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A DESCRIPTION OF THE APPLICATION OF FACTOR ANALYSIS TO LAND USE CHANGE IN METROPOLITAN AREAS

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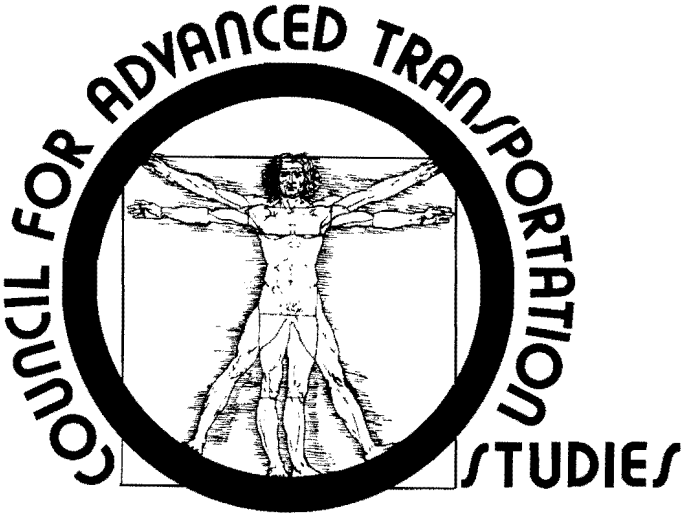

The University of Texas at Austin

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RESEARCH REPORT

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16. Abstract

The Dallas-Fort Worth SMSA is studied using an R-mode factor analytical procedure for selected 1960 census characteristics across four hundred and fifty census tracts. The results seem to verify the traditional delineations of data patterning, i.e., "Black ethnicity," "socio-economic status," and "stage in life cycle," except for a strong indication of "economic attractiveness." The correspondence of the results of the analysis for this area with results for other cities using the same or similar procedures, leads us to believe that the next stage of analysis (1970 Census) will isolate an airport-related change dimension. This new "economic vitality" measure could help structure a point of comparison between airport-related urban growth and normal, pre-existing growth trends.

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Executive Summary

I. Introduction

Factor analysis has traditionally been associated with urban geographers and social analysis. This multivariate procedure has delineated patterns of urban soical-economic, family and ethnic status in past applications. The present investigation describes how factor analysis may be used to investigate land use changes by census tract following a major change in transportation. This report concerns the first of three research stages, a factor analysis of land use before major transportation investment in 1960. The other stages will deal with land use after investment in 1970, and the nature of the changes between 1960 and 1970.

II. Problem

The problem studied concerns the effects and repercussions of associated changes in land utilization whenever large transport investments are committed to specific metropolitan areas. The objective of the research is to extract from the data patterning one factor which may be labeled as airport-related growth. This will be accomplished by investigating the percentage change in each census variable over a time period beginning prior to investment decisions and covering the following decade.

The work is centered in the Dallas-Fort Worth Regional Airport and the surrounding "metroplex." The U.S. Bureau of the Census delineation of the Dallas SMSA and the Fort Worth SMSA contain the formal boundaries of the study (approximately 5,000 square miles). The scope of inquiry is largely quantitative in the sense that four hundred and fifty census tracts will be matched against seventy-eight census variables. Qualitatively, the census variables chosen are good indicators of land use activities and changes. Hard, compatible, physical indicators of land use change over the ten year period have been difficult to find. A search is currently underway to realize this goal.

In stage one of the analysis, using an R-mode factor analytical procedure, 1960 census characteristics are plotted against census tracts covering

the two SMSA's. Five separate passes (Factor run A, B, C, D, and E) at the information are reported here. Seven independent factors are delineated for each factor run. Eigenvalues, percent of total variance and communality scores of .90 and above are included for each of the four runs. Each of the seven factors per run set are identified along with reasons explaining their identification and comments expressed, if any. A reduced diagram of results lists the five separate factor runs on the 1960 data, the resulting factor names and percent of total variance explained.

III. Results of the First 1960 Census Factor Runs (see Table 1)

"Black ethnicity" is consistently a large factor on all five runs, as is "socio-economic status." These two factors are generally expected results, given the data used. "Economic attractiveness" is one resulting factor not traditionally delineated. This "economic attractiveness" factor is expected to play a major role in the 1970 census factor run evaluations. It will be compared with variables which load significantly on a similar factor for 1970 data. In this manner meaningful conclusions may be drawn from the associated variable changes.

Less significant factors delineated by all five 1960 census data runs include "life cycle stage," "multi-unit dwelling," "suburban residency," "blue-collar labor market," "urban location," "single unit dwelling," "rural location," "non-Black ethnicity," "intra-city movement," and "metal industry" (see accompanying diagram).

Table 1. Diagram of Results

FACTOR RUN	FACTOR	PERCENT OF TOTAL VARIANCE EXPLAINED
A.	1. Black ethnicity	27.7%
	2. Socio-economic status	19.9%
	3. Life cycle stage	11.7%
	4. Multi unit dwelling pattern	8.8%
	5. Urban location	5.2%
	6. Non-Black ethnicity	4.3%
	7. Single unit dwelling pattern	3.2%
B.	1. Socio-economic status	29.5%
	2. Black ethnicity	20.8%
	3. Multi-unit dwelling pattern	10.5%
	4. "Blue collar labor market"	6.8%
	5. Single unit dwelling pattern	4.2%
	6. Non-definable	3.7%
	7. Non-Black ethnicity	3.2%
C.	1. Black ethnicity	37.8%
	2. Socio-economic status	20.1%
	3. Economic attractiveness	8.4%
	4. Non-definable	4.5%
	5. Life cycle stage	3.6%
	6. Intra-city movement or relocation	3.5%
	7. Non-definable	2.8%
D.	1. Black ethnicity	30.4%
	2. Economic attractiveness	20.1%
	3. Socio-economic status	9.6%
	4. Suburban residency	6.9%
	5. Rural location	4.5%
	6. Non-definable	3.4%
	7. Non-definable	2.6%
E.	1. Black ethnicity	31.9%
	2. Socio-ecomic status	19.8%
	3. Multi unit dwelling pattern	9.3%
	4. Non-definable	6.1%
	5. Occupational status	4.0%
	6. Occupational class	3.5%
	7. Urban location	2.4%

IV. Conclusion

In terms of results for 1960 Census data, the Dallas-Fort Worth region appears to be a "normal area." A significant dimension of in-migration related to economic vitality (labeled as "economic attractiveness") emerges from the multivariate procedure. The correspondence of the results for Dallas-Fort Worth with other cities leads us to believe that the next stage of analysis will be able to isolate an airport-related change dimension.

Results of this report may be viewed as static at this stage of investigation. 1960 data have been run and categorized so that they will be ready for 1970 data comparisons. This report may then be viewed as part of a larger three part study; that being the construction of a methodology used to evaluate major impacts of transportation facilities on urban areas anywhere.

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I. INTRODUCTION

I.1. General Use of Factor Analysis Procedures in Urban Studies

With modern computational methods and reliable quantities of census data, urban ecologists have been able to identify and describe specific patterns of social interaction associated with metropolitan growth. The multivariate procedure known as factor analysis is expressly suited for table or matrix data. Patterns can be distinguished from data and delineated into a distinct area or areas of interrelationships. In previous factorial studies, traditional patterns of "social-economic, family, and ethnic status" have been delineated from census data for a number of major metropolitan areas.[1] Similarly, Robert Murdie discovered these same patterns for metropolitan Toronto in 1951 and 1961, with the exception of a strong emerging pattern structure for 'recent growth and household and employment characteristics.'[2] It is claimed that "factor analysis can simultaneously manage over a hundred variables, compensate for random error and invalidity, and disentangle complex interrelationships into their major and distinct regularities."[3] This inquiry proposes to use this same multivariate method of data extraction and management and apply it descriptively to geographically assoc-

[1] In 1955, W. Bell used factor analysis to help delineate economic, family, and ethnic status patterns for Los Angeles and San Francisco; in 1961, Anderson and Bean confirmed these social areas for Toledo, Ohio; Schmid and Tayashira expanded this social index somewhat in 1964 for Seattle, by asserting a structural pattern of maleness population stability; and G.W. Carey, in his Regional Interpretation of Manhattan Population and Housing Patterns Through Factor Analysis, mapped his factor scores.

[2] Robert Murdie, Factorial Ecology of Metropolitan Toronto, 1951-1961, Department of Geography, University of Chicago, 1969.

[3] R.J. Rummel, Understanding Factor Analysis, Reprinted from The Journal of Conflict Resolution, Vol. XI, No. 4, December 1967, pp. 444-480.

iated economic, social, and land use characteristics for the Dallas-Fort Worth region.

I.2. How Factor Analysis Reduces and Describes Data in General

Since its initial development as a psychological tool, factor analysis has increased in sophistication as a mathematical technique. Particularly with the advent of electronic computers and their ability to handle large amounts of computation, the use of the rigorous principal-factor method[4] has become practical for data reduction at a large scale (e.g., in a study of conflict resolution, the principal-factor method was applied to ten characteristics (variables) of fourteen nations (observational units) to identify four major factors describing the interrelationships of those national characteristics[3]). Such added computational power facilitates even more the chief aim of the process, i.e., "to attain scientific parsimony or economy of description."[4]

Given a set of n variables (Fig 1) occurring within a discrete set of k observation units (in this case, census tracts), an initial data matrix may be drawn (Fig 2). Principal-factor analysis uses known matrix operations to calculate many essential properties of this matrix (e.g., eigenvalues) which may then be interpreted in terms of the nature of the original data. In so doing, useful information for a social science perspective is obtained that is often not apparent from the matrix, yet is both extensive in detail and succinct in form. (These data are then quite suited as input for further studies, as will be shown specifically below.) A brief description of the mathematics involved follows.

Using common statistical definitions, let z_j be the set of all standardized values of a variable j over all observational units. It is then postulated

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[4] Harry H. Harman, Modern Factor Analysis, the University of Chicago Press, Chicago, Ill., 1965, p. 4.

[3] Rummel, Understanding Factor Analysis, pp. 444-480.

[4] Harman, Modern Factor Analysis, p. 4.

FIGURE 1: 'Population & Housing Characteristics'

1960 U.S. Census

Variable 1. Total population under five years;
2. ... 5 - 19 years;
3. ... 20 - 44 years;
4. ... 45 - 64 years;
5. ... 65 - over years;
6. Total population Negro;
7. Total population other than Negro and White;
8. Occupation: professional, technical, and kindred workers;
9. ... farmers and farm managers;
10. ... clerical and kindred workers;
11. ... sales workers;
12. ... craftsmen, foremen, and kindred workers;
13. ... operatives and kindred workers;
14. ... private household workers;
15. ... service workers, except household;
16. ... farm laborers and foremen;
17. ... not reported.
18. Industry (employed civilians 14 years and over): mining;
19. ... construction;
20. ... furniture, lumber, and wood;
21. ... metal industry;
22. ... machinery;
23. ... food and kindred industry;
24. ... printing, publishing, and allied;
25. ... R.R. and Railway Express;
26. ... communications, utilities, sanitary services;
27. ... wholesale trade;
28. ... eating and drinking places;
29. ... business and repair services;
30. ... hospitals;
31. ... public administration.
32. Means of transportation to work (14 years and over): railroad;
33. ... bus, streetcar;
34. ... private auto or carpool;
35. ... walk;
36. Family income: Less than or equal to $4,999.00;
37. ... $5,000 - 9,999;
38. ... $10,000 - 14,999;
39. ... $15,000 - 24,999;
40. ... $25,000 - over.
41. Value of housing (owner occupied): under $5,000;
42. ... $5,000 - 9,999;
43. ... $10,000 - 14,999;
44. ... $15,000 - 19,999;

Fig 1. (continued)

variable 45. Value of housing (owner occupied): $20,000 - 24,999;
46. ... $25,000 - 34,999;
47. ... $35,000 - over.
48. Gross Rent by month (renter occupied): less than $99.00;
49. ... $100 - 199;
50. ... $200 - more.
51. Units in structure (all occupied and vacant units): one unit; structure;
52. ... 2 unit structures;
53. ... 3 - 4 unit structures;
54. ... 5 - 9 unit structures;
55. ... 10 or more unit structures.
56. Year housing structure built (all occupied and vacant): 1960 and before.
57. Residence in 1955 (65): same house as 1960 (70);
58. ... different house in central city of this SMSA;
59. ... different house in other part of this SMSA;
60. ... different house outside this SMSA in North and West;
61. ... different house outside this SMSA in South;
62. ... different house, same county.
63. Tenure and vacancy status: total units owner occupied;
64. ... total units renter occupied;
65. ... vacant units.
66. Persons in unit (no. of persons all occupied housing units): 1 - 2 persons;
67. ... 3 - 5 persons;
68. ... 6 persons or more.
69. Years school completed (25 years and over): no school years completed;
70. ... 1 - 8 years of school;
71. ... high school, 1 - 3 years;
72. ... high school, 4 years;
73. ... college, 1 - 3 years;
74. ... college, 4 or more years.
75. Employment status (14 years and over): employed civilians;
76. ... unemployed;
77. ... armed forces;
78. ... not in labor force.

1960 and 1970 U.S. CENSUS OF

POPULATION AND HOUSING CHARACTERISTICS

Each census tract for both Dallas and Fort Worth SMSA's.	Bureau of the census data characteristics for population and housing.
	1 2 3 4 ...
1	
2	
3	
4	
... (450 tracts)	

Census tracts	Growth Characteristics (%)
	1 2 3 4 5 6 7 8 9 10 ...
1	
2	
3	
4	
5	
... (450 tracts)	

1960 to 1970 - % Change

Fig 2. Data matrix.

that Z may be represented as the sum of some coefficients a_{jm} times some functions F and U, i.e.,

$$Z_{ji} = a_{ji} F_{1i} + a_{j2}F_{2i} + \ldots + a_{jm}F_{mi} + a_{j}U_{ji}$$

$$(j = 1, 2, \ldots n) \; (i = 1, 2, \ldots k).^{4}$$

The functions U are considered to be involved only in the variable defined by their equation, while the functions F are common factors present in the equations of some or all variables. (The number of factors (functions) is (usually) less than or equal to the number of variables ($m \leq n$).)

The communality of a variable is a measure of that variable's involvement with all other variables through the common functions, and so is defined mathematically as the sum of the squares of the common-factor coefficients[4]:

$$h_j^2 = a^2_{j1} + a^2_{j2} + \ldots + a^2_{jm}.$$

These communalities are the basic quantities to be analyzed, but there is no a priori knowledge of their values - hence the development of various solutions for estimating communalities, of which the "principal-factor method" is one. The method seeks to determine those functions F "in decreasing order of their contribution to communalities of the variables having as great a total as possible."[4]

The first factor F_1 would be that function with the largest sum of squared coefficients (Σa^2_{j1}) which occur in each communality equation.[4] A symmetric correlation matrix (n x n) is first constructed. (Fig 3) The original data matrix is "plotted" as a set of n vectors in a k-dimensional space. The

[4]Harman, Modern Factor Analysis, pp. 12-13.

[4]Ibid, p. 14.

[4]Ibid, p. 155.

[4]Ibid.

FACTOR ANALYSIS FOR 1960 CENSUS DATA

Correlation Coefficients:

	VAR001	VAR002	VAR003
VAR001	1.00000	.89373	.77532
VAR002	.89373	1.0000	.77296
VAR003	.77532	.77296	1.00000
VAR004	.42264	.64242	.63667
VAR005	.26028	.46922	.51449

	VAR004	VAR005
VAR001	.42264	.26028
VAR002	.64242	.46922
VAR003	.63667	.51449
VAR004	1.00000	.87823
VAR005	.87823	1.00000

Fig 3. Section of correlation matrix 1960 census data.

cosines of the angles between these vectors are the correlation coefficients between the original variables,[3] forming the correlation matrix. It is observed that the largest eigenvalue λ_1 of the correlation matrix is equal to the desired maximum sum of squared coefficients, and also that each coefficient a_{j1} may be computed from the associated eigenvector of λ_1. Similarly, the coefficients for the decreasingly contributing $F_2 \ldots F_m$ may be derived from the decreasing eigenvalues and their eigenvectors.

In our study two computer programs which determine the principal factors are used. One follows the procedure described above, the other first forms a "reduced correlation matrix" by replacing the principal diagonal values (all = 1) of the correlation matrix with communality estimates (all $\leq$ 1).[4] The eigenvalues of the reduced correlation matrix are then used as new communality estimates for the principal diagonal, forming a new reduced correlation matrix whose eigenvalues and eigenvectors are obtained. The iterations continue until the principal diagonal values converge. (Squared multiple correlations, or "observed communalities" are used as the initial estimates.[4]) For strict definitions, the non-iterative procedure is often referred to as the principal-component method.

From this process, then, the common factors are isolated and ordered by their contribution to the total communality. A usable number of the highest factors are chosen as principal factors, and their coefficients construct a "loadings table." The coefficients, or "loadings," may be seen as projections of the k-dimensional variable points onto the principal axes (factors).[3]

A matrix of these loadings reveals the communality, percent of total variance, and percent of common variance figures showing the relationships of variables to each principal factor, and the relationships between the

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[3]Rummel, Understanding Factor Analysis, p. 461.

[4] Ibid, Harman, Modern Factor Analysis, p. 159.

[4]Harman, Modern Factor Analysis, p. 89.

[3]Rummel, Understanding Factor Analysis, p. 461.

factors themselves (Fig 4).[3] The first factor may be seen as an axis drawn through the variable points as closely as possible to the "center of gravity" of the points; all succeeding axes are orthogonal to the first and to each other. The first factor tends to load significantly (positively) on every variable; the second (and, to a lesser degree, the rest) tends to be bipolar, i.e., the projections of the points onto the second axis fall approximately half in the positive direction and half in the negative direction from the origin. A "rotated factor" table is produced by orthogonally rotating the axes to emphasize groups of closely-related variable points, and by "projecting" these points onto the axes to produce a loadings table.[3] Oblique rotation of axes is used for factors not required to be orthogonal; this study uses a VARIMAX method of orthogonal rotation to simplify the columns of the factor matrix and still preserve the communality and variance information available from the unrotated loadings table.

From these tables certain measures of each variable's relationship to the principal factors and to each other within those relationships can be obtained to allow the variables to be weighted according to their "involvement" with each factor. The original data matrix is then multiplied by the vectors of these weights to produce a factor score matrix of observation units by factors. Each observational unit, (e.g., census tract) then, has a score in terms of the factor-related variables active within it. As will be noted later, these scores may be input into a grouping algorithm to delineate patterns of observational units containing similar variable relationships.

While the mathematics of the principal-factor process have only been briefly discussed here, some observations related to this study may be made. First, the method involves many computational stages, each of which supplies results that can become data for a later operation or may be interpreted as elucidating some feature of the original data relationships - (See Fig 4). The results, of course, are specific to the method and qualified by both the original data matrix and the subjective options chosen (number of factors,

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[3] Rummel, Understanding Factor Analysis, pp. 463-465.

[3] Ibid, pp. 466-468.

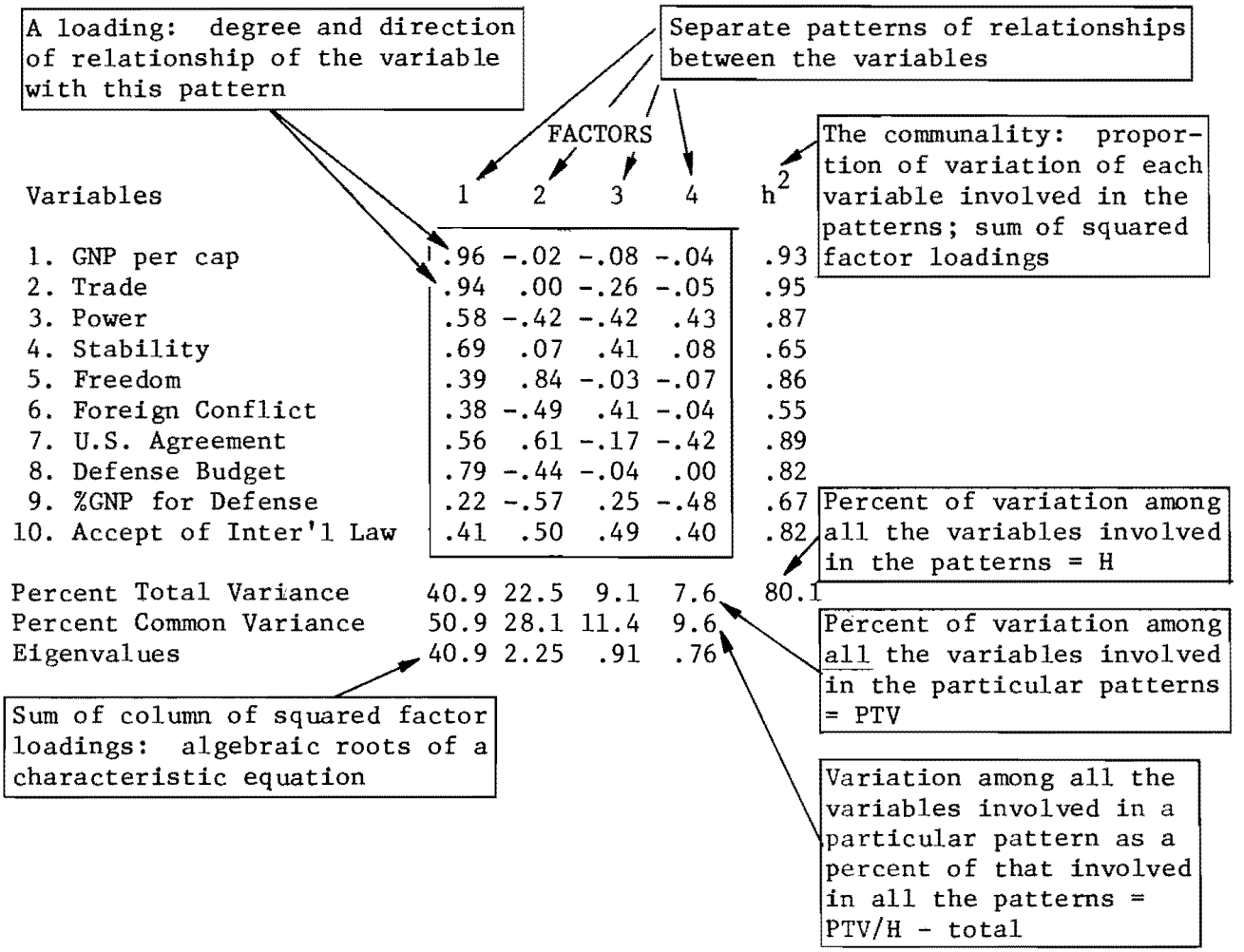

Fig 4. Example of Factor Matrix (Rummel), Sections from 1960 Census Data.

VARIABLE	COMMUNALITY	FACTOR	EIGENVALUE	PCT OF VAR
VAR001	.89373	1	25.13064	32.6
VAR002	.89373	2	15.02004	19.5
VAR003	.79905	3	7.31969	9.5
VAR004	.89081	4	4.64617	6.0
VAR005	.87823	5	3.12902	4.1

CHM PCT	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
32.6	.54165	-.65319	.25453	.16584	-.01593
52.1	.62169	-.37616	.45830	.08851	.04241
61.6	.80413	-.26002	-.03502	.10472	-.02228
67.7	.77040	.19253	.36513	.10415	-.11923
71.7	.69030	.22907	.23305	-.11590	.01496

Fig 4. (continued).

clusters).

II. HOW FACTOR ANALYSIS IS USED IN THE DALLAS-FORT WORTH PROBLEM

II.1. Area Description

The study area is formally defined by the 1960 and 1970 Bureau of the Census delineation of the Dallas SMSA and the Fort Worth SMSA. The two SMSA's contain Dallas, Collin, Denton, Ellis, Kaufman, Rockwall, Johnson, and Tarrant counties. Data are available at the census tract level for each of the counties listed above. The Dallas and Fort Worth SMSA's were chosen because of the existing opportunity in which to study an area and its associated land use changes; changes in relation to the decision and execution of locating the world's largest regional airport.

The effects and repercussions of such a large airport facility bring both quantitative and qualitative associated changes to a region. What might have been labeled "rural fringe" of metropolitan Dallas in 1960 is in 1970 a completely different area. The census characteristics chosen should give a thorough indication of this change occurring over the ten year period. Effects of land use change might well be exemplified as rapid increases in retail and commercial activity or rises in personal income throughout the affected area. Whatever the case, the factorial technique helps to describe the occurring changes by type as well as by degree of interrelationship.

II.2. Methodology

Figure 1 lists and defines the Population and Housing Characteristics which are used in each factorial run. The census characteristics are assembled as columns in a matrix representing a cross between themselves and the rows of numbered census tracts. For each factor run a matrix such as described in Fig 2 illustrates the form in which each census tract is analyzed.

Separate factor analyses are to be performed on 1960 data, 1970 census data, and percentage change data between this ten year span. The methodology has been divided into three separate stages.

STAGE I

Principal-factor analysis is the analytical technique used to describe the interrelationships among 1960 census data chosen for the combined Dallas and Fort Worth SMSA's. Data are available for each characteristic by census tract for this entire region. This initial run should show no airport related growth dimensions associated with the area data, the reason being the airport location had not yet been decided. However, from this first factor routine, we are anticipating dimensions of a more traditional metropolitan type.[5] This first procedure is intended to produce a 'snap-shot' representation of the patterns associated with the interrelated characteristics used to describe the metropolitan region. Evaluation of the factor results support this hypothesis; they are discussed in the conclusion to this paper.

STAGE II

Stage two will essentially follow the same procedure as stage one, with one exception. The data being analyzed are for 1970, the time period after the airport location had been announced and construction begun. Noticable differences in the results of this factor run should be evident when compared to the 1960 run. Differences in characteristic changes in the region should result in different factors being found for the same census characters as in 1960. Hopefully, one such new dimension may be labeled as 'airport-related'. Again, an evaluation of the results will accompany the 1970 fixed-time factor analysis.

STAGE III

The third set of analytical factor scores will be generated from the percentage change on each census characteristic between the 1960 and 1970 data. In this way change may be viewed over a ten year period by census tract with the

[5]Refer to footnote number one for a brief history of traditional factor results.

important addition of a regional airport being located in the area. Assuming an 'airport-related' dimension has been identified, a modification of Wards grouping algorithm (CONGROUP)[6] will be used to identify a predetermined number of clusters delineating the observational units (census factors) scoring similarly in terms of the principal dimensions chosen (one being airport-related growth) (see Fig 5). By specifying a contiguity constraint in the algorithm, a set of contiguous homogeneous areas will be isolated. From these areas, one or two will be chosen that score high in 'airport-related' activity for more in-depth study and investigation.

III. STUDY OVERVIEW

The study is most likely one of the first attempts aimed at isolating transportation related factors from all other growth generating dimensions for a metropolitan area by factor analytical techniques. A number of urban scholars have investigated differences and trends between central cities and their associated suburbs by similar multivariate techniques.[7] Such reports include characteristics associated with population densities, ethnic origins, age distribution, occupations, and income. The present study includes the above mentioned variables as well as housing characteristics, personal transportation modes, education levels, and industry associations. Only a few of these factorial studies have been applied to "percentage-change" figures over time; most have been 'static' interpretations. The present study will recognize a ten year period of change, as well as serving as one of the first attempts at creating a dynamic, managable system of information from which future analyses of transportation growth and associated change may be viewed.

With 450 census observation tracts to key on, the factorial technique serves as a geographical mapping tool from which relative evaluations of some

[6] CONGROUP, University of Texas, Department of Geography, Computer Programs for Spatial Analysis, (1974).

[7] Leo F. Schnore, "Urban Form: The Case of the Metropolitan Community," Urban Life and Form, ed. Werner Z. Hirsch (N.Y.: Holt, Rinehart, and Winston, 1963), pp. 167-197.

Census tract	Factors or Dimensions			
	A	B	C	D*
1	2	3	4	5
2	2	3	4	5
3	1	7	2	1
4	1	7	2	1
...				
N				

grouping of census tracts

airport-related

* airport or transportation related

Fig 5. Ward's Grouping Algorithm

eight counties may be attempted. According to the literature, this scale of inquiry revolves around a much larger area than has before been attempted. With Dallas and Fort Worth serving as foci for rural farm and ranch migration paths, the present investigation should be of noticeable importance to various governmental levels as well as private enterprises.

Two general and somewhat related problems are associated with the application of correlation and factor analyses to data ordered spatially such as census tract data. The literature refers to these as (1) the problem of "modifiable units" and (2) the relationship between "economical correlations" and the "behavior of individuals."

In general, the problem of "modifiable units" arises from the fact that the results of correlation analyses between the same characteristics but for different sized areal units may differ markedly.[8] Two solutions have been postulated for dealing with the problem. A.H. Robinson has suggested that because the correlation coefficients of spatially arrayed variables are affected by the size and shape of the areal units to which they refer the individual values when used in the equation for a correlation coefficient should be weighted by the area of their respective spatial units.[9] Researchers Thomas and Anderson propose a solution based on the statistical evaluation of differences between correlation coefficients obtained at various levels of aggregation.[10] The correlation coefficients calculated for different sized areas by Gehlke and Biehl were evaluated using this method and found to be not statistically different. Similar results were found for evaluations of A.H. Robinson's data.[11] As a result, differences between correlation coefficients

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[8]Otis Dudley Duncan, Statistical Geography: Problems in Analyzing Areal Data (Glencoe: the Free Press, 1961), pp. 109-111.

[9]A.H. Robinson, "The Necessity of Weighting Values in Correlation Analysis of Areal Data," Annals of the Association of American Geographers, XLVI (1956), pp. 233-236.

[10]Edwin N. Thomas and David L. Anderson, "Additional Comments on Weighting Values in Correlation Analysis of Areal Data," Annals of the Association of American Geographers, LV (1965), pp. 492-505.

[11]G.U. Yule and M.G. Kendall, An Introduction to the Theory of Statistics (New York: Hafner Publishing Co., Inc., 1950), pp. 310-314.

calculated at various levels of analysis could have arisen from chance and thus "... geographic significance should not be attached to them."[10] Clearly, considerably more research is required on this problem.

The second problem addresses the application of correlation techniques to areal data; specifically the relationship of the association between "ecological correlations" and the "behavior of individuals." Generally, inferences about the behavior of individuals cannot be made from ecological correlations which are based on data summarized by areal units.[8] For the present study, we are interested in areas rather than individuals. For a discussion of methods which have been developed for estimating individual correlations from ecological data see footnote 12. Both problems will be investigated more fully in future reports as they relate to the transportation topic.

Generally, factor analysis holds potential for extension into many more data fields besides the traditional census characteristics. Although hard to obtain, data such as employment records, industrial figures, sales transactions, tax (land use) rolls, land values, number of building permits issued, and number of times land has changed hands would be more than useful in the present investigation. These would give further indicators of change on an urban scale. A search is currently underway to realize this potential.

IV. FACTOR RESULTS OF 1960 CENSUS DATA

Results of the factor analysis for 1960 census characteristics by census tract are interpreted by individual output per computer run. Each run is assigned a letter and analyzed for the first seven resulting factors. Seven factors were chosen because they most nearly approximated 80% of the cumula-

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[10] Thomas and Anderson, Annals of the Association of American Geographers.

[8] Duncan et al., Statistical Geography: Problems in Analyzing Areal Data, pp. 111-113.

[12] Otis Duncan and Beverly Davis, "An Alternative to Ecological Correlation," American Sociological Review, XVIII (Dec., 1953), pp. 665-666.

tive variance. Factors are discussed in descending order of percent of total variance explained. Communality scores are compiled in ascending order by score and subdivided into four different ranges. Variables scoring between .90 and .99 in terms of their communality are listed in three separate range groups.

Each factor per run is described by its associated variable list. Variables with loadings of ± .500 (25% commuanlity)[3] or more have been chosen for description and listing. Factor loadings measure the association of the original variables with each factor and may vary between +1.0 and -1.0, the extremes of perfect correlation. A zero factor loading indicates no association between that variable and the corresponding factor. The signs show the direction of association between variables and factors.

In determining a name for a factor, communality scores, eigenvalues, percent of (total) variance, and factor loadings are used extensively. For a brief description of each measure, please refer to Fig 4 and the associated explanation which follows:

factor: the number of factors is the number of substantively meaningful independent patterns of relationship among the variables; these factors may be viewed as evidencing the number of different kinds of influence (causes) on the data; as presenting categories by which these data may be classified;[3]

communality scores: proportion of a variable's total variation that is involved in the factors; when multiplied by one hundred, gives the percent a variable has in common with each factor;

eigenvalue: measures the amount of variation accounted for by a pattern or factor;

percent of (total) variance: the percent of total variation among the variables that is related to a factor pattern; measures the amount of data in the original matrix that can be reproduced by a pattern; measures a pattern's comprehensiveness and strength; measures how much of the data variation is involved in a pattern.

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[13] ±.5 factor loading describes 25% of the variation that a variable has in common with the rotated factor; the square of the factor loading multiplied by 100 equals the percent variation. (Rummel)

[3] All definitions are taken from Rummel, Understanding Factor Analysis, pp. 462-468.

As can be seen from the results on the following page, Table 1, Dallas-Fort Worth was a "normal area" in 1960. The outstanding dimensions of its spatial structure were "Black ethnicity," "socio-economic status," and "stage in life cycle." Using socio-economic surrogates, a significant dimension of in-migration related to economic vitality also emerged. The correspondence of the results for Dallas-Fort Worth with other cities leads us to believe that the next stage of analysis will be able to isolate an airport related change dimension. The new in-migration factor could help structure a point of comparison between airport related change and normal, pre-existing growth trends. This will be the main aim of the new phase of analysis.

TABLE 1. SYNTHESIS OF FACTOR DELINEATIONS

FACTOR RUN	FACTOR	PERCENT OF TOTAL VARIANCE EXPLAINED
A.	1. Black ethnicity	27.7%
	2. Socio-economic status	19.9%
	3. Life cycle stage	11.7%
	4. Multi unit dwelling pattern	8.8%
	5. Urban location	5.2%
	6. Non-Black ethnicity	4.3%
	7. Single unit dwelling pattern	3.2%
B.	1. Socio-economic status	29.5%
	2. Black ethnicity	20.8%
	3. Multi-unit dwelling pattern	10.5%
	4. "Blue collar labor market"	6.8%
	5. Single unit dwelling pattern	4.2%
	6. Non-definable	3.7%
	7. Non-Black ethnicity	3.2%
C.	1. Black ethnicity	37.8%
	2. Socio-economic status	20.1%
	3. Economic attractiveness	8.4%
	4. Non-definable	4.5%
	5. Life cycle stage	3.6%
	6. Intra-city movement or relocation	3.5%
	7. Non-definable	2.8%
D.	1. Black ethnicity	30.4%
	2. Economic attractiveness	20.1%
	3. Socio-economic status	9.6%
	4. Suburban residency	6.9%
	5. Rural location	4.5%
	6. Non-definable	3.4%
	7. Non-definable	2.6%
E.	1. Black ethnicity	31.9%
	2. Socio-ecomic status	19.8%
	3. Multi unit dwelling pattern	9.3%
	4. Non-definable	6.1%
	5. Occupational status	4.0%
	6. Occupational class	3.5%
	7. Urban location	2.4%

FACTOR RUN A

FACTOR RUN A

Factor Run A consists of selected categories of census characteristics displaying a socio-economic mix. A list of these characteristics follow on the next page. Factors delineated and named from Run A are:

Factor Name

1. Black ethnicity
2. Socio-economic status
3. Life cycle stage
4. Multi unit dwelling pattern
5. Urban location
6. Non-Black ethnicity
7. Single unit dwelling pattern.

Factor Run A: Variable list

"Population & Housing Characteristics" 1960 U.S. Census

Age Distribution

Variable 1. Total population under five years;
2. ... 5 - 19 years;
3. ... 20 - 44 years;
4. ... 45 - 64 years;
5. ... 65 and over.

Ethnicity

6. Total population Negro;
7. Total population other than Negro and White.

Occupation

variable 8. Professional, technical, and kindred workers;
9. ... farmers and farm managers;
10. ... clerical and kindred workers;
11. ... sales workers;
12. ... craftsmen, foremen, and kindred workers;
13. ... operatives and kindred workers;
14. ... private household workers;
15. ... service workers, except household;
16. ... farm laborers and foremen;
17. ... not reported.

Mode of Transportation

32. Railroad;
33. ... bus, streetcar;
34. ... private auto or carpool;
35. ... walk.

Value of Housing

41. Under $5,000;
42. ... $5,000 - 9,999;
43. ... $10,000 - 14,999;
44. ... $15,000 - 19,999;
45. ... $20,000 - 24,999;
46. ... $25,000 - 34,999;
47. ... $35,000 - over.

Units/Dwelling Structure

51. One unit structure;
52. ... 2 unit structures;
53. ... 3 - 4 unit structures;
54. ... 5 - 9 unit structures;
55. ... 10 or more unit structures.

Persons per Housing Unit

variable 66. 1 - 2 persons;

67. 3 - 5 persons;

68. 6 or more persons.

Factor Run A

Factor	Eigenvalue	Percent of Variance	Cumulative percent of variance
1	9.68	27.7%	27.7%
2	6.96	19.9%	47.6%
3	4.10	11.7%	59.3%
4	3.07	8.8%	68.1%
5	1.18	5.2%	73.3%
6	1.52	4.3%	77.6%
7	1.11	3.2%	80.8%
		cut-off	
-	-	-	-
-	-	-	-
35	-	.1%	100%

1. 35 Census Characteristics
2. 450 geographic census tracts
3. First seven factors explain 80.8% of the total variance
4. First four factors explain 68.1% of the total variance
5. Range of communality scores:

(.00 - .69) = 0
(.70 - .79) = 4
43% of total -- (.80 - .89) = 15
46% of total -- (.90 - .99) = 16
35 total variance

6. Variables with communality scores of .90 and above:

-Score range (.90-.92)-

variable number	variable name
2	total population 5 - 19 years
4	total population 45 - 64 years
8	occupation: professional, technical, and kindred
11	occupation: sales workers
12	occupation: craftsmen, foremen, and kindred workers
13	occupation: operatives and kindred workers
14	occupation: private household workers
15	occupation: service workers, except household
16	occupation: farm laborers and foremen
32	means of transportation to work: railroad
34	means of transportation to work: private auto or carpool
51	units in housing structure: one

-Score range (.93-.96)-

1	total population under five years
10	occupation: clerical and kindred workers
45	value of housing: $20,000 - 24,999
46	value of housing: $25,000 - 34,999

-Score range (.97-.99)-

none

7. Significant variables loading onto factor 1:

Var. No.	Census Description	Loading on Factor 1
1	total population under 5 years.	.931
68	six or more people per housing unit	.913
2	total population 5 - 19 years	.868
6	number of persons Negro	.797
15	number of people in service occupation	.741
14	number of people employed in private households	.724
67	3 - 5 people per housing unit	.699
13	number of people employed as operatives, mine	.636
17	number of people in occupation category not reported	.543

8. Name of factor 1: Black Ethnicity.

9. Reasons for choosing name:

   a. Significant positive loadings: measures of low socio-economic status, Negro population.

   b. Significant negative loadings: none.

   c. Comments: the socio-economic variables are recognized as ethnic related; also variable six loaded significantly only on this factor.

10. Significant variables loading onto factor 2:

Var. No.	Census Description	Loading on Factor 2
46	housing value $25 - 35,000	.969
45	housing value $20 - 25,000	.957
47	housing value $35,000 and up	.863
44	housing value $15 - 20,000	.782

11. Name of factor 2: Socio-Economic Status.

12. Reasons for choosing name:

    a. Significant positive loadings: measures of high socio-economic status.

    b. Significant negative loadings: none.

    c. Comments: no income or education levels used in A run; therefore housing value is primary measure of socio-economic status.

13. Significant variables loading onto factor 3:

Var. No.	Census Description	Loading on Factor 3
5	total population 65 years old and over	.832
4	total population between 45 - 64 years	.792
11	number of people in sales occupations	.750
10	number of people in clerical occupations	.746
8	number of people in proffessional and technical occupations	.713
43	housing value between $10 - 15,000	.644
34	number of people using private auto to work	.627
67	3 - 5 people per unit (housing)	.519

14. Name of factor 3: Life Cycle Stage.

15. Reasons for choosing name:

    a. Significant positive loadings: measures of middle age/retirement life cycle bracket; non-manual labor.

    b. Significant negative loadings: none.

    c. Comments: this factor measures the last of three life cycle stages ("childhood," "childraising and peak production," "middle age/retirement"). These stages appear in our study due to the broad age deliniations chosen for the data.

16. Significant variables loading onto factor 4:

Var. No.	Census Description	Loading on Factor 4
54	5 - 9 housing units per structure	.832
55	10 or more housing units per structure	.812
53	3 - 4 housing units per structure	.812
10	number of people employed in clerical occupations	.534
17	number of people not reported in occupations	.533

17. Name of factor 4: Multi-Unit Dwelling Pattern.

18. Reasons for choosing name:

a. Significant positive loadings: measures of multi-unit living quarters.

b. Significant negative loadings: none.

c. Comments: measures a clustering tendency in dwelling patterns. The lack of significant occupational or socio-economic delineations precludes distinguishing between public housing and apartment development (this factor might be used to indicate changes in "privacy standards").

19. Significant variables loading onto factor 5:

Var. No.	Census Description	Loading on Factor 5
16	number of people employed as farm labor	-.918
9	number of people employed as farmers and farm managers	-.896

20. Name of factor 5: Urban Location.

21. Reasons for choosing name:

a. Significant positive loadings: none.

b. Significant negative loadings: measures of farming activity

c. Comments: this factor identifies an urban area by the non-employment of farm workers.

22. Significant variables loading onto factor 6:

Var. No.	Census Description	Loading on Factor 6
7	number of people classified as other non-White (excluding Negro)	.796

23. Name of factor 6: Non-Black Ethnicity.

24. Reasons for choosing name:

a. Significant positive loadings: measure of non-White, non-Black ethnicity.

b. Significant negative loadings: none.

c. Comments: this is probably a measure of Mexican-American ethnicity assuming Mexican-American's are not classified "White" as in many Texas governmental agencies.

25. Significant variables loading onto factor 7:

Var. No.	Census Description	Loading on factor 7
41	housing value $0-5,000	.760
42	housing value $5-10,000	.740
51	one housing unit per structure	.600

26. Name of factor 7: Single Unit Dwelling Pattern.

27. Reasons for choosing name:

    a. Significant positive loadings: measures of lower housing values and single unit dwelling.

    b. Significant negative loadings: none.

    c. Comments: there are indications from all runs of a high correlation between lower housing values and single unit structures.

FACTOR RUN B

FACTOR RUN B

Factor Run B contains categories of census characteristics displaying a socio-econimic mix. A list of these characteristics follow below. Factors delineated and named from Run B are:

Factor Run B

1. Socio-economic status
2. Black ethnicity
3. Multi unit dwelling pattern
4. "Blue collar labor market"
5. Single unit dwelling pattern
6. Non-definable
7. Non-Black ethnicity.

Factor Run B: Variable List

"Population & Housing Characteristics" 1960 U.S. Census

Age Distribution

variable
1. Total population under five years;
2. ... 5 - 19 years;
3. ... 20 - 44 years;
4. ... 45 - 64 years;
5. ... 65 and over.

Ethnicity

6. Total population Negro;
7. Total population other than Negro and White.

Industry

variable 18. Mining;

19. ... construction;

20. ... furniture, lumber, and wood;

21. ... metal industry;

22. ... machinery;

23. ... food and kindred industry;

24. ... printing, publishing, and allied;

25. ... R. R. and Railway Express;

26. ... communications, utilities, sanitary services;

27. ... wholesale trade;

28. ... eating and drinking places;

29. ... business and repair services;

30. ... hospitals;

31. ... public administration.

Family Income

36. Less than or equal to $4,999;

37. ... $5,000 - 9,999;

38. ... $10,000 - 14,999;

39. ... $15,000 - 24,999;

40. ... $25,000 - over.

Value of Housing

41. Under $5,000;

42. ... $5,000 - 9,999;

43. ... $10,000 - 14,999;

44. ... $15,000 - 19,999;

45. ... $20,000 - 24,999;

46. ... $25,000 - 34,999;

47. ... $35.000 - over.

Units/Dwelling Structure

variable 51. One unit structure;

52. ... 2 unit structure;

53. ... 3 - 4 unit structure;

54. ... 5 - 9 unit structure;

55. ... 10 or more unit structure.

Persons/Unit of Housing

66. 1 - 2 persons;

67. ... 3 - 5 persons;

68. ... 6 or more persons.

Factor Run B

Factor	Eigenvalue	Percent of Variance	Cumulative percent of variance
1	11.80	29.5%	29.5%
2	8.33	20.8%	50.4%
3	4.20	10.5%	60.9%
4	2.71	6.8%	67.7%
5	1.69	4.2%	71.9%
6	1.49	3.7%	75.6%
7	1.27	3.2%	78.8%

1. 40 Census Characteristics
2. 450 geographic census tracts
3. First seven factors explain 78.8% of the variance
4. First four factors explain 67.7% of the variance
5. Range of communality scores:

	(.00 - .69)	= 0
	(.70 - .79)	= 9
55% of total --	(.80 - .89)	= 22
22% of total --	(.90 - .99)	= 9
		40 total variance

6. Variables with communality scores of .90 and above:

-Score range (.90-.92)-

variable number	variable name
1	total population under five years
2	total population 5 - 19 years
4	total population 45 - 64 years
5	total population 65 and over
36	family income: less than or equal to $4,999
38	family income: $10,000 - 14,999

-Score range (.93-.96)-

37	family income: $5,000 - 9,999
45	value of housing: $20,000 - 24,999
46	value of housing: $25,000 - 34,999

-Score range (.97-.99)-

none

7. Significant variables loading onto factor 1:

Var. No.	Census Description	Loading on Factor 1
46	housing value $25 - 35,000	.955
45	housing value $20 - 25,000	.948
39	family income $15 - 25,000	.898
47	housing value $35,000 or more	.874
40	family income $25,000 or more	.832
44	housing value $15 - 20,000	.826
38	family income $10 - 15,000	.742
18	number of people in mining industry	.625

8. Name of factor 1: Socio-Economic Status.

9. Reasons for choosing name:

   a. Significant positive loadings: measures of high socio-economic status.

   b. Significant negative loadings: none.

   c. Comments: mining industry in region seems to indicate oil and natural gas affiliations.

10. Significant variables loading onto factor 2:

Var. No.	Census Description	Loading on Factor 2
1	number of people under 5 years	.927
68	6 or more people per unit (housing)	.903
2	total people 5 - 19 years	.866
6	number of persons Negro	.810
36	family income less than or = to $4,999	.760
3	total population 20 - 44 years	.728
67	3 - 5 people per unit (housing)	.690
19	number of people in construction industry	.608
23	number of people in food industry	.558
28	number of people in eating and drinking industry	.539

11. Name of factor 2: Black Ethnicity.

12. Reasons for choosing name:

a a. Significant positive loadings: measures of low socio-economic status, Negro population.

b. Significant negative loadings: none.

c. Comments: the socio-economic variables are recognized as ethnic related; also variable six loaded significantly only on this factor.

13. Significant variables loading onto factor 3:

Var. No.	Census Description	Loading on Factor 3
53	3 - 4 units of housing per structure	.892
54	5 - 9 units of housing per structure	.800
29	business and repair services	.741
55	10 or more units of housing per structure	.739
52	2 units of housing per structure	.676
27	number of people in wholesale industry	.590
24	number of people in printing industry	.525
28	number of people in eating and drinking industry	.516

14. Name of factor 3: Multi-Unit Dwelling Pattern.

15. Reasons for choosing name:

a. Significant positive loadings: measures of multi-unit living quarters.

b. Significant negative loadings: none.

c. Comments: measures a clustering tendency in dwelling patterns and indicates at least a correlation with service industry employment.

16. Significant variables loading onto factor 4:

Var. No.	Census Description	Loading on Factor 4
22	number of people in machinery industry	.783
21	number of people in metal industry	.744
37	family income $5,000 - 10,000	.672
26	number of people in communications, utilities industry	.596
24	number of people in printing industry	.506

17. Name of factor 4: "Blue Collar Labor Market".

18. Reasons for choosing name:

a. Significant positive loadings: diffuse measures of "blue-collar" employment.

b. Significant negative loadings: none.

c. Comments: Factor Run C, factor 3 indicates correlation between these measures and measures of in-migration.

19. Significant variables loading onto factor 5:

Var. No.	Census Description	Loading on Factor 5
41	house value $0 - 5,000	.864
51	one unit of housing per structure	.663
30	number of people in hospital related industry	.641
42	housing value $5,000 - 10,000	.530

20. Name of factor 5: Single Unit Dwelling Pattern.

21. Reasons for choosing name:

a. Significant positive loadings: measures of lower housing values and single unit dwelling.

b. Significant negative loadings: none.

c. Comment: there are indications from all runs of a high correlation between lower housing values and single unit structures.

22. Significant variables loading onto factor 6:

Var. No.	Census Description	Loading on Factor 6
43	housing value $10 - 15,000	.815
25	number of people in railroad industry	.741

23. Name of factor 6: Non-Definable.

24. Reasons for choosing name:

a. Significant positive loadings: none.

b. Significant negative loadings: none.

25. Significant variable loading onto factor 7:

Var. No.	Census Description	Loading on Factor 7
7	total population - other than Negro and being non-White	.916

26. Name of factor 7: Non-Black Ethnicity.

27. Reasons for choosing name:

a. Significant positive loadings: measure of non-White, non-Black ethnicity.

b. Significant negative loadings: none.

c. Comments: this is probabily a measure of Mexican-American ethnicity assuming Mexican-Americans are not classified "White" as in many Texas governmental agencies.

FACTOR RUN C

FACTOR RUN C

Factor Run C consists of selected categories of census characteristics displaying a demographic mix. A list of these characteristics follow below. Factors delineated and named from Run C are:

Factor Name

1. Black ethnicity
2. Socio-economic status
3. Economic attractiveness
4. Non-definable
5. Life cycle stage
6. Intra-city movement or relocation
7. Non-definable.

Factor Run C: Variable list

"Population & Housing Characteristics" 1960 U.S. Census

Age Distribution

Variable

1. Total population under five years;
2. ... 5 - 19 years;
3. ... 20 - 44 years;
4. ... 45 - 64 years;
5. ... 65 and over.

Ethnicity

6. Total population Negro;
7. Total population other than Negro and White.

Industry

variable 18. Mining;

19. ... construction;

20. ... furniture, limber, and wood;

21. ... metal industry;

22. ... machinery;

23. ... food and kindred industry;

24. ... printing, publishing, and allied;

25. ... R. R. and Railway Express;

26. ... communications, utilities, sanitary services;

27. ... wholesale trade;

28. ... eating and drinking places;

29. ... business and repair services;

30. ... hospitals;

31. ... public administration.

Family Income

36. Less than or equal to $4,999;

37. ... $5,000 - 9,999;

38. ... $10,000 - 14,999;

39. ... $15,000 - 24,999;

40. ... $25,000 - over.

Migration Status

57. Residence in 1955: same house as 1960;

58. ... different house in central city of this SMSA;

59. ... different house in other part of this SMSA;

60. ... different house outside this SMSA in North and West;

61. ... different house outside this SMSA in South;

62. ... different house, same county.

Occupancy Status

variable 63. Total units owner occupied;

64. ... total units renter occupied;

65. ... vacant units.

Persons/Housing Unit

66. 1 - 2 persons;

67. ... 3 - 5 persons;

68. ... 6 or more persons.

Education

69. No school years completed;

70. ... 1 - 8 years of school;

71. ... high school, 1 - 3 years;

72. ... high school, 4 years;

73. ... college, 1 - 3 years;

74. ... college, 4 or more years.

FACTOR RUN C

Factor	Eigenvalue	Percent of Variance	Cumulative percent of variance
1	17.76	37.8%	37.8%
2	9.43	20.1%	57.9%
3	3.95	8.4%	66.3%
4	2.13	4.5%	70.8%
5	1.71	3.6%	74.4%
6	1.64	3.5%	77.9%
7	1.32	2.8%	80.7%

1. 47 Census Characteristics
2. 450 geographic Census tracts
3. First seven factors explain 80.7% of the variance
4. First four factors explain 70.8% of the variance
5. Range of communality scores:

(.00 - .69) = 1
(.70 - .79) = 9
(.80 - .89) = 13
51% of total -- (.90 - .99) = 24
47 total variables

6. Variables with communality scores of .90 and above:

-Score range (.90-.92)-

variable number	variable name
1	total population under five years
2	total population 5 - 19 years
3	total population 20 - 44 years
4	total population 45 - 64 years
5	total population 65 - over years
22	industry: machinery
38	family income: $10,000 - 14,999
40	family income: $25,000 - over
60	residence 1955 different house outside SMSA North and West
61	residence 1955 outside this SMSA in South
62	residence 1955 different house, same county
74	years school completed: college, 4 or more years

-Score range (.93-.96)-

36	family income: less than or equal to $4,999
37	family income: $5,000 - 9,999
39	family income: $15,000 - 24,999
58	residence 1955 different house in central city of this SMSA

59	residence 1955 different house in other part of this SMSA
64	number total housing units renter occupied
70	years school completed: 1 - 8 years
71	years school completed: 1 - 3 years high school
72	years school completed: high school 4 years
73	years school completed: college 1 - 3 years
75	employment status: employed civilians

-Score range (.97-.99)

none

7. Significant variables loading onto factor 1:

Var. No.	Census Description	Loading on factor 1
1	total population under 5 years	.933
36	family income less than or equal to $4,999.	.886
68	six or more people per unit (housing)	.865
70	1-8 years school completed	.856
2	total population 5-19 years	.839
76	number of persons unemployed	.792
6	number of persons Negro	.788
62	different house, same county as 1955	.786
3	total population 20-44 years	.724
19	number of people in construction industry	.722
71	1-3 years of high school completed	.690
28	number of people in eating and drinking industry	.678
23	number of people in food industry	.677
67	3-5 people per unit (housing)	.602
75	number of employed civilians	.586
58	residence in 1955 different house in central city	.579
69	Zero years of school completed	.555
57	residence in 1955 same as 1960	.536
78	number of people not in labor force	.527
30	hospital industry	.526

8. Name of factor 1: Black Ethnicity.

9. Reasons for choosing name:

   a. Significant positive loadings: measures of low socio-economic status, Negro population.

   b. Significant negative loadings: none.

   c. Comments: the socio-economic variables are recognized as ethnic related; also variable six loaded significantly only on this factor.

10. Significant variables loading onto factor 2:

Var. No.	Census Description	Loading on factor 2
39	family income $15 - 25,000	.947
40	family income $25,000 and up	.906
74	school completed - four or more years of college	.833
38	family income $10 - 15,000	.812
73	school completed - 1-3 years of college	.801
18	number of people in mining industry	.701
4	number of people 45 - 64 years old	.558
63	number of owner occupied units	.538
27	number of people in wholesale industry	.529
57	1960 residence same as in 1955	.520

11. Name of factor 2: Socio-Economic Status.

12. Reasons for choosing name:

   a. Significant positive loadings: measures of high socio-economic status.

   b. Significant negative loadings: none.

   c. Comment: no housing value used in C Run; some measures of life cycle stability are indicated. Mining industry in region seems to be oil and gas related.

13. Significant variables loading onto factor 3:

Var. No.	Census Description	Loading on factor 3
60	residence in 1955 outside SMSA, N & W.	.894
61	residence in 1955 outside SMSA, S	.829
22	number of people in machinery industry	.755
24	number of people in printing industry	.670
26	number of people in communications, utilities industries	.560
37	family income $5,000 - 10,000	.537
3	number of people 20 - 44 years old	.526

14. Name of factor 3: Economic Attractiveness.

15. Reasons for choosing name:

a. Significant positive loadings: measures of in-migration, diffused "blue-collar" indicators.

b. Significant negative loadings: none.

c. Comments: factor seems to measure transients with indications that in-migration correlates with job opportunities.
: could be a measure of economic growth patterns prior to airport development.

16. Significant variables loading onto factor 4:

Var. No.	Census Description	Loadings on factor 4
31	number of people in public administration	.732
63	number of owner occupied units	.634
30	number of people in hospital industry	.609

17. Name of factor 4: Non-Definable.

18. Reasons for choosing name:

a. Significant positive loadings: none.

b. Significant negative loadings: none.

19. Significant variables loading onto factor 5:

Var. No.	Census Description	Loading on factor 5
5	number of people 65 years and older	.712
72	school completed: high school 4 years	.657
4	number of people 45 - 64 years old	.627
71	school completed: high school 1 - 3 years	.610

20. Name of factor 5: Life Cycle Stage.

21. Reasons for choosing name:

a. Significant positive loadings: measures of middle age/retirement life cycle bracket; non-manual labor.

b. Significant negative loadings: none.

c. Comments: this factor measures the last of three life cycle stages ("childhood," "childraising and peak production," "middle age/retirement"). These stages appear in our study due to the broad age delineations chosen for the data.

22. Significant variables loading onto factor 6:

Var. No.	Census Description	Loading on factor 6
58	residense 1955 different in central city	.690
59	residense 1955 other part SMSA	-.853

23. Name of factor 6: Intra-City Movement or Relocation.

24. Reasons for choosing name:

    a. Significant positive loadings: measure of intra-city movement.

    b. Significant negative loadings: measure of inter city movement.

25. Significant variables loading onto factor 7:

Var. No.	Census Description	Loading on factor 7
21	number of people in metal industry	.689

26. Name of factor 7: Non-Definable.

27. Reasons for choosing name:

    a. Significant positive loadings: none.

    b. Significant negative loadings: none.

FACTOR RUN D

FACTOR RUN D

Factor Run D contains selected categories of census characteristics displaying a physical space use. A list of these characteristics follow below. Factors delineated and named from Run D are:

Factor name

1. Black ethnicity
2. Economic attractiveness
3. Socio-economic status
4. Suburban residency
5. Rural location
6. Non-definable
7. Non-definable

Factor Run D: Variable list

"Population & Housing Characteristics" 1960 U.S. Census

Age Distribution

Variable
1. Total population under five years;
2. ... 5 - 19 years;
3. ... 20 - 44 years;
4. ... 45 - 64 years;
5. ... 65 and over.

Ethnicity

6. Total population Negro;
7. Total population other than Negro and White.

Occupation

variable 8. Professional, technical, and kindred workers;

9. ... farmers and farm managers;

10. ... clerical and kindred workers;

11. ... sales workers;

12. ... craftsmen, foremen, and kindred workers;

13. ... operatives and kindred workers;

14. ... private household workers;

15. ... service workers, except household;

16. ... farm laborers and foremen;

17. ... not reported.

Industry

18. Mining;

19. ... construction;

20. ... furniture, lumber, and wood;

21. ... metal industry;

22. ... machinery;

23. ... food and kindred industry;

24. ... printing, publishing, and allied;

25. ... R. R. and Railway Express;

26. ... communications, utilities, sanitary services;

27. ... wholesale trade;

28. ... eating and drinking places;

29. ... business and repair services;

30. ... hospitals;

31. ... public administration.

Mode of Transportation

32. Railroad;

33. ... bus, streetcar;

34. ... private auto or carpool;

35. ... walk.

Family Income

variable 36. Less than or equal to $4,999;

37. ... $5,000 - 9,999;

38. ... $10,000 - 14,999;

39. ... $15,000 - 24,999;

40. ... $25,000 - over.

Value of Housing

41. Under $5,000;

42. ... $5,000 - 9,999;

43. ... $10,000 - 14,999;

44. ... $15,000 - 19,999;

45. ... $20,000 - 24,999;

46. ... $25,000 - 34,999;

47. ... $35,000 - over.

Rent

48. Less than $99.000.

49. ... $100 - 199.

50. ... $200 - more.

Units/Dwelling Structure

51. One unit structure;

52. ... 2 unit structure;

53. ... 3 - 4 unit structure;

54. ... 5 - 9 unit structure;

55. ... 10 or more unit structure;

Year Housing Structure Built

56. 1960 and before.

Migration

variable 57. Same house as 1960;

58. ... different house in central city of this SMSA;

59. ... different house in other part of this SMSA:

60. ... different house outside this SMSA in North and West;

61. ... different house outside this SMSA in South;

62. ... different house, same county.

Occupancy Status

63. Total units owner occupied;

64. ... total units renter occupied;

65. ... vacant units.

Persons/Housing Unit

66. 1 - 2 persons;

67. ... 3 - 5 persons;

68. ... 6 or more persons.

Education

69. No school years completed;

70. ... 1 - 8 years of school;

71. ... high school, 1 - 3 years;

72. ... high school, 4 years;

73. ... college, 1 - 3 years;

74. ... college, 4 or more years.

Employment Status

75. Employed civilians;

76. ... unemployed;

77. ... armed forces;

78. ... not in labor force.

FACTOR RUN D

Factor	Eigenvalue	Percent of Variance	Cumulative percent of variance
1	19.46	30.4%	30.4%
2	12.84	20.1%	50.5%
3	6.13	9.6%	60.1%
4	4.42	6.9%	67.0%
5	2.86	4.5%	71.5%
6	2.19	3.4%	74.9%
7	1.68	2.6%	77.5%

1. 64 Census characteristics
2. 450 geographic Census tracts
3. First seven factors explain 77.5% of the variance
4. First two factors explain 50.5% of the variance
5. Range of communality scores:

	(.00 - .69)	= 5
	(.70 - .79)	= 11
48% of total --	(.80 - .89)	= 31
26% of total --	(.90 - .99)	= 17
		64 total variables

6. Variables with communality scores of .90 and above:

-Score range (.90-.92)-

variable number	variable name
11	occupation: sales worker
12	occupation: craftsmen, foremen, and kindred workers
15	occupation: service workers, except household
33	mode of transportation: bus, streetcar
38	family income: $10,000 - 14,999
47	value of housing: $35,000 - over
51	units in structure: one
70	years school completed: 1 - 8 years
71	years school completed: high school, 1 - 3 years

-Score range (.93-.96)-

4	total population 45 - 64 years
10	occupation: clerical and kindred workers
13	occupation: operatives and kindred workers
34	mode of transportation: private auto or carpool
36	family income: less than or equal to $4,999
37	family income: $5,000 - 9,999
63	number total units owner occupied
75	employement status: employed civilians

-Score range(.97-.99)-

none

7. Significant variables loading onto factor 1:

Var. No.	Census Description	Loading on factor 1
15	number of people in service occupation	.922
14	number of people employed in private households	.901
6	number of people Negro	.854
36	family income less than or equal to $4,999	.841
1	total population under five years	.838
68	six or more people per unit of housing	.792
28	number of people employed in eating and drinking industry	.745
33	means of transportation to work - bus	.743
62	residence different house same county as 1955	.742
70	1-8 years of school completed	.735
17	number of people in not reported occupation category	.684
19	number of people in construction industry	.673
13	number of people with occupation as operatives, mine	.652
71	1-3 years of high school completed	.614
75	number of employed civilians	.586
23	number of people in food industry	.577
67	3-5 people per unit of housing	.503

8. Name of factor 1: Black Ethnicity.

9. Reasons for choosing name:

   a. Significant positive loadings: measures of low socio-economic status; Negro population.

   b. Significant negative loadings: none.

   c. Comments: the socio-economic variables are recognized as ethnic related; also variable six loaded significantly only on this factor.

10. Significant variables loading onto factor 2:

Var. No.	Census Description	Loading on factor 2
60	residence in 1955 outside SMSA N&W	.872
61	residence in 1955 outside SMSA, S	.838
10	number of people employed in clerical occupations	.815
49	rental monthly payments $100 - 200	.752
55	10 or more units of housing per structure	.748
26	number of people employed in communication and utilities industry	.712
22	number of people in machinery industry	.712
24	number of people in printing industry	.670
18	number of people employed in mining industry	.635
11	number of people in sales occupations	.628
75	number of employed civilians	.586
53	3-4 units of housing per structure	.564
27	number of people in wholesale industry	.545
54	5-9 units of housing per structure	.528
37	family income $5,000 - 10,000	.522
34	number of people using private auto to work	.515
31	number of people employed in public administrative, industry	.505

11. Name of factor 2: Economic Attractiveness.

12. Reasons for choosing name:

    a. Significant positive loadings: measures of in-migration, multi-unit dwelling, and diffuse employment indicators.

    b. Significant negative loadings: none.

    c. Comments: factor correlates in-migration with employment measures and clustered dwelling patterns. Could be a measure of economic growth patterns prior to airport development.

13. Significant variables loading onto factor 3:

Var. No.	Census Description	Loading on factor 3
46	housing value between $25-35,000	.934
45	housing value between $20-25,000	.924
39	family income $15-25,000	.903
47	housing value $35,000 or more	.871
40	family income $25,ooo or more	.851
44	housing value $15-20,000	.794
74	school completed - college, four years or more	.704
18	number of people employed in oil industry	.590
11	number of people with occupations in sales	.581
63	number of owner occupied units	.569

14. Name of factor 3: Socio-Economic Status.

15. Reasons for choosing name:

    a. Significant positive loadings: measures of high socio-economic status.

    b. Significant negative loadings: none.

16. Significant variables loading onto factor 4:

Var. No.	Census Description	Loading on factor 4
43	housing value between $10 - 15,000	.790
63	number of owner occupied units	.652
31	number of people employed in public administration	.626
25	number of people employed in railroad industry	.612
37	family income between $5 - 10,000	.565
51	number of units per structure of housing	.543
34	means of transportation to work - private auto	.542
42	housing value $5 - 10,000	.538

17. Name of factor 4: Suburban Residency.

18. Reasons for choosing name:

a. Significant positive loadings: measures of middle income, middle class profile.

b. Significant negative loadings: none.

c. Comments: this factor could seem to measure socio-economic status, however, correlation with single unit, owner occupied structure, justifies a more spatial perspective.

19. Significant variables loading onto factor 5:

Var. No.	Census Description	Loading on factor 5
16	number of people in occupation of farm labor	.899
9	number of people in occupation of farmer, managers	.858
59	residence in 1955, other part of SMSA	.592
41	housing value $0 - 5,000	.562

20. Name of factor 5: Rural Location.

21. Reasons for choosing name:

a. Significant positive loadings: measures of farming activity.

b. Significant negative loadings: none.

c. Comments: seems to indicate an inverse relationship with factor 5 in Factor Run A.

22. Significant variables loading onto factor 6:

Var. No.	Census Description	Loading on factor 6
12	number of people occupied as craftsmen, foremen	.719
20	number of people employed in furniture industry	.661
21	number of people employed in metal industry	.659
13	number of people occupied as operatives	.567
23	number of people employed in food industry	.534

23. Name of factor 6: Non-Definable.

24. Reasons for choosing name:

a. Significant positive loadings: none.

b. Significant negative loadings: none.

25. Significant variables loading onto factor 7:

Var. No.	Census Description	Loading on factor 7
35	number of people who walk to work	.783
30	number of people employed in hospital industry	.663
41	housing value between $0 - 5,000	.520

26. Name of factor 7: Non-Definable.

27. Reasons for choosing name:

    a. Significant positive loading: none.

    b. Significant negative loading: none.

FACTOR RUN E

FACTOR RUN E

Factor Run E consists of all census characteristics chosen except numbers 56 and 64. These variables were not included because they were rejected by the factor routine used; specifically they formed linear combinations of other census variables thus making the factor matrix ill conceived and shedding doubt on factor score coefficients.

A list of the characteristics employed in Run E follows on the next page. It is noted that the factor patterns formed from this most complete run set correspond to the various subsets selected in Runs A through D.

Factor patterns delineated and named for Run E are as follows:

Factor name

1. Black ethnicity
2. Socio-economic status
3. Multi-unit dwelling pattern
4. Non-definable
5. Occupational Status
6. Occupational Class
7. Urban location.

Factor Run E: Variable list

"Population & Housing Characteristics" 1960 U.S. Census

Age Distribution

Variable 1. Total population under five years;
2. ... 5 - 19 years;
3. ... 20 - 44 years;
4. ... 45 - 64 years;
5. ... 65 and over.

Ethnicity

variable 6. Total population Negro;

7. Total population other than Negro and White.

Occupation

8. Professional, technical, and kindred workers;

9. ... farmers and farm managers;

10. ... clerical and kindred workers;

11. ... sales workers;

12. ... craftsmen, foremen, and kindred workers;

13. ... operatives and kindred workers;

14. ... private household workers;

15. ... service workers, except household;

16. ... farm laborers and foremen;

17. ... not reported.

Industry

18. Mining;

19. ... construction;

20. ... furniture, lumber, and wood;

21. ... metal industry;

22. ... machinery;

23. ... food and kindred industry;

24. ... printing, publishing, and allied;

25. ... R.R. and Railway Express;

26. ... communications, utilities, sanitary services;

27. ... wholesale trade;

28. ... eating and drinking places;

29. ... business and repair services;

30. ... hospitals;

31. ... public administration

Mode of Transportation

variable 32. Railroad;

33. ... bus, streetcar;

34. ... private auto or carpool;

35. ... walk.

Family Income

36. Less than or equal to $4,999;

37. ... $5 - 9,999;

38. ... $10 - 14,999;

39. ... $15 - 24,999;

40. ... $25 - over.

Value of Housing

41. Under $5,000;

42. ... $5 - 9,999;

43. ... $10 - 14,999;

44. ... $15 - 19,999;

45. ... $20 - 24,999;

46. ... $25 - 34,999;

47. ... $35 - over.

Rent

48. Less than $99;

49. ... $100 - 199;

50. ... $200 - more.

Units/Dwelling Structure

51. One unit structure;

52. ... 2 unit structure;

53. ... 3 - 4 unit structure;

54. ... 5 - 9 unit structure;

55. ... 10 or more unit structure.

Migration

variable 57. Same house as 1960;

58. ... different house in central city of this SMSA;

59. ... different house in other part of this SMSA;

60. ... different house outside this SMSA in North and West;

61. ... different house outside this SMSA in South;

62. ... different house, same county.

Occupancy Status

63. Total units owner occupied;

65. ... vacant units.

Persons/Housing Unit

66. 1 - 2 persons;

67. ... 3 - 5 persons;

68. ... 6 or more persons.

Education

69. No school years completed;

70. ... 1 - 8 years of school;

71. ... high school, 1 - 3 years;

72. ... high school, 4 years;

73. ... college, 1 - 3 years;

74. ... college, 4 or more years.

Employment Status

75. Employed civilians;

76. ... unemployed;

77. ... armed forces;

78. ... not in labor force.

Factor Run E

Factor	Eigenvalue	Percent of Variance	Cumulative percent of variance
1	24.25	31.9%	31.9%
2	15.05	19.8%	51.7%
3	7.05	9.3%	61.0%
4	4.64	6.1%	67.1%
5	3.04	4.0%	71.1%
6	2.68	3.5%	74.7%
7	1.84	2.4%	77.1%

1. 76 census characteristics
2. 450 geographic census tracts
3. First seven factors explain 77.1% of the total variance
4. First three factors explain 61.0% of the total variance
5. Range of communality scores:

45% of total-- (.00 - .69) = 8
(.70 - .79) = 14
(.80 - .89) = 34
(.90 - .99) = 20
76 total variables

6. Variables with communality scores of .90 and above:

-Score range(.90-.92)-

variable number	variable name
11	occupation: sales worker
12	occupation: craftsmen, foremen, and kindred workers
15	occupation: service workers, except households
33	mode of transportation: bus, streetcar
34	mode of transportation: private auto or carpool
38	family income: $10,000 - 14,999
51	units in structure: one unit
70	years school completed: 1 - 8 years
71	years school completed: 1 - 3 years, high school
72	years school completed: 4 years high school
73	years school completed: college, 1 - 3 years
78	employment status: not in labor force

-Score range(.93-.96)-

4	total population 45 - 64 years of age
8	occupation: professional, technical and kindred
10	occupation: clerical and kindred workers
13	occupation: operatives and kindred workers
37	family income: $5,000 - 9,999
63	total units owner occupied
75	employment status: employed civilians

-Score range(.97-.99)-

none

7. Significant variables loading onto factor 1:

Var. No.	Census Description	Loading on Factor 1
1	total population under 5 years	.900
15	occupation: service workers, except household	.897
36	family income: less than or equal to $4,999	.875
14	occupation: private household workers	.869
68	persons in unit: 6 or more	.831
70	years school completed: 1 - 8 years	.822
6	Negro population	.819
76	employment status: unemployed	.793
2	total population: 5 - 19 years	.782
62	residence 1955: different house, same county	.770
13	occupancy: operatives and kindred workers	.724
28	industry: eating and drinking places	.719
19	industry: construction	.698
3	total population: 20 - 44 years	.689
17	occupation: not reported	.685
33	means of transport to work: bus, streetcar	.671
71	school completed: high school, 1 - 3 years	.666
23	industry: food and kindred	.638
58	residence 1955: different hosue in central city of this SMSA	.622
75	employment status: employed civilians	.572
67	persons in unit: 3 - 5	.550
57	residence 1955: same as 1960	.528
69	no school years completed	.515
30	industry: hospitals	.501

8. Name of factor 1: Black Ethnicity .

9. Reasons for choosing name:

   a. Significant positive loadings: measures of low socio-economic status, only loading of Negro population.

   b. Significant negative loadings: none.

   c. Comments: the socio-economic variables are recognized as ethnic related, variable six loaded significantly on only this factor.

10. Significant variables loading onto factor 2:

Var. No.	Census Description	Loading on Factor 2
46	value of housing: $25 - 34,999	.919
45	value of housing: $20 - 24,999	.906
39	family income: $15 - 24,999	.902
47	value of housing: $35,000 and over	.883
40	family income: $25,000 and over	.863
44	value of housing: $15 - 19,999	.761
38	family income: $10 - 14,999	.721
74	school completed: college, 4 or more years	.705
73	school completed: college, 1 - 3 years	.638
18	industry: mining	.601
11	occupation: sales workers	.578
63	total housing units owner occupied	.531
8	occupation: professional, technical, kindred	.518

11. Name of factor 2: Socio-Economic Status

12. Reasons for choosing name:

    a. Significant positive loadings: measures of high socio-economic status.

    b. Significant negative loadings: none.

    c. Comments: measures of life cycle stability indicated, housing values seem to reinforce factor name.

13. Significant variables loading onto factor 3:

Var. No.	Census Description	Loading on Factor 3
53	housing units in structure: 3 - 4 units	.840
65	vacant units	.804
55	10 or more units in structure	.740
54	5 - 9 units in structure	.781
29	industry: business and repair services	.664
49	gorss rent by month: $100 - 199	.652
48	gross rent by month: less than $99	.582
52	2 housing units to a structure	.555
10	occupation: clerical and kindred	.547
61	residence 1955: different house outside this SMSA in South	.525
27	industry: wholesale trade	.523

14. Name of factor 3: Multi Unit Dwelling Pattern

15. Reasons for choosing name:

a. Significant positive loadings: dwelling structures of multi unit nature; indication of major rent area.

b. Significant negative loadings: none.

c. Comments: the significant loading of gross rent variables might possibly indicate apartment dwelling phenomena; this factor might be used to indicate changes in privacy standards.

16. Significant variables loading onto factor 4:

Var. No.	Census Description	Loading on Factor 4
51	one unit dwelling structures	.643
30	industry: hospitals	.618
41	value of housing: under $5,000	.614
31	industry: public administration	.577
63	total housing units owner occupied	.572
34	means of transportation: private auto or carpool	.516
35	means of transportation: walk	.502

17. Name of factor 4: Non-Definable.

18. Reasons for choosing name:

    a. Significant positive loadings: none.

    b. Singificant negative loadings: none.

19. Significant variables loading onto factor 5:

Var. No.	Census Description	Loading on factor 5
72	years of shcool completed: high school, 4 years	.826
5	total population: 65 and over years	.819
4	total population: 45 - 64 years	.776
66	persons in housing units: 1 - 2	.739
73	years school completed: college, 1 - 3 years	.653
37	family income: $5,000 - 9,999	.645
10	occupation: clerical and kindred workers	.634
71	years of school completed: high school, 1 - 3 years	.612
67	persons in unit: 3 - 5	.608
26	industry: communications, utilities, sanitary services	.607
11	occupation: sales workers	.584
43	value of housing: $10,000 - 14,999	.556
31	industry: public administration	.554
8	occupation: professional, technical, kindred	.523
38	family income: $10,000 - 14,999	.516

20. Name of factor 5: Occupational Status.

21. Reasons for choosing name:

    a. Significant positive loadings: levels of education, family income, and housing value coinciding with significant occupational variables.

    b. Significant negative loadings: none.

    c. Comments: evidence of scaled occupational profiling with socio-economic variable support.

22. Significant variables loading onto factor 6:

Var. No.	Census Description	Loading on Factor 6
12	occupation: craftsmen, foremen, kindred	.753
21	industry: metal industry	.687
37	family income: $5,000 - 9,999	.607
22	industry: machinery	.585
20	industry: furniture, lumber, wood	.507
13	occupation: operatives and kindred workers	.500

23. Name of factor 6: Occupational Class

24. Reasons for choosing name:

a. Significant positive loadings: variables loading along comparitive industrial and occupational classes.

b. Significant negative loadings: none.

c. Comments: variables splitting along major lines of occupation and industry classes; differentiated from "occupational status" in that no housing or educational variables emerged.

25. Significant variables loading onto factor 7:

Var. No.	Census Description	Loading on Factor 7
16	occupation: farm laborers and foremen	-.884
9	occupation: farmers and farm managers	-.843
59	residence 1955: different house in other part of this SMSA	-.630
41	value owner occupied housing: under $5,000	-.510

26. Name of factor 7: Urban Location

27. Reasons for choosing name:

a. Significant positive loadings: none.

b. Significant negative loadings: measures of farming activity.

c. Comments: identifies an indirect change in farming activity variables pointing to a strong non-rural location; may be compared with factor five, Factor Run D, for an exact inverse pattern formation.

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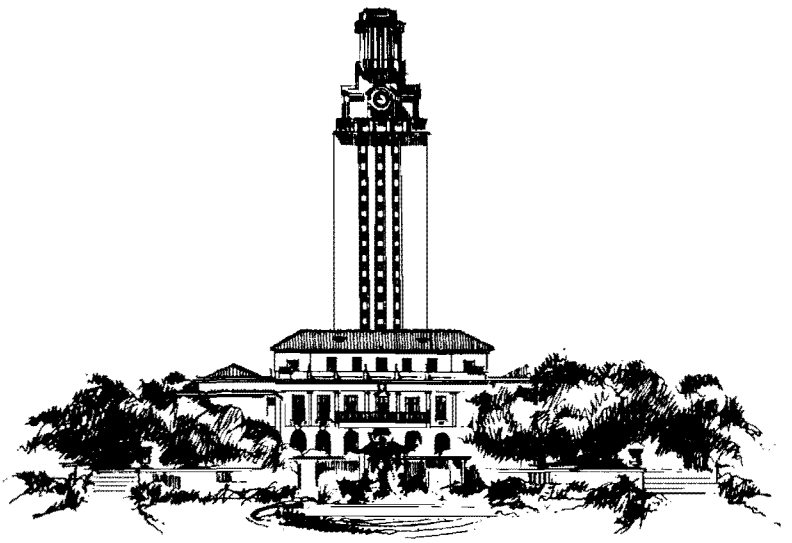

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