Evaluating Spatiotemporal Consistency of Secondary Office Market Data

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Abstract. **This article examines variations among three widely used secondary information sources for aggregate office-supply data in the Atlanta MSA. "Market Analysis Surfaces" (MAS are used in the study to bypass problems of geo-boundary match among submarkets and to efficiently compress, represent, manipulate, scan, and analyze the data. The study finds excessive variations and inconsistencies among the alternative sources: in simple quantitative terms, in spatial structure of reported market activities, and in spatiotemporal changes in data.**

Introduction

During the last ten years, the demand for, and availability of, secondary information sources for market supply data have increased with growth of real estate markets. While developers, market analysts, and appraisers have generally accepted secondary market supply data without questioning its accuracy, real estate researchers have continued to focus their attention on the market demand side. And despite the emphasis in real estate theory on identification of submarkets and their geographic disaggregation, the lack of scrutiny of secondary sources also encompassed their implied spatial distribution of submarkets, and the related spatiotemporal[1] changes in market activity.

This paper evaluates the accuracy of secondary market supply information by assessing the consistency of data from different sources. The paper focuses more intensively on the spatial and spatiotemporal variations among secondary sources. The paper is composed of three parts: The first contains a brief overview of office market analysis, with a literature review and a focus on the role of secondary information sources in supply analysis, as it pertains to both quantitative and spatial data. The second part presents systems and procedures for storage, juxtaposition, retrieval, analysis, and display of spatial data. In the third part, results of evaluation of secondary information sources are presented in both quantitative and spatiotemporal terms, with an emphasis on the latter.

Overview of Office Market Analysis

Market studies involve projection and analysis of the determinants of "demand" and "supply". Numerous models and approaches have been developed for estimating the *demand* side in office market analysis. Dasso [4], and Rosen [21] among others provided models for office market related analysis of employment, population, and per capita

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income. Rabianski [3 and 18] introduced an extrapolation and shiftshare technique to distinguish external effects of national and regional changes, and Weaver [27] presented the use of the conjoint measurement technique. Numerous articles discussed forecasting office demand including Detoy and Rabin [6], Downs [7], and Kimball and Bloomberg [13] on office demand in general; Martin and English [15] on multi-tenant office space; and Bible and Whaley [2], and Kelly [12] on urban office markets.

Unlike the demand side, there is little coverage of the *supply* side of office market analysis in research literature, even though "historic" supply data for office space net absorption (NA), vacancy rates (VR), and rental rates (RR) are most critical in predicting "future" net operating incomes (NOI). Accurate projection of net operating incomes (NOI) is central to all development, investment, and finance decisions; since value is coupled with NOI through capitalization rates; and debt is coupled with NOI through debt coverage ratios, and with value through loan-to-value ratios.

The supply side in office market analysis documents observed levels and trends by examining competitive properties in the marketplace. Supply analysis of office space depends on the availability of quality secondary market information, since primary research to gather an extensive volume of "historic" data on competitive properties is rather problematic. Secondary sources, equipped with trained field personnel capable of making the required assumptions and judgments, have assumed the time-consuming costly survey process, and provide data readily available on office space supply. However, the accuracy of data on net absorption (NA), vacancy rates (VR), and rental rates (RR) provided by secondary market information sources seems to be accepted at face value, in the absence of any studies to the contrary.

Similarly accepted at face value, is the quantitative tabular-data emphasis of secondary information sources, at the expense of presenting the spatiotemporal changes in the marketplace. This is particularly important with office space where office submarkets are often links in a chain of substitutability. Spatial and spatiotemporal analyses of changes among the submarkets require a system of relating quantitative data to spatial locations. Pure mapping of data could be provided by Computer-Aided Mapping Systems (CAM). Ideally, a Geographic Information System (GIS) would provide such a relational database management system. In addition, spatial and spatiotemporal analyses also require a manageable procedure to compress the datasets from different secondary information sources into one manageable database, to represent attributes (e.g., net absorption, vacancy rates, etc.) for each dataset, to scan data-layers for spatial patterns of submarkets, and to manipulate datasets for spatial and spatiotemporal analyses. This could be provided by computer programs that combine data and graphics in what is referred to sometimes as "intelligent maps". Such "visualization of data interaction" is often provided through "Isarithmic mapping" and "Trend Surface Analysis" (TSA).

Since it appears that many in the real estate field are not aware of the above systems and procedures, a brief conceptual description of CAM and GIS systems, and of procedures of Isarithmic Mapping and TSA are presented.

Introduction to Mapping Systems for Market Analysis

As identified earlier, spatial and spatiotemporal analyses of market activity require both a system of relating quantitative data to spatial locations,[2] and a procedure for visualization of data interaction. The first can be provided through CAM, GIS, or even simple computerized spreadsheets as Lotus 1–2–3.[3] The latter could involve Isarithmic Mapping or Trend Surface Analysis (TSA).

Computer-Aided Mapping (CAM)

CAM is a display-oriented technology of points and lines stored in data "layers". Data are structured on a grid base with $(x\&y)$ as Cartesian or geographic coordinates, and $(x \times y)$ as identical "grid cells" used to link "data-layers". Each (x,y) pair denotes a location within the geo-coordinates, and attributes (e.g., topographic elevations, land values, etc.) are projected at each of the (xy) points on separate layers, with each layer containing discrete information from one dataset for one attribute or feature. For example, the road network could be stored on a separate layer, overlaid later on other data-layers containing other attributes or features.

CAM systems do not have the capability to relate data across layers, but can merely overplot separate layers of data together. The "overlay" procedure was brought into focus by McHarg's [16] use for natural resources computerized inventory and analysis. His use of the procedure involved mapping data (soils, topography, etc.); and derived ratios and ratings (slope, suitabilities for different land uses, etc.) on individual transparencies, as a "stack" or "bundle" of computer files, all geocoded to the same grid cells. Different overlays were then combined to systematically deduce land use and locational decisions.

Geographic Information Systems (GIS)

Like a CAM system, GIS includes automated mapping of data into layers. Unlike CAM, GIS incorporates a relational data management system that facilitates the extraction and manipulation of information and its spatial display. "Relational join" among data-layers is established with procedures for data storage, juxtaposition, retrieval, analysis, and display. In addition, GIS systems can accept data from three sources: direct digitizing; entry of coordinate geometry from computerized spreadsheets; and existing digital databases provided by the Bureau of Census, U.S. Geological Survey, sources of satellite images and remote sensing data, and occasionally public works departments and utility companies.

All such data can be street-address-referenced, making GIS a remarkably versatile new tool for a variety of continuously increasing applications in demography-based decisions (e.g., locating schools, fire stations, etc.); in natural resources-based decisions (e.g., pipeline and highway alignment, environmental impact analysis, etc.); in land parcel-based decisions (e.g., real estate property taxation, oil lease map records, etc.); and a multitude of other novel applications (e.g., dispatching Yellow Cabs, UPS vehicles and ambulances, tracking wildlife, etc.). GIS provides a broad, yet hardly explored potential for use in appraisal, real estate market analysis, and parcel-based asset management.

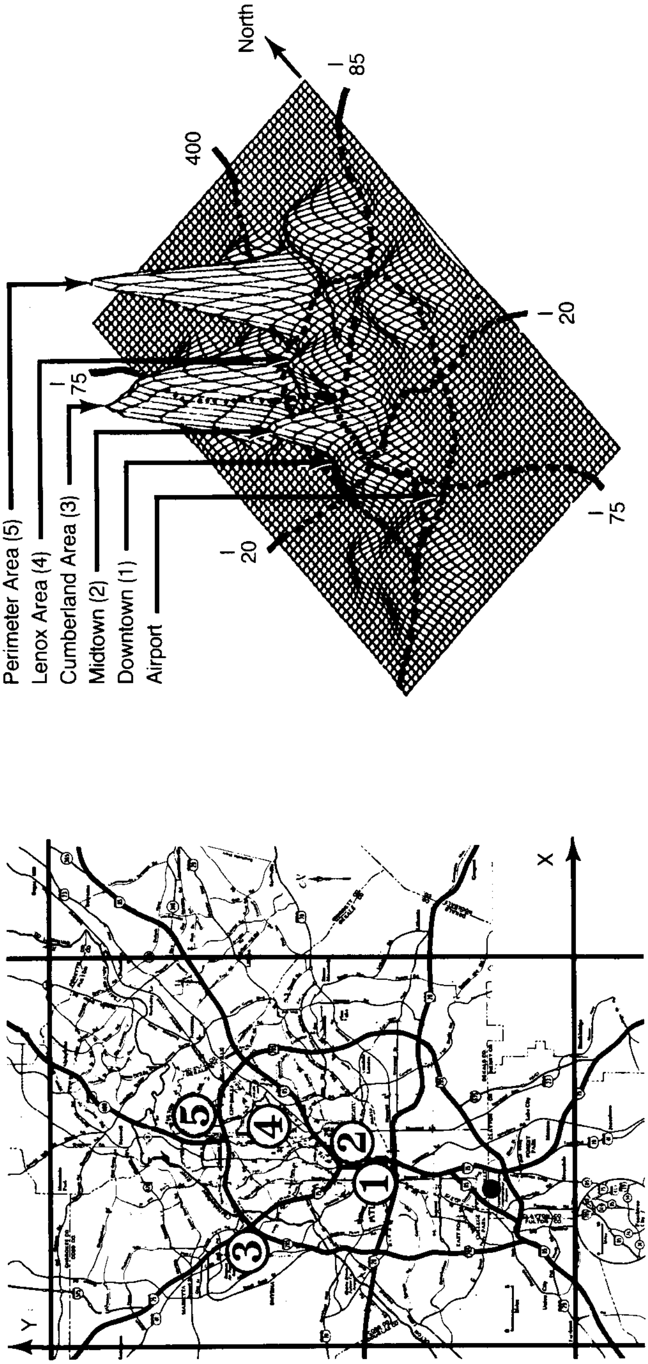
Isarithmic Mapping

A three-dimensional surface can be viewed as a function of three variables (x,y,z), with the geographic or Cartesian coordinates (x,y) as independent variables, and with a variable (z) projected at each of the (x,y) points. With the data at hand in the form of $(x,y,z))$ triplets, a three-dimensional surface can then be viewed as a *statistical surface* fitted to the form $z=f(x,y)$. Isarithmic Mapping [5] involves producing a planimetric graphic repre-

Exhibit 1
Class A Office Space Secondary Market Data for the Atlanta MSA

Geo-Boundaries of Study Area
726 (33 N-S × E-W) Grid Cells

Market Analysis Surfaces (MAS)
1986/87 Net Absorption Per Source C



Source: From a paper titled "Applying Statistical Surfaces to Spatial Analysis of Office Markets," presented by author at the 1990 Annual Conference of the American Real Estate Society at Lake Tahoe, Nevada.

sentation of any given variable (z) within a specified geo-boundary. (z) could represent real simple values (topographic elevations, land values, etc.), or conceptual derived ratios (vacancy rates, etc.). Isarithmic Mapping could produce contour-maps with "isolines",[4] or could be a scaled-down version of a representative three-dimensional volume as in Exhibit 1.

The key activity in Isarithmic Mapping[5] is interpolation, which is a procedure for positioning isolines with the (z) values, in relation to a grid matrix with the (x,y) geo-coordinates. Computer-Aided Mapping (CAM) [25] has made interpolation much easier and faster, using any one of a number of mathematical models: inverse-distance, weighted, planar, quadratic, or cubic. On the other hand, three-dimensional splines and partial splines utilize "bi-variate interpolation",[6] with the same (x,y,z) triplets used in Isarithmic Mapping.

Early CAM programs in the late 1970s[7] included SYMAP and SYMVU at Harvard University; later programs in the early 1980s included PILLAR at University of Ottawa; WISMAP at University of Wisconsin; GIMMS at University of Edinburgh; and PRISM and CALFORM distributed by Harvard, to name a few. In the last few years, many three-dimensional programs for desk-top computers have become available for both Computer-Aided Drafting (CAD) and Computer-Assisted Cartography (CAC) systems.

Trend Surface Analysis (TSA)

TSA is a procedure of fitting spatial data by means of regressing the dependent variable (z); using polynominal equations of progressively higher order with the independent variables (the geo-coordinates (x,y)); and transforming (x,y) into various powers (e.g., x, x^2, x^3), and interactions (e.g., (xy), $(xy)^2$). The TSA procedure fits a surface from the (x,y,z) original triplets of data, separating a surface into two parts consisting of "signal" (systematic pattern and trend), and "noise" (nonsystematic variations, and random errors); and molding the "signal" by a polynomial form. The trend component is associated with "large scale" systematic changes that extend from one map edge to the other. The "signal" is accordingly predictable since it varies systematically. Mathematically:

$$\begin{matrix} \textit{observed value } (z) \\ \textit{of surface} \end{matrix} = \begin{matrix} \textit{trend component} \\ \textit{at } (x,y) \end{matrix} + \begin{matrix} \textit{residual at} \\ (x,y) \end{matrix}$$

As described by Hembd and Infanger [9], TSA is simply a least squares regression analysis, with restrictions on the independent variable (z) to locational indices. The end product in Trend Surface Analysis is two-part: the ordinary regression coefficients and associated statistics, and contour-map plots of the estimated surfaces and residuals.

Trend Surface Analysis has been used in a number of real estate market-related studies involving population, land values, retail trade areas, urban growth, and residential land-use. Sjoquist and Schroeder of GSU [23] studied population distribution and density gradients in the Atlanta MSA, using contour-map format; and Barnbrock and Greene [1] completed a similar study for the Baltimore MSA. Hembd and Infanger [9] used TSA to explore "land value surfaces" in contour-map format to study the rural-urban land market; and Johnson and Ragas [11] applied TSA and three-dimensional mapping to study the centrality-externality effects on value gradients, and the spatial distribution of land values in the New Orleans CBD.

Mackay [14] used TSA to construct "market-penetration" maps in contour-format, for spatial measurement of retail store demand, while Rust and Brown [22] used squared surface density analysis to generate three-dimensional "demand surfaces" to estimate and compare retail market area densities of customers. Robinson and Salih [20] used TSA to test economic development around Kuala Lumpur under the growth-pole model, and Parker [17] applied TSA at the intrametropolitan scale to explore the spatiotemporal patterns of residential land-use intensity and housing expenditures in Los Angeles County, using "residential land-use intensity surfaces".

Evaluating Spatiotemporal Consistency of Secondary Office Market Data

Secondary Office Market Data

A survey of secondary information sources for office market supply data in the Atlanta MSA[8] revealed seven different periodical reports:

- Carter & Associates, divided into twenty-two (22) submarkets
- Adams/Gates, divided into six (6) submarkets
- Rubloff, divided into eight (8) submarkets
- BOMA/Dorey, divided into seventeen (17) submarkets
- Royal LePage, divided into nine (9) submarkets
- Data Bank, divided into twenty-two (22) submarkets
- Cushman & Wakefield, divided into sixteen (16) submarkets

The four secondary information sources with sixteen or more submarkets were selected and designted A, B, C, and D. A was later dropped due to inadequate information, leaving secondary sources B, C, and D in the database for the study.

Some differences were found among the three secondary information sources in "office" definitions, and in geo-boundries. It was noted that the survey cut-off point for building size ranged from 10,000 to 12,000 sq. ft.; that government-occupied rental space was included in data from source D but not in datasets B or C.; and that owner-occupied buildings were excluded in all three. As expected, the geo-boundaries for submarkets used by all three office market secondary information sources rarely coincided, and typically overlapped. Only the submarket boundaries of the central business district coincided among all three secondary sources, and those for only one additional submarket coincided between two.

A 10% margin of variation in data among the three secondary sources was allowed in hypothesis development to accommodate the above referenced differences in definition. To address differences in geo-boundaries of submarkets and achieve a boundary match for the database, the (x,y) independent variables were set as geo-coordinates in a spatial grid with 33 North-South (y) units, and 22 East-West (x) units yielding 726 (x,y) coordinates. Data from each secondary source were then entered in individual data-layers as (x,y,z) triplets, with (z) designating specific dependent variables for specific time periods. Areas with land uses other than office space were given $(x,y,$ zero$)$ triplets.

The following attributes were selected as dependent variables for comparing the three secondary information sources:

1. "Total Existing Rentable Space" (TE_n): The total of "rentable" office areas, occupied or available for occupancy on the date of the survey. A "Rentable Office Area" is defined as the floor area of an office building, less all vertical penetrations of the floors (such as stairs, elevators, pipe shafts, flues, and vertical ducts).
2. "Net Occupied Rentable Space" (NO_n): The total of leased office areas actually occupied, including new tenants and net gain or loss from tenant moves since last survey. Pre-leases are not included.
3. "Net Absorption" (NA_n): The net change in occupied rentable space between survey dates.

$$NA_n = NO_n - NO_{n-1}$$

4. "Vacancy Rate" (VR_n): The percentage of unoccupied space of the "total existing rentable space" on the date of the survey.

$$VR_n = \frac{TE_n - NO_n}{TE_n}$$

Methodology

To examine spatiotemporal consistency among secondary information sources of office space data in the Atlanta MSA, for each of the identified attributes, the following four hypotheses were tested:

H1: Quantitative variations in total existing rentable office space (TE), net occupied space (NO), net absorption (NA), and vacancy rates (VR) among the different secondary information sources will not exceed $\pm 10\%$.

H2: Variations in NA and VR among secondary information sources will be proportionately distributed over submarket units.

H3: Spatial distribution of NA and VR among secondary information sources will be similar.

H4: Spatiotemporal trends in NA and VR among secondary information sources will be similar.

Preparation of the database for analysis involved generating simple charts, compressing data-layers into Market Analysis Surface (MAS),[9] and selective juxtaposition into composite MAS:

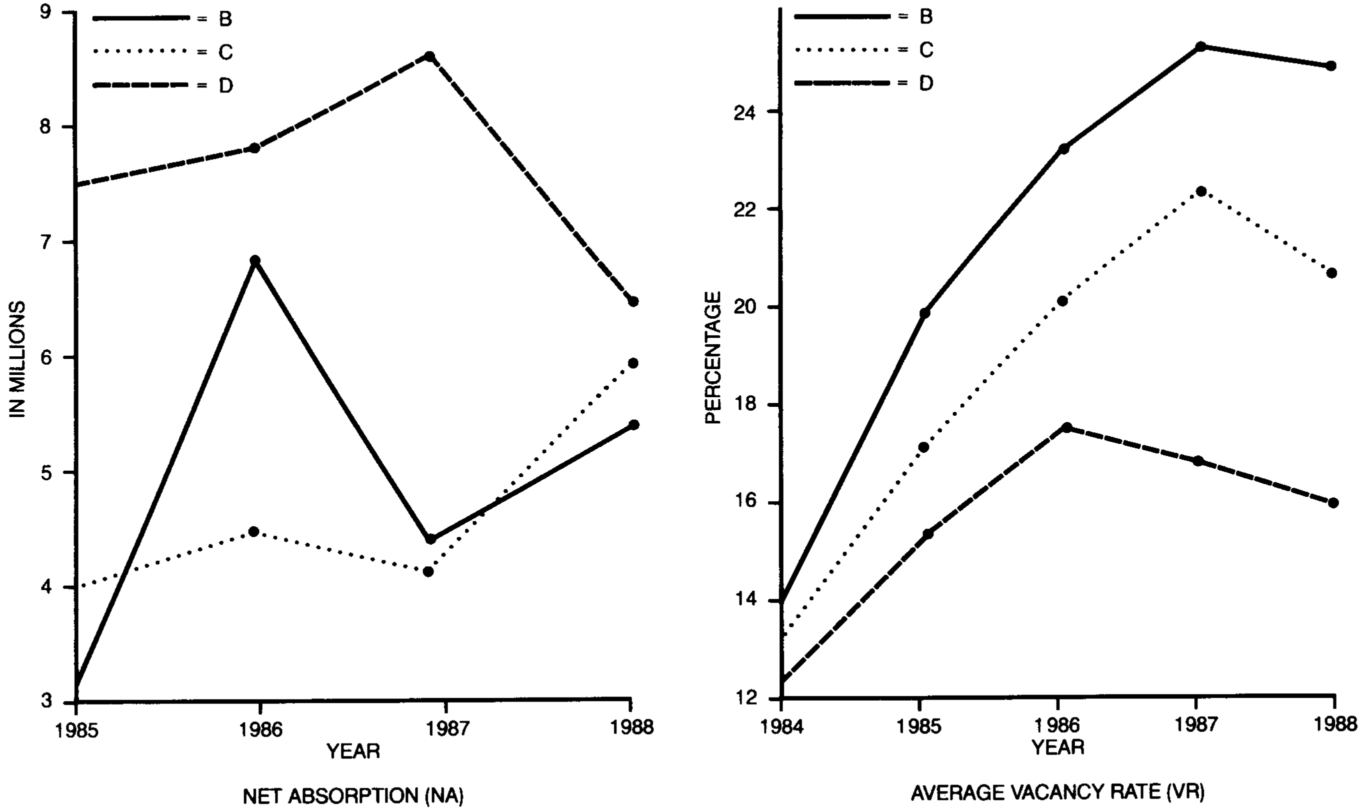
First, simple four-year graphs, like those in Exhibit 2, were generated for total existing rentable office space (TE), net occupied space (NO), net absorption (NA), and vacancy rates (VR) covering the total Atlanta MSA, for each of the datasets B, C, and D. These graphs were used for analysis of quantitative variations.

Second, simple four-year graphs, like those in Exhibit 4, were generated for NA, and VR by submarket in each of the three datasets, in order to test for proportionate distribution of variations.

Third, individual Market Analysis Surfaces, like those in Exhibit 3, were generated for NO, NA, and VR for datasets B, C, and D. These Market Analysis Surfaces were used in comparing reported changes in spatial and spatiotemporal office market disaggregation between 1984/85 and 1987/88. The use of MAS made it possible to:

Exhibit 2
Net Absorption and Vacancy Rates from 1984/85 to 1987/88 per Sources B, C and D

Class A Office Space Secondary Market Data for the Atlanta MSA



Source: From a paper titled "Applying Statistical Surfaces to Spatial Analysis of Office Markets," presented by author at the 1990 Annual Conference of the American Real Estate Society at Lake Tahoe, Nevada.

- bypass the need for boundary match of submarkets among the three secondary information sources;
- compress each complete data-layer in one visual representation, as in Exhibit 1;
- scan for spatial variations among three data-layers from three different sources in one visual representation, as in Exhibit 3.

Fourth, composite Market Analysis Surfaces, like those in Exhibit 5, were created by use of the "overlay" technique. A composite MAS visually presents compressed data in each of the two juxtapositioned Market Analysis Surfaces as well as the spatial or spatiotemporal differences between them. The use of composite MAS made it possible to:

- bypass the need for submarket boundary match;
- compress two data-layers from one or two data sources into one visual representation;
- scan for spatiotemporal variations among six data-layers in one vivid visual representation like as in Exhibit 5.

Analysis of Results

The first hypothesis regarding quantitative variations among the secondary information sources is rejected. Although some variations were predictable, the magnitude far exceeded expectations. Representative of other graphs, Exhibit 2 shows that variations in net absorption and in vacancy rates almost always exceeded 10%, generally exceeded 25%+, and often reached 100%. Exhibit 3 compares MASs denoting reported vacancy rate by the three sources. Note the significant differences in height of surfaces (denoting vacancy levels), and in volume (denoting distribution of activity).

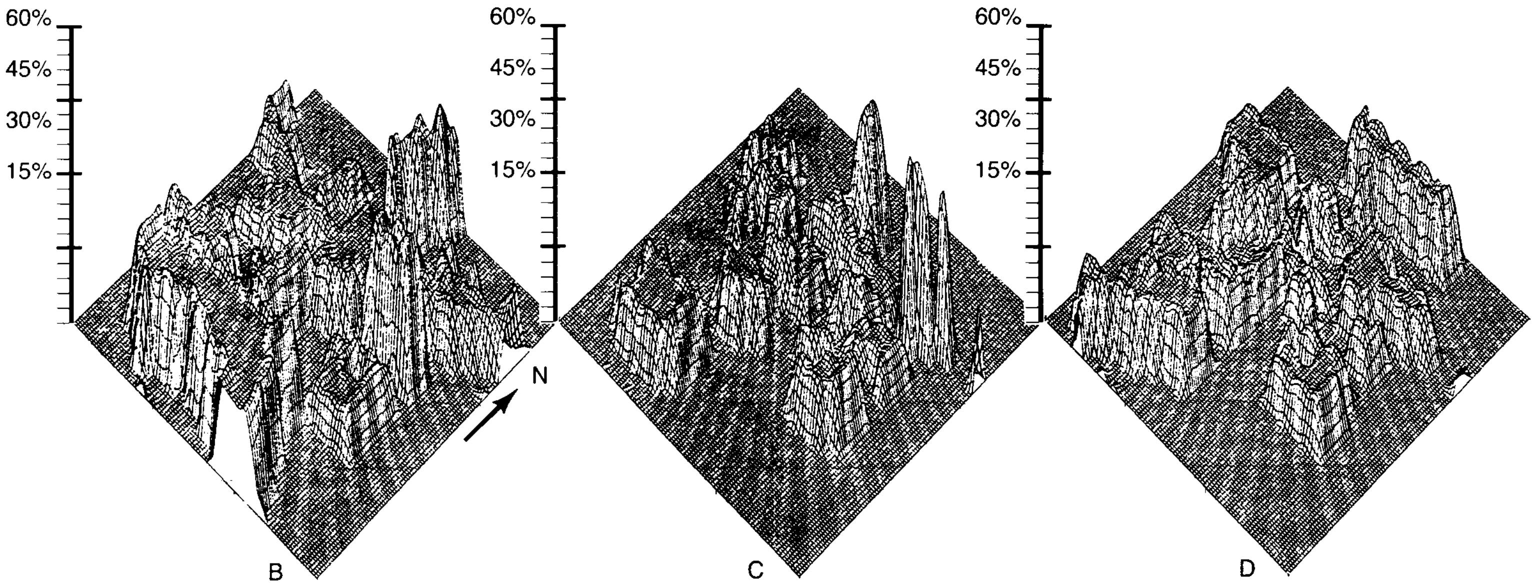
The second hypothesis tested for consistency of distribution of variations among submarkets in comparison to variations among the three datasets. Representative of other graphs, Exhibit 4 presents net absorption by submarket over four years as reported by the three sources. The graph lines denoting the Central Business District (the single submarket with identical geo-boundaries in all three datasets) are somewhat similar, but not identical to graph lines for total net absorption in Exhibit 2. However, extreme fluctuations in datasets B and D confirm inconsistency and redeem Hypothesis 2 null.

The MASs in Exhibit 3, denoting 1983/84 vacancy rates, show significant differences in the spatial distribution of rates reported by the three secondary information sources. MASs for other attributes and periods showed similar significant variations. The hypothesis that spatial distributions among the different secondary sources are identical, is accordingly rejected.

The composite MAS in Exhibit 5 illustrates how the different secondary information sources could lead the analyst to conflicting conclusions as to spatiotemporal shifts in office supply. Note that while source B shows the bulk of increase in net occupied space between 1984/85 and 1987/88 concentrated in a broad Northwest market area, source C shows a more proportionate distribution over the four major submarket areas. Unlike B and C, source D shows growth in the North and Northeast market areas. The hypothesis of comparable spatiotemporal market trends in the data from the different secondary information sources must thus be rejected.

Exhibit 3
1983/84 Vacancy Rate Comparison of Sources B, C and D

Class A Office Space Secondary Market Data for the Atlanta MSA

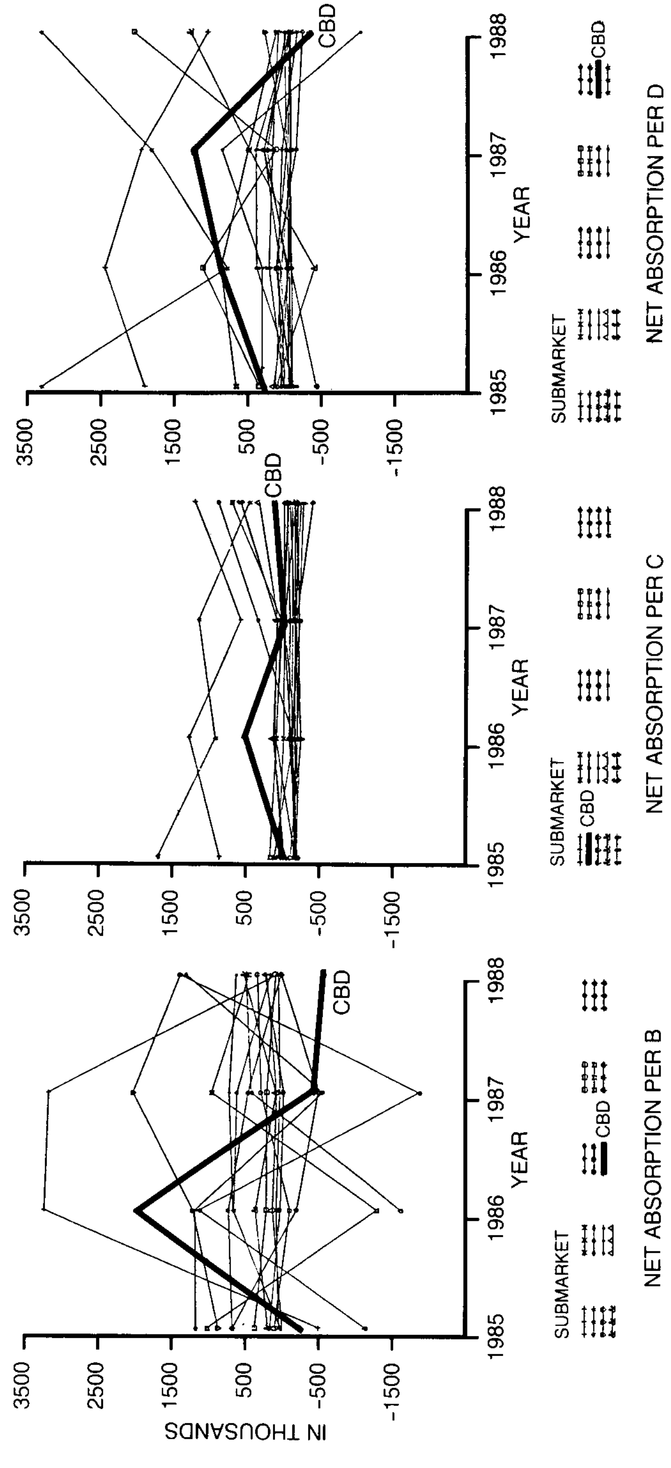


MARKET ANALYSIS SURFACES (MAS)

Source: From a paper titled "Applying Statistical Surfaces to Spatial Analysis of Office Markets," presented by author at the 1990 Annual Conference of the American Real Estate Society at Lake Tahoe, Nevada.

Exhibit 4
Net Absorption by Submarket from 1984/85 to 1987/88 per Sources B, C and D

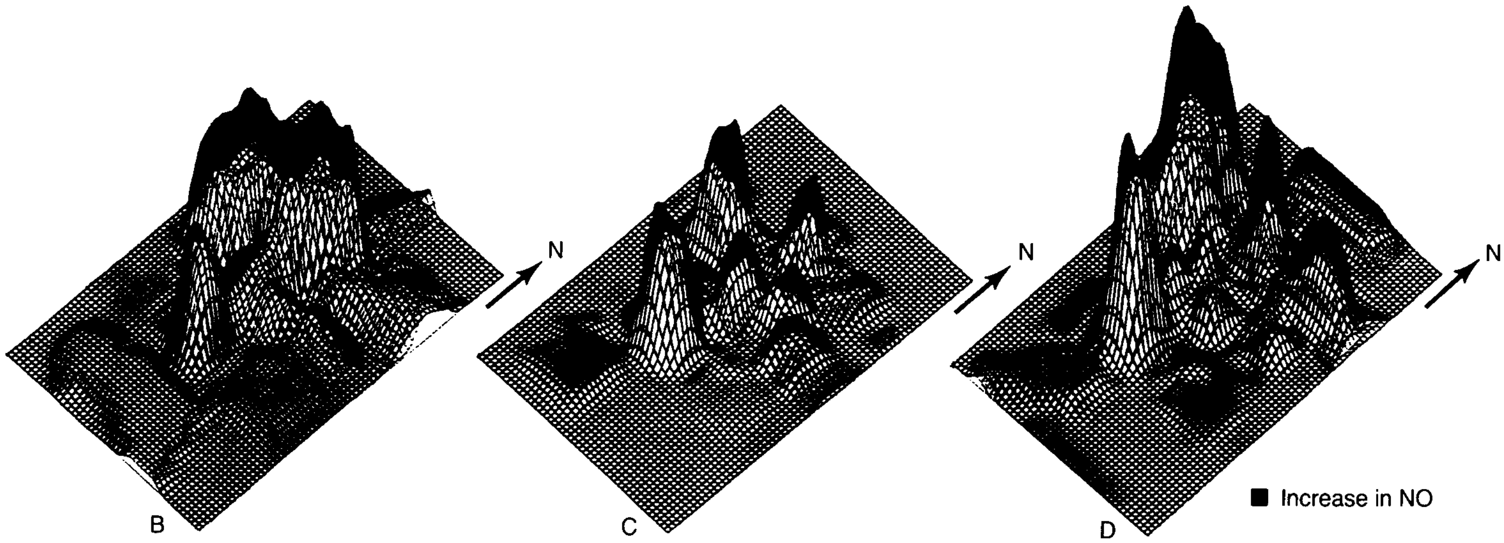
Class A Office Space Secondary Market Data for the Atlanta MSA



Source: From a paper titled "Applying Statistical Surfaces to Spatial Analysis of Office Markets," presented by author at the 1990 Annual Conference of the American Real Estate Society at Lake Tahoe, Nevada.

Exhibit 5
Net Occupied Space from 1984/85 to 1987/88 per Sources B, C and D

Class A Office Space Secondary Market Data for the Atlanta MSA



COMPOSITE MARKET ANALYSIS SURFACES (MAS)

Source: From a paper titled "Applying Statistical Surfaces to Spatial Analysis of Office Markets," presented by author at the 1990 Annual Conference of the American Real Estate Society at Lake Tahoe, Nevada.

Conclusions

The results of this study provide conclusive evidence that serious inconsistencies exist among secondary information sources for office space in the Atlanta MSA. Given that the companies involved in this study are either national in scope of activity, and/or provide data on other land uses, it is almost certain that secondary information sources in other market areas, and for other land uses are similarly inconsistent. The findings imply that developers, market analysts, and appraisers should obtain and compare secondary information from as many sources as economically feasible, but certainly from more than one source. The findings also support the use of Market Analysis Surface (MAS) for compressing, representing, manipulating, and scanning data from such sources.

The research reveals distinct quantitative inconsistencies and serious discrepancies in spatiotemporal trends of market activity among data offered by the different secondary information sources. These results highlight the need to incorporate formalized spatio-temporal analysis procedures in market and marketability studies. It also alerts appraisers, lenders, and investors to a detrimental source of distortion of absorption, vacancy, and rental rates; and accordingly potential erroneous appraisal of collateral values, and misrepresentation of project feasibility.

Notes

[1]The dictionary defines spa.ti.o.tem.po.ral as: 1. Of, pertaining to, or existing in both space and time. 2. Of or relating to space-time (Latin *spatium* SPACE + TEMPORAL).

[2]Upton and Fingleton [26] present many non-real estate examples in their book on spatial data analysis.

[3]See Falkenberg [8] for a discussion of "Transformation of DATA," and Tanaka and Tsuda [24] regarding "Decomposition and Composition".

[4]Isolines refer to a system of quantitative line symbols that portray the undulating surface.

[5]For a good overview of mapping in general, and Isarithmic mapping in particular, see Robinson, Sale, Morrison and Muehrcke [19].

[6]As described by Rust and Brown [22], cubic spline fitting does not entail estimation of a surface per se; it instead estimates the location of a boundary approximated by a series of fitted cubic polynomials.

[7]One of the earliest applications involved three-dimensional "visualization of data" to analyze and present distribution of medical and dental services in the State of Iowa [10].

[8]The author is indebted to Carter & Associates, BOMA/Dorey, and Data Bank for sharing their datasets.

[9]CAC-program SURFER by Golden Software, and SAS: G3GRID Partial Spline, are used in this study to generate three-dimensional "Market Analysis Surfaces".

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