NEEDLESS COMPLEXITY IN THE IDENTIFICATION OF INDUSTRIAL COMPLEXES

William R. Latham III*

1. INTRODUCTION

Recent papers (Czamanski [3] and Richter [13]) have proposed factor analysis of input-output tables as a new technique in the identification of industrial complexes. Others have proposed graph-theoretic analysis (Campbell [1], Slater [15, 16]). Either implicit or explicit in these papers is the proposition that such analysis may be useful in regional development and planning. In the following section of this paper it is argued that any meaningful analysis of industrial complexes, especially for regional development and planning purposes, must consider spatial factors in some way. This leads to the conclusion that purely aspatial methods, such as factor analysis of input-output tables, are not useful for policy purposes. Despite this conclusion, in the next section aspatial methods of identifying complexes are reviewed critically so that others will not be tempted to salvage these methods by simply coupling them with a supplemental spatial analysis. The criticism of the factor analytic methods shows that some "complexes" identified by factor analysis are based upon relationships that are obvious without use of factor analysis. In Section 4, an alternative methodology for identifying industrial complexes which may be intuitively more appealing than others is discussed. The alternative is more readily performed than others and explicitly incorporates spatial factors. An example of its application is presented.

2. DEFINING AN INDUSTRIAL COMPLEX

Czamanski defines an industrial complex as "a set of activities . . . occurring at a given location, and belonging to a subsystem subject to important production, marketing or other interrelations" [1, p. 139]. This definition seems to be directly drawn from Isard's work [4, pp. 375–412]. Roepke *et al.* [14, p. 27] also rely on Isard for a definition of an industrial complex, quoting Isard and Smolensky's definition of an industrial complex as "a set of activities occurring at a given location and belonging to a group . . . of activities which reap important external economies because of their close production, marketing or other linkages." For the purposes of this paper the most significant feature of these definitions is their clear specification of two criteria necessary for the identification of a complex: the component industries must be both (1) interrelated through trading relationships, and (2) located in close geographic proximity to each other. The second criterion is

* Assistant Professor of Economics, University of Delaware.

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especially important in regional analysis; the locational aspect of the definition injects spatial considerations into the notion of an industrial complex.

Because they explicitly and efficiently summarize the trading relationships between industries, input-output tables have been used in most attempts to identify industrial complexes.[1] Unfortunately, by themselves, I-O tables do not necessarily contain any spatial or locational information. An exception might be an I-O table for an economic region of a size sufficiently small to permit the assumption that most internal transportation costs are significantly less than most external costs. With such a table one could identify both interindustry relationships and a "place" in a locationally significant sense. Surely I-O tables for the whole U.S., the state of Washington or West Virginia, or the province of Ontario cannot be identified with a locationally significant "place" because these areas are too large. Yet Czamanski [3], Campbell [2], and Roepke *et al.* [14] have attempted to identify industrial complexes in each of these areas using only input-output tables even though these writers accept completely the locational aspects of an industrial complex.[2] Roepke *et al.* explicitly recognize that their analysis is aspatial in using only an input-output table [14, pp. 16, 27]. They also recognize [14, p. 17] that when a spatial industrial complex is to be identified, "the size of the observational unit is of critical importance." They proceed with their aspatial analysis primarily because "the identification of aspatial complexes can serve as an input to locational studies searching for spatial relationships within functioning complexes in specific regions" [14, p. 17]. Here Roepke *et al.* seem to ignore the critical importance of region size that they identify earlier (on the same page) in their article.

An indication of the extent of the problem of using purely aspatial techniques to identify an industrial complex becomes evident in examining particular industrial complexes identified by these methods. For example, Roepke *et al.* [14, p. 19] identify a Metal Using Industries complex in Ontario composed of six industries: (1) Metal Stamping, Pressing, and Coating; (2) Fabricated and Structural Metals; (3) Electrical Applicances; (4) Other Metal Fabricating; (5) Other Transport Equipment; and (6) Electrical Industrial Equipment. Both Roepke *et al.* and Czamanski imply that results for one region will be useful for others. Thus one might examine the locations of firms in these six industries in the United States to judge whether or not the industries form complexes in the spatial sense.[3] Using

[1] Isard's [4] approach relies not only on input-output relationships but also on detailed production, transportation, and marketing information. Klassen [7] suggests calculating coefficients of attraction, which calculations require knowledge of both transport costs and regional input-output relationships to determine the demand or supply orientation of industries. This information, he suggests, can be used in determing which industries may form complexes.

[2] Czamanski includes Nova Scotia and the Philadelphia SMSA among the areas to which he applied his method. These areas do qualify as economic regions in the sense described above. However, because Czamanski also applies his method to the U.S., Washington, and West Virginia, it is apparent that he does not recognize the area size problem identified in the text here.

[3] While the following example does rely on the assumption that results can be generalized, the overwhelming nature of the results of the comparison indicates that the assumption is probably not the crucial element.

S.I.C. codes 3461, 3441, 3644, 3499, 3799 and 3629 to represent each of the six industries, accepted measures of geographic association were computed between the 15 pairs of industries (see Latham [10] and Section 4 below for a description of the measures). The results indicated that only four of the 15 industry pairs have an identifiable tendency to locate near to each other. Thus the six industries do not form an industrial complex as defined above.

Czamanski [3, p. 145] identified an industrial complex for the whole United States containing (1) Farm Machinery and Equipment; (2) Other Fabricated Metal Products; (3) Heating, Plumbing, and Structural Metal Products; (4) Stamping, Screw Machine Products, and Bolts; (5) Electric Lighting and Wiring Equipment; (6) Other Transportation Equipment; (7) Special Industrial Machinery and Equipment; and (8) Metal Containers. Using S.I.C. codes (1) 3522; (2) 3499; (3) 3432, 3433, and 3441; (4) 3461; (5) 3641 and 3642; (6) 3799; (7) 3559, and (8) 3491 to represent these industries, measures of geographic association between pairs were again computed. Because only four of the 28 pairs of industries were found to be geographically associated with each other, the eight industries again do not appear to form an industrial complex.

These two examples indicate clearly that aspatial methods are not likely to identify industrial complexes as defined in this section.

3. COMPLEX METHODS OF IDENTIFYING INTERINDUSTRY RELATIONSHIPS

Even if the argument of the preceding section is accepted and the necessity of a spatial or locational component in the identification of industrial complexes is affirmed, the techniques of factor and graph-theoretic analyses might still be valid techniques for identifying interindustry relationships. Campbell [2], Roepke *et al* [14], Czamanski [3] and Slater [15, 16] all make claims, implicitly or explicitly, for their techniques beyond the more limited purpose of identifying interindustry relationships, but each still focuses on the identification of interindustry relationships. It is the purpose of this section to show that these techniques introduce needless complexity into the identification of industrial complexes and that their use is questionable in other regards as well.

Perhaps the most fundamental criticism that can be leveled at the use of these sophisticated techniques to identify interindustry relationships is that they fail to identify, in many cases, unanticipated interindustry relationships. Roepke *et al.* label their factors quite unambiguously as Metal Using Industries, Textiles, Chemical Industries, Farm Products, Food Products Industries, Paper and Printing, etc., and the component industries in each of the factors are ones that can be expected a priori (see Table 1). Thus, the factor analysis may be a needless complexity. That this is true in comparison with another available method will become clear in the next section. Czamanski does not give his factors names, but again the component industries of each factor are frequently those that one would expect to be associated with each other in some way. The graph-theoretic analysis of Slater [15] is also based on input-output flows in the U.S. economy and consequently yields groups of industries linked by flows from one to another. While his groups

TABLE 1: First Five Factors From Roepke *et al.* [14, p. 19]

Factor I—Metal Using Industries	Factor IV—Farm Products
Metal Stamping, Pressing, Coating	Grain Mills
Fabricated and Structural Metals	Dairy Products
Electrical Appliances	Meat and Poultry
Other Metal Fabricating	
Other Transportation Equipment	
Factor II—Textiles	Factor V—Food Products Industries
Knitting Mills	Biscuits and Bakeries
Other Textiles	Soft Drinks
Clothing Industries	Other Food Industries
Cotton, Yarn, and Textiles	Distilleries, Breweries, and Wineries
Synthetic Textiles	Sugar and Confectionaries
Factor III—Chemical Industries	
Plastics and Synthetic Resins	
Pharmaceuticals and Medicines	
Paint and Varnish	
Other Chemical Industries	

TABLE 2: Linkage Group From Slater [15, p. 12]

Transportation and Warehousing	Finance and Insurance
Other Transportation Equipment	Maintenance and Repair Construction
Aircraft and Parts	Electric, Gas, Water and Sanitary Services
Automobile Repairs and Services	Communications, except Radio and TV Broadcasting
Wholesale and Retail Trade	Nonferrous Metals Manufacturing
Real Estate and Rental	
Iron and Steel Manufacturing	

are not quite as predictable as those of Roepke *et al.*, they are still not surprising in composition (see Table 2).

Another example of needless complexity is provided by Roepke *et al.*'s [14, p. 24] use of three different factor analyses of the Ontario input-output table. A major result of these analyses is the discovery that the Clothing Industry does not tend to be a supply source for Textile Products and that the Synthetic Textile Industry is not often the product market or destination of Textile Products.

It is interesting to note that Roepke *et al.* [14, pp. 24, 25] justify and test their complexes by appealing to the results that would have been obtained using a weighted mean of the simple bilateral linkage relationships between the industries in a complex. That their complexes are justified by this measure gives one reason to wonder whether or not bilateral linkage measures might not themselves be used to identify interindustry relationships. In the next section of this paper these simpler measures are so used.

In the discussions of sophisticated techniques applied to input-output tables to identify interindustry relationships considered in this paper (Campbell [1, 2], Czamanski [3], Roepke *et al.* [14] and Slater [15, 16]) there is an implicit assumption that these techniques will yield results not obtainable from the analysis of the simple bilateral exchanges which the input-output table summarizes. This does not appear to be true. For example, Czamanski [3, p. 149] claims that his factor analysis shows that "the exchange of goods and services between unrelated industries exceeds in volume that between technically related ones." One must wonder how it is that a table based on bilateral exchanges reveals industries that exchange goods and services without being related.

Both Czamanski and Roepke *et al.* state that their factor analytic methods will reveal interrelated industries which do not trade directly with each other, but which instead have (1) common supply source industries, (2) common product market industries, or (3) common sets of third industries that are a product market for one group and a supply source for the other. Such relationships may be illustrated as follows:

$L \leftarrow \quad S \rightarrow K$ (L and K have common suppliers)
$L \rightarrow \quad D \leftarrow K$ (L and K have common markets)
$L \rightarrow D,\ S \rightarrow K$ (L's markets are K's sources)
$L \leftarrow S,\ D \leftarrow K$ (L's sources are K's markets)

where L and K are a particular pair of industries and S and D represent sets of other industries which are supply sources, S, or product markets, D, for L and K. This writer agrees with Slater [15, p. 1] that it is illogical to claim that K and L are related to each other more strongly than they are to those industries in the sets S and D. It seems logical that in each case all three industry sets are interrelated, with D or S being the more central set of L and K. Roepke *et al.* identify as an interrelated set the six industries discussed in the preceding section which are not closely related to each other, but which are heavily dependent upon Iron and Steel Mills which is not in the complex. Thus Iron and Steel Mills should be part of the interrelated set with the other six of Roepke *et al.* In this regard the graph-theoretic methods of Campbell and Slater are superior in that they recognize as interrelated sets of industries all those which are connected by paths consisting of sets of exchange relationships or links from industry to industry.[4]

The preceding comments have been directed toward the particular ways in which several investigators have used input-output tables to identify interindustry relationships. The following paragraphs in this section advise caution in the use of input-output tables for this purpose regardless of the particular techniques employed.

For the purpose of regional industrial development through industry attraction, it is inappropriate to use an input-output table of the economy of the region in question. One of Czamanski's purposes [3, p. 138] is "identifying, from among all the sectors of which a regional economy is comprised, those forming an industrial cluster . . . since by fostering the establishment of new complementary plants the emergence of a full industrial complex may be advanced." The particular industry which would most complement those already present might not be discovered by examining those already present. Rather, one should examine an input-output table for an entire country to discover through less limited interrelationships what

[4] Unfortunately, in a later paper Slater [16, p. 5] criticizes the placing of two industries in the same group when they do not have a direct relationship to each other even when they are connected by a series of links as are L and K in the illustration in the text.

industry might be most complementary to those already present. In the following section this suggestion is followed and industrial complexes are identified using a national input-output table.

Two final comments on the use of factor analyses to identify groups of interrelated industries are based on the level of aggregation in input-output tables. Both Czamanski [3, p. 150] and Roepke [14, p. 27] recognize that aggregate input-output tables, such as each used, mask too many significant relationships and also produce results that are not useful for policy purposes. Identification of a two- or three-digit S.I.C. code industry as a target for industrial development is not sufficient to identify which particular four- or five-digit industry contains the firms likely to be most complementary to those already present. For example, a relationship with Heating, Plumbing, and Structural Metal Products might be based on firms in Plumbing Fittings and Brass Goods or on firms in Heating Equipment except Electrical, or on some other component industry of the aggregate group, Heating, Plumbing Fittings and Brass Goods. A related problem occurs when intrasectoral relationships are eliminated from consideration, as is true in Czamanski, Roepke *et al.*, and Slater. Significant information on linkages may be lost, especially when highly aggregated sectors are used. For example, the linkage of Heating, Plumbing, and Structural Metal Products with itself may indicate a strong relationship between the Plumbing Fittings and Brass Goods industry and the Heating Equipment except Electrical industry. In the following section a less highly aggregated input-output table, including intrasectoral trades, is employed to identify interindustry relationships.

The preceding evidence illustrates that use of factor analysis and graph-theoretic analysis of aggregate input-output tables to identify interindustry relationships is questionable for a number of reasons.[5, 6]

4. A SIMPLER METHOD OF IDENTIFYING INDUSTRIAL COMPLEXES

In this section a method of identifying industrial complexes is employed that recognizes the necessity for both the explicit locational considerations of Section 2 and the identification of interindustry relations as discussed in Section 3. This method has the further advantage of avoiding some of the flaws of the techniques reviewed in Section 3. To identify a complex in this section, an industry is first selected from a group of industries identified as having their locations determined in part by interindustry linkages. The measure of location for each is the coefficient of correlation computed between each pair of industries' employment distribution over 377 regions in the U.S. (See Latham [9, 10] or Streit [18] for an explanation and discussion of the measure.) The measure of industrial linkage is similar to one employed by Streit [18] and Roepke *et al.* [14], being the sum of the ratios of an industry's inputs and outputs bought from or sold in another industry to each industry's total inputs or outputs, i.e.,

$$\text{Linkage}_{ij} = a_{ij}/\textstyle\sum_i a_{ij} + a_{ij}/\sum_j a_{ij} + a_{ji}/\sum_i a_{ji} + a_{ji}/\sum_j a_{ji}$$

[5] Stevens *et al.* [17, p. 21] report that they attempted a factor analysis approach to the identification of complexes several years prior to 1969. Unfortunately, they do not specify what the results of the attempt were or precisely how they proceeded. Thus their work is not reviewed here.

[6] Other, more technical comments on the methodologies of Czamanski, Roepke *et al.*, and Slater are possible, but seem superfluous in view of those discussed above.

where a_{ij} is the output which i sells to j. An industry is said to have its location determined in part by linkages if linkages to other industries are significant variables in a regression equation that attempts to explain the variation in the measure of association between one industry and all others.[7] (See Latham [11] or Streit [18] for a more complete discussion of the regression analysis.)

Once an industry is found for which interindustry linkages are important in its location decisions, the set of industries to which it has both significant linkages and significant geographic associations is found. (When both relationships are identified for a single pair of industries, a Locational Relationship exists.) The industries which have Locational Relationships with those in the first set are then identified. This process is continued for several iterations until circularity occurs or is found to be absent. (Circularity occurs when an industry of a lower numbered iteration reappears at a higher number iteration.) The type of complex identified by this method is likely to be more interdependent than hierarchal in nature as Streit has pointed out [18, p. 182]. It may be more important to identify this type of complex than a more hierarchal type because the latter type is more readily identifiable by simply using associations and the input-output table.[8]

Electronic Components, S.I.C. code 3679, offers a possible starting point for identifying a complex using the method described. Linkages are found to be significant in attempting to explain its geographic associations by the regression analysis described above. As shown in Table 3, industry 3679 has Locational Relationships with three industries which, in turn, have Locational Relationships with 3679; these are 3611, 3651 and 3662. Neither industry 3611 nor industry 3651 possesses additional reciprocal relationships with industries other than 3662 and 3679. Industry 3662 has additional reciprocal relationships with 3499 and 3811. Industry 3811 has no other reciprocal relationships but industry 3499 has such relationships with industries 2499, 2514, and 2515. The latter three, in turn, have reciprocal relationships with other industries as indicated in Figure 1. The figure shows the complex identified by the relationships in Table 3. This complex is self-contained, or closed, because there are no industries which have reciprocal relationships with those shown.[9] There are other industries which have relationships with

[7] In the regression analysis other variables in addition to linkages are used which account for generalized urbanization economies and other highly correlated sources of variation. The use of these variables should overcome the objections of Roepke *et al.* [1., p. 17] to attempt to identify spatially-defined industrial complexes.

[8] Leontief has suggested a means of identifying the hierarchal structure of industry by triangulation of an input-output table [12, p. 4]. In this process, material-oriented industries are listed first, then the industries linked to them, and so on until the market-oriented industries are listed.

[9] This statement applies to 199 industries used in the study. Reciprocal relationships with industries not in the study might exist, but the only error possible is that some industries might be omitted from the complex. Links to industries in the study but not in the complex could be important locationally for some not shown. However, it remains true that among those industries in the complex, each might be interested in the location of another in it which might reciprocate this interest. For example, a firm producing electric instruments would be interested in being close to a firm producing electronic components and the latter would like to locate close to the former. The presence of both of these would make a location highly attractive to the firm producing communications equipment.

TABLE 3: Identification of an Industrial Complex

Industry S.I.C. Code	Has Relationship with Industries	Which Have Relationships with Industries
3679	3499	2499, 2514, 2515, *3662*
	3611	*3662*, 3679
	3651	3679
	3662	3446, 3499, 3611, 3679, 3729, 3811, 3821
	3811	2541, *3662*
	3842	2844
	3931	
3662	3446	
	3499	2499, 2514, 2515, *3662*
	3611	3662, 3679
	3679	3499, 3611, 3651, *3662*, 3811, 3842, 3931
	3729	3679, 3721
	3811	3541, *3662*
	3821	3843

those shown in the complex, but none of those shown has a reciprocal relationship with any industry not in the complex. Thus, mutual interdependence is stressed in this formulation.

In Figure 1, an arrow from one industry to another indicates a relationship from the first to the second. Arrows in both directions indicate a reciprocal relationship. Numbers in parentheses are coefficients of correlation measuring geographic associations and D, S, SD, and SS refer, respectively, to demand, supply, strong demand and strong supply links from the initial to the terminal industry of the nearest arrow.[10] Clearly, industries 3611, 3662, and 3679 are part of an industrial complex because each has strong relationships with the other two. Industries 3651 and 3811 are probably additional members of the complex. Industry 3499 might also be included in the complex or it could be considered to be the key industry in a small complex formed by industries 2514, 2515, and 3499. Along with industry 2499, industry 3499 could also be considered to be part of the complex formed by industries 2541, 2542, 2599, and 2514. However the industries in Figure 1 are ultimately divided into complexes, the central roles played by industries 3662, 2499, and 2542 are clear.[11]

The linkage information in Figure 1 can be used to comment further on some

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[10] Industry A is said to be linked to B in demand if B demands more than $1/n$th of the total output of A, where n is the number of nonfinal-demand industries to which A sells positive amounts of output. Similarly, a supply linkage, indicating that A depends upon B as a supplier, exists if A purchases more than $1/n$th of its inputs from B, where n is the number of industries, other than primary resource extractors, from which A buys inputs. The quantities that industry A sells to, or purchases from, B may also be compared to $1/n$th of B's output or inputs to determine whether B is linked to A in supply or demand. Flows representing more than 7.5 percent of inputs or outputs as defined above identify strong links.

[11] Note that other practioners have allowed the same industry to be part of more than one complex so that it is not necessary to allocate each industry to only one complex.

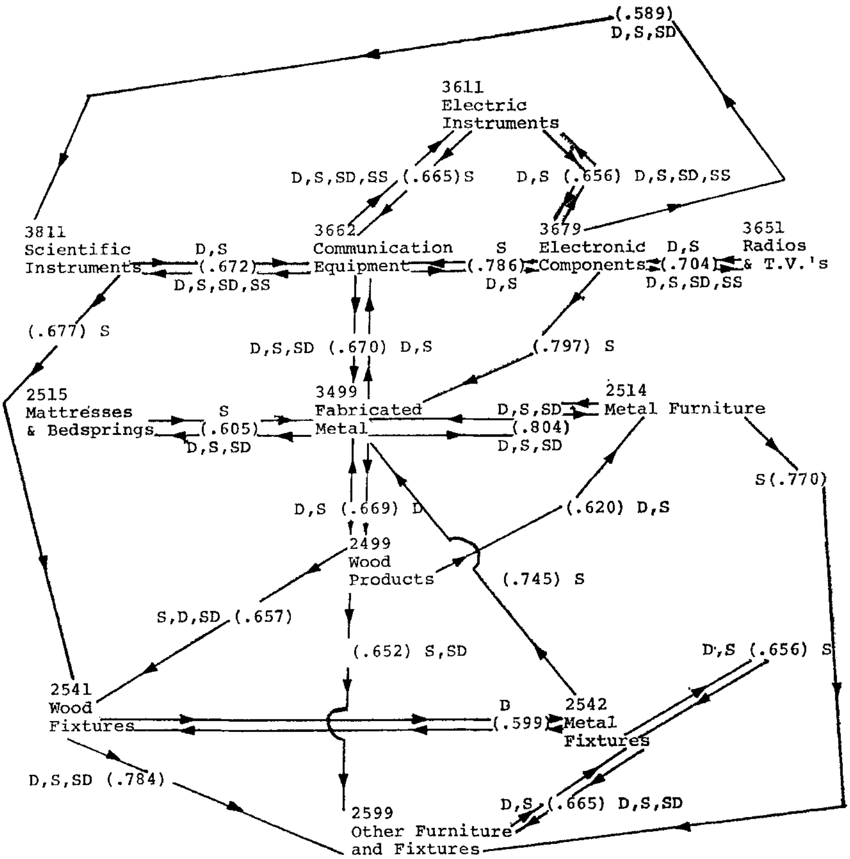

FIGURE 1: Identification of Industrial Complexes. (Numbers above abbreviated industry names are industry numbers; numbers in parentheses are coefficients of geographic association; *D*, *S*, *SD* and *SS* represent demand, supply, strong demand and strong supply links from initial industry to terminal industry on nearest arrow.)

of the interdependencies that have been accompanied by geographic associations among these industries. In most cases where a reciprocal relationship exists, one industry is more strongly linked to the other. For example, the Electronic Components industry (3679) is strongly linked in demand and supply to the Electric Instruments industry (3611) as is the Communication Equipment industry (3662). The Electric Instruments industry (3611) has only weak links to each of these however, and might be considered less dependent on them than they are on it. The existence of both demand and supply links from one member of a pair to the other in many cases may indicate that even within the four-digit S.I.C. industries used here there are quite different firms.

The method of identifying a complex used here is similar to that used by Streit [18, p. 182]. According to Streit's method, a complex exists only if, for all pairs of industries in the complex, both (1) the coefficient of correlation measuring

TABLE 4: Comparison of Industry Average and Single Pair Links

Industry (i)	$\frac{\sum_{j=1}^{n} L_{ij}}{n}$	Linked and Associated Industries (j)	L_{ij}
2514	.00472	2499	.00659
		2542	.02416
		2599	.01610
		3499	.02488
3499	.00483	2499	.00922
		2542	.00942
		2514	.02488
		2515	.03741
		3662	.01402
		3679	.00244*
3679	.00882	3499	.00244*
		3611	.05969
		3651	.12524
		3662	.17883
		3811	.01369

* Indicates average link between industry i and industry j is less than average of all links for industry i.

geographic association is statistically greater than zero (at some level of significance), and (2) the average value of the four linkage relationships between the pair is greater than the average value of this average for at least one member of the pair. All significant measures of association in the present study have values greater than .5 at the .05 level of significance, so that Streit's criterion (1) is fulfilled for all pairs in a complex identified by the methods of the present study. The average value of the average of the four possible links between one industry and another was computed for industries 2514, 3499, and 3679. Table 4 shows these values and the values of the average linkage with a number of other industries from Figure 1. The Table shows that the method used in identifying a complex illustrated above results in Streit's second criterion being fulfilled for 13 of 15 pairs. Thus while Streit's criterion is less stringent than that used here for geographic associations, and his criterion for linkages is slightly more stringent, the complexes identified using the two methods would probably be quite similar. Detailed comparisons with complexes identified by Streit are not possible because of the level of aggregation in his study.

This section has shown that measures of geographic association and interindustry linkages can be employed to identify a type of industrial complex that is characterized by a high degree of mutual interdependence. The method has also been compared favorably with other methods of identifying industrial complexes.

5. CONCLUSION

This paper has argued that the concept of an industrial complex must include information regarding both spatial or locational behavior and interindustry relationships. Methods not including both considerations were held to be invalid.

Among the methods for identifying interindustry relationships, factor analysis and graph theory were found to be needlessly complex and deficient in other respects as well. A simpler, more intuitive procedure for identifying an industrial complex was proposed and demonstrated to be effective.

REFERENCES

[1] Campbell, J. "Growth Pole Theory, Digraph Analysis and Interindustry Relationships," *Tijdschrift voor Economische en Sociale Geographie*, 63 (1972), 79–87.

[2] ———. "Selected Aspects of the Interindustry Structure of the State of Washington," *Economic Geography*, 50 (1974), 35–46.

[3] Czamanski, S. "Some Evidence of the Strengths of Linkages Between Groups of Related Industries in Urban-Regional Complexes," *Papers, Regional Science Association*, 27 (1971), 137–150.

[4] Isard, W. *et al.* *Methods of Regional Analysis: An Introduction to Regional Science*. Cambridge: The M.I.T. Press, 1956.

[5] ——— and E. Smolensky. "Application of Input-Output Techniques to Regional Science," in T. Barna (ed.), *Structural Interdependence and Economic Development*. London: Macmillan, 1963.

[6] Karaska, G. J. "Manufacturing Linkages in the Philadelphia Economy: Some Evidence of External Agglomeration Forces," *Geographical Analysis*, 1 (1969), 354–369.

[7] Klassen, L. H. "The Analysis of Industrial Relationships in Location Theory," *Papers, Regional Science Association*, 16 (1966), 123–128.

[8] Kolosovsky, N. N. The Territorial-Production Combination (Complex) in Soviet Economic Geography," *Journal of Regional Science*, 3 (1961), 1–25.

[9] Latham, W. R. III. "Biased Correlation Coefficients and Chi-Square Statistics with Regional Data," *Review of Regional Studies*, 3 (1974), 125–132.

[10] ———. "Measurement of Spatial Association: Some Comparative Empirical Results," unpublished paper presented at Mid-Continent Regional Science Association Meetings, Urbana, Illinois, 1974.

[11] ———. "The Impact of Industrial Linkages on Geographic Association: Further Results," unpublished paper presented at North American Regional Science Association Meetings, Chicago, 1974.

[12] Leontief, W. "The Structure of Development," *Scientific American*, 209 (1963), 25–35.

[13] Richter, C. E. "The Impact of Industrial Linkages on Geographic Association," *Journal of Regional Science*, 9 (1969) 19–28.

[14] Roepke, H. *et al.* "A New Approach to the Identification of Industrial Complexes Using Input-Output Data," *Journal of Regional Science*, 14 (1974), 15–29.

[15] Slater, P. B. "Graph-Theoretic Clustering of Transaction Flows: An Application to the 1967 United States Interindustrial Transactions Table," Regional Research Institute, West Virginia University, October, 1974.

[16] ———. "Weak Components of the 1967 United States Interindustrial Transactions Table," Regional Research Institute, West Virginia University, no date.

[17] Stevens, B. H. *et al.* "Trends in Industrial Location and Their Impact on Regional Economic Development," Regional Science Research Institute Discussion Paper No. 31. Philadelphia: Regional Science Research Institute, 1969.

[18] Streit, M. E. "Spatial Associations and Economic Linkages Between Industries," *Journal of Regional Science*, 9 (1969), 177–188.