Evolution of Street Networks in Adriatic and Ionian Coastal Cities 1769-2007

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Abstract
Coastal cities in the Adriatic and Ionian region are studied according to three evolution stages spanning from the end of eighteenth century to the present. The urban growth during this period has occurred according to successive additions without significant modifications of inner city areas. Street networks are represented with linear maps and are analyzed according to measures of connectivity and integration. The study shows that cities tend to become consistently less connected and more biased; and they tend to become consistently less integrated as they evolve over the years. The evolution trends are attributed to various configurations of street patterns of urban additions and to generic aspects of growth. The study suggests projections for the evolution of street networks in the future.

Introduction

This study is aimed at discovering morphogenetic principles of urban growth concerning the configuration of street networks. In one hand, the evolution of street networks is related to planning models, past and present, as manifested in various street patterns. In the other hand, it is possible to hypothesize that the evolution of street networks conforms to generic laws of growth that transcend the specificity of street patterns. This ambiguity is confronted by analyzing historical periods of a considerable number of cities of various sizes, street patterns and physiographic conditions. The Adriatic and Ionian coastal cities represent perfect cases for the study of urban evolution due to their rich variety.

Many space syntax studies have addressed the comparative analysis of urban form based on the linear representations of street networks. Some have focused on specific geographical areas and have discovered regional traits of urban morphology (Kubat, 1997; Read, 1999, Asami et al, 2001; Azimzadeh and Klarqvist, 2001), whereas others have compared how different cultural contexts have affected the evolution of urban form (Karimi 1997). In general, syntactic studies on the historical evolution of cities have addressed single cases (Jo, 1996; Kubat, 1999; Karimi and Motamed, 2003; Rigatti, 2005). In contrast, this study will address the understanding of generic aspects of urban evolution in a large scale.

The argument is in four main parts: First, the historical context of the region during the period 1769 to the present will be discussed from the viewpoint of the factors and events that have influenced urban growth. Second, the urban evolution is discussed in terms of the accretion with various street patterns as related to planning models. Third, linear map representations of three evolution stages of the cities are analyzed according to space syntax measures. Fourth, growth trends for the future are conjectured based on the discussion of the evolution patterns. In the next section, I discuss some important considerations for the selection of the sample including the historical context, urban growth, and cartography.

Historical Context

Historically, shipping played a major role in the region's trade, therefore the two narrow inland seas, Adriatic and Ionian, united urban centers on both sides rather than separated them (Hohenberg and Lees, 1995). Venice created a maritime trading empire that took advantage of the strategic location of this narrow sea channel centrally placed in the Mediterranean, linking Europe to Middle East and beyond. The Venetian colonies spread along eastern Adriatic from Istria to Ionian Islands, and thus brought a wide section of the Balkans into the trading radius (Georgopoulou, 2001). The rise and fall of Venice, from the Fourth Crusade in 1204 to Bonaparte's conquest in 1797, resulted in the gradual conversion of the Adriatic and Ionian from a linkage waterway into a dividing barrier. The fall of the Balkans under the Turkish rule had two main effects: on one hand it limited the influence of the Venetian coastal strongholds in the hinterland; on the other hand it left the occupied coastal towns in the periphery of the Ottoman Empire. During this period, the coastal cities of Calabria and Puglia also became somehow peripheral parts of the Kingdom of Naples [6]. They had little trade with overseas and remained fortified outposts against the Ottomans. The ever-shifting separation and unification between the two sides continued in one form or another well into the period covered by this study. Historical milestones include the fall of Venice and the Napoleonic control of Italy and northern Adriatic in 1797, the Italian reunification in 1815, the Greek Independence in 1821, the end of the Ottoman dominance in the region in 1912, the fall of Austro-Hungarian Empire in 1918, and the division between the West and the Communist Block 1944-1990. The historical shifts in the region have influenced models of urban planning which, in some periods, transcend national boundaries, and in some others produce isolated developments.

With the growing influence of the North Sea centers in the 16th century, cities in the Mediterranean changed from being the core of Europe to being a semipheriphery (Wallerstein 1974; Wynn, 1984). In comparison to the rest of the Mediterranean, the region became even more peripheral due to unique local factors that were discussed earlier. In 1750, only three cities in the region, Venice, Messina and Catania, are included in the list of European cities with population over 20,000. Trieste is added to this list in 1800, and by 1850, Bari, Corfu and Reggio Calabria overcome the 20,000 threshold (Chandler, 1987). While Venice is part of the 40 largest European cities 1750-1850, no city from the region is ranked on the 40 list by 1950 (Hohenberg and Lees, 1995). The late development of urban centers in this region therefore justifies the study of the urban evolution starting with the 1750 threshold, and the choice for the first evolution stage around 1850.

The Adriatic and Ionian region includes cities that primarily belong to the Network System[1] (Hohenberg and Lees, 1995; De Landa, 1997). According to Robson (1973), growth is inversely proportional to size in the Network System, i.e. smaller cities in the system grow much faster than the larger ones. While most cities in the region have grown quite recently, their growth has been fast, therefore providing ideal cases for studying the evolution of street systems.

By the end of the 17th century, accurate planar projections were widely used for the maps of port cities in Northern Europe (Konvitz 1978). In contrast, urban cartography of the Adriatic and Ionian region of this period still relied on axonometric views and stylized plans with overemphasized street widths (Coronelli, 1687; Blaeu, 1724; Albrizzi, 1761). It remains a challenging task to interpret these maps for the purpose of correctly defining the street network (Conzen, 1960). The earliest map found that gives a precise depiction of a city in the region is 'Plan de Venise' by the French cartographer Lalande dated 1769. The availability of reliable historical maps has therefore dictated the start of the study from the end of 18th century. The historical maps have been acquired from various sources including Archivio di Stato di Roma, Georgia Institute of Technology Library, Library of Congress, and National Library of Scotland. Digital maps of the period 2002-2007 have been accessed online from the planning departments of cities and communes, and Google Earth.

The sample has been chosen with the aim of including a range of cities in the region, rather than selecting a few well published cases. In general, finding historical maps of small towns that developed late has been far more challenging than finding sources for larger cities. However, overcoming this difficulty has guaranteed an unbiased sample that covers various conditions and is likely to discover widely applicable principles of urban evolution. This ongoing study presents findings based on the analysis of 23 cases (table 1).

Ref	City	Country	Evolution Stage			Street Pattern			Conn. Drift	Integ. Drift
			1	2	3	1	1 - 2	2 - 3		
1	Syracuse		1842	1942	2005	O	G	DG + D		
2	Augusta		1823	1943	2007	BG	BG	BG		
3	Messina		1873	1942	2002	BG	BG	D + S		
4	Reggio Calabria		1907	1943	2002	BG	BG	D + S		
5	Crotone		1905	1943	2005	O + D	G	D		
6	Taranto		1863	1943	2007	O	BG	BG + D		
7	Gallipoli	Italy	1836	1943	2006	O	BG	BG + D		
8	Brindisi		1908	1943	2005	O + G	DG	DG + D		
9	Bari		1896	1942	2006	O + G	G + DG	DG + D		
10	Barletta		1886	1943	2006	O + DG	DG	DG + D		
11	Manfredonia		1808	1937	2007	G	G	G + D		
12	Venice		1769	1838	2005	O	O	D		
13	Grado		1911	1943	2005	O + DG	DG	D		
14	Monfalcone		1892	1944	2005	DG	DG	DG		
15	Pula		1886	1942	2007	DG	BG	DG + D		
16	Rijeka		1900	1950	2007	O + BG	DG + S	DG + S		
17	Zadar	Croatia	1899	1943	2006	BG	DG	DG + D		
18	Šibenik		1825	1956	2002	O	DG	DG + D		
19	Split		1846	1951	2003	BG + DG	DG	DG + D		
20	Dubrovnik		1837	1943	2003	BG + DG	DG + S	DG + S		
21	Durrës	Albania	1943	1982	2007	DG	BG	BG + S		
22	Vlorë		1943	1982	2007	DG	DG + S	DG + S		
23	Patras	Greece	1905	1943	2007	G	G	DG		

Table 1
Catalogue of evolution stages of the cities; the predominant street patterns of the earliest stage and the additions during the two subsequent periods; and street pattern types abbreviated as O – mediaeval organic; G – non-hierarchical grid; BG - 'biased grid'; DG – deformed grid; D – distributory; S - serpentine.

Tree Trunk Analogy

The historic cores of most cities in the region are generally characterized by dense street networks which define urban blocks of small size[2]. Cities have grown by gradual overlaying; however, most streets in the historic centers have changed little over the millennia. There are some exceptions to this, including the complete replacement of mediaeval street patterns with orthogonal grids in Messina and Reggio Calabria after the earthquake in 1783 [3], and the new grid of Patras after the burning by the Turks in 1828. The historic centers in all cities remain unchanged over the entire period of study. These areas comprise invaluable architectural and urban monuments; therefore regulatory plans have carefully considered their preservation.

The study of various evolution stages reveals two important characteristics of the urban growth in the region. On one hand, urban growth has occurred in peripheral areas[4], thus adding subsequent concentric layers. These layers, as it will be discussed below, are constituted in various street patterns according to specific planning models of the evolution stages. Depending on the rate of growth and the change in planning strategies, or informal development[5], patches or layers with varied street patterns have formed around the city over the years. This is reminiscent of the tree trunk growth, where each ring records the growth condition of the tree in a given time.

On the other hand, for most cities, hardly any change occurs in the street system of areas already developed. This is made evident by overlaying different evolution stages of cities and enumerating the streets that do not fully overlap. The more recently developed areas surrounding the historic centers remain stable for most cities on the Italian coast, Istria, Northern Dalmatia and Greece. The major planning decisions had already been taken by early 19th century and later interventions incrementally built upon rather than altered the inner areas. In contrast, inner city areas in Albania underwent considerable changes during the period 1944-1990 according to the Eastern Bloc planning models. New boulevards and high-rise housing blocks were inserted in the older street systems inherited from the Ottoman period. A few cities in southern Dalmatia also show considerable changes of the existing street structure in the first years soon after the war: new highways crisscrossing the city (Split); widening and straightening of main streets, and remodeling of streets in sloped ground (Dubrovnik). It is therefore possible to discuss the urban evolution in the Adriatic and Ionian according to two models: The first model has a crystallized nature and is constituted as a process of growth by accretion over time with few changes occurring in the inner areas; the second model is fluid and is characterized by ongoing modifications of the inner street patterns occurring simultaneous to outward urban extensions. Most cases in the sample grew according to the crystallized model.

Street Patterns

Street patterns have resulted from the dynamic balance of two kinds of actions. On one hand, street patterns have an underlying social logic reflected in unplanned growth, planning strategies and regulations, and ownership models. On the other hand, the natural terrain has influenced the extent to where it was feasible to build such as the limitation from the water edge and the surrounding hills. From this viewpoint, the coastal region includes a wide variety of physiographic conditions of bays, islands, and peninsulas, which have strongly influenced the extent of urban growth. Understanding this effect involves a thorough analysis of the evolution of urban shape (Shpuza, 2007) that will be addressed in the future as part of this ongoing research.

The terrain has also influenced the street patterns found in steep grounds. This pattern constitutes a distinct category termed ‘serpentine’ (S). Serpentines are often found in the fringe belts on the hillsides. In syntactic terms, they constitute patterns with low connectivity due to segments consecutively linked in chains, and high connectivity bias[7] due to the existence of main connecting streets located in valleys.

The orthogonal grid is the most common street pattern found in the region. It belongs to two different historical settings. Grids are found inside historic centers that originate from the Roman period and still bear clear marks of organization with cardo and decumano. Grids were also the predominant planning model for the cities on the Italian coast, Istria, Dalmatia, and Greece during the Napoleonic era. The Napoleonic influence was exerted during the French control of Northern Italy and the province of Illyria (Calabi, 1984), the French affiliation of the Kingdom of Naples, and from German and French-trained planners in Greece (Wassenhoven, 1984; Biris and Kardamitsi-Adami 2004). Grids appear in two distinct types depending on the geometry of the area where they extend: First, ‘unbiased’ or ‘non-hierarchical grids’ (G) are found in compact areas where each direction is of a comparable length. Often patches of grids with different orientations are placed next to each other (e.g. Patras); Second, ‘biased grids’ (BG) extend unevenly, thus differentiate one direction of lines over the other from the viewpoint of connectivity.

The ‘deformed grid’ (DG) is a predominant type found across the sample in the 20th century. This pattern is characterized by longer radial streets that connect a large number of secondary streets organized in tiers. The pattern is differentiated from the viewpoint of both connectivity and integration, with the main boulevards taking a hierarchical role.

The ‘distributory’ type (D) is representative of modern hierarchical layouts, and is characterized by curvilinear tributaries that connect smaller isolated branching patterns (Marshall, 2005). This pattern appears after WW2 in the recent peripheral urban extensions in Italy and Croatia. In syntactic terms, this type has low connectivity and high bias.

Analysis of Street Networks

The street network for a city consists of all the streets that fall inside the urban area, which in turn is defined according to the contiguity of built form. The definition of urban boundary follows two rules: First, when traveling outward from the city center, one has reached the urban boundary when there are no buildings but farmland in both sides of the street. When one side of the street is constituted with buildings, the street falls inside the urban area. Second, streets which provide short cut connections between outlying peripheral fringes are included in the urban area.

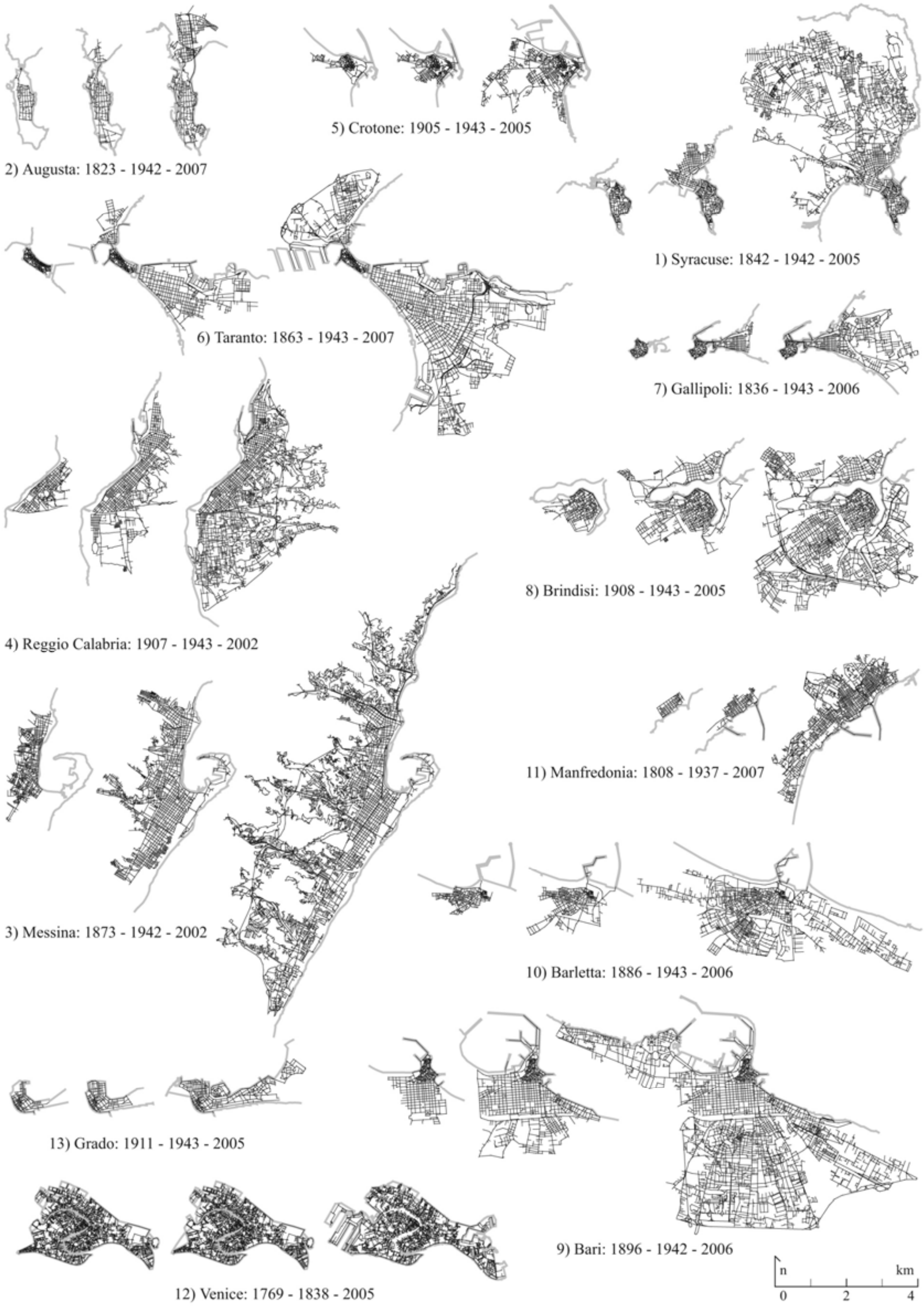

Figure 1

Linear maps of three evolution stages of cities on the Adriatic and Ionian western coast.

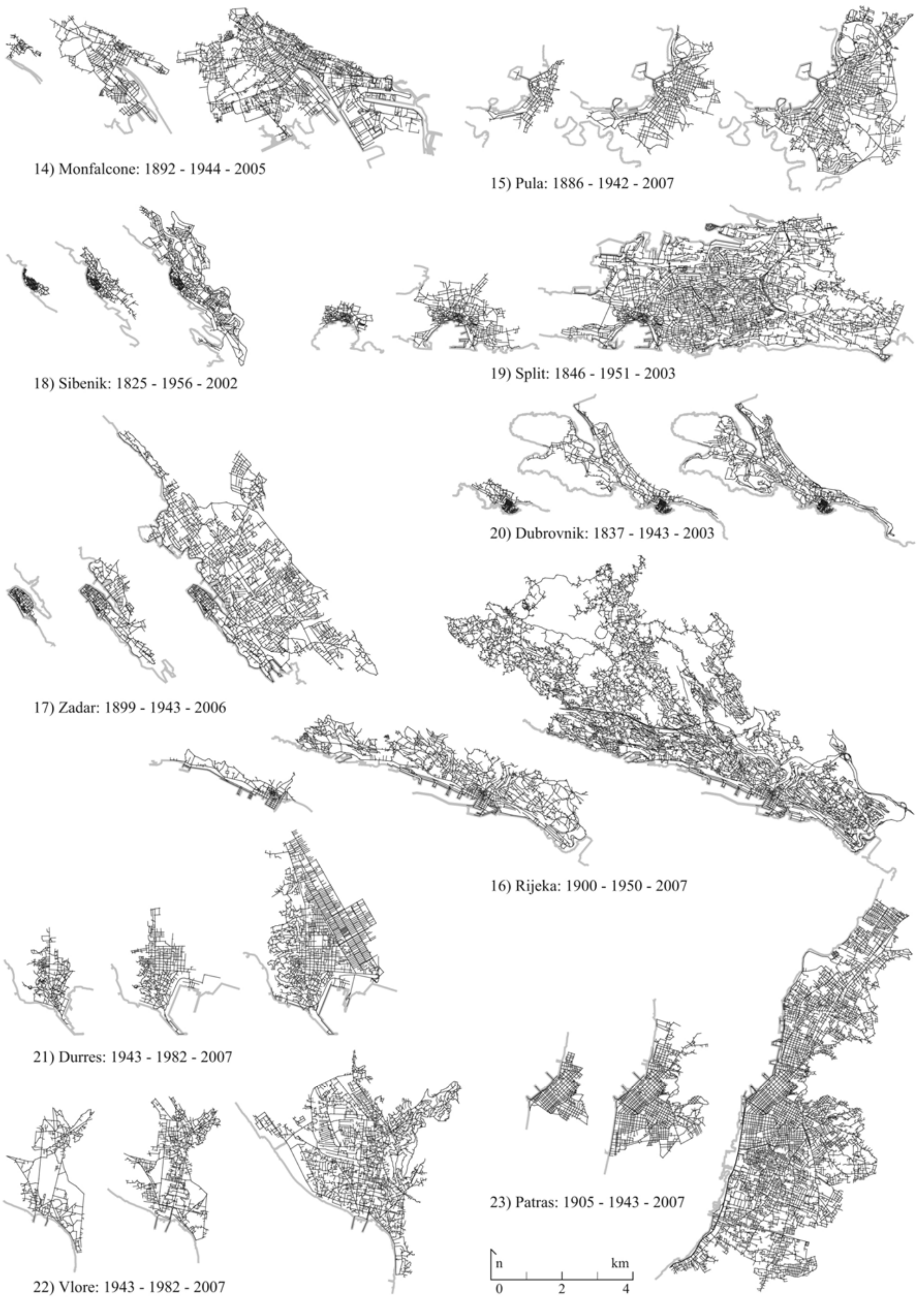

Figure 2
Linear maps of three evolution stages of cities on the Adriatic and Ionian eastern coast.

The evolution stages for each city are represented with linear maps (figure 1 and 2), and analyzed according to standard measures of Line Length, Connectivity, and Integration (Hillier and Hanson, 1987; Peponis et al 1998). Each case is discussed according to the mean value and the statistical skewness of distribution of the measures. It is argued that Skewness gauges a fundamental property of linear maps, the way a complex is biased or differentiated as opposed to being neutral. Mean Integration quantifies the average integration of a city; however, it does not account for the way integration is distributed in the street network. For example, despite the fact that Taranto-2007 and Zadar-2006 have similar Mean Integration values respectively at 0.59 and 0.57, their linear maps differ starkly. In Taranto-2007, a large number of lines, which correspond to the orthogonal grid in the peninsula, form a sizeable integration core, while the segregated streets on the periphery are considerably fewer. Zadar-2006 shows just the opposite, a handful of highly integrated lines, corresponding to long connecting boulevards, are outnumbered by a large number of segregated lines on the periphery. The skewness of distribution quantifies this difference. Accordingly, Taranto-2007 shows a right-skewed distribution of integration at 0.21, and Zadar-2006 a left-skewed distribution at -0.44. Similarly, Connectivity Skewness and Line Length Skewness are used to characterize each case.

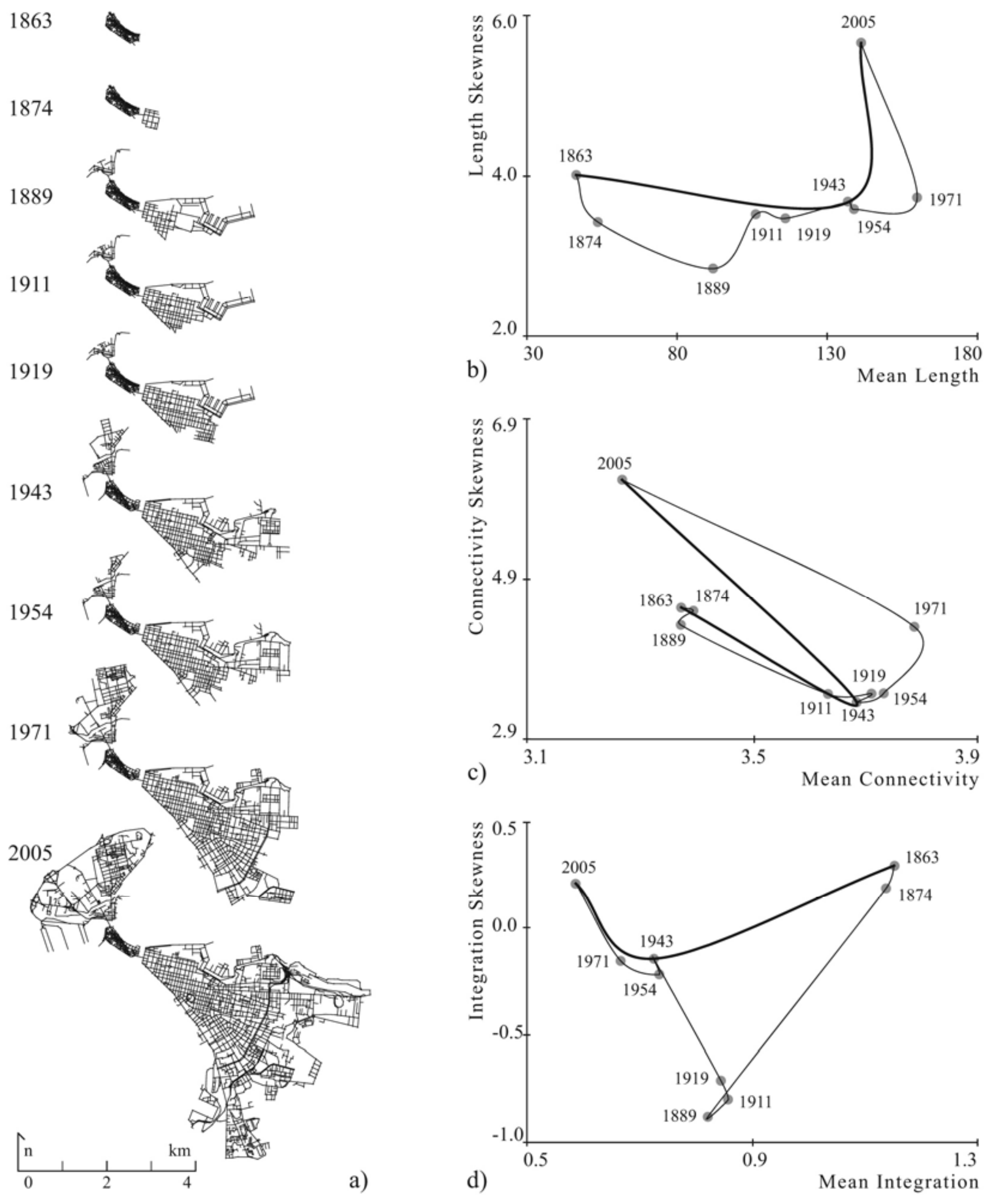

Figure 3

Representing the continuous urban evolution with discrete points over time. a) Linear map representation of 9 evolution stages of Taranto, Italy; b), c), and d) The 9-stage curves for the city in the scatterplots (shown with thin stroke) are simplified with 3-stage curves using 1943 as a middle point (shown with heavy stroke).

Three evolution stages have been chosen to discuss the evolution of each city during the period 1769 to the present. It is important to discuss the effect of simplifying a continuous process of change with three discrete moments in time. Due to practical reasons and the availability of historical maps, only a limited number of stages can be considered to begin with. In the case of Taranto, the historical maps are well documented and depict the evolution stages of the city separated by small gaps in time (Porsia and Scionti, 1989). Nine evolution stages from the period 1863-2007 are thus analyzed, and the evolution is represented with curves that connect consecutive points in time on the plots between the mean and the skewness for the three measures (figure 3). In a phenomenon shared among all three measures, the curves take strong turns during the period 1911-1943. It is suggested that sudden growth and change in planning models before and after World War II account for this reverse of course. A simplified sequence is therefore constructed considering three points in time: the earliest record, 1863; a middle stage around WW2 coinciding with major changes in the street structure, 1943; and the most recent record, 2007. The simplified 3-stage curve approximates well the 9-stage curve since there are no major overlaps and the overall change of direction remains common between the two. A similar argument can be made for the other cities in the region that during the post-war era grew according to the same planning models. The criterion for selecting the evolution stages for most cities thus consists of choosing a first stage from the 19th century, a middle stage around WW2 and the current condition 2002-2007 (table 1).

The analysis is aimed at discovering common generic principles of the urban evolution in the region. Therefore, the focus is on understanding the changes in the syntactic structure from a historical period to another. The analysis is carried in two levels: First, point scaterplots between various measures are constructed with 69 data points for the three evolution stages of the cities; Second, evolution curves are constructed by connecting the consecutive evolution stages of each city in the scatterplots. The two representations will be scrutinized in detail in the following section with the aim of exploring generic trends of urban evolution in the region.

Connectivity Drift

The pattern of connectivities is fundamental for depicting structural properties of street networks (Hillier, 1999). The point scatterplot between Mean Connectivity and Connectivity Skewness shows an approximate L-shape cluster (inset, figure 4). Points in the lower right show cities with dense grids and low differentiation, points in the lower left include cities with low connectivity and low bias, whereas points in the upper left show cities with low connectivity and high differentiation. The shape of the cluster reinforces the earlier findings about the morphogenetic limits of circulation systems in the built environment (Shpuza 2007; Shpuza and Peponis, 2008).

The evolution curves in the scatterplot (figure 4), reveal two main trends: First, a number of cities result in almost straight curves that point towards left and top-left during the entire period (e.g. 3-Messina, 10-Barletta, 11-Manfredonia, 16-Rijeka, 17-Zadar, 21-Durres, 22-Vlore, and 23-Patras) (table 1). Over the years, these cities become less connected and more biased. In these cities, the original ‘grid’ and ‘biased grid’ patterns are augmented with additional ‘biased grid’, ‘deformed grid’ and ‘serpentine’ patterns. These cases indicate urban evolution with gradual increase of bias and gradual decrease of connectivity through time. This trend can be represented with a simplified arrow that points towards the top-left side, termed ‘drift’ (table 1).

Second, most cities result in bent curves whose first phase points towards right, top-right, while the second phase takes a turn and points towards left, top-left (e.g. 1-Syracuse, 4-Reggio Calabria, 5-Crotone, 6-Taranto, 7-Gallipoli, 9-Bari, 13-Grado, 14-Monfalcone, 15-Pula, 18-Sibenik, and 19-Split). The drift for this category is shown with turning arrows (table 1). Starting with sparsely connected and unbiased ‘organic’ patterns of the historic centers, these cities evolve into becoming more connected and more biased during the period before WW2 due to the addition of ‘grid’ and ‘biased grid’ patterns. The addition of ‘deformed grid’, ‘distributory’ and ‘serpentine’ patterns after WW2 lowers their overall connectivity and increases their bias even further.

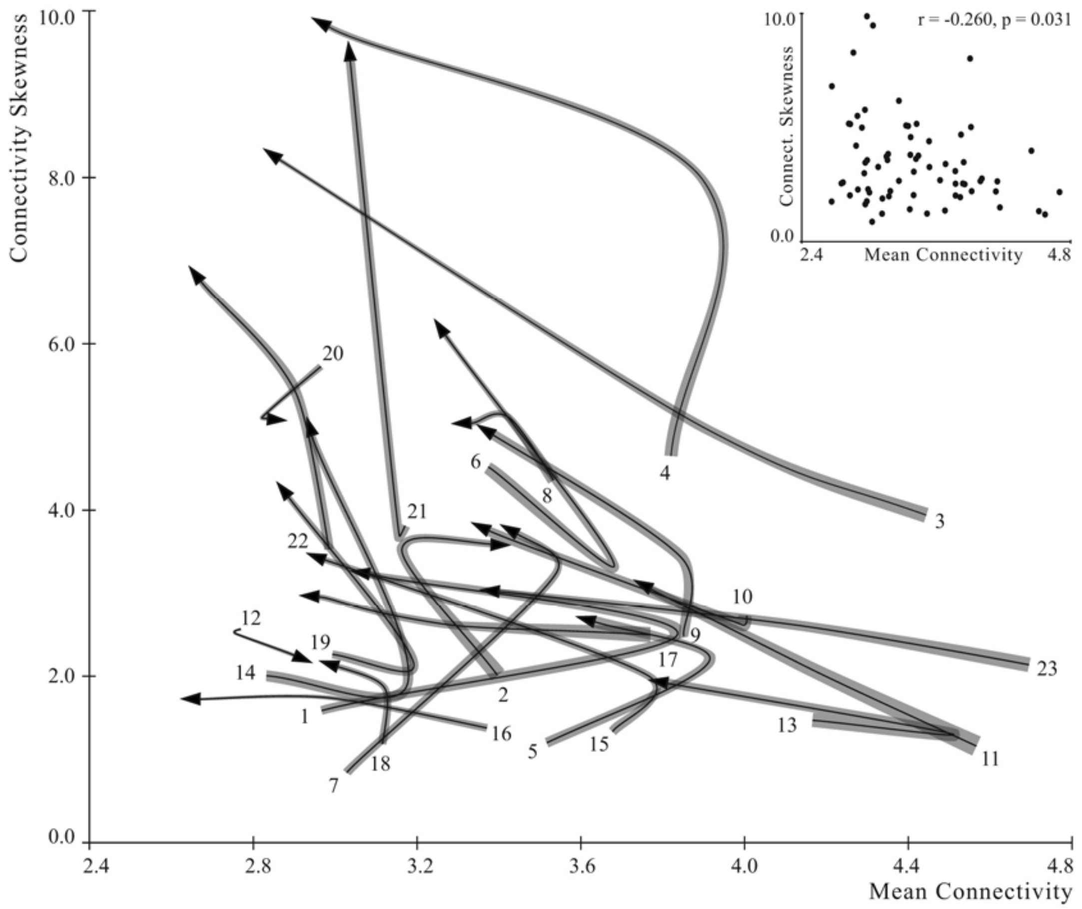

Figure 4

Evolution curves for 23 cities compared by Mean Connectivity and Connectivity Skewness. Data points and correlations are shown in the inset on the top right. The thickness of the curves in gray is proportional to Mean Integration for each historical stage.

Three cases are not part of the two trends previously discussed: 2-Augusta, 12-Venice and 20-Dubrovnik. Venice is a unique case where several new bridges were added and many smaller canals were filled and converted into roads during the 19th century. These changes increased the overall connectivity. In the case of Augusta, the first phase, which points towards top-left, shows the extension of the grid beyond the walls on the remainder of the island and the mainland. Just like Venice, the second phase after WW2 shows a stark increase in connectivity due to the construction of the second bridge to the mainland. Dubrovnik starts as a highly differentiated system due to the 'biased grid' of the historic center. The later extensions with 'deformed grids' decrease the overall bias and connectivity. Nevertheless, changes in Dubrovnik and Venice are quite small as indicated by the short curves.

Despite the two different scenarios before WW2, in general, most cities join a common drift after the war and become increasingly biased and less connected. The nature of recent modern planning strategies that have favored the use of distributory schemes is one important factor that has influenced this condition. However, I would argue that this phenomenon might as well be indicative of an emergent morphogenetic principle of growth that is founded on two main processes: On one hand, longer and more connected street are needed to overcome distance and connect between remote parts of the city, hence increasing the bias. On the other hand, new peripheral city neighborhoods create local structures that work in isolation and increasingly lag in maintaining high connectivity with the older inner city areas, therefore reducing the overall connectivity.

Integration Drift

The measure of Mean Integration is plotted against Integration Skewness (figure 5). The point plot suggests a weak but significant positive correlation between the two measures. In general, more integrated cities are also more differentiated from the viewpoint of integration. The evolution curves appear oriented in several directions which are classified according to 8 drifts (table 1). At first, this suggests the lack of consistent patterns of integration during the evolution of cities. However, all curves, with the exception of Dubrovnik and Venice, point towards the left in the post-war era, indicating the consistent decrease of integration during the recent evolution of cities. As discussed earlier, Dubrovnik and Venice represented exceptions also with regards to the connectivity drift. Nineteen data points, belonging to present day and WW2 stages fall in the negative zone of the Integration Skewness. This indicates left-skewed distributions where a considerable number of peripheral lines result highly segregated.

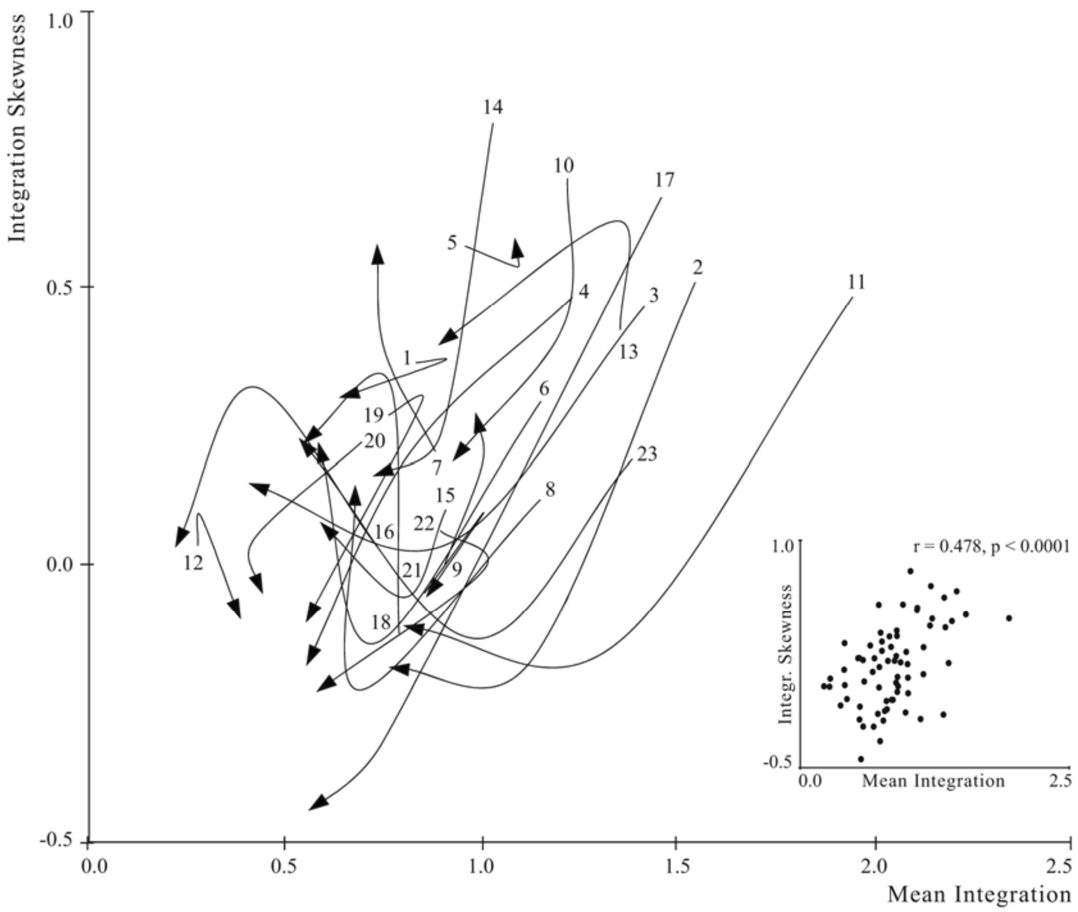

Figure 5

Evolution curves for 23 cities compared by Mean Integration and Integration Skewness. Data points and correlations are shown in the inset on the lower right.

The measure of Mean Connectivity is plotted against Mean Integration (figure 6). As expected there is a strong and significant positive correlation between the two measures, better connected street networks are also more integrated. However, the evolution curves reveal a striking tendency by pointing towards the lower left during their growth. The only exception to this is 12-Venice which becomes more integrated at the present time. In conclusion, cities tend to become simultaneously less connected and less integrated over the years. This feature is rather consistent and points towards a clear morphogenetic principle of urban evolution in the Adriatic and Ionian region. This fact is also made evident by showing Integration values with widths of the evolution curves in the scatterplot between Connectivity and Connectivity Skrewness, discussed earlier (figure 4). The curves tend to become thinner as they point towards the left, thus indicating a decrease of Integration.

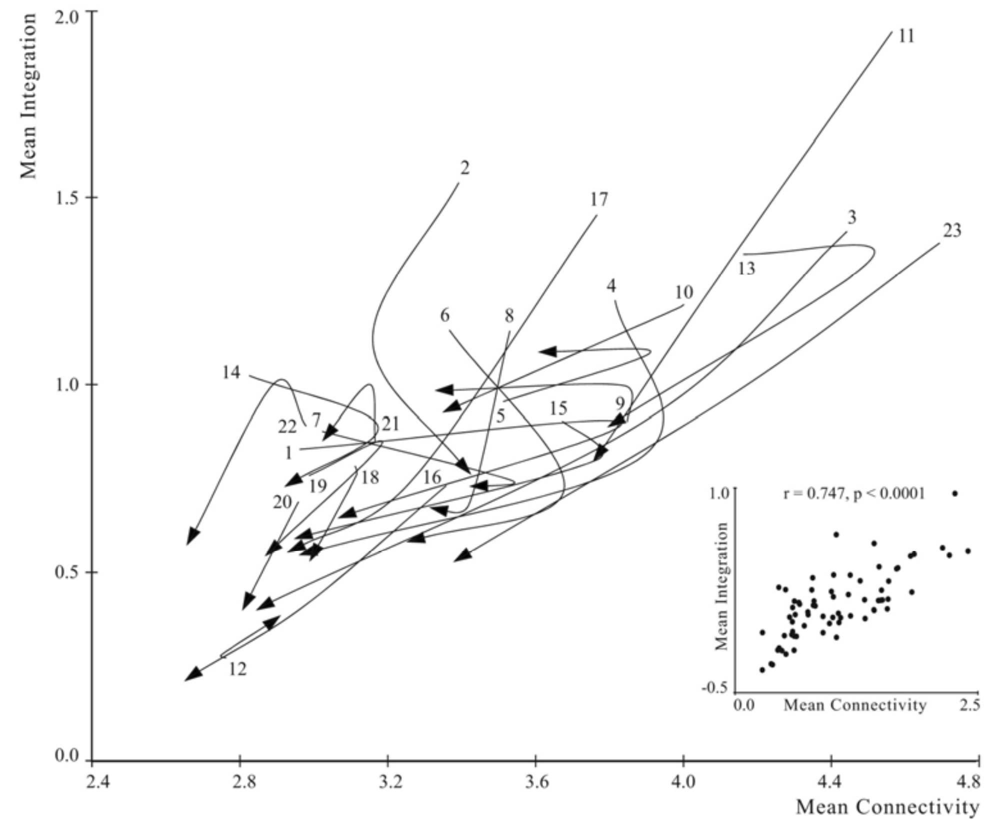

Figure 6

Evolution curves for 23 cities compared by Mean Connectivity and Mean Integration. Data points and correlations are shown in the inset on the lower right.

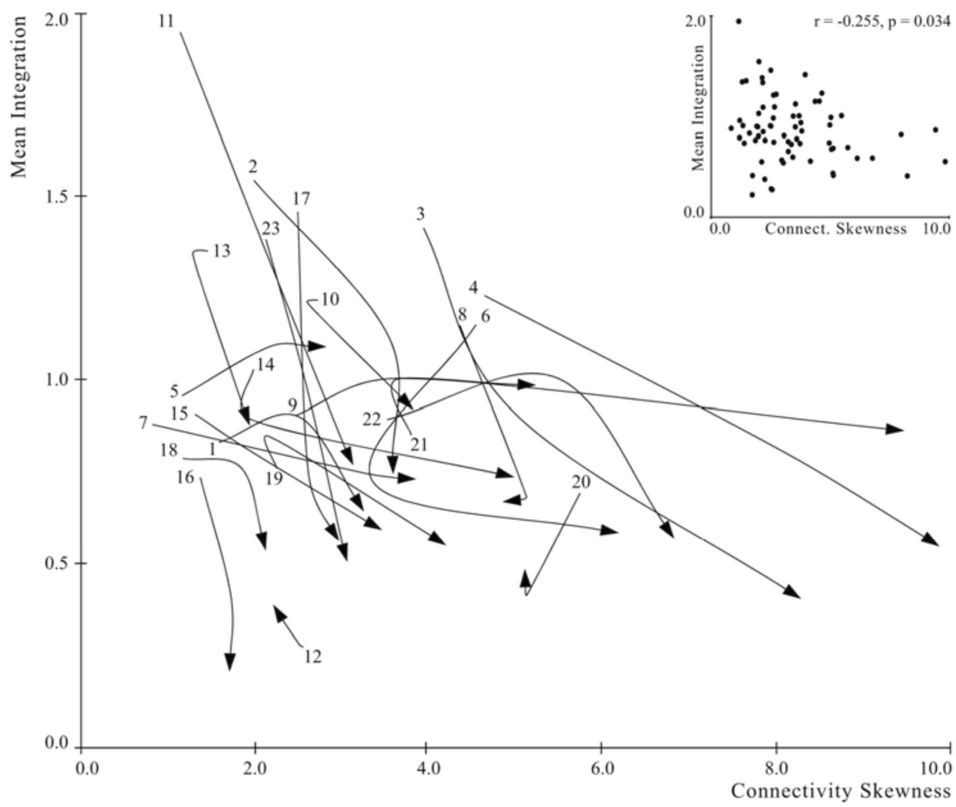

Figure 7

Evolution curves for 23 cities compared by Connectivity Skewness and Mean Integration. Data points and correlations are shown in the inset on the top right.

The scatterplot between Connectivity Skewness and Mean Integration shows a weak and insignificant correlation (figure 7). The evolution curves, however, indicate a consistent pattern of orientation pointing towards the lower end and towards the right. Only 12-Venice and 20-Dubrovnik make exceptions to this trend. Cities tend to become less segregated by time, and in general, they tend to become more biased with regard to connectivity.

Evolution Trends

This part of the discussion is aimed at identifying general trends of change in the syntactic measures over the years, which can serve to pinpoint generic principles of urban growth in the future. The argument is developed under the assumption that the current growth patterns will continue unaltered.

The scatterplot between Mean Connectivity and Connectivity Skewness curves point consistently toward the left and the top-left. The evolution trend for the connectivity will move most cities close to the line with Connectivity at 2.6 and upwards towards the Connectivity Skewness between 6 and 8 (figure 8a). All cities will grow inside an L-shaped or triangular region, and no cases will exceed the boundary in the top right.

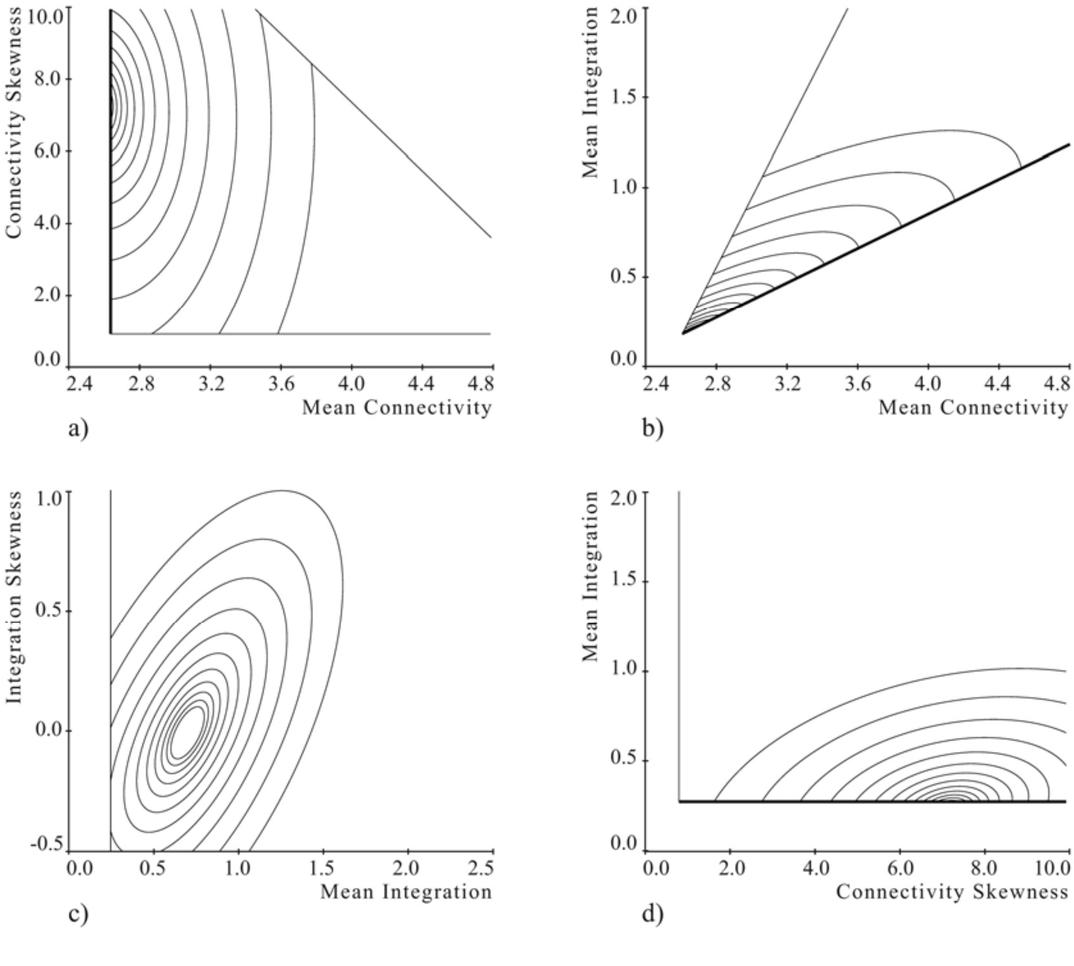

Figure 8

Evolution trends for the future growth of cities according to the covariance among Integration, Integration Skewness, Connectivity and Connectivity Skewness. Growth limits are shown with thick line; boundaries with thin line; concentration of cities in the future with dense concentric curves.

In the scatterplot between Mean Connectivity and Mean Integration, the data points form a cone-shaped cluster pointed towards the lower left corner. Most curves are directed towards the lower end of the cone roughly coinciding with the diagonal across the scatterplot. This edge of the cone acts like a limit whereby closer the curves come to it, more they conform to following the orientation towards lower left. Provided that the growth trend will remain unchanged from the viewpoint of reducing connectivity and increasing bias, it is suggested that cities will evolve by moving towards the lower edge of the cone-shaped region and towards the lower left alongside the limit line. The lower left is therefore likely to include the highest concentration of the cities in the future (figure 8b).

There are no clear evolution tendencies for the relationship between Integration and Integration Skewness. It is however possible to suggest that most cases in the future will congregate towards a region spread according to a 60 degree angle in the plot (figure 8c). The future growth will include cases in both sides of the y=0 line, left-skewed, normal and right-skewed distributions.

The evolution trend for the variance between Connectivity Skewness and Mean Integration consist of a clear boundary around y=0.25 with a concentration at the zone between skewness values of 6 and 8.

Conclusions

The study shows consistent trends of evolution of street networks in the Adriatic and Ionian region. With the exception of two cities built in islands, all cases become less connected and more differentiated as their street patterns evolve from mediaeval organic forms into gridirons, biased grids, deformed grids and modern distributory schemes. The decrease of connectivity is associated with a consistent decrease of integration across the sample. While strong correlations between Connectivity and Integration are reported by many space syntax studies in the past, the paper suggests that in addition, the direction of change between the two measures is consistent and significant.

The analysis shows that the drifts for integration are complex and involve two main categories: First, cities that become less integrated while becoming also more positively biased, i.e. a distinct integration core is differentiated in comparison to the rest of the system; Second, cities that become less integrated while becoming also more negatively biased, i.e. a distinct cluster of peripheral lines becomes far more segregated that the rest of the complex.

From the viewpoint of studies in urban history, in one hand, the paper contributes findings about the evolution of street patterns as related to main historical events; in the other hand, it enriches the historical research with quantitative analytical methods. The paper suggests ideas that concern the formulation of theories of urban dynamics based on a thorough understanding of the historical evolution of cities (Batty, 2007). This makes it possible to project growth trends for the future, and thus inform planning and policy making decisions.

Notes

1 The Network System brings together cities which function as gateway for the towns in the regional hinterland and are linked to the larger network via the foreland. The key systemic property of a Network System city is nodality, whereas the hierarchical differences derive only partly from size and more from the nature of the dominant urban function. In contrast to cities in the Central System, Network System cities are not bound by linear distance but rather by their strategic position in trade routes.

2 Most cities in the region have ancient origins and were founded well before the region was incorporated in the Roman Empire between the 4th and the 2nd centuries B.C. These include Greek colonies in Italy and Albania, Celtic centers in the upper Adriatic (Gutkind, 1969), Illyrian settlements in Puglia, Istria, and Dalmatia, and Greek towns in the Peloponnese. Only a few important centers were established in mediaeval times (e.g. Venice and Dubrovnik).

3 The subsequent earthquake of 1908 was even more destructive; however the street system in these two cities remained unchanged afterwards.

4 Often, patches of farmland, caught inside the built areas in the peripheral fringes, form large numbers of holes in the urban shape. The holes tend to fill up over time given permissible physiographic conditions.

5 Vlorë, and especially Durrës, witnessed an unprecedented growth during the decade of weak government control following the fall of the communist dictatorship in Albania in 1991. On flat areas, the new informal squatters were based on biased grid street systems which emerged along standardized irrigation canals of cooperative farms; whereas in hilly terrains they formed serpentine street systems.

6 The then main centers of the kingdom, Naples and Palermo, are located on the Tyrrhenian coast.

7 Bias, or differentiation, characterizes the property of networks to include outstanding elements with regard to a given measure. For example, a network with high connectivity bias is structured according to a few longer lines that connect most other lines. The statistical skewness of distribution is used to quantify this property.

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