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# A SPATIAL COMPLEX ANALYSIS OF AGGLOMERATION AND SETTLEMENT PATTERNS

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## Preface

This paper is an outgrowth of the author's lecture delivered at IIASA in September 1977. The lecture was jointly organized by Integrated Regional Development Task and Human Settlement Systems Task, both of which are sharing the common research interests in the analytical methods, planning means and policy implementation instruments with respect to spatial allocation interaction of activities in a functionally integrated economic and social subsystem.

This paper presents a new analytical technique concerning the internal and external agglomeration economies which have become increasingly significant to spatial issues. It also intends to provide a reasonable background for a better understanding of the characteristics of changes actually taking place in spatial systems. Therefore, it will serve as a complementary output to the results stemming from the research activities of both Tasks which will be carried out at IIASA.

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Abstract

Traditional location theory and modern spatial interaction theory are important but nonetheless unsatisfactory tools to analyze the determinants of spatial agglomeration patterns.

Efficiency principles and organizational principles do not provide a sufficiently broad framework for an analysis of human settlement systems, as will be illustrated by means of several examples (comparative-cost analysis, industrial complex analysis, attraction analysis, etc.).

Therefore it is worthwile to explore new ways of thinking. Spatial complex analysis may be a useful approach to provide an integrated view of the agglomeration phenomena inherent in human settlement patterns. By means of vector profile methods a quantitative frame of reference can be provided for a further study of the determinants and the coherence of a certain agglomeration pattern.

The use of a newly developed multivariate statistical technique, viz interdependence analysis, provides a reasonable background for a more profound analysis based on spatial correspondence techniques. Given this technique, the determinants of a certain spatial allocation pattern can be identified.

The analysis will be illustrated by means of several empirical results for the province of North-Holland in the Netherlands.

Finally, the attention will be focused on an integration of the foregoing approach with spatial processes, while urban and physical planning aspects will also be discussed.

## A Spatial Complex Analysis of Agglomeration and Settlement Patterns

### 1. INTRODUCTION

In the post-war period industrial location patterns and human settlement systems have been characterized by rapid changes. Urbanization and spatial agglomeration were a first major trend, followed by a large-scale suburbanization movement and urban decay in a broader sense. At the moment a more diffuse pattern arises: on the one hand, the suburbanization movement appears to continue as a movement toward rural and even peripheral areas, while on the other hand some big cities tend to start again acting as an engine of new agglomeration forces. Problems of an optimal city size, but even more important: of an optimal spatial lay-out, are becoming increasingly important. Operational insight into the various forces determining the development of location patterns and human settlements is still lacking. Can traditional location theory serve to fill this gap in our knowledge?

Location theory is usually considered as a core theory of regional economics and economic geography. The determinants of location behavior of households and firms have been studied at length in the past (see for a survey inter alia Carlino [1977] and Paelinck and Nijkamp [1976]).

From the seventies onwards, however, the focus of regional economists and geographers has been shifted gradually from location analysis per se to spatial interaction analysis. In the latter analysis the attention for the determinants of geographical associations of economic activities has been substituted for a closer examination of spatial mobility patterns associated with a given location pattern of human settlement systems (df. the popularity of entropy maximizing models or gravity-type models, and of spatial allocation models).

During the last years, however, it has become increasingly evident that the overwhelming amount of literature in the field of spatial interaction analysis has sometimes tended to neglect the intricate interrelationship between spatial structure and spatial interaction. Especially the determinants of urban agglomeration forces appear to deserve more attention due to the negative externalities of urban growth processes. The development of urban systems can, however, hardly be explained by means of traditional location analysis. Therefore, a broader view of urban phenomena seems to be necessary, in which the spatial, social and economic aspects of urban systems are integrated.

In this paper a brief survey of some recently developed spatial agglomeration theories will be presented. Then the notion of a spatial complex analysis will be introduced, followed by an exposition of this type of analysis on the basis of spatial activity profiles.

Spatial complex analysis will be used by its nature in this paper to investigate in an operational sense the main characteristics and determinants of spatial activity and interaction patterns of human settlement systems. The multivariate nature of spatial complex analysis will be studied by means of a rather new statistical technique, viz interdependence analysis. This analysis will be set out in more detail in this paper. Finally, the use of interdependence analysis in the framework of spatial complex analysis will be illustrated by means of a numerical application to one of the Dutch provinces, viz North-Holland. Both the data base and the various results achieved will be discussed, followed by an evaluation of the methodology employed, an outline of further research and a discussion of some policy implications.

## 2. AGGLOMERATION ANALYSIS

The theoretical underpinnings of traditional location and agglomeration theory were mainly provided by the Weberian approach based on a cost minimizing behavior of private firms taking into account the spatially dispersed locations of inputs and outputs as well as the benefits from a joint spatial juxtaposition of firms. The latter agglomerative economies from the point of view of both entrepreneurs and households were studied extensively in the Christaller-Lösch framework, while the study of spatial associations between economic activities was stimulated from the fifties onwards especially by Isard [1956].

In the post-war period, agglomeration economies have mainly been studied from the point of view of entrepreneurial behavior. Firms acting on a private land use market were supposed to determine for a major part the land use and location pattern of a society. The locational decisions of private households and of public agencies and even the whole human settlement system were frequently regarded as a derivative of private locational behavior of entrepreneurs based on micro- or macro-economic efficiency principles.

Examples of this approach are inter alia the comparative-cost analysis, the industrial complex analysis and its related growth pole theory, and the attraction theory.

The comparative cost analysis (see Isard et al. [1959]) is essentially a cost-effectiveness approach based on a detailed calculation of all private costs involved in constructing an integrated complex of economic activities at a certain place. An evaluation of alternative configurations (i.e., activities) of this complex takes place on the basis of a comparative frame of reference for costs of an already existing complex.

The industrial complex analysis as well as the growth pole theory are based on savings on transportation and production costs due to a spatial concentration of industries (Czamanski and Czamanski [1976], Nijkamp [1972], Richter [1969] and Streit

[1969]). These cost reductions may arise from scale advantages, market access for inputs and outputs, and decline in transportation costs. In this case the profits $p_i$ of a private firm i may be equal to:

$$p_i = \pi_i q_i (1 + \alpha_1) - \sum_{j=1}^{J} \pi_j a_{ji} q_i (1 - \beta_j) - w_i l_i - \rho_i k_i \quad (1)$$

where: $\pi_i$ = C.I.F. price of product i.

$\alpha_i$ = market access coefficient of firm i ($\alpha_i > 0$) representing the degree at which firm i will increase its sales due to a good market access.

$q_i$ = production volume of firm i.

$a_{ji}$ = input-output coefficient for deliveries from firm j to i.

$\beta_j$ = transport savings coefficient ($\beta_j > 0$) representing the percentage decline in transportation costs due to a spatial juxtaposition of firm j and i.

$w_i$ = average wage rate for production of type i.

$l_i$ = demand for labor by firm i.

$\rho_i$ = average capital costs for productive of type i.

$k_i$ = capital equipment of firm i.

In case of a separate and independent location of firms without any agglomeration advantages, $\alpha_i$ and $\beta_i$ may be assumed to be equal to zero. The scale advantages within each firm may be taken into account by assuming a production function of the general type:

$$q_i = f_i(l_i, k_i), \quad (2)$$

on the basis of which via the marginality rules on optimal input mix can be calculated. An alternative approach is the use of technological ("engineering") functions of the following type:

$$\left. \begin{aligned} l_i &= \bar{\lambda}_i q_i^{\lambda_i}, & 0 < \lambda_i \leq 1 \\ k_i &= \bar{\kappa}_i q_i^{\kappa_i}, & 0 < \kappa_i \leq 1 \end{aligned} \right\} \quad (3)$$

where $\bar{\lambda}$ and $\bar{\kappa}$ are constant coefficients.

Relationships (1) through (3) contain all the elements of agglomeration economics distinguished by Hoover [1948], viz scale advantages (internal to the firm), localization advantages (external to the firm but internal to the industry concerned) and urbanization economies (external to the firm and external to the industry). These types of models can be used in a combinational planning framework, in which different sets of industrial activities are to be evaluated against each other (see, for example Albegov [1972] and Nijkamp [1972]).

Relationships (1) to (3) may be used to calculate the gain in private efficiency due to a spatial concentration of economic activities. In the growth pole theory these efficiency gains have been assumed to stimulate a wide-spread process of economic growth. In this theory the agglomeration benefits are considered as the source of a spatial diffusion of economic growth.

It should be noted that these benefits were only calculated in aggregate terms, while the distributional implications of such a growth process were mainly left aside. It should also be added that a precise computation of the order of magnitude of agglomeration benefits is very difficult due to lack of information and of a standard of reference (Van Delft and Nijkamp [1977]).

Another method for studying spatial association between economic activities at a sectoral level is the attraction theory (Klaassen [1976] and Van Wickeren [1972]). The strength of attraction theory is that it attempts to use communication costs inherent to demand and supply relations for interindustrial deliveries from an input-output table as a basis for assessing the relative spatial attraction power of a certain industry.

In addition to efficiency principles as an explanatory device for geographical associations of firms, organizational principles may be assumed as well (a survey can be found in Hamilton [1974]). The idea underlying the organizational principle is that especially large-scale plants need an industrial framework with a spatial access to and a geographical association with other firms. These factors are sometimes hard to quantify, but by means of multi-attribute methods applied to interview data a quantitative analysis is in principle possible (Keeble [1969]).

The organizational and the efficiency principle provide an explanatory basis for a spatial concentration of activities and for the presence of agglomeration economics. Beside explanatory theories, in the past much attention has been paid to the calculation of measures for spatial concentrations between activities. These measures were mainly based on economic linkages such as intermediate and final deliveries of a firm within a certain area (Britton [1969], Czamanski [1972], Goddard [1973], Hoare [1975], Latham [1976] and McCarty et al. [1956]). Especially the correlation coefficients between employment data of manufacturing industries in the same area have frequently been used as a measure of geographic-economic linkage. A good example of the latter type of analysis applied to an enormous data base for the U.S. is contained in Latham [1976].

In the case of a large number of activites an analysis of the associated correlation matrix is rather time-consuming, so that the principal component techniques can be used to reduce the data base (see among others Bergsman et al. [1972], Van Holst and Molle [1977], and Roepke et al. [1974]). It is clear, however, that the use of principal component techniques gives rise to additional problems such as the lack of a theoretically-based explanation of the results of this statistical procedure.

In addition to explanatory and descriptive devices an alternative approach to urban agglomeration analyses may be found by means of a general urban production function (see inter alia Carlino [1977], Isard [1956] and Kawashima [1975]). The underlying idea is that the externalities of urban size may lead to productivity increases in the city, until beyond a certain city size negative externalities are coming about (caused by population density, congestion, decline in quality of life, etc.).

An example of an empirically tested relationship for urban agglomeration economies is (see Kawashima [1975]):

$$\frac{q}{l} = \alpha\frac{\rho k}{l} + \beta + \gamma p - \delta p^2 \qquad (4)$$

where p represents the population size; $\alpha$, $\beta$, $\gamma$ and $\delta$ are coefficients; and the other symbols are defined in equation (1). The negative term in (4) represents the existence of a certain optimal city size from the point of view of population size, given the fact that (4) can be transformed into an urban production function (see Kawashima [1975]). Other contributions along similar lines can be found among others in Baumol [1967], Rasmussen [1973] and Segal [1976].

Clearly, these approaches are rather aggregate and may perhaps be disaggregated into other components associated with optimal urban size. A good example of such an approach is found in Carlino [1977] who first assesses the returns to scale coefficient of an urban production function, followed by a decomposition of this measure of scale into internal economies of scale, localization economies, urbanization economies, and urbanization diseconomies.

The foregoing approaches may be extremely useful to obtain more insight into the complicated spatial patterns of economic activities. Yet, in our opinion, two elements are still lacking in these types of analyses. First, the location of economic activities takes place normally in an existing social, cultural and physical environment of an integrated human settlement system which may influence to a considerable extent the locational decisions of a firm (Bakker [1975]). Second, spatial patterns of economic activities are also determined by historically grown conditions, physical accessibilities and subjective entrepreneurial preferences. Consequently, a proper analysis of spatial agglomeration patterns and of urban agglomerations should take place in a broader framework of social, public, residential and environmental policy factors, while also the dynamics of spatial location patterns have to be taken into account.

These elements bring us to the notion of a spatial complex analysis as a generalization of an industrial complex to indicate that an existing spatial agglomeration pattern cannot be properly understood via the restricted concepts of industrial complexes or spatial economic associations, but have to be placed in a broader framework of spatial integrations of socio-economic, cultural, physical and public amenities. A spatial complex can be conceived of as a coherent set of diverse human activities with a high degree of interaction and located in the same region. The notion of a spatial complex analysis indicates that the explanation of a certain spatial lay-out cannot be based on a single efficiency criterion, but on a wide variety of determinants of spatial behavior and of a human settlement pattern. This will be discussed more thoroughly in the next section.

## 3. SPATIAL ACTIVITY PROFILES

Suppose an area subdivided into a set of regions (r = 1, ..., R). Suppose also a set of economic sectors (s = 1, ..., S) and a set of indicators k characterizing the spatial complex at hand (k = 1, ..., K). Then the question arises: how can the regional differences between the diverse sectors and between the complex indicators be explained? Which determinants are especially responsible for a certain spatial agglomeration pattern?

The answer to these questions requires a systematic analysis of the spatial complex pattern concerned. An operational tool for representing a certain spatial lay-out in a quantitative manner is the use of a spatial activity profile. A spatial activity profile is a multidimensional (vector) representation of the elements or activities characterizing the spatial pattern (concentration, association, etc.) of a certain region. Needless to say that such a spatial activity profile should not only relate to economic activities but to a broader set of variables (like public facilities) pertaining to the special complex of the region concerned.

The elements characterizing a spatial complex may be distinguished into individual and relational elements. Individual elements are separate elements pertaining to a property of a certain economic sector or of a human settlement pattern without any relation to other sectors (for example, employment per sector, population density, etc.). Relational elements pertain to linkages with other sectors or with a human settlement system (for example, the degree of intersectoral interaction, or the sectoral degree of final demand orientation).

Clearly, the relational elements of a certain spatial complex are especially linked to spatial agglomeration patterns, so that these elements reflect mainly localization and urbanization economies.

The spatial activity profiles can now be distinguished into individual and relational profiles. For both profiles a multiregional matrix presentation can be constructed, indicated by $P_1$ and $P_2$, respectively. Examples of such profiles can be found in (5) and (6), respectively.

$P_1$ =

| profile elements | region: 1 2 3 . . . . . . R |
|---|---|
| total employment | |
| population density | |
| capital stock | |
| total income | |
| cultural facilities | |
| public facilities | |
| . | |
| . | |
| . | |
| . | |
| . | |
| . | |

(5)

and:

$P_2 =$ (6)

| profile elements | 1 2 3 . . . . . . R |
|---|---|
| industrial density | |
| intermediate demand orientation | |
| final demand orientation | |
| degree of specialization | |
| degree of social interaction | |
| . | |
| . | |
| . | |
| . | |
| . | |

Obviously, (5) and (6) may also contain some of the spatial agglomeration measures discussed in Section 2, so that these profile matrices contain a significantly rich information.

On the basis of the information contained in (5) and (6) an attempt may be made to answer the question: which profile elements are mainly responsible for the configuration represented by (5) and (6)? The answer to this question provides more insight into the characteristics and the determinants of a spatial complex, so that this framework can be considered to be of utmost importance for urban and spatial agglomeration analysis based on a broad integrated view of agglomeration phenomena. The technique to be used to select the most relevant elements from (5) and (6) is a multivariate analysis based on pattern recognition techniques; it is called interdependence analysis. This technique will be discussed in Section 4.

A more detailed investigation of the agglomeration patterns of all economic sectors (including the public sector) in a certain region may take place by including sectoral characteristics (for example, location quotients, sectoral labour and capital stocks, etc.). This implies that for each region separately a sectoral activity profile $P_r$ can be constructed [see (7)].

$P_r$ =

| profile elements | 1 | 2 | 3 | . . . . . . . | S |
|---|---|---|---|---|---|
| location quotient | | | | | |
| volume of labor | | | | | |
| capital stock | | | | | |
| spatial externalities | | | | | |
| . | | | | | |
| . | | | | | |
| . | | | | | |
| . | | | | | |
| . | | | | | |
| . | | | | | |
| . | | | | | |

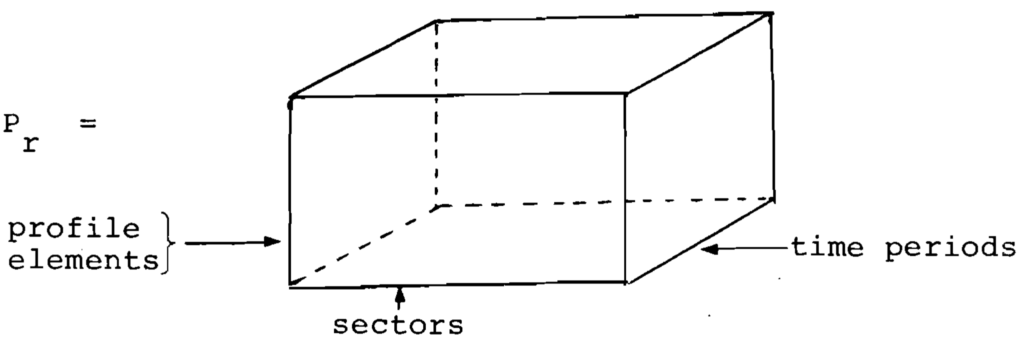
(7)

It is clear that (7) can again be distinguished into individual and relational profiles, so that various measures for the degree of spatial association (for example, input-output linkages) can be included in (7). The regional activity profile represented by (7) may provide more insight into the main determinants of the sectoral location pattern for each region separately. Here again the same technique, viz interdependence analysis, may be used.

An alternative approach may be to create a sectoral activity profile, in which the profile elements are linked to the various regions involved. In this case the characteristics of footloose industries, labor- and input-oriented industries or market-oriented industries can be studied in more detail.

Obviously, the time dimension may also be added to the abovementioned profile analysis, so that the dynamics in the spatial and sectoral agglomeration pattern may be studied as well. This would simply lead to a three-dimensional activity profile of region r [see (8)]. In this way more insight

$P_r$ =




(8)

may be obtained into shifts in the main profile elements determining the dynamics or spatial activity and agglomeration patterns over a number of years. Interdependence analysis may also be a useful tool for studying these developments.

Consequently, the analysis may be carried out in various directions through the data material, leading to region-specific, sector-specific or time-specific results.

Finally, the discrepancy between each pair of profile vectors (either at the regional or at the sectoral level) may be calculated by means of a distance metric d for these vectors:

$$d = \{(\underline{p}_1 - \underline{p}_2)' \ (\underline{p}_1 - \underline{p}_2)\}^{\frac{1}{2}} \tag{9}$$

where $\underline{p}_1$ and $\underline{p}_2$ represent an activity profile of sector 1 and 2 (or, alternatively, of region 1 and 2).

In an analogous way, the actual dispersion of activities compared with a random distribution may be studied as well (see also Artle [1965] and Latham [1976]).

In the next section, some key elements of interdependence analysis will be presented.

## 4. INTERDEPENDENCE ANALYSIS

Interdependence analysis is an optimal subset selection technique, by means of which a subset of variables which best represents an entire variable set can be chosen (see Beale et al. [1967], and Boyce et al. [1974]). In the past several multivariate data-reducing techniques have been developed, such as principal component analysis and factor analysis. A basic shortcoming in the use of these techniques has always been the lack of a clear theoretical interpretation of the statistically calculated components or factors.

Interdependence analysis attempts to side-step the latter problem by selecting an optimal subset of the original variables, so that a data transformation is not necessary. Suppose a data matrix with N observations on K variables. Suppose next that P variables are to be selected from the K variables such that these P variables reflect an optimal correspondence with respect to the original data set. Consequently, (K - P) variables are to be 'rejected' or eliminated.

Now the interdependence analysis starts with a successive regression analysis between the 'dependent' (K - P) variables to be rejected and the 'independent' P variables to be retained. Suppose that ${}_1X_p$ is the N x P reduced matrix pertaining to variables 1,..., P. Then the following regression equation is obtained for each variable P + 1,..., K:

$$\underline{x}_\ell = {}_1X_p \, \underline{\beta}_\ell + \underline{\varepsilon}_\ell \qquad , \ell = P + 1, \ldots, K \qquad (10)$$

where $\underline{x}_\ell$ is a (N x 1) vector with observations on the $\ell$th variable, $\underline{\beta}_\ell$ is a (P x 1) regression coefficient, and $\underline{\varepsilon}_\ell$ a (N x 1) vector of disturbance terms. The estimated squared multiple correlation coefficient of (10) will be denoted by $R^2_\ell$. It is clear that for $\ell = P + 1, \ldots, K$ (K - P) regression equations have to be calculated, so that there are also (K - P) correlation coefficients. Next, the minimum value of $R^2_\ell$ ($\ell = P + 1, \ldots, K$) is selected:

$$R^2_{min} = \min_\ell R^2_\ell . \qquad (11)$$

The reason to select a regression equation with a minimum correlation coefficient is that in this case the presence of multi-collinearity can be avoided as much as possible.

It is clear that the abovementioned regression procedure can be repeated for each permutation of P and (K-P) variables, so that theoretically the total number of regressions to be carried out is equal to $\binom{K}{P}$ (K - P). Then the optimal subset is defined as that subset which maximizes over all $\binom{K}{P}$ permutations the values of $R^2_{min}$, i.e.,

$$R^{*2} = \max R^2_{min}$$

Essentially this solution can be seen as the equilibrium solution of a game procedure, in which the information contained in a data matrix is reduced such that the selected variables constitute a maximum representation of the information pattern with a minimum of multicollinearity. This max-min solution might lead to an enormous computational load, but the strength of interdependence analysis is that it finds the optimal subset without a complete enumeration of all possible regressions. Instead, a set of demarcation criteria and bounding rules are introduced to speed up the search for an optimal subset. By means of elimination procedures via critical threshold levels based on statistical properties of the successive correlation coefficients, the computational work can be facilitated significantly, so that in principle an optimal subset can be selected within a reasonable time limit (Boyce et al. [1974]).

The appealing feature of interdependence analysis is that it selects a subset of rather independent variables which have a maximum correspondence with the original data set without using arbitrary or artificial data transformations. Hence, the interpretation of the results is straightforward.

Interdependence analysis has been applied inter alia in optimal network algorithms (see Boyce et al. [1974]), in multicriteria analyses (Nijkamp [1977a]) and in multi-dimensional analyses of human settlements (Nijkamp [1977b]). The experiences with interdependence analysis are rather favourable so far; a broader application of this technique may be worthwile.

In the following Section an empirical application of spatial complex analysis and interdependence analysis will be presented.

## 5. EMPIRICAL APPLICATION*

The abovementioned analysis has been applied in an investigation into agglomeration phenomena in the province North-Holland in the Netherlands. This province has been subdivided into 11 separate areas. These areas are mainly based on an existing spatial delineation of the province concerned for labor market regions (see Figure 1). For each of these small-scale regions 23 economic sectors have been distinguished (see Table 1). Furthermore, in relation to these 11 regions and 23 sectors several agglomeration variables and indicators (10 in total) were employed (see Table 2). Needless to say, the data collection at such a detailed spatial level was fraught with difficulties and often liable to inaccuracies. A total description of the data base will not be given here but can be found in Van den Bor [1977]. Suffice it for the moment to pay somewhat more attention to the definition of the 10 agglomeration variables and indicators included in the spatial complex analysis. These variables and indicators are:

Table 1. List of economic sectors

| | | | |
|---|---|---|---|
| 1. | agriculture & fishery | 13. | public utilities |
| 2. | resource extraction | 14. | building sector |
| 3. | food | 15. | retailing |
| 4. | textile | 16. | hotels and restaurants |
| 5. | leather, rubber & chemicals | 17. | reparation services |
| 6. | wood | 18. | railway, road and waterway services |
| 7. | paper | 19. | sea & air services |
| 8. | graphical industry | 20. | communication services |
| 9. | building materials | 21. | banks |
| 10. | metals industry | 22. | insurances |
| 11. | electro-technical industry | 23. | real estate |
| 12. | transport means | | |

*The author wishes to thank Johan van den Bor who carried out the computational work in this section.

Table 2. List of agglomeration variables and indicators

| | |
|---|---|
| 1. location quotient | 6. concentration index for output orientation |
| 2. growth indicator | 7. concentration index for consumer orientation |
| 3. labor share | 8. concentration index for investment orientation |
| 4. capital share | 9. specialization indicator |
| 5. concentration index for input orientation | 10. accessibility indicator |

1. *location quotient.* This index for the spatial concentration of activities is defined as:

$$L_i^r = \frac{q_i^r}{q_{\cdot}^r} \Bigg/ \frac{q_i^{\cdot}}{q_{\cdot}^{\cdot}} \quad , \tag{12}$$

where $q_i^r$ represents the production volume of activity i in region r, and where $q_{\cdot}^r$, $q_i^{\cdot}$ and $q_{\cdot}^{\cdot}$ are defined respectively as:

$$q_{\cdot}^r = \sum_{i=1}^{I} q_i^r ; \; q_i^{\cdot} = \sum_{r=1}^{R} q_i^r \; ; \; q_{\cdot}^{\cdot} = \sum_{i=1}^{I} \sum_{r=1}^{R} q_i^r \tag{13}$$

Sometimes a location quotient is also measured in terms of investment or employment variables depending on the available information.

2. *growth indicator.* This indicator measures the relative discrepancy between the actual sectoral size and the projected sectoral size on the basis of average aggregate developments, and is defined as:

$$G_i^r = \left( q_{i,t_1}^r - \frac{q_{\cdot}^{\cdot},\, t_1}{q_{\cdot}^{\cdot},\, t_0}\, q_{i,t_0}^r \right) \Bigg/ q_{i,\, t_0}^r \tag{14}$$

It should be noted that the denominator of (14) corresponds to the differential shift from a traditional shift-and-share analysis.

3. *labor share.* This coefficient measures the share of labor inputs in total production, or more precisely: the share of wages W and salaries S in sectoral value added Y. The labor share coefficient, based on constant returns to scale, is equal to:

$$E_i^r = \left( W_i^r + S_i^r \right) / Y_i^r \tag{15}$$

4. *capital share.* This coefficient which measures the relative share of capital inputs is defined as:

$$C_i^r = 1 - E_i^r \tag{16}$$

5. *concentration index for input orientation.* This index represents the regional attraction force for a sector i, as far as the productive inputs (intermediate deliveries) are concerned. This index is:

$$I_i^r \text{ (input)} = \frac{V_i^r}{q_i^r} , \tag{17}$$

where $V_i^r$ represents the total intermediate deliveries <u>to</u> sector i in region r. Clearly, the calculation of (17) requires detailed input-output information; otherwise, by means of a reasonable disaggregation procedure (for example, via an employment weight) an assessment of $V_i^r$ has to be made.

6. *concentration index for output orientation.* This index measures the orientation toward sellers of intermediate products and is defined as:

$$I_i^r \text{ (output)} = \frac{\bar{V}_i^r}{q_i^r} , \tag{18}$$

where $\bar{V}_i^r$ represents the total deliveries of intermediate goods <u>by</u> sector i in region r.

7. *concentration index for consumer orientation*. This index is related to regional attraction forces to the final commodity market and is defined as:

$$I_i^r \text{ (cons)} = \frac{f_i^r}{q_i^r} , \qquad (19)$$

where $f_i^r$ represents the volume of final deliveries by sector i in region r to the final market in region r.

8. *concentration index for investment orientation*. This index is related to the regional investment attractiveness and is defined as:

$$I_i^r \text{ (inv)} = \frac{i_i^r}{q_i^r} , \qquad (20)$$

where $i_i^r$ is the volume of investment goods produced by sector i in r and delivered within region r.

9. *specialization indicator*. This index measures the degree of specialization of a certain sector:

$$P_i^r = \frac{L_i^r}{L_\cdot^r} - \frac{L_i^\cdot}{L_\cdot^\cdot} , \qquad (21)$$

where $L_i^r$ is the labor volume of sector i in r, and where $L_\cdot^r$, $L_i^\cdot$ and $L_\cdot^\cdot$ are defined respectively as:

$$L_\cdot^r = \sum_{i=1}^{I} L_i^r \; ; \; L_i^\cdot = \sum_{r=1}^{R} L_i^r \; ; \; L_\cdot^\cdot = \sum_{i=1}^{I} \sum_{r=1}^{R} L_i^r \qquad (22)$$

10. *accessibility index*. This index measures the sectoral share of transportation costs in total value added, i.e.

$$A_i^r = \frac{T_i^r}{Y_i^r} , \qquad (23)$$

where $T_i^r$ represents the sectoral expenditures to the transportation and communication sector.

It is clear that for a deep-going analysis much more data would be required, but unfortunately at this detailed spatial level no more information was available. Therefore, the above-mentioned spatial complex analysis via the interdependence technique was applied to the data base described above. This data base was thus composed of 10 tables of the order (23 x 11) for the year 1973.

A twofold interdependence analysis was carried out, viz a <u>sectoral</u> one and a <u>regional</u> one. Assuming that 4 variables had to be selected from the 10 original ones, one may show for the <u>regional</u> analysis which factors explain the major part of the spatial pattern for each region, as far as it is reflected in the sectoral data. On the other hand, by means of a sectoral analysis one may indicate the determinants of the sectoral pattern, as far as this pattern can be recognized from the <u>regional</u> data set. The results of both types of analysis are represented in tables 3 and 4, respectively. An asterisk in the table means that the corresponding variable has been selected in the regional analysis (Table 3) or in the sectoral analysis (Table 4).

Table 3. Results of a regional analysis

| region \ variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | * | * | * | * |
| 2 | * | * | * | | | | | | * | |
| 3 | * | | | * | | | * | | | * |
| 4 | * | | | * | | | | * | * | |
| 5 | * | * | * | | | | * | | | |
| 6 | * | | | | | | * | * | | * |
| 7 | * | * | | | | | * | * | | |
| 8 | * | | | | | | * | | * | * |
| 9 | * | | | | | | * | * | | * |
| 10 | | | | * | | | * | * | * | |
| 11 | | * | * | * | | | | | * | |

Table 4. Results of a sectoral analysis*

| sector \ variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | * | * | * | | | | * | | | |
| 2 | - | - | - | - | - | - | - | - | - | - |
| 3 | * | * | | | | | * | - | * | |
| 4 | * | * | | | | | * | - | * | |
| 5 | | * | | * | | | * | - | * | |
| 6 | * | * | | * | | | | * | | |
| 7 | | * | * | | | | * | - | * | |
| 8 | | * | * | | | | * | - | * | |
| 9 | | * | | * | | | * | - | * | |
| 10 | | * | * | | | | * | | * | |
| 11 | * | * | | * | * | | | | | |
| 12 | * | * | | * | | | | * | | |
| 13 | | * | | * | | | * | - | | * |
| 14 | | * | | | * | | * | | * | |
| 15 | | * | | | | | | * | * | * |
| 16 | | * | * | | * | | * | - | | |
| 17 | * | * | | | | | * | | * | |
| 18 | | * | | * | | | * | - | * | |
| 19 | * | * | * | | - | - | * | - | | - |
| 20 | * | * | | | | | * | - | * | |
| 21 | * | * | * | | | | * | - | | |
| 22 | * | * | | | | | * | - | * | |
| 23 | | * | | | * | - | * | - | * | - |

*The symbol - means: no observation available on the variable at hand.

## 6. TOWARD AN INTEGRATED AGGLOMERATION ANALYSIS

The use of spatial activity profiles and interdependence techniques can be considered as an important systematic tool for a detailed analysis of agglomeration phenomena and location patterns. The results of this approach are straightforward and easy to interpret. Clearly, the data base of this approach is rather extensive, but the use of all available information in a meaningful manner may lead to a selection of variables or indicators which are mainly characterizing or determining a certain spatial activity pattern or a human settlement system.

Another advantage of the method used is that, in addition to private efficiency variables, several other relevant variables related to a spatial agglomeration pattern can be taken into account as well, as has been shown in the numerical illustration.

The next step after the selection of the subset of representative variables is to relate the results to traditional agglomeration theory in order to examine whether the results support the traditional agglomeration paradigms. The provisional conclusion on the basis of some empirical experiments is that, in addition to traditional agglomeration factors like specialization and market orientation, also sectoral growth and specialization potentials may play an important role in explaining a certain spatial complex.

Finally, some outlines of future research may be presented. Once the spatial complex analysis has been carried out, the selected variables representing an optimal picture of a spatial agglomeration pattern can be used for a further analysis of spatial complex concerned. Assume, for example, a set of variables related to spatial interactions (such as migration, commuting, recreation, etc.). Then this latter set of process variables can be related to the subset of structure variables selected by means of the abovementioned interdependence analysis in order to examine the correlation between spatial processes and spatial agglomeration.

| set of process variables | ⟷ | set of structure variables |
|---|---|---|

The latter correlation is essentially of a multivariate nature, because the one set of variables has to be related simultaneously to the other set. In this respect a canonical correlation technique may be useful (see Nijkamp [1977b]). This technique may provide a simultaneous multidimensional explanation of spatial processes and structures and may also be quite useful for a further analysis of the determinants of the size of urban agglomerations.

The abovementioned approach illustrates once more that problems of an optimal city size are of a multidimensional nature: a single cost or efficiency criterion is hardly sufficient to provide a reasonable explanation for urban size. It should rather be noted that in this respect especially threshold levels for the various (multidimensional) determinants of a spatial complex may determine a best-compromise solution for problems of urban size.

Clearly, these threshold levels of spatial complex variables are codetermined by preferences of citizens, industries and urban policy-makers. For example, in the case of urban renewal projects the rank of the city in the urban hierarchy, the degree of urban externalities and their spatial sphere of influence have to be taken into account in order to select those projects which fit best into the existing location and agglomeration pattern of a spatial complex. On the basis of a set of profiles for alternative projects one may analyze again by means of the abovementioned multivariate techniques which project possesses an optimal correspondence with respect to the existing spatial complex. Obviously, the application of these methods in a planning framework has to be based on a set of alternative scenario's and on a sequential or interactive information processing.

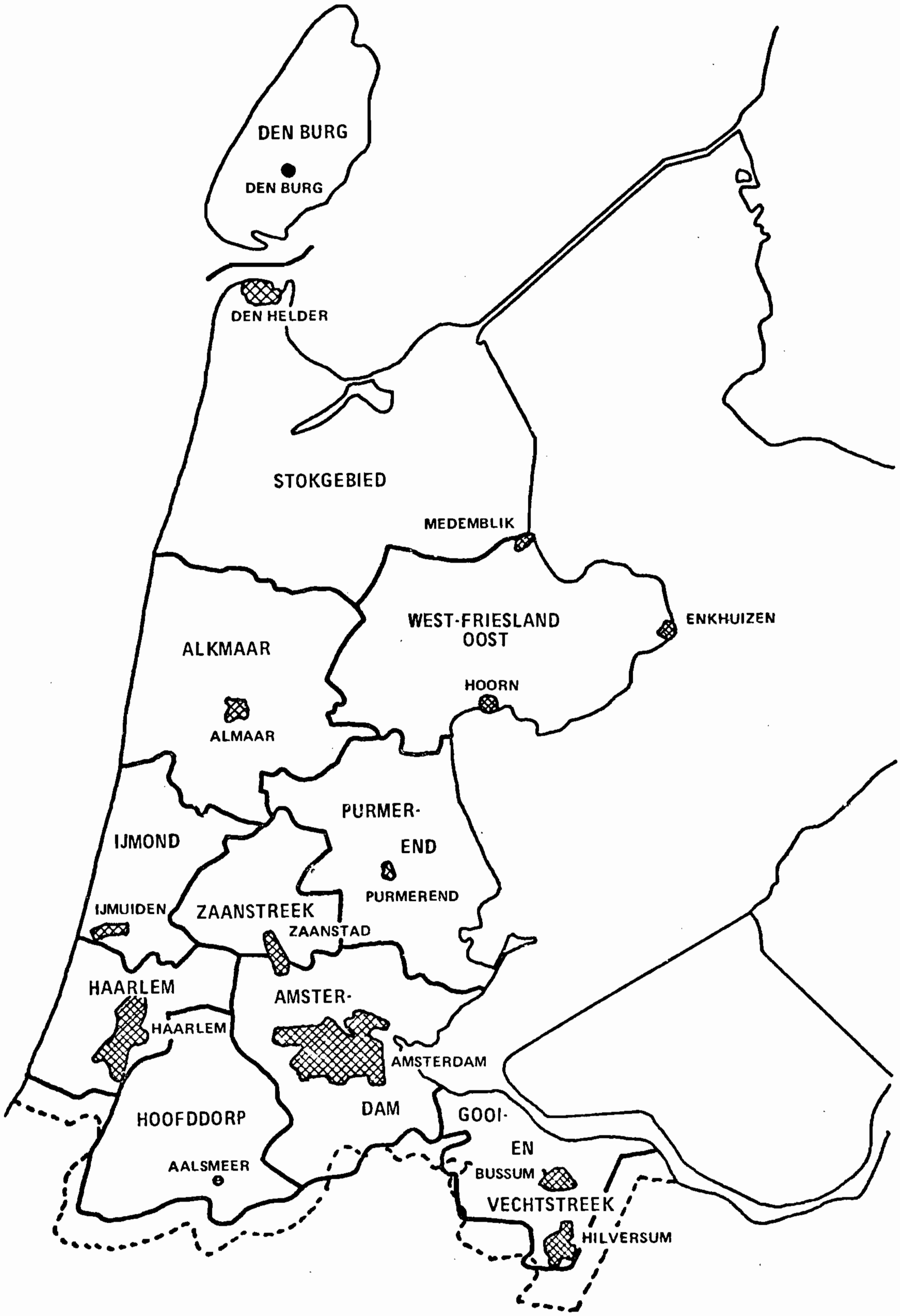



Figure 1. The province North-Holland

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