Studying urban development in Tel Aviv, based on its morphology alone

March 31, 2009 · Academic
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Abstract

It is possible to understanding the spatial behavior and structure of cities based on urban morphology alone. The units of analysis are urban clusters, defined as contiguous built-up urban areas instead of municipalities defined by politically determined boundaries. By means of historic data of the Tel-Aviv metropolis we present analyses of urban cluster statistics from 1935 to 2000. We focus on the largest cluster which includes the city of Tel-Aviv and several surrounding municipalities. The results suggest anomalies in the years 1964 and 1985. Based on the character of cities as self-organizing systems, our study suggests that the analysis of urban cluster dynamics is an efficient tool to study urban phenomena.

Introduction

The spatial evolution of cities has been the subject of many studies for over a century. Previous work attempted to find explanations for the way cities evolve and arrange themselves in space, based on data collected at the municipal level (Jefferson, 1939; Zipf, 1941; Anas et al., 1998). In reality, however, the spatial evolution of cities extends beyond municipal boundaries. The nature of the data used in past studies created distortions in the description of urban phenomena and in tests of hypotheses. Furthermore, the models used to study urban dynamics, whether they originated in fields of cultural studies, politics, sociology, or economics, utilized unrealistic mathematical functions (Christaller, 1933; Alonso, 1964). Thus, no existing model provides a complete and precise explanation of the physical similarity found among urban structures (Batty & Longley, 1994).

Recent research has illustrated that it is useful to think of cities as self-organizing (Batty and Longley, 1994; Portugali, 2000). The presented work relies on this conception of cities and the fact that urban morphology is amenable to mathematical description and analysis. It utilizes concepts and tools from theories of complexity, self-organization, chaos, and fractal geometry. Previous work has shown that urban areas can be characterized as fractals (Batty & Longley, 1987, 1994; Battye et al., 1989; Frankhauser, 1990, 1994; Batty & Xie, 1996; Shen, 1997, 2002; White & Engelen, 1993; White & et al., 2001). Makse et al. (1995) proposed a percolation model that relates the morphology of built areas to the location decisions of its population. Benguigui et al. (2001a) developed a cellular automaton model that simulated the development of the footprint of the built areas in one city within the Tel-Aviv metropolis.

Patterns of urban morphology exhibit similarity to phenomena known in physics as cluster formation. This led to the hypothesis that there may be a general explanation of the arrangement of these structures in space (Schweitzer, 1997). In a previous work we presented an approach to understanding the spatial distribution and structure of cities based on morphology alone (Benguigui et al., 2006). The novelty in this approach is the replacement of municipalities as units of examination by urban clusters, defined as contiguous built areas. This enabled us to ignore changes of the cities’ boundaries that are related to political decisions rather than to real changes in the city spatial distribution.

In this study we focus on the largest cluster in the Tel-Aviv metropolis and show how changes in its morphology might be used to identify socio-economic changes. This is as the largest cluster is compounded of the core city of the metropolis (i.e., Tel Aviv) and its surrounding municipalities. This agglomeration of cities works as the financial, political, and cultural center of the metropolis and in many terms of the entire country.

The next section provides a methodological discussion at the backdrop of the research. Section 3 focuses on the analysis of the morphology of the largest cluster. The discussion in Section 4 relates the mathematical results with socio-economic phenomena in the history of the Tel-Aviv metropolis. Based on this analysis several conclusions and recommendations are presented in the final section.

Methodology

We identified urban clusters in the Tel-Aviv metropolis based on a series of maps of the Tel-Aviv region representing the years 1935 and 2000. The boundaries of the area analyzed remained fixed throughout the study period. Thus, the boundaries were...
determined independently of the boundary of the metropolitan area. The latter changed with time. The area studied is bounded by the city of Natanya in the north and by the city of Yavne in the south. These outer borders of the Tel-Aviv metropolis are widely accepted and include the metropolis in all the periods included in the study.

We digitized the historic maps and copied the built areas into new maps, suppressing non-built areas such as roads and railroads. The new maps are presented in Figures 1a to 1h. We used a black and white reduction of the maps. A black pixel represents an occupied site (a built area) while a white pixel an empty one. We defined a cluster by contiguity properties of the black pixels. The contiguity was determined as the sequence created by the touch of each pixel with its eight closest neighbors on a square lattice. Small clusters that had no urban characteristics (e.g., military facilities) were defined as noise. Such clusters were deleted. Each of the deleted clusters was smaller than 45,000 m².

In order to conduct a precise analysis of the clusters, we calculated the values of the area and the perimeter of each using the MATLAB computer software. The basic unit of the measurement was 1 pixel which represents a length of 30 meters.

Several different analyses of the data for each of the clusters were carried out at two levels: the first for the entire Tel-Aviv metropolis and the second examined the largest cluster alone. In Benguigui et al. (2006) we focused on the morphology of the entire metropolis and Table 1 presents the summary of these results.

One can distinguish three stages in the city’s evolution, based on the changes presented in Table 1. The first stage occurred between the 1930s and the 1960s. The second was between the 1960s and the 1980s. And the third took place in the years between the 1980s and the 2000s. The changes observed in the 1980s were found in all the examined parameters. Thus, we assumed the processes that led to these changes were more varied and powerful. As a result when we tried to associate the socio-economic trends and processes we have decided to focus on these years.

The next section presents the analysis of the data for the largest cluster comprised of the city of Tel-Aviv and its adjacent towns.

**The Largest Cluster in the Metropolitan Context**

**Cluster size**

The area of the cluster was used as its main indicative characteristic. Figure 2a presents the growth of the area A(t) of the largest cluster and of all the clusters in the

<table>
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<th>Table 1</th>
<th>Summary of the Analysis of Clusters in the Tel-Aviv Metropolis</th>
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<tr>
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<td>(dN/dt)</td>
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<td>1935-1964</td>
<td>&gt; 0</td>
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<td>1964</td>
<td>0</td>
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<td>1964-1985</td>
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The development of the cities near Tel-Aviv can be divided into two processes. At first there was enough space to allow a significant growth of the population. From 1990s onward the population of these cities hardly changed as did the area of the largest cluster.


Where DL represents the fractal dimension of the perimeter and DA represents the fractal dimension of the area of the clusters. Values that are close to 0.5 indicate a quasi-circular cluster while values close to 1 indicate a highly irregular shape.

The second factor that influenced the morphology of the largest cluster was the increase in the population of cities. As seen in the Figure 1, the urban clusters in the Tel-Aviv metropolis have irregular shapes. We used the box-counting method on a random sample of 20 clusters (including the largest cluster), and found that all of the examined clusters displayed fractal behavior. The fractal dimension of the clusters area was found to be 1.8 and the average fractal dimension of the clusters perimeter was 1.3.


Most of the cities in the Tel-Aviv metropolis, (presented in Figure 4,) reached the third stage by the 1980s, i.e., they expanded toward the periphery. Thus, prior to the mid 1980s, all these cities faced an intensive development which influenced their built area.


The rank size distribution of the clusters in the Tel-Aviv metropolis shows a resemblance of the largest cluster to a primate city. To conclude, this work considers the urban area as a physical object, disregarding municipal boundaries. It is based on the premise that urban structures are fractals, their fractal dimension can be used in order to discover phenomena connected with their evolution.

