| Ann Arbor, Mich. | 49.6 | 83 45 | Laredo, Tex. | 63.7 | 99 29 | Jackson Heights, N.Y. | 8.3 | 73 50 |
| Flint, Mich. | 51.6 | 83 45 | El Paso, Tex. | 63.7 | 106 27 | New York, N.Y. | 6.3 | 73 58 |
| Bay City, Mich. | 38.2 | 83 55 | Tucson, Ariz. | 56.9 | 111 00 | East Meadow, N.Y. | 6.3 | 73 58 |
| Jackson, Mich. | 55.6 | 84 25 | Phoenix, Ariz. | 50.7 | 112 00 | Brooklyn, N.Y. | 6.3 | 73 58 |
| Fort Wayne, Ind. | 22.7 | 85 10 | San Diego, Calif. | 63.7 | 117 10 | West Coxsackie, N.Y. | 6.3 | 73 58 |
| Kalamazoo, Mich. | 43.5 | 85 40 | San Bernardino, Calif. | 63.7 | 117 19 | Louisville, Ky. | 17.0 | 85 45 |
| South Bend, Ind. | 53.4 | 86 20 | Riverside, Calif. | 63.7 | 117 21 | Indianapolis, Ind. | 6.0 | 86 08 |
| Gary, Ind. | 33.7 | 87 21 | Oceanside, Calif. | 63.7 | 117 22 | Urbana, Ill. | 1.0 | 88 15 |
| Chicago, Ill. | 33.7 | 87 37 | Garden Grove, Calif. | 63.7 | 117 56 | Decatur, Ill. | 2.0 | 88 59 |
| Racine, Wis. | 48.8 | 87 49 | Norwalk, Calif. | 63.7 | 118 05 | Peoria, Ill. | 1.0 | 89 35 |
| Kenosha, Wis. | 48.8 | 87 50 | Montebello, Calif. | 63.7 | 118 06 | Springfield, Ill. | 2.0 | 89 37 |
| Waukegan, Ill. | 33.7 | 87 51 | Long Beach, Calif. | 63.7 | 118 12 | Bridgeport, Conn. | 16.5 ↑ | 73 12 |
| Des Plaines, Ill. | 33.7 | 87 54 | Los Angeles, Calif. | 63.7 | 118 15 | Stamford, Conn. | 16.5 ↑ | 73 32 |
| Milwaukee, Wis. | 48.8 | 87 55 | Santa Monica, Calif. | 63.7 | 118 19 | Asheville, N.C. | 15.9 ↑ | 82 35 |
| Joliet, Ill. | 33.7 | 88 05 | Gardena, Calif. | 63.7 | 118 19 | Charleston, W.Va. | 12.8 ↑ | 81 35 |
| Elgin, Ill. | 28.4 | 88 16 | Torrance, Calif. | 63.7 | 118 20 | Huntington, W.Va. | 12.8 ↑ | 82 25 |
| Aurora, Ill. | 28.4 | 88 18 | Bakersfield, Calif. | 59.9 | 119 00 | Baltimore, Md. | 15.9 ↑ | 76 38 |
| Appleton, Wis. | 32.0 | 88 27 | Ventura, Calif. | 63.7 | 119 18 | Roanoke, Va. | 20.3 | 79 55 |
| Oshkosh, Wis. | 32.0 | 88 35 | Santa Barbara, Calif. | 63.7 | 119 42 | Boise, Idaho | 67.7 ↑ | 116 12 |
| Rockford, Ill. | 28.4 | 89 07 | Fresno, Calif. | 59.9 | 119 47 | | | |
| Madison, Wis. | 48.3 | 89 23 | Stockton, Calif. | 63.7 | 121 16 | | | |
| Rock Island, Ill. | 28.0 | 90 37 | Sacramento, Calif. | 50.7 | 121 30 | | | |
| Davenport, Iowa | 28.0 | 90 38 | Monterey, Calif. | 63.7 | 121 53 | | | |
| Dubuque, Iowa | 54.1 | 90 43 | San Jose, Calif. | 63.7 | 121 54 | | | |
| La Crosse, Wis. | 33.6 | 91 14 | Santa Cruz, Calif. | 63.7 | 122 02 | | | |
| Cedar Rapids, Iowa | 54.1 | 91 43 | Oakland, Calif. | 63.7 | 122 16 | | | |
| Duluth, Minn. | 91.7 | 92 07 | Seattle, Wash. | 51.1 | 122 20 | | | |
| Waterloo, Iowa | 41.9 | 92 22 | San Mateo, Calif. | 63.7 | 122 20 | | | |
| St. Paul, Minn. | 43.5 | 93 05 | San Francisco, Calif. | 63.7 | 122 21 | | | |
| Des Moines, Iowa | 44.8 | 93 37 | Tacoma, Wash. | 47.0 | 122 27 | | | |
| St. Cloud, Minn. | 43.5 | 94 08 | Salem, Oreg. | 53.4 | 123 03 | | | |
| Sioux City, Iowa | 53.7 | 96 25 | Eugene, Oreg. | 51.1 | 123 06 | | | |
| Lincoln, Nebr. | 54.2 | 96 43 | Portland, Oreg. | 50.7 | 123 41 | | | |
| Fargo, N.Dak. | 31.9 | 96 48 | | | | | | |
| Omaha, Nebr. | 52.3 | 97 57 | | | | | | |
| Colorado Springs, Colo. | 83.6 | 104 48 | | | | | | |
| Denver, Colo. | 97.4 | 104 59 | | | | | | |
| Salt Lake City, Utah | 96.2 | 111 52 | | | | | | |
| Spokane, Wash. | 95.0 | 117 25 | | | | | | |

[a] Arrows indicate "above" (↑) or "below" (↓) average norm.

were placed at an appropriate distance in the above average zone, and those with only negative or zero entries were located in the below average zone. The distance $\|V\|$ of a vector $V = (p, q, r)$ from the origin $(0, 0, 0)$ is computed as $\|V\| = (p^2 + q^2 + r^2)^{1/2}$ (4). However, vectors with both positive and negative entries could be misplaced using this norm. For example, a high positive Visher value coupled with negative indices far below zero on "frequency of storm" and "total snowfall amount" would represent a city with a norm larger than seems reasonable.

The degree of exaggeration depends directly on

TABLE 2 Vector Rank-Ordering of Transit Authorities Within Climate Peer Groups[a]

| Norm | Cities |
|---|---|
| 100+ | Binghamton, N.Y.; Syracuse, N.Y.; Rochester, N.Y.; Buffalo, N.Y.; Erie, Pa. |
| 90-99.9 | Springfield, Mass.; Duluth, Minn.; Denver, Colo.; Salt Lake City, Utah; Spokane, Wash. |
| 80-89.9 | Portland, Maine; Manchester, N.H.; Worcester, Mass.; Colorado Springs, Colo. |
| 70-79.9 | Albany, N.Y.; Utica, N.Y.; Cleveland, Ohio |
| 60-69.9 | Scranton, Pa.; Youngstown, Ohio; Boise, Idaho |
| 50-59.9 | Flint, Mich.; Jackson, Mich.; Kalamazoo, Mich.; Dubuque, Iowa; Waterloo, Iowa; Sioux City, Iowa; Lincoln, Nebr.; Omaha, Nebr.; Albuquerque, N.Mex. |
| 40-49.9 | Allentown, Pa.; Kingston, Pa.; Altoona, Pa.; Johnstown, Pa.; Pittsburgh, Pa.; Detroit, Mich.; Ann Arbor, Mich.; Milwaukee, Wis.; Madison, Wis.; St. Paul, Minn.; Des Moines, Iowa; St. Cloud, Minn. |
| 30-39.9 | Boston, Mass.; Hartford, Conn.; New Haven, Conn.; Toledo, Ohio; Chicago, Ill.; Appleton, Wis.; La Crosse, Wis.; Fargo, N.Dak. |
| 20-29.9 | White Plains, N.Y.; Yonkers, N.Y.; Roanoke, Va.; Kent, Ohio; Canton, Ohio; Akron, Ohio; Fort Wayne, Ind.; Rock Island, Ill.; Davenport, Iowa; Amarillo, Tex. |
| 10-19.9 | New Bedford, Mass.; Brockton, Mass.; Providence, R.I.; Bridgeport, Conn.; Stamford, Conn.; Philadelphia, Pa.; Lancaster, Pa.; Baltimore, Md.; Lynchburg, Va.; Asheville, N.C.; Charleston, W.Va.; Huntington, W.Va.; Columbus, Ohio; Louisville, Ky.; Topeka, Kans.; Kansas City, Mo.; Lubbock, Tex. |
| 0-9.9 | New York City and suburbs; Wilmington, Del.; Washington, D.C.; Oklahoma City, Okla. |
| (-10)-(-0.1) | Knoxville, Tenn.; Cincinnati, Ohio; Newport, R.I.; Lexington, Ky.; Dayton, Ohio; Chattanooga, Tenn.; Indianapolis, Ind.; Urbana, Ill.; Decatur, Ill.; Peoria, Ill.; Springfield, Ill.; St. Louis, Mo.; Tulsa, Okla.; Wichita, Kans. |
| (-20)-(-10.1) | Richmond, Va. |
| (-30)-(-20.1) | Winston-Salem, N.C.; Charlotte, N.C.; Atlanta, Ga.; Nashville, Tenn.; Memphis, Tenn.; Little Rock, Ark. |
| (-40)-(-30.1) | Norfolk, Va.; Hampton, Va.; Raleigh, N.C.; Fayetteville, N.C.; Birmingham, Ala.; Columbus, Ga. |
| (-50)-(-40.1) | Augusta, Ga.; Montgomery, Ala.; Jackson, Miss.; Dallas, Tex.; Fort Worth, Tex.; Tacoma, Wash. |
| (-60)-(-50.1) | Savannah, Ga.; Shreveport, La.; San Antonio, Tex.; Austin, Tex.; Tucson, Ariz.; Phoenix, Ariz.; Bakersfield, Calif.; Fresno, Calif.; Sacramento, Calif.; Seattle, Wash.; Salem, Oreg.; Eugene, Oreg.; Portland, Oreg. |
| below (-60) | All of Florida; New Orleans, La.; Baton Rouge, La.; Houston, Tex.; Corpus Christi, Tex.; Laredo, Tex.; El Paso, Tex.; Los Angeles, Calif. and suburbs; San Francisco, Calif. and suburbs |

[a]Transit authorities are listed by semicircular bands from Figure 3 and ordered from east to west within a semicircular band.

the size of the spread between positive and negative values; frequent freezing and thawing may be irrelevant if there is no snow, and will be if there is no rain. To overcome this, we computed the distance from the origin $\|w\|$ of a vector $w = (-s, -t, u)$, $s, t, u > 0$, as $\|w\| = |(s^2 + t^2)^{1/2} - (u^2)^{1/2}|$; this procedure reduced the distortion in the norm of "mixed" vectors by preserving the difference in sign between entries of opposite sign. Corresponding calculations were used for $w = (-s, t, -u)$, $w = (s, t, -u)$, and for all of the other possibilities. The vector head of a mixed vector was placed in the above average zone of Figure 3 if the difference inside the absolute value sign was positive, and in the below average zone if that difference was negative. Entries in Table 1 that are followed by arrows suggesting "above" or "below" in the column displaying climate vector length, represent positions for "mixed" vectors that are not classified in the natural manner.

Thus, Figure 3 shows the entries in Table 1 positioned by longitude and by climate vector norm. Grouping these vector heads by state produces a political subdivision of the United States based on climate and longitude. In this map, distortion of the state boundaries away from the standard subdivision, based on latitude and longitude, is due entirely to climatic effects. For example, Washington is fragmented into two parts: coastal Washington, with a mild climate, lying between 115- and 125 degrees west in the below average zone, and mountainous Washington, with a harsh climate, lying between 115+ and 125 degrees west in the above average zone. In a similar manner, cities in Ohio south of Columbus lie below the center between 75- and 85-, and lie in the region labeled MW in Figure 3, while those in northern Ohio fall above the center between 75+ and 85+. The elongation away from the map center between 75+ and 85+ represents the presence of lake effect snow in Cleveland and Youngstown. Indiana is fragmented in the same way as Ohio, with Indianapolis, Muncie, and others south of the map center, Fort Wayne above the map center, and elongation away from the center out to South Bend. Further, southern Pennsylvania cities near the coast (e.g., Philadelphia and Lancaster) have vector heads lying just above the map center although those in mountainous Pennsylvania lie away from it. Again, this boundary stretches out from the center to pick up lake effect snows in Erie. Finally, New York exhibits the most extreme form of this sort of climatic distortion; a coastal section above, but close to, the map center includes New York City and suburbs, and an upstate section, which contains a number of lake effect cities, exhibits climatic indices for buses that are in the harshest climates in the nation.

What this suggests, of course, is that a transit manager in a given city should not necessarily look to another in his own state for a climatic peer; Erie is better advised to examine the climatic problems of Buffalo or Rochester than those of Philadelphia. Thus, the semicircular bands in the above the below average zones of Figure 3 suggest rank ordering for transit authorities within climate peer groups (Table 2). Extremes in the longitudinal spacing within such bands show nearest and remotest peer, and it is on account of this that entries in Tables 1 and 2 are ordered by longitude.

Based on this more technically precise vector approach, Figure 3 and Tables 1 and 2 were used to generate vector boundaries separating harsh, intermediate, and benign climate peer groups. To find these boundaries, note that in Figure 3, cities that are close to the center (whether above or below the center) have a climate vector length close to the national mean. Consequently, the transit authorities associated with these vectors lie in an intermediate climate. One place to separate the intermediate positions from the harsh positions in the above average zone, that appeared to be reasonable in terms of the climatic data, was along the semicircle 20 units from the center. In the below average zone, the semicircle 30 units below the center appeared to be a natural choice. When these vector boundaries were superimposed on the map in Figure 2, they were coincident with the simple boundaries, determined in the first part of this paper, in all but five locations.

In particular, Boise, Roanoke, Albuquerque, and Amarillo belonged in the intermediate climate peer group according to the simple partition, but shifted to the harsh climate peer group in the vector partition. At the other extreme, Birmingham was classified as intermediate initially but as benign in the vector approach (Figure 2). The content of the climate vectors suggests reasons for these transit authorities to be climatic "boundary dwellers" (5). In all cases, the Visher index had by far the greatest numerical value, often because of the presence of mountains, suggesting that in a rain- or snowstorm, the frequent freezing and thawing might cause difficulties for buses. Thus, in mild winters, these cities might be classified in the more benign of the two peer groups because there would be little need for salt (although in severe winters, the more frequent use of salt would push them into the harsher of the two peer groups). Cities in this position certainly appear to have the potential for a significant problem that may arise only every few years. The indices associated with Birmingham show it to have the slightest such potential and those linked to Boise indicate that it has the greatest. Other than these boundary dwellers, the harsh, intermediate, and benign climate peer groups that were formed using the simple procedure correspond identically to those generated by the vector approach. Thus, the vector approach serves not only to pinpoint nearest climate peers but also to verify the more broadly based scheme displayed in Figure 2, within which the next consideration is of other factors such as age profiles and performance.

## AGE STRUCTURE BY CLIMATE PEER GROUP OF THE U.S. BUS POPULATION

The application of these climate peer groups to the Section 15 indicator, "Age Distribution of Revenue Vehicle Inventory," produces evidence to support the hypothesis that harsh climates speed bus deterioration. The "Stratification Charts by Climate Peer Group" of Figure 4 show the expected, versus the actual, annual and aggregate age stratification of the bus population by climate peer group. For example, in 1978-1979, 35.8 percent of all buses were in transit authorities in a harsh environment; thus, one would expect that 35.8 percent of 0- to 5-year-old buses, 35.8 percent of 6- to 10-year-old buses, 35.8 percent of 11- to 15-year-old buses, and so forth, would lie in the harsh class in 1978-1979. The position of the horizontal line in Figure 4A represents this expected value. In fact, however, this harsh class contained 38.7 percent of 0-5 year olds, 34.7 percent of 6-10 year olds, 36.8 percent of the 11-15 year olds, 29.8 percent of the 16-20 year olds, 23.0 percent of the 21-25 year olds, and 21.3 percent of the 25+ group (Figure 4A.i). The remaining frames in Figure 4 display similar breakdowns of data on bus age across climate peer groups; frames ii, iii, and iv (Figure 4) show age stratification in the harsh class for the remaining 3 years while frame 4A.v displays the aggregate of frames

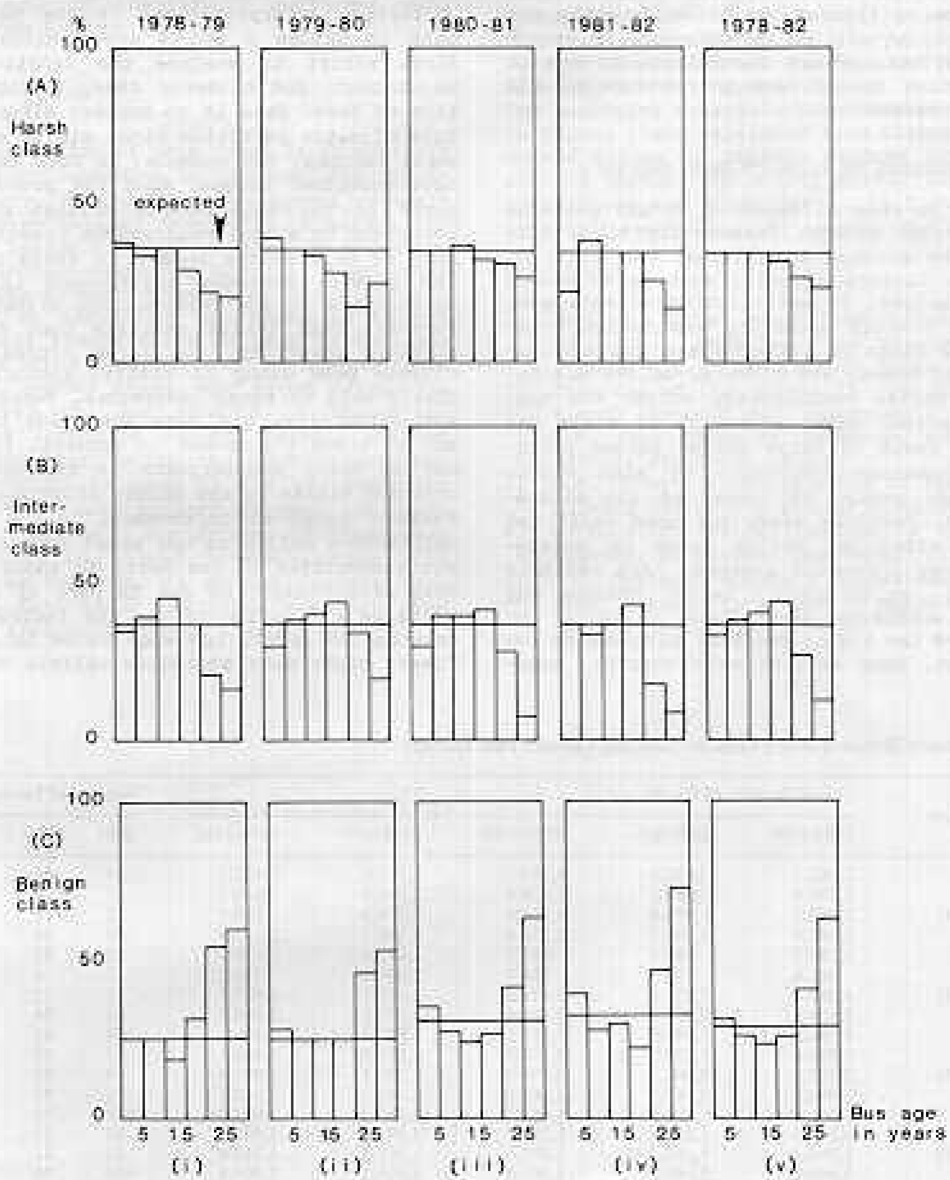


FIGURE 4 Time-series and aggregate stratification charts by climate peer group.

i-iv. Figure 4B shows five frames depicting, in chronological sequence, the annual and aggregate age stratification of the bus population in the intermediate climate peer groups and Figure 4C represents the same sequence for the benign climate peer group.

Of particular note is the distribution of the oldest buses across these peer groups. The harsh group has 23.8 percent of the oldest buses, rather than the expected 34.8 percent (Figure 4A.v); the intermediate group has 12.4 percent rather than the expected 38.1 percent (Figure 4B.v); and the benign group has 63.8 percent rather than the expected 28.9 percent (Figure 4C.v). The fact that the intermediate peer group has a smaller percentage of old buses than does even the harsh peer group, might suggest the (a) lack of expenditure in maintaining intermediate-climate buses, or (b) small size of many transit authorities in this peer group 20 to 30 years ago. The benign climates have far more than their share of old buses; the authors suspect that the graphic distinctions already evident in Figure 3 might become even more apparent if buses could be identified and eliminated subject to airborne salt in warm, humid climates. Figure 4C also shows bus fleets growing through time in sun-belt cities through the rise in the left-hand (0-5) column across the series of figures. As these recently enlarged fleets age, it will be significant, in evaluating climatic effects on bus durability, to see if the trend continues toward high percentages of old buses in benign climates.

## MAINTENANCE INDICATORS IN CLIMATE PEER GROUPS

Figure 4 serves to show differences in age profiles between climate peer groups; reasons for these differences might be related to climate, but might be related to other factors as well, such as tightness of maintenance budget. In establishing climate peer groups, size of transit authority was deemed unimportant; general climatic patterns are not a function of number of buses, and climate, unlike maintenance budgets, varies continuously across the map. Thus with maintenance data, economies of scale and increased labor costs in large cities forced partitioning of maintenance indicators by size within each climate peer group. We looked at the maintenance indicators, "vehicle miles per road call" and "total vehicle miles per dollar spent on maintenance." The former indicator appeared less reliable than the latter, on an annual basis, because any single transit authority might have a cluster of road calls toward the end of one year followed by few in the next year. Many entries were missing, especially in the first year, but were filled in, where possible, for "distance between road calls," using data from "total vehicle miles" divided by "total road calls," and for "miles per maintenance dollar" by dividing "total vehicle miles" by the product of "total operating expenses" and "percent of operating budget spent on maintenance." Two outliers were removed, and only entries reporting data in all categories for more than 2 years were included. The total sample for these indicators ranged in size from 138 to 178 authorities.

Table 3 gives distances between road calls over the entire 4-year span for the national bus population and for the bus population in the three climate peer groups. The breakdown into size peer group uses boundaries that appear, from hand-sorting of the data, to record positions of sharp change in indicator values and to separate data along boundaries already present in the tabular data. Table 4 gives miles per maintenance dollar on an annual basis for the bus population by size peer group within each climate peer group. All three climate peer groups show declining mileage per maintenance dollar from 1978-1979 to 1981-1982 (Table 4), suggesting that inflation has eaten into the mileage figures as a result of higher labor and parts costs.

Various interpretations of the patterns in the data in Tables 3 and 4 are available. This is a first effort to analyze the relationship between maintenance and climate; thus, a significant function of these data is to suggest directions in which this climatic partition might aid in controlling for other factors. For example, in both tables, the climate groupings suggest that the poorest performance rests in the intermediate climate class. Is this borne out by actual maintenance practices, by tightness of maintenance budget in these regions, or by the general economic environment in most transit authorities in the intermediate climate peer group? Further, both tables indicate that despite general climatic adversity, the large cities in the harsh climate peer group of transit authorities do relatively well on these indicators. Perhaps these transit authorities are more sensitive to maintenance, and to transit problems in general, than are a number of their counterparts in the more automobile-oriented cities in the benign climate group. Finally, Table 4 gives an improvement in vehicle miles per maintenance dollar as one moves from the small transit authorities in the north to those in the south. This effect might be due in part to climate, or it might be a function of how the indicator itself was constructed (e.g., low wage rates in small southern fleets might make aggregate vehicle miles per main-

TABLE 3 Distance Between Road Calls by Size and Climate Peer Groups

| Number of Buses per Transit Authority | Year of Section 15 Report | | | | | Number of Entries | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1981-1982 | 1980-1981 | 1979-1980 | 1978-1979 | 1978-1982 | 1982 | 1981 | 1980 | 1979 |
| Harsh | 2,665.2 | 2,487.1 | 2,547.7 | 2,993.0 | 2,652.1 | 64 | 64 | 62 | 50 |
| Large (500+) | 2,789.4 | 2,688.1 | 2,829.9 | 2,991.9 | 2,818.2 | 9 | 9 | 9 | 9 |
| Midsize (100-499) | 2,066.2 | 1,876.6 | 1,896.6 | 3,439.9 | 2,119.9 | 15 | 15 | 13 | 13 |
| Small (25-99) | 3,008.9 | 2,548.7 | 2,233.4 | 2,558.1 | 2,559.9 | 40 | 40 | 40 | 28 |
| Intermediate | 1,104.3 | 929.5 | 953.1 | 1,872.6 | 1,118.2 | 52 | 52 | 51 | 48 |
| Large (500+) | 981.6 | 756.9 | 796.9 | 2,059.3 | 979.2 | 7 | 6 | 6 | 6 |
| Midsize (100-499) | 1,398.2 | 1,423.9 | 1,418.3 | 1,427.7 | 1,417.2 | 21 | 22 | 19 | 19 |
| Small (25-99) | 1,824.9 | 2,208.6 | 2,229.6 | 2,427.8 | 2,153.8 | 24 | 24 | 26 | 23 |
| Benign | 1,596.8 | 1,445.8 | 1,551.1 | 2,072.4 | 1,621.7 | 62 | 62 | 57 | 49 |
| Large (500+) | 1,396.4 | 1,250.2 | 1,259.6 | 2,525.1 | 1,464.1 | 12 | 12 | 8 | 6 |
| Midsize (100-499) | 2,305.2 | 2,006.7 | 2,374.3 | 1,245.6 | 1,902.6 | 14 | 14 | 16 | 18 |
| Small (25-99) | 2,488.9 | 2,514.5 | 2,269.0 | 2,567.9 | 2,448.5 | 36 | 36 | 33 | 25 |
| National | 1,618.1 | 1,403.0 | 1,457.3 | 2,230.0 | 1,611.9 | 178 | 178 | 170 | 147 |
| Large (500+) | 1,503.5 | 1,250.9 | 1,293.8 | 2,490.2 | 1,509.3 | 28 | 27 | 23 | 21 |
| Midsize (100-499) | 1,791.6 | 1,685.2 | 1,822.6 | 1,564.6 | 1,716.6 | 50 | 51 | 48 | 50 |
| Small (25-99) | 2,446.2 | 2,443.9 | 2,245.6 | 2,521.2 | 2,404.6 | 100 | 100 | 99 | 76 |

TABLE 4 Vehicle Miles per Maintenance Dollar by Climate and Size Peer Groups[a]

| Number of Buses per Transit Authority | Year of Section 15 Report | | | | | Number of Entries | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1981-1982 | 1980-1981 | 1979-1980 | 1978-1979 | 1978-1982 | 1982 | 1981 | 1980 | 1979 |
| Harsh | 1.57 | 1.71 | 1.92 | 2.61 | 1.84 | 63 | 64 | 58 | 49 |
| Large (500+) | 1.44 | 1.55 | 1.74 | 2.45 | 1.69 | 9 | 9 | 9 | 8 |
| Midsize (100-499) | 2.00 | 2.25 | 2.72 | 3.36 | 2.41 | 15 | 15 | 13 | 11 |
| Small (25-99) | 2.21 | 2.36 | 2.62 | 3.22 | 2.52 | 39 | 40 | 36 | 30 |
| Intermediate | 1.17 | 1.32 | 1.50 | 1.64 | 1.39 | 48 | 48 | 46 | 44 |
| Large (500+) | 1.01* | 1.11* | 1.28* | 1.41* | 1.18 | 7 | 6 | 6 | 6 |
| Midsize (100-499) | 1.70 | 2.00 | 2.18 | 1.40 | 2.03 | 19 | 20 | 17 | 17 |
| Small (25-99) | 2.55 | 2.73 | 3.35 | 3.66 | 3.00 | 22 | 22 | 23 | 21 |
| Benign | 1.65 | 1.81 | 2.29 | 2.80 | 1.99 | 61 | 62 | 55 | 45 |
| Large (500+) | 1.46 | 1.56 | 2.05 | 2.59 | 1.73 | 12 | 12 | 8 | 4 |
| Midsize (100-499) | 2.09 | 2.58 | 2.44 | 2.90 | 2.50 | 14 | 14 | 16 | 17 |
| Small (25-99) | 2.90 | 3.08 | 3.99 | 3.98 | 3.33 | 35 | 36 | 31 | 24 |
| National | 1.34 | 1.59 | 1.85 | 2.19 | 1.71 | 172 | 174 | 159 | 138 |
| Large (500+) | 1.29 | 1.39 | 1.62 | 1.94 | 1.50 | 28 | 27 | 23 | 18 |
| Midsize (100-499) | 1.91 | 2.21 | 2.41 | 2.76 | 2.28 | 48 | 49 | 46 | 45 |
| Small (25-99) | 2.53 | 2.70 | 3.26 | 3.55 | 2.91 | 96 | 98 | 90 | 75 |

[a]Entries marked with an asterisk include data from New York City; without it, they become: 1.41, 1.65, 1.84, and 2.21.

tenance dollar appear higher if they constitute a relatively small percentage of the total benign maintenance budget). Thus, Tables 3 and 4 provide yet another means of identifying different subclasses within the Section 15 data.

## CONCLUSION

The primary contribution of this paper is to classify transit authorities according to climate. The typology has two layers. First, it sorts transit authorities into the three general categories of harsh, intermediate, and benign climates. Second, it pinpoints the nearest climatic peers of transit authorities within each of the broader categories.

In addition, an indication was given as to how these climate peer groups might be used to increase understanding of other factors, such as age profiles and performance. Beyond these, the broad categories might be employed in, for example, a regression analysis context involving several factors related to vehicle performance, while the nearest neighbor map (Figure 3) might be used to run corresponding studies on more narrowly defined climate subgroupings. Ultimately, however, the utility of these peer groups will likely be judged in conjunction with other factors, as they do, or do not, permit distinctions to be made among variables that are significant in the implementation of transit policy.

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