How networks are shaping the city of Tshwane

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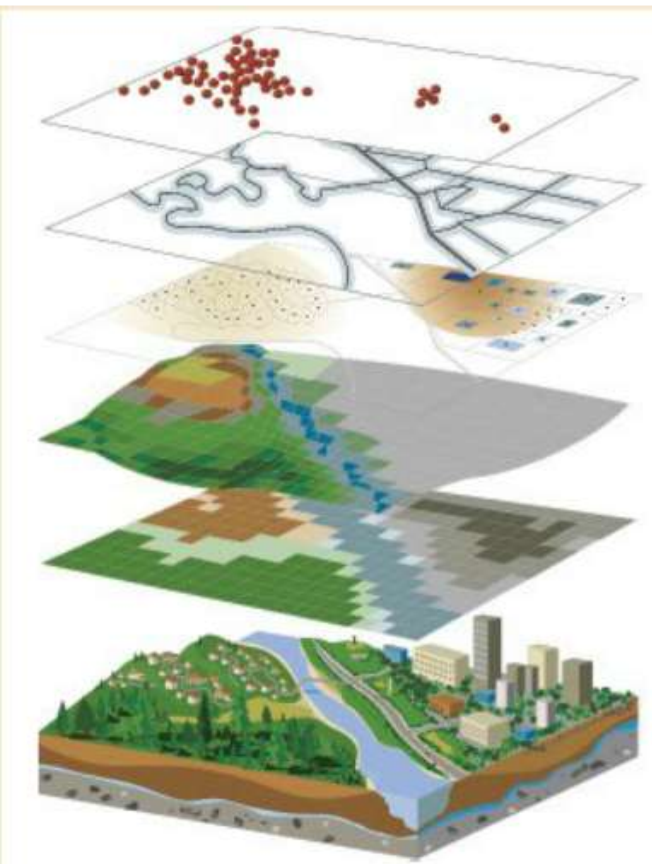


Citizens patterns of interaction

Street patterns

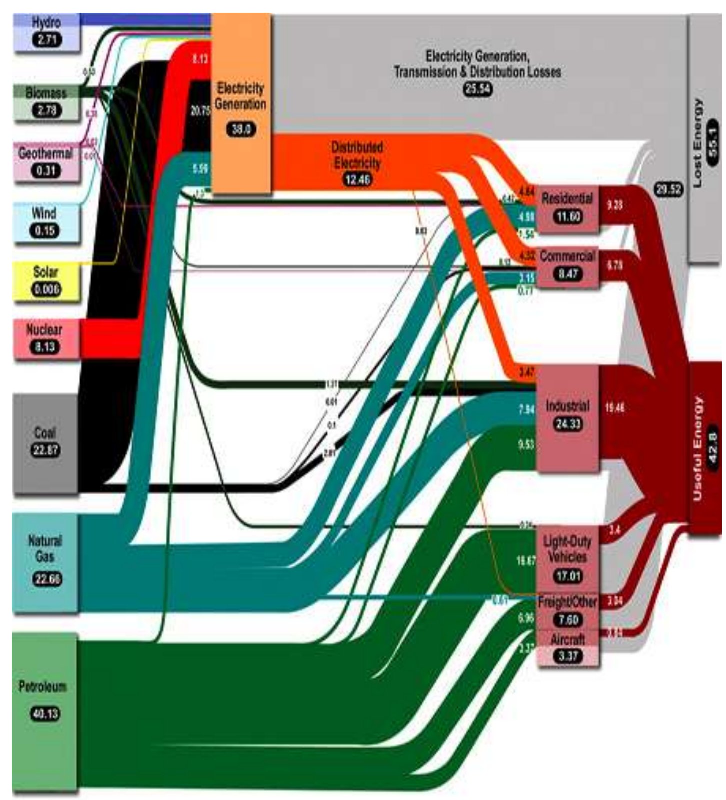
Plot subdivisions

Land use

Topography

Built environment

Energy flows



WHAT IS A COMPLEX SYSTEM ?

- Herbert Simon:

  "By a *hierarchic system, or hierarchy, I mean* a system that is composed of **interrelated subsystems**, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem."

- 4 types of hierarchy:
  - Inclusion
  - Control
  - Order
  - Level

What is a complex system ?

- Bad and good hierarchies
  - Inclusion leads to trees and constrained organisations (car oriented road networks)
  - Control and inclusion are extremely rigid and make adaptive growth impossible

  - Order and level hierarchies are adaptive
  - Complexity is a subtle form resulting from order and level hierarchies.

WHAT IS RESILIENCE ?

- Dynamic resilience: the system is able to recover from an endogenous or exogenous shock or stress

- Structural resilience: the system absorbs a shock (natural catastrophe, change of civilization) by an adaptive complexification process

- Adaptive resilience: The system evolves constantly far from the equilibrium and constructs new structures while keeping memory of its previous states

Resilience and hierarchy, the watchmakers parable

- Hora builds watches by 10-pieces subassemblies
- Tempus doesn't

- They randomly pick the phone to answer clients:
  - Hora looses a subassembly
  - Tempus looses an entire watch

- Probability to complete a watch:
  - Tempus needs 20 times more time !

Resilience and hierarchy, the watchmakers parable

- Hierarchic structure have a structural ability to evolve more quickly
- Hierarchic processes most robust ones.
- Better adaptation
- Quicker evolution

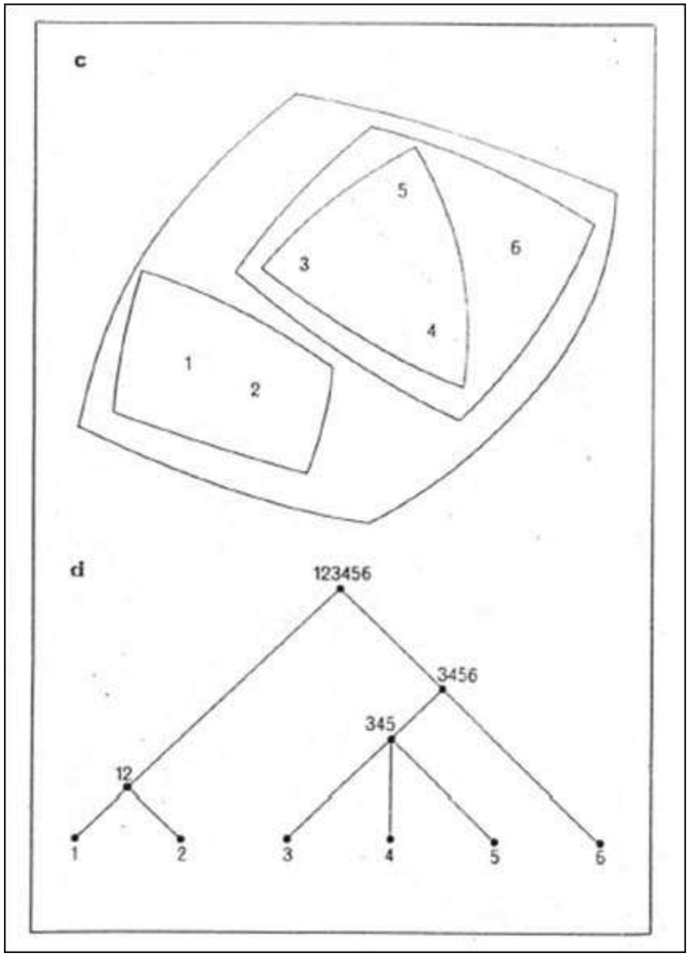
TREES AND SEMI LATTICES
Leaves are more than trees : they are scale free, clustered in Small Worlds and connected by loops

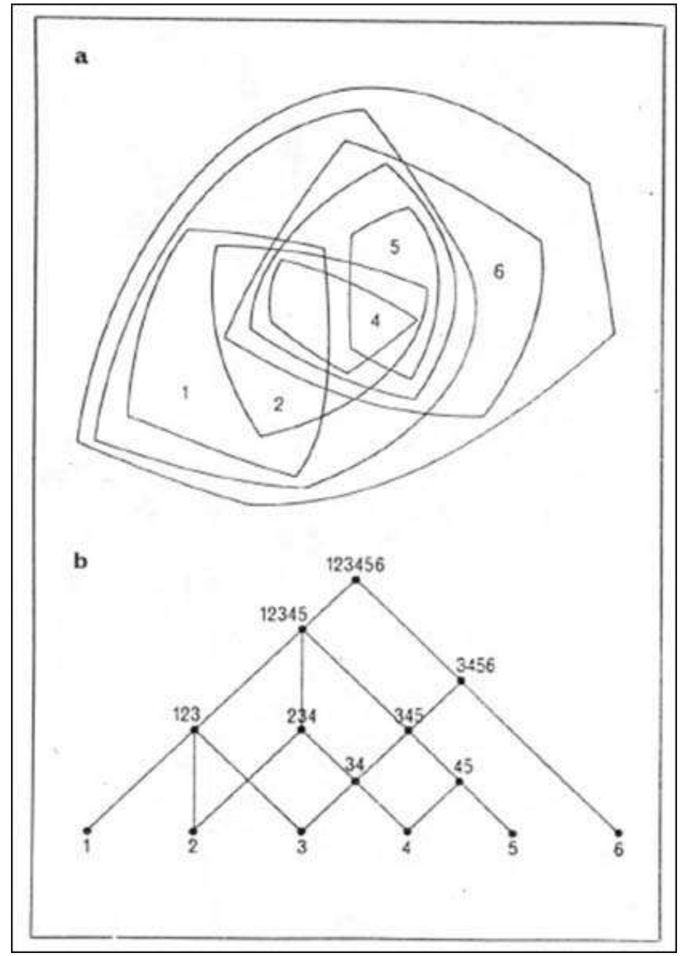
- The tree axiom states:

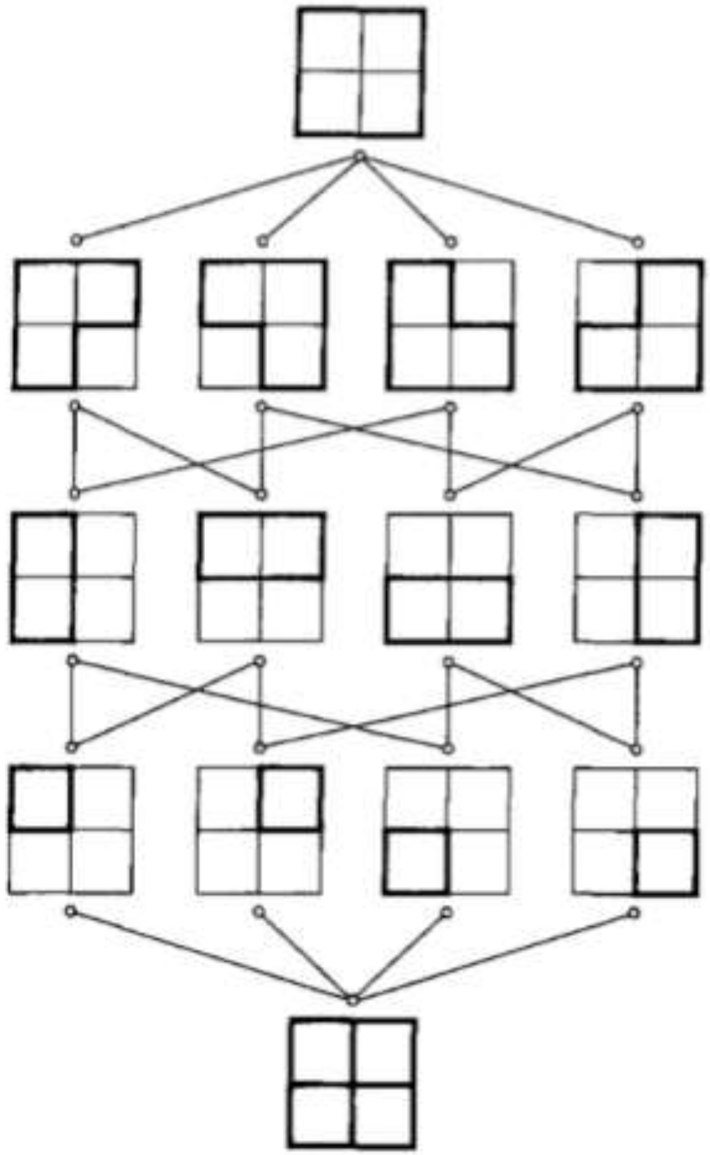
« a collection of sets forms a tree if, and only if, for any two sets that belong to the collection, either one is wholly contained in the other or else they are wholly disjoint »

- The semi lattice states:
« a collection of sets forms a semi lattice if and only if, when two overlapping sets belong to the collection, then the set of elements common to both also belongs to the collection »

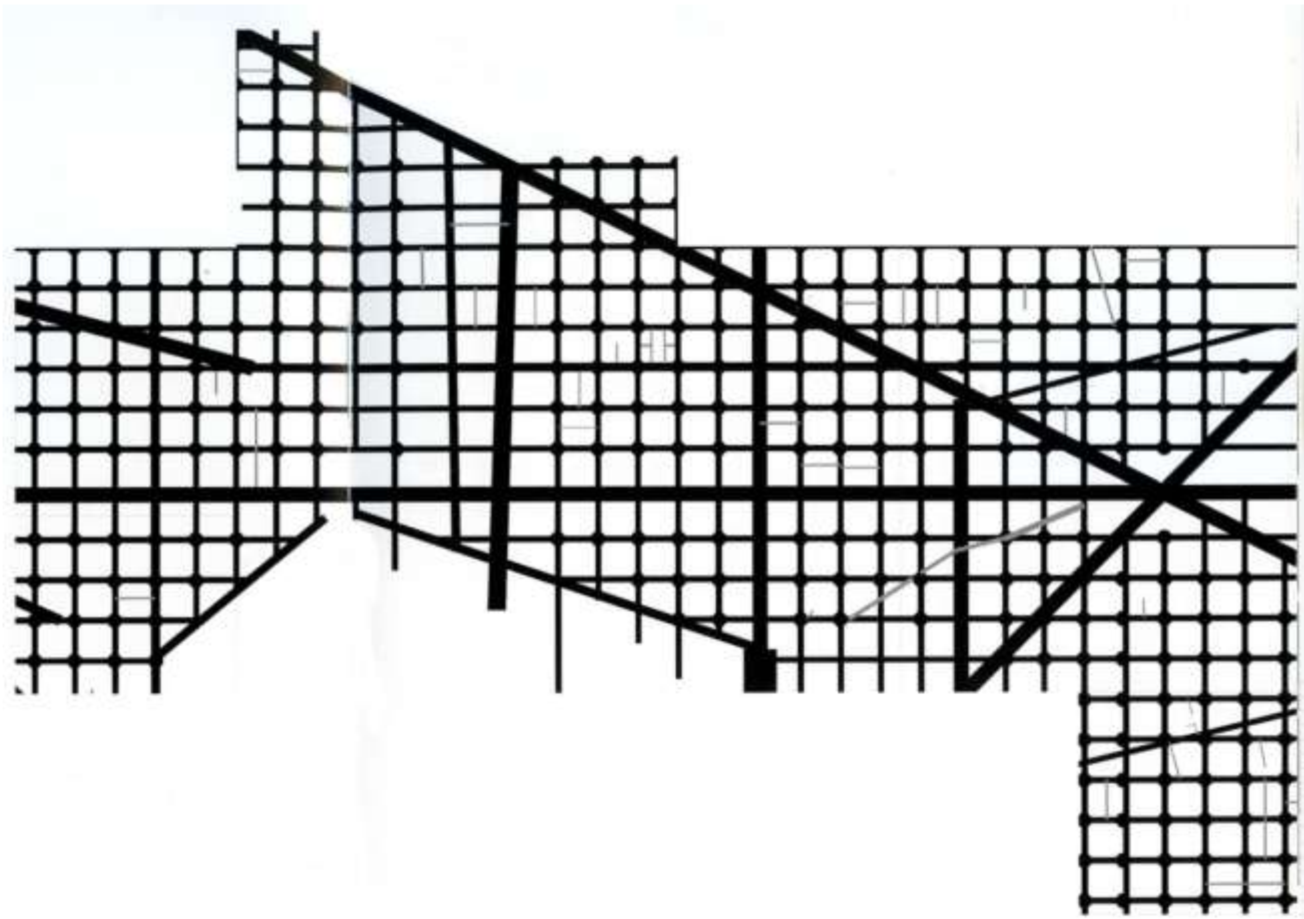
« A city is not a tree », C. Alexander





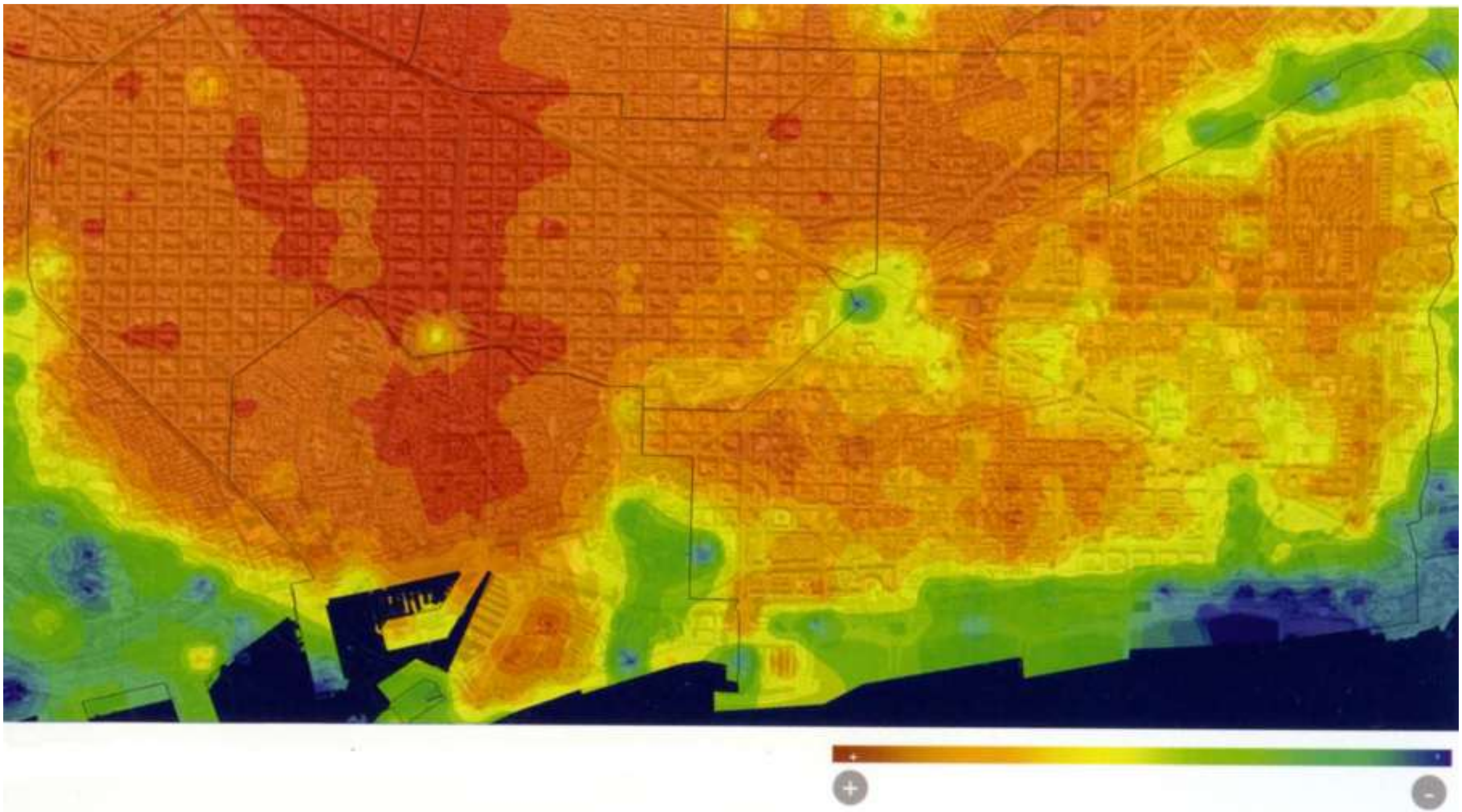


Breaks of symmetry and emergence of complexity



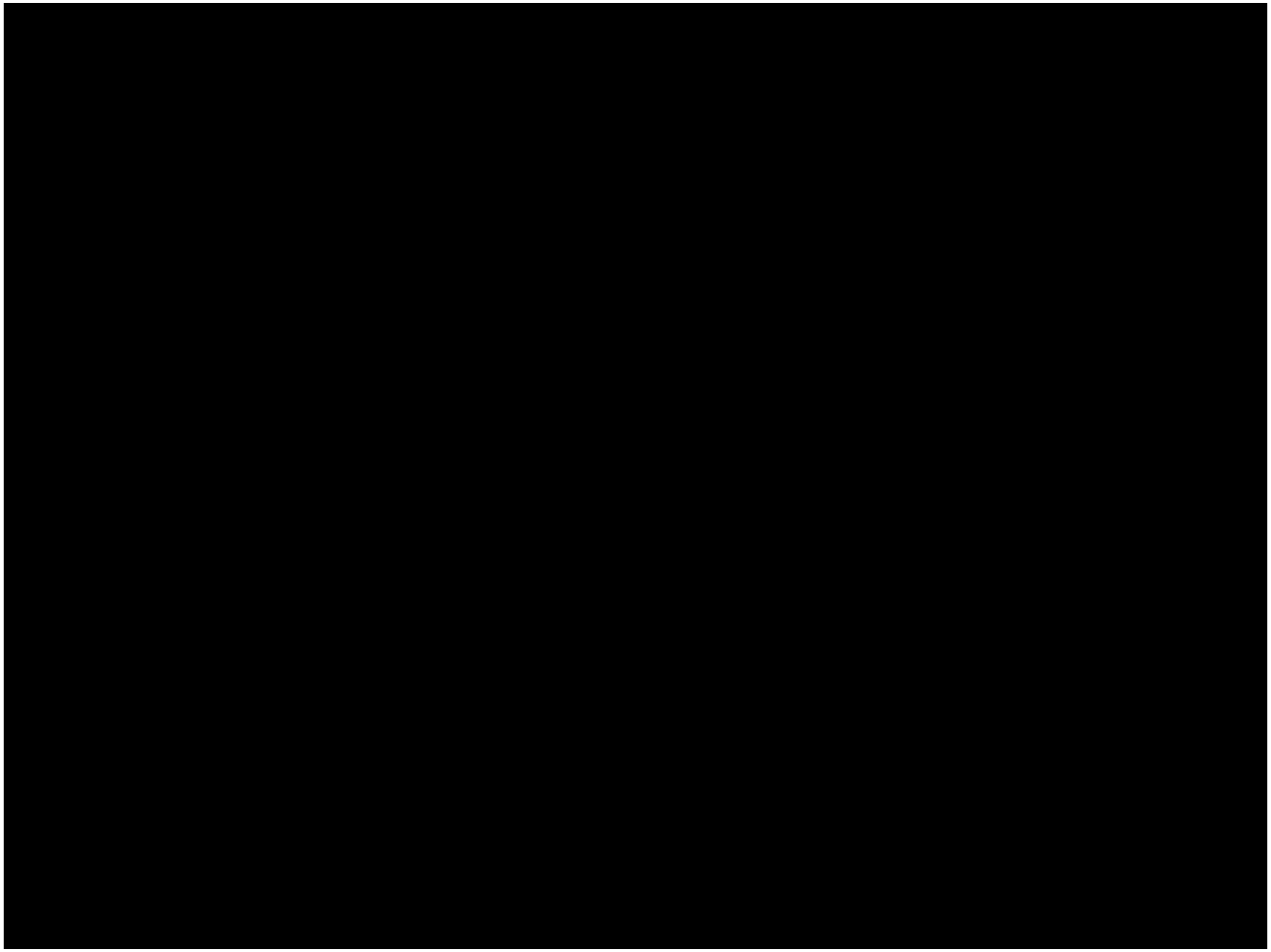
Breaks of symmetry and emergence of complexity

Breaks of symmetry and emergence of complexity

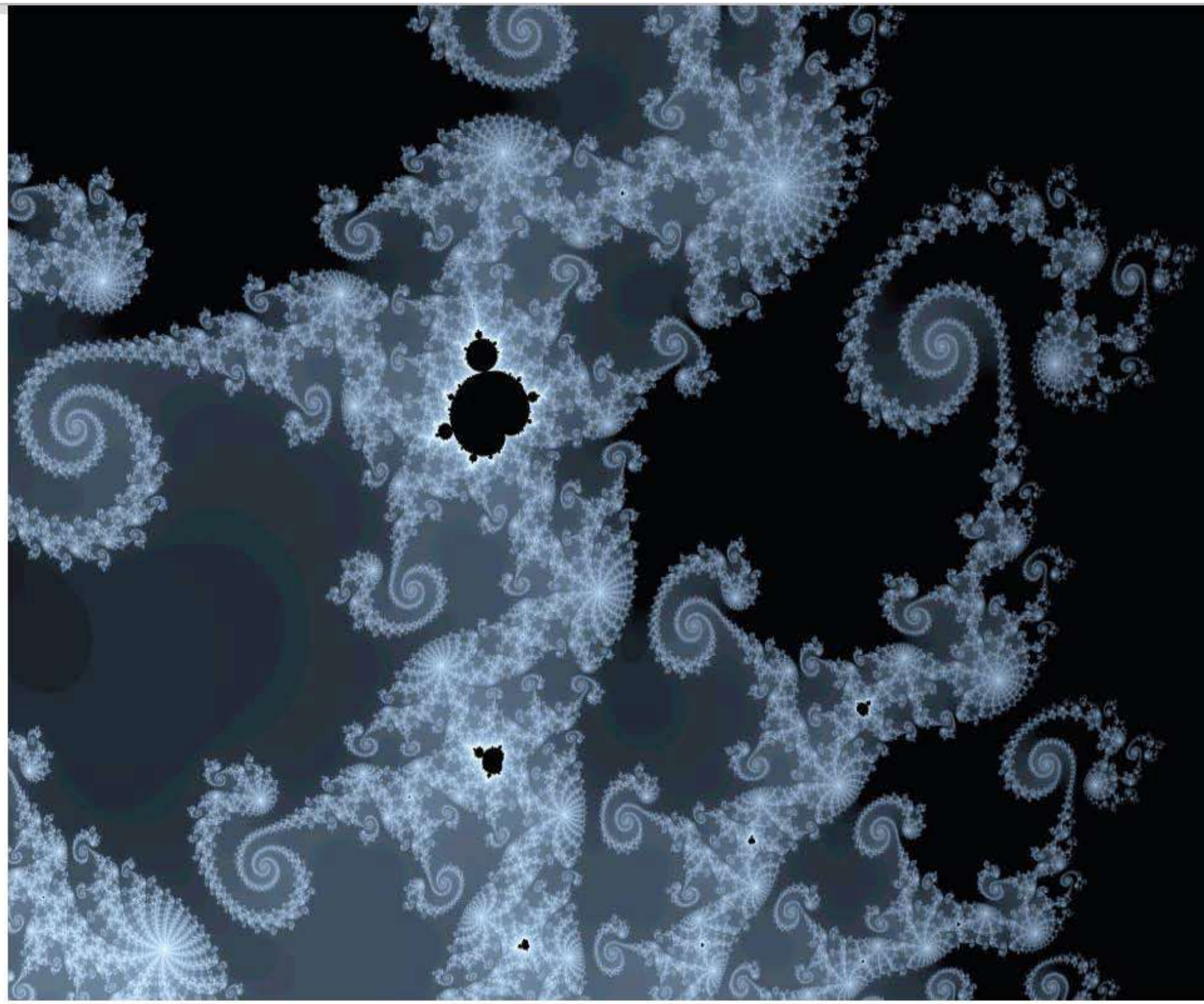


Resilience and loops

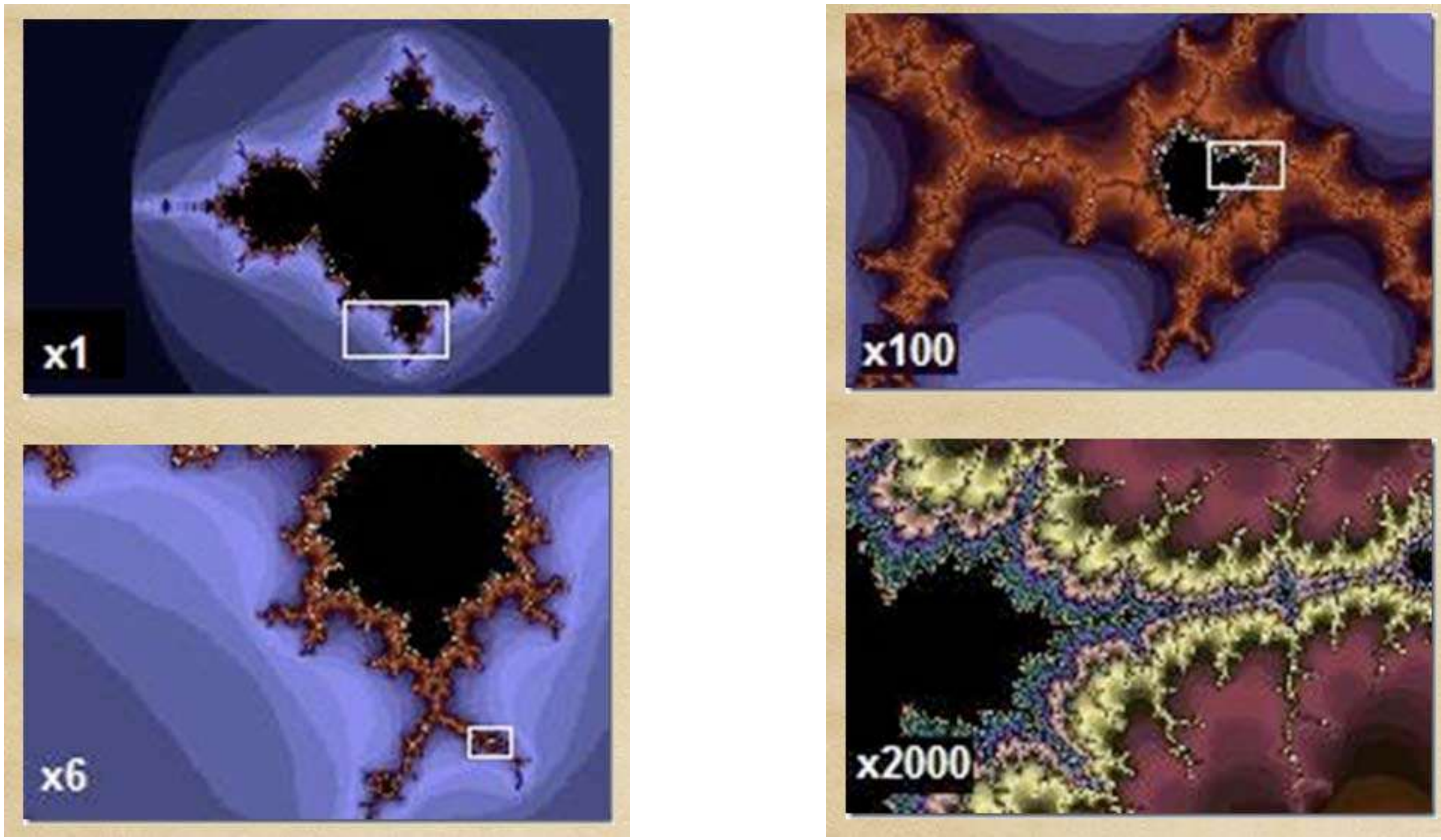
Resilience and loops



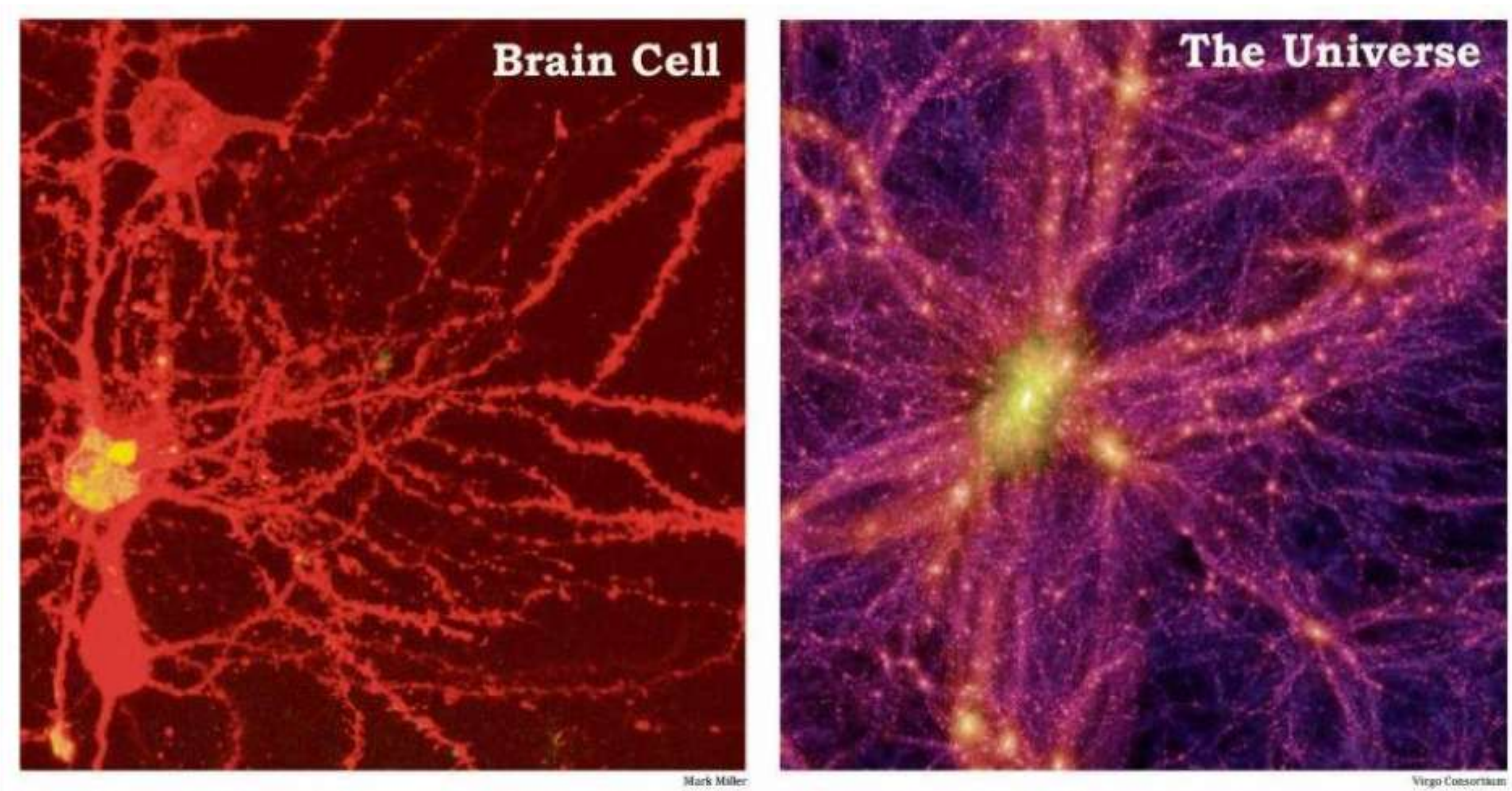
Universality of fractals



Fractal systems are scale free. They present complex self similar patterns at all scales when we zoom in and out



Our brain cells and the universe are similar scale free fractal networks



Fractal connect all scales : from galaxies to hurricanes

M51 the "Whirlpool Galaxy". Scale approximately 100,000 light years. Image Courtesy Nasa.

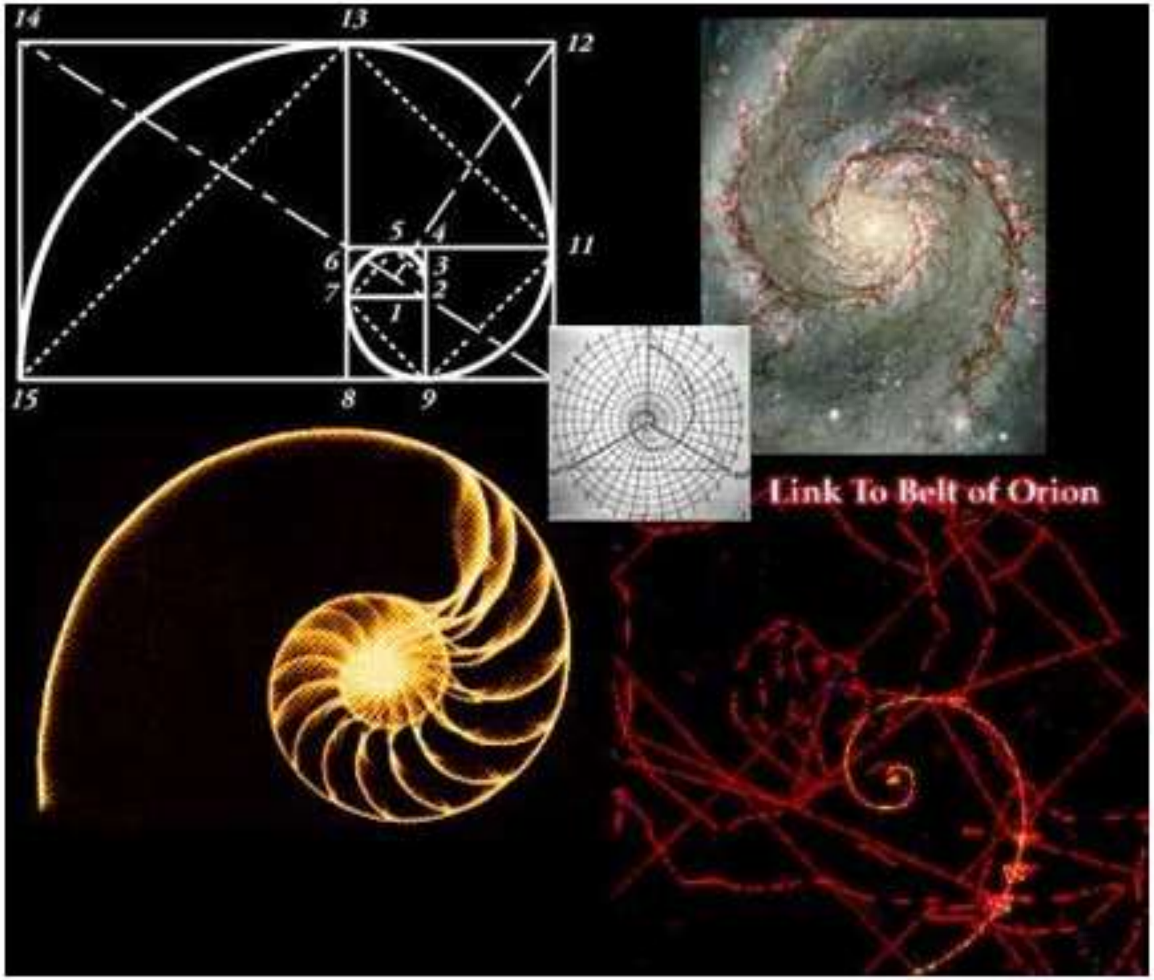
Hurricane Katrina, 2005. The state of Florida is visible for scale. Image courtesy NWS.

To flower and shell

Agave Cactus. Image courtesy of Francesco Hamamatsu.

Nautilus shell. Image courtesy of Wikimedia Commons.

Fractals are patterns of order at the edge of chaos



The universality of fractals and inverse power laws stems from dynamical chaos and from self organized critical systems

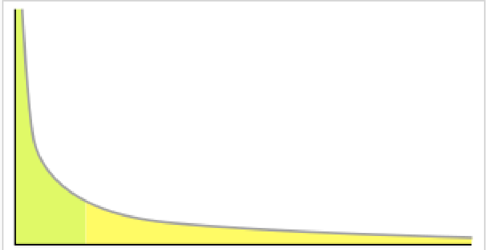
- Universality

  The equivalence of power laws with a particular scaling exponent can have a deeper origin in the dynamical processes that generate the power-law relation. In physics, for example, phase transitions in thermodynamic systems are associated with the emergence of power-law distributions of certain quantities, whose exponents are referred to as the critical exponents of the system. Diverse systems with the same critical exponents—that is, which display identical scaling behaviour as they approach criticality—can be shown, via renormalization group theory, to share the same fundamental dynamics. For instance, the behavior of water and CO_2 at their boiling points fall in the same universality class because they have identical critical exponents. In fact, almost all material phase transitions are described by a small set of universality classes. Similar observations have been made, though not as comprehensively, for various self-organized critical systems, where the critical point of the system is an attractor. Formally, this sharing of dynamics is referred to as universality, and systems with precisely the same critical exponents are said to belong to the same universality class.

Fractals are inside us

Fractals are inside us

Power law distributions



An example power-law graph, being used to demonstrate ranking of popularity. To the right is the long tail, and to the left are the few that dominate (also known as the 80-20 rule).

A **power law** is a mathematical relationship between two quantities. When the frequency of an event varies as a power of some attribute of that event (e.g. its size), the frequency is said to follow a power law. For instance, the number of cities having a certain population size is found to vary as a power of the size of the population, and hence follows a power law. There is evidence that the distributions of a wide variety of physical, biological, and man-made phenomena follow a power law, including the sizes of earthquakes, craters on the moon and of solar flares, the foraging pattern of various species, the sizes of activity patterns of neuronal populations, the frequencies of words in most languages, frequencies of family names, the species richness in clades of organisms, the sizes of power outages and wars, and many other quantities.

Scale invariance

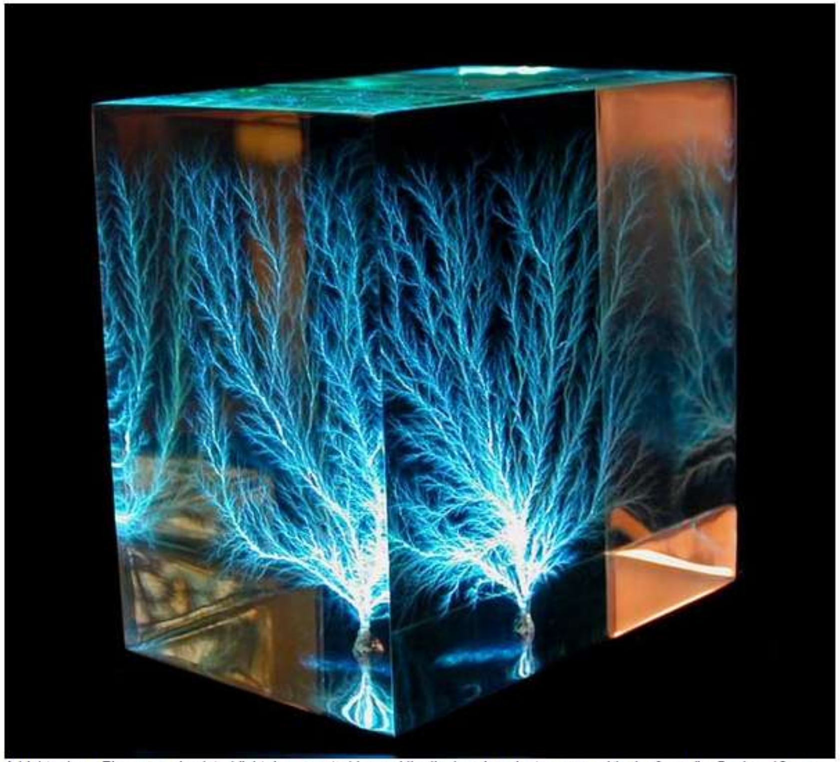
The main property of power laws that makes them interesting is their scale invariance. Given a relation $f(x) = ax^k$, scaling the argument x by a constant factor c causes only a proportionate scaling of the function itself. That is,

$$f(cx) = a(cx)^k = c^k f(x) \propto f(x).$$

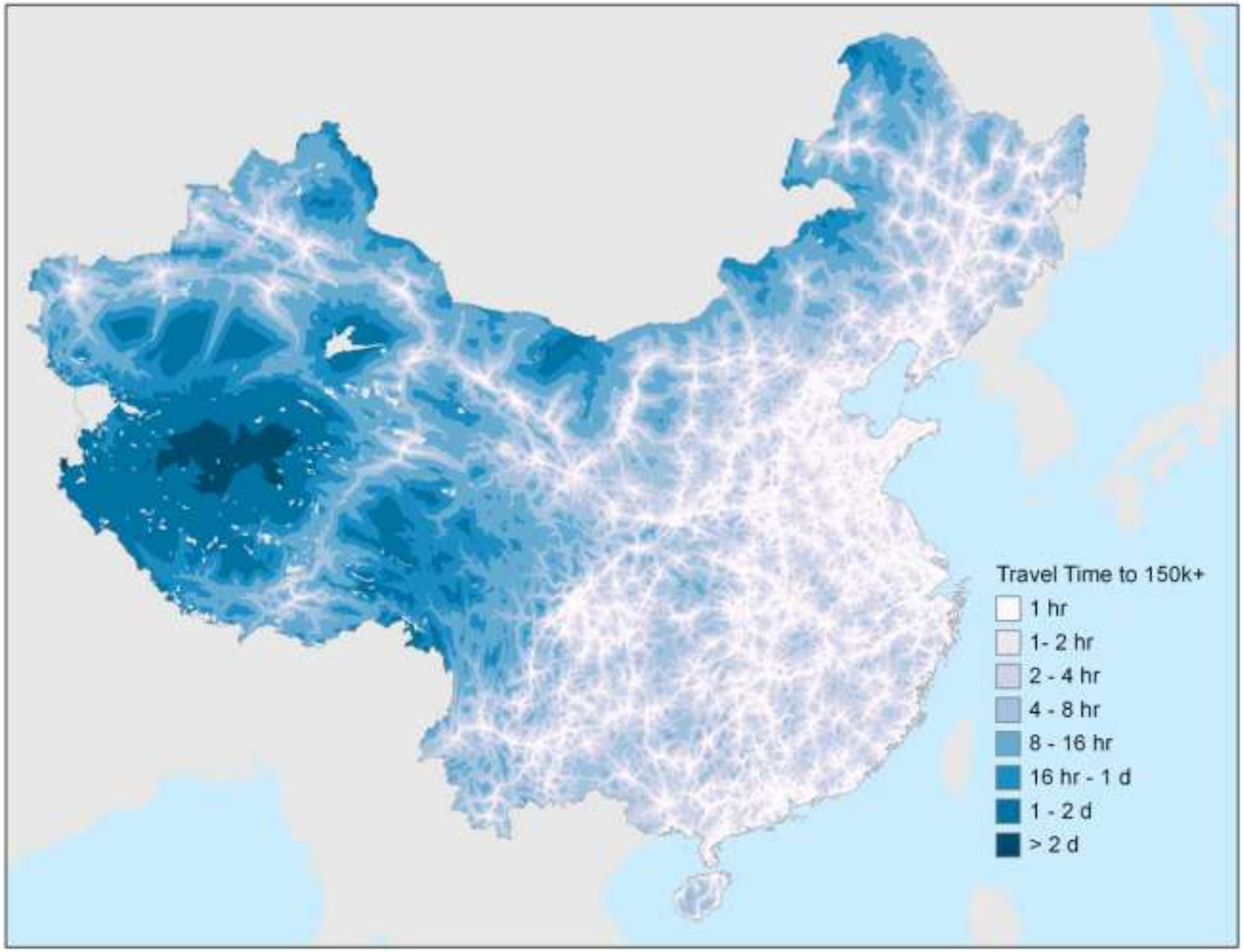
That is, scaling by a constant c simply multiplies the original power-law relation by the constant c^k. Thus, it follows that all power laws with a particular scaling exponent are equivalent up to constant factors, since each is simply a scaled version of the others. This behavior is what produces the linear relationship when logarithms are taken of both $f(x)$ and x, and the straight-line on the log-log plot is often called the *signature* of a power law. With real data, such straightness is a necessary, but not sufficient, condition for the data following a power-law relation. In fact, there are many ways to generate finite amounts of data that mimic this signature behavior, but, in their asymptotic limit, are not true power laws. Thus, accurately fitting and validating power-law models is an active area of research in statistics.

Frozen patterns of energy look like ferns

ern is an ancient, primitive plant that is made up of the same pattern at different scales.
Photo courtesy of Jonathan Wolfe.

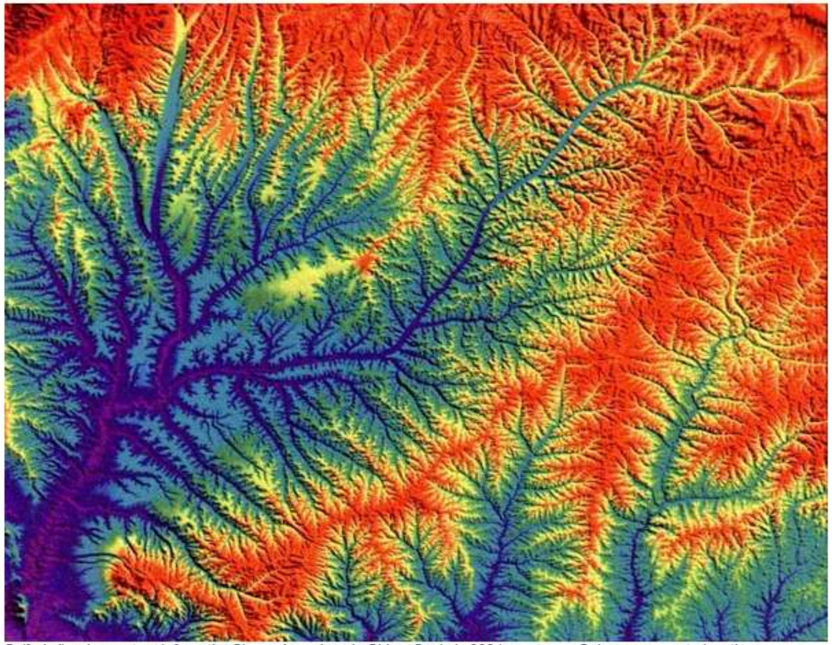


A Lichtenberg Figure, or simulated lightning, created by rapidly discharging electrons on a block of acrylic. Scale = 10 cm.
Photo courtesy of Bert Hickman, Teslamania.com.



Source: World Bank

Fractals are patterns of flows : river basins and leaves show the same type of fractal order but leaves show a higher level of connection

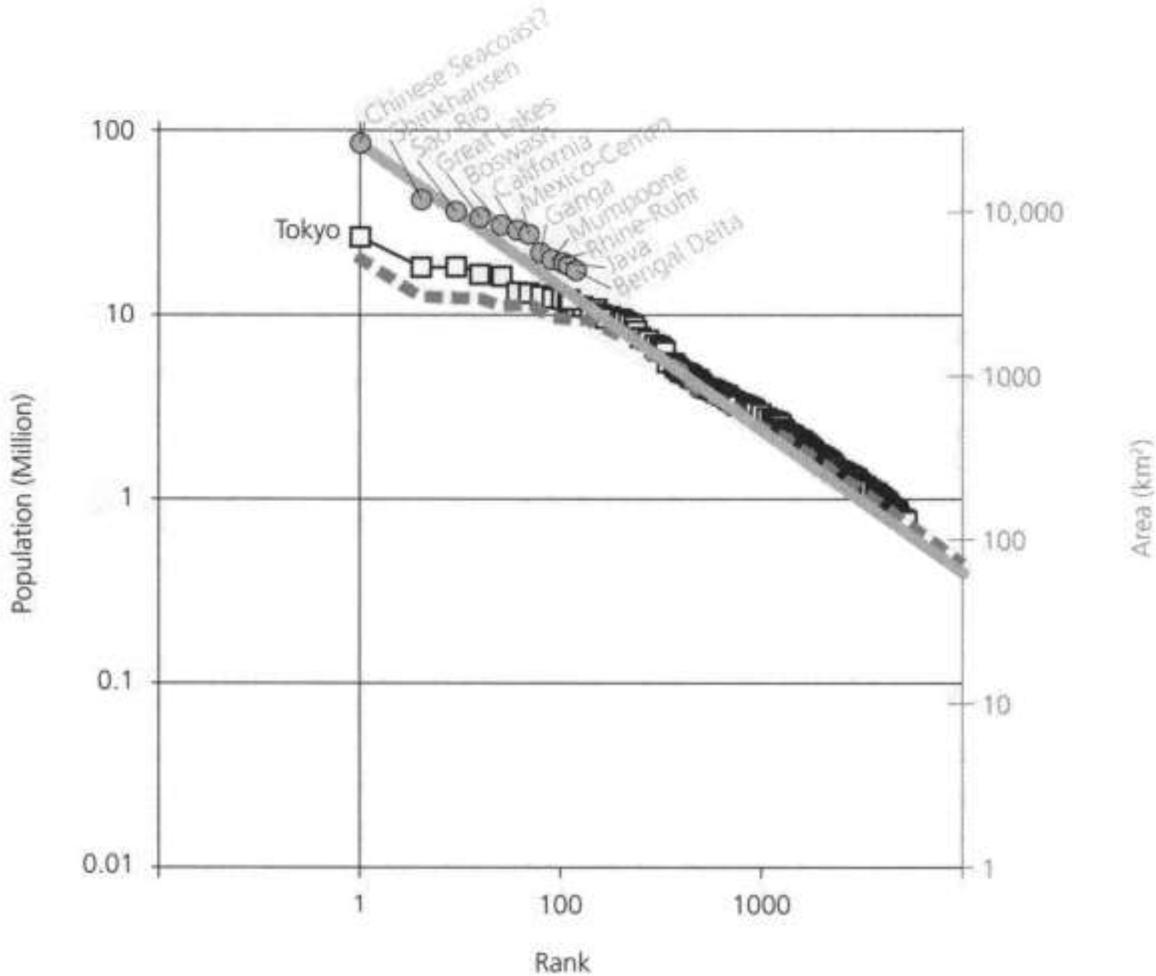


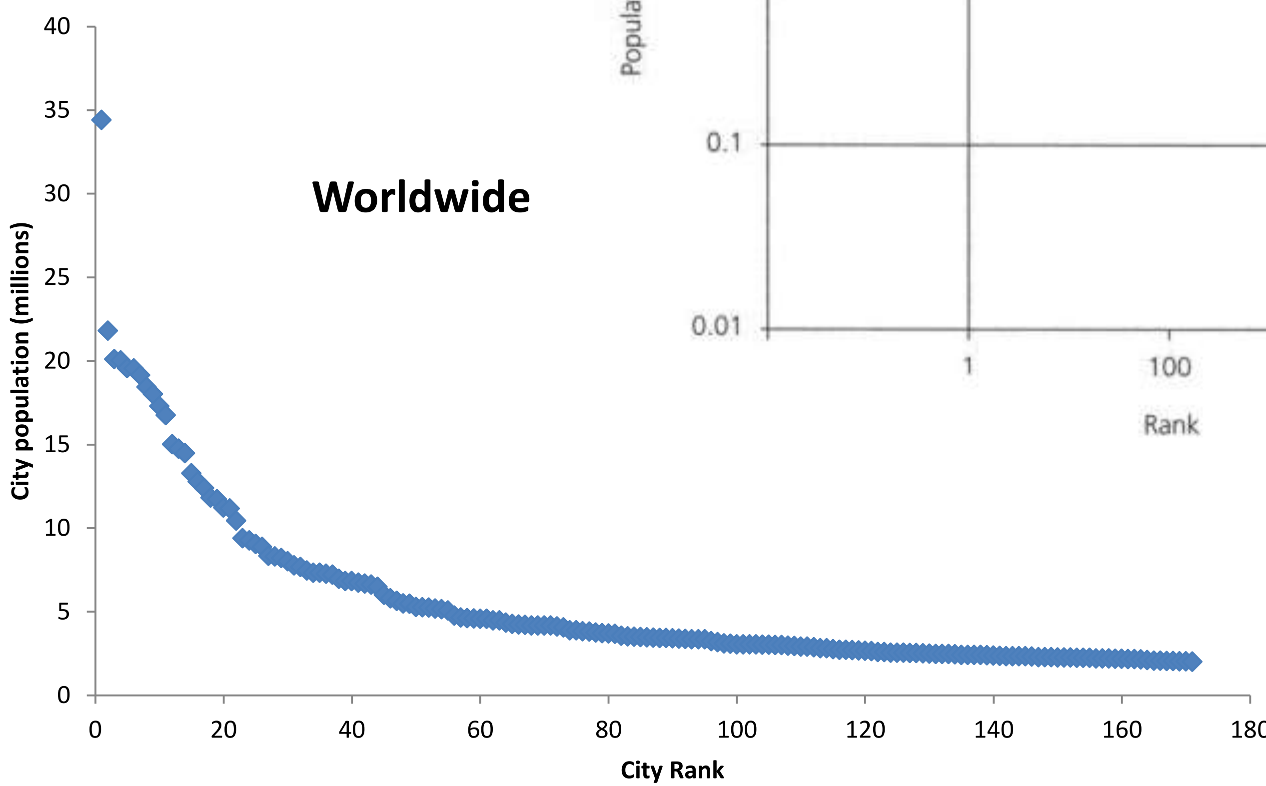
Self-similar river network from the Shaanxi province in China. Scale is 300 km across. Colors represent elevation.
Image Courtesy Bruce D. Malamud, Kings College London.

Scaling in urban systems

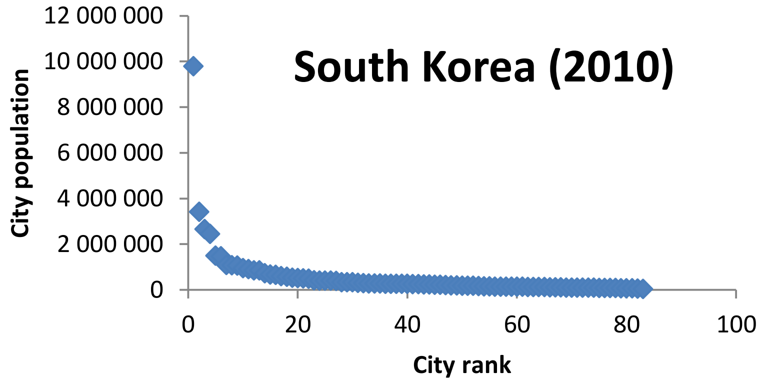
From the country scale down to the block scale

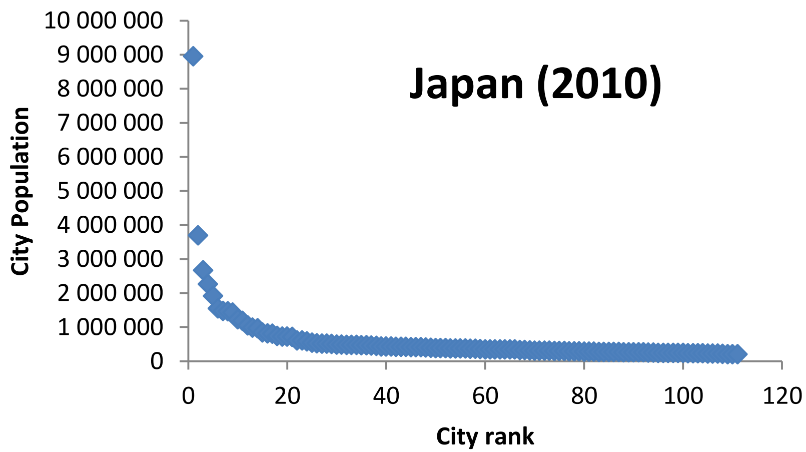
The two charts provide quantitative informations on the distribution of the global urban system. The above chart is the samed as the bottom chart, but population and rank are plotted according to their logarithm and tend to align.

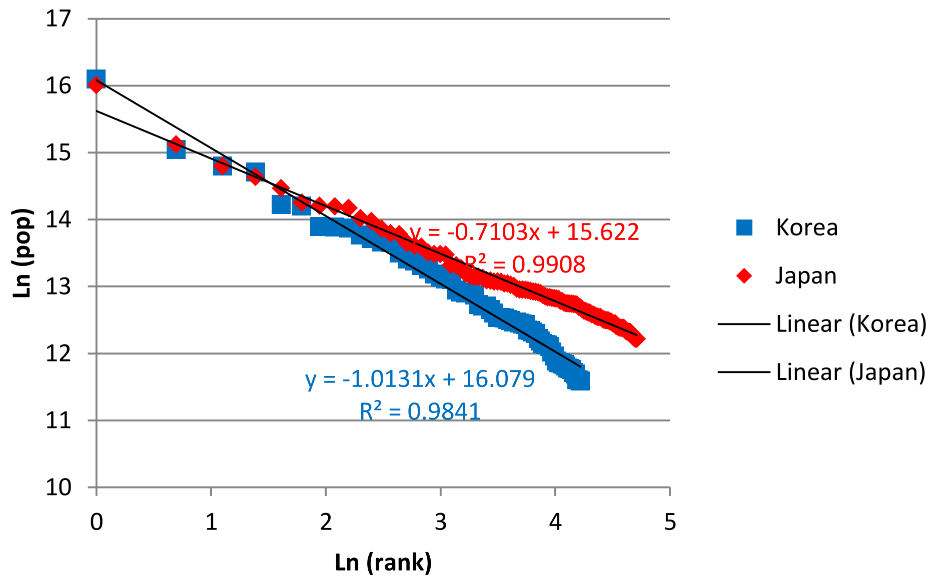




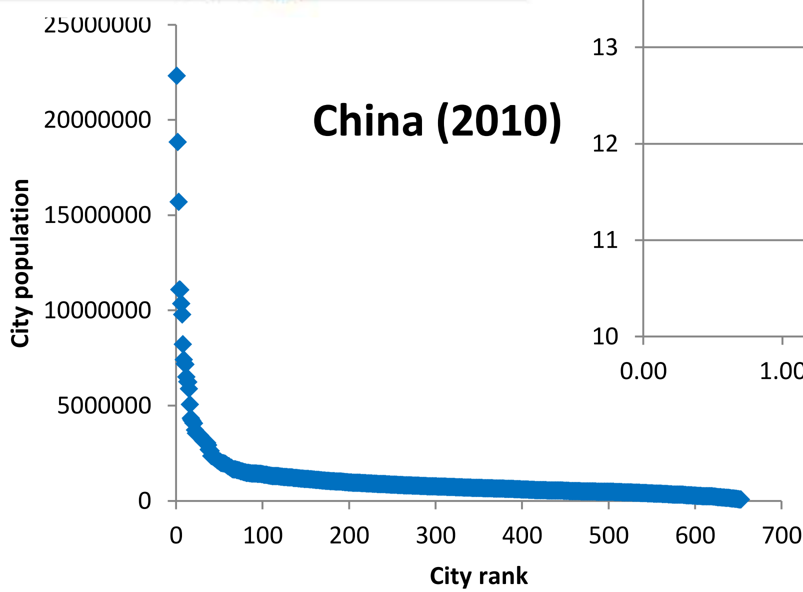
Country scale

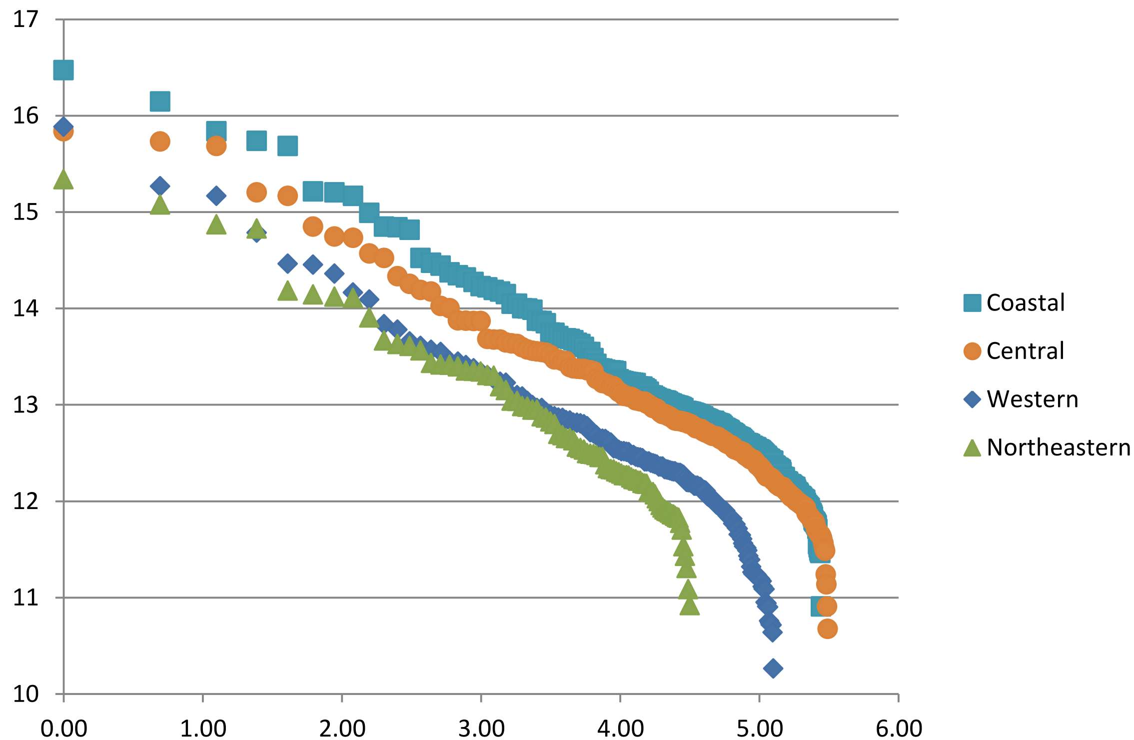




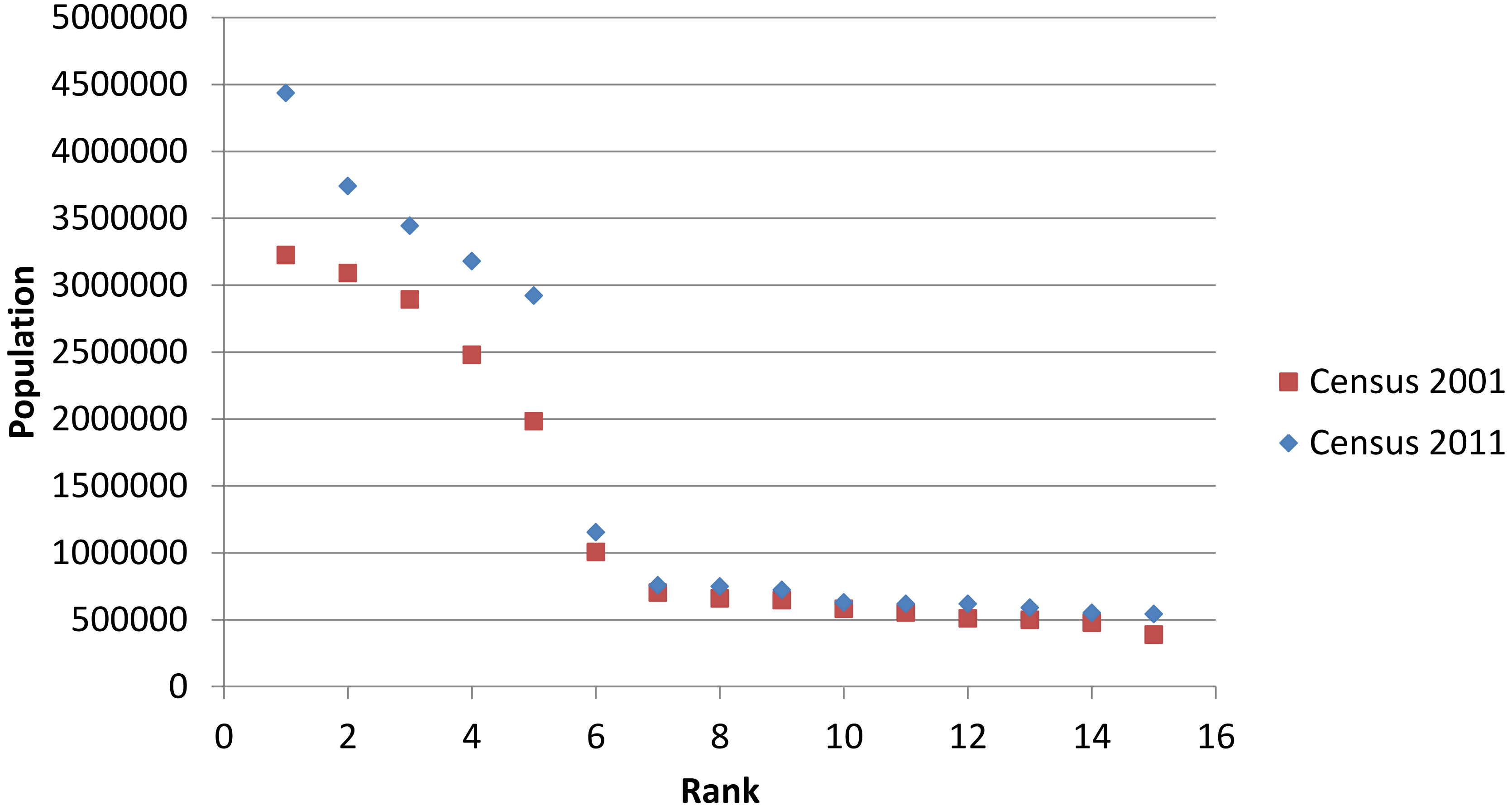


Regional scale

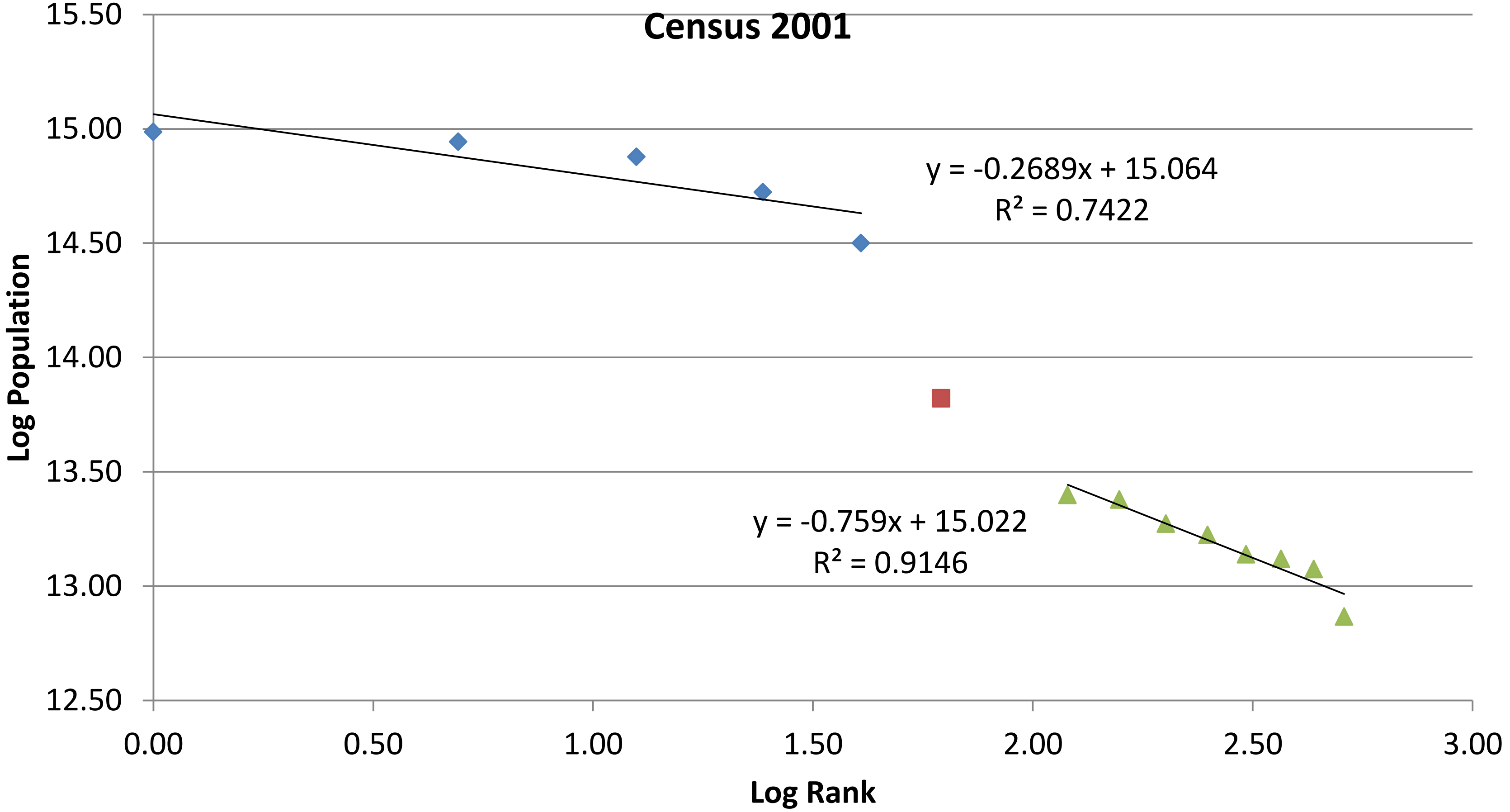




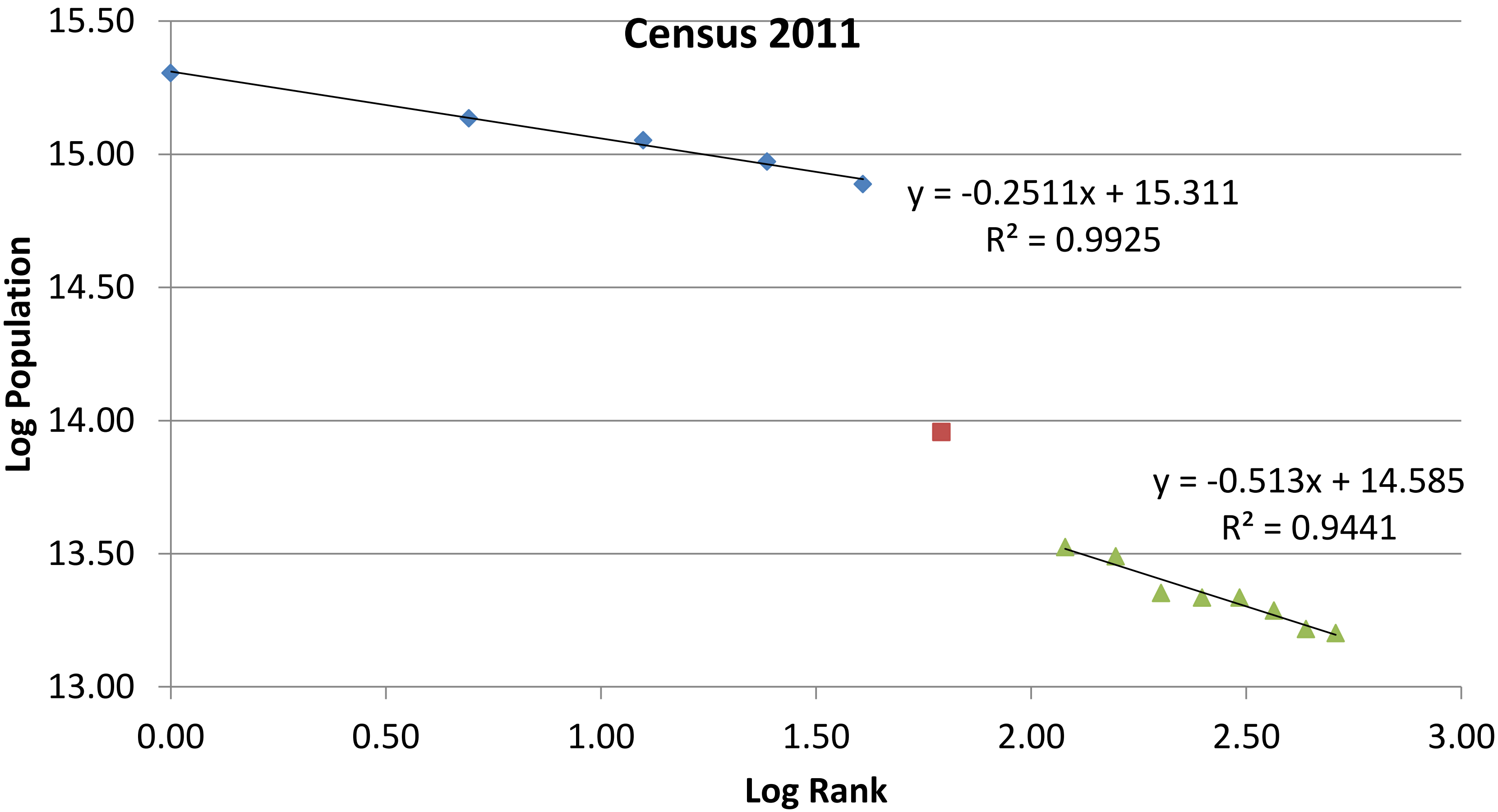
The South African urban system is dual



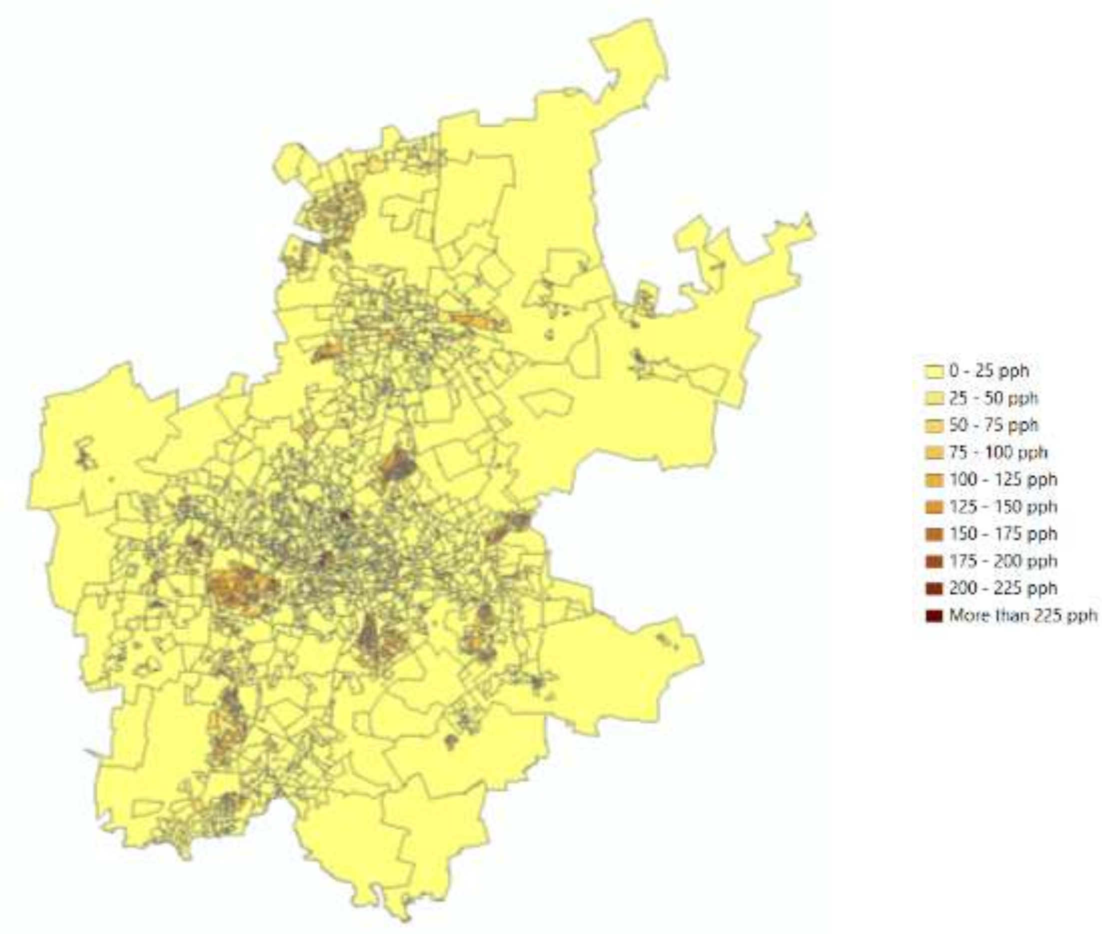
Log Rank Log Size analysis of South African Cities in 2001



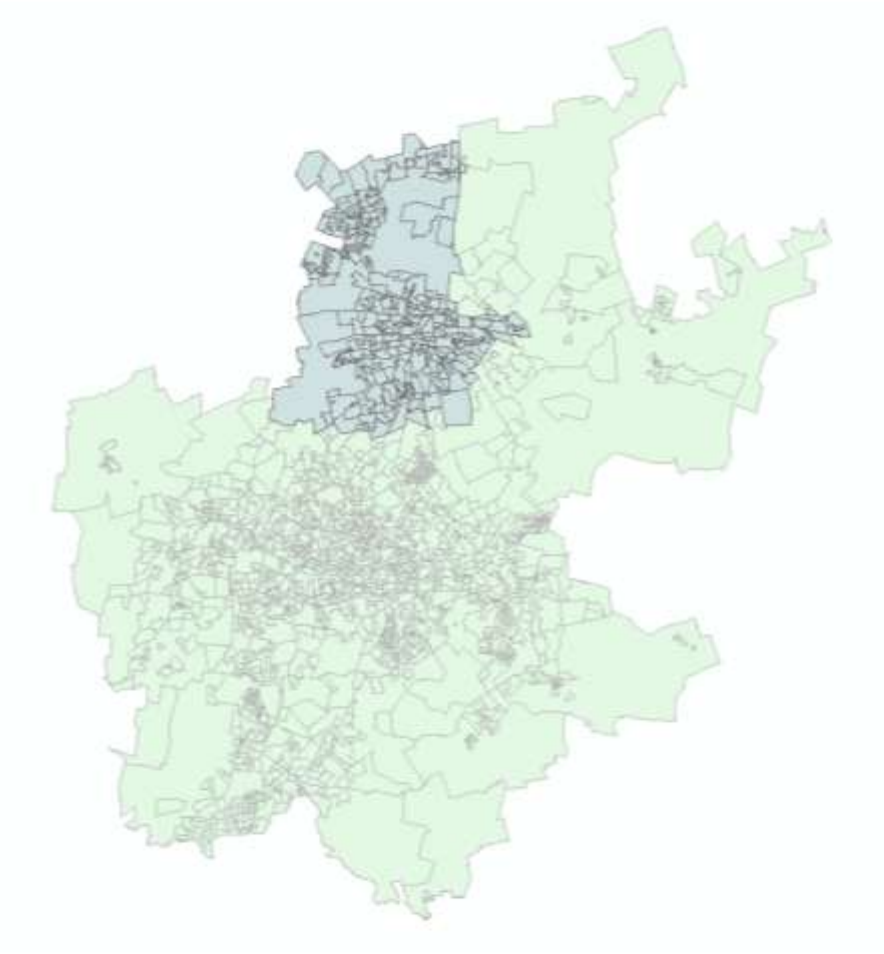
Log Rank Log Size analysis of South African Cities in 2011



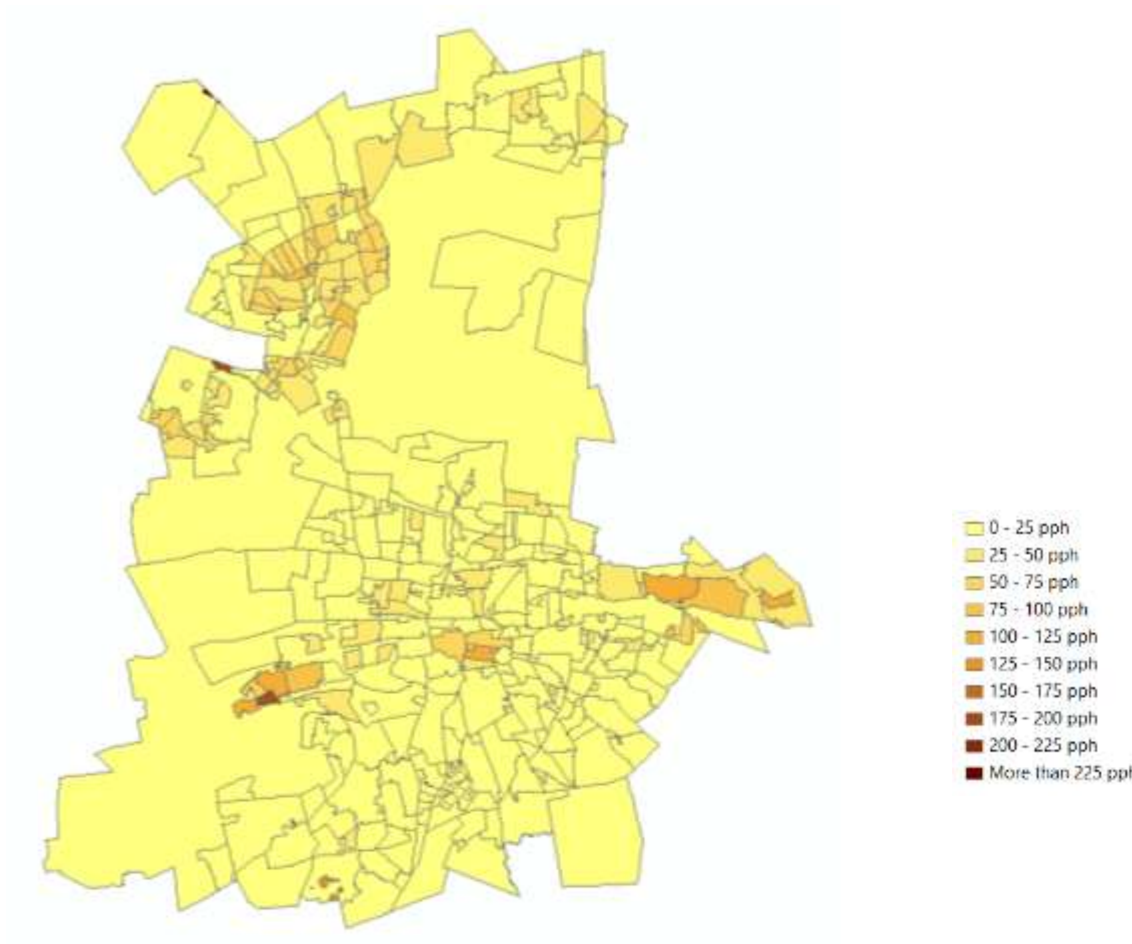
Gauteng density map (Census 2001)



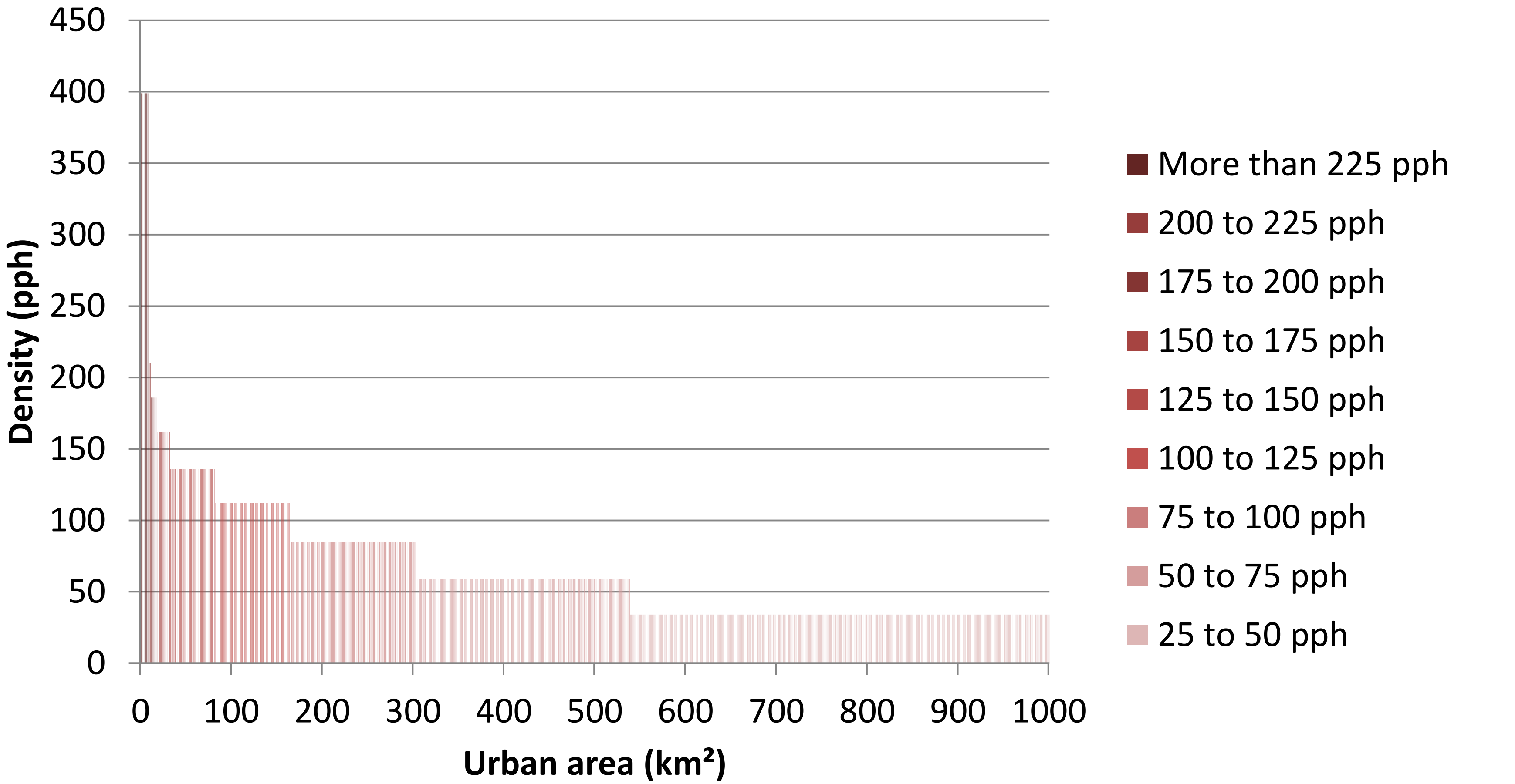
Scaling down to Tshwane



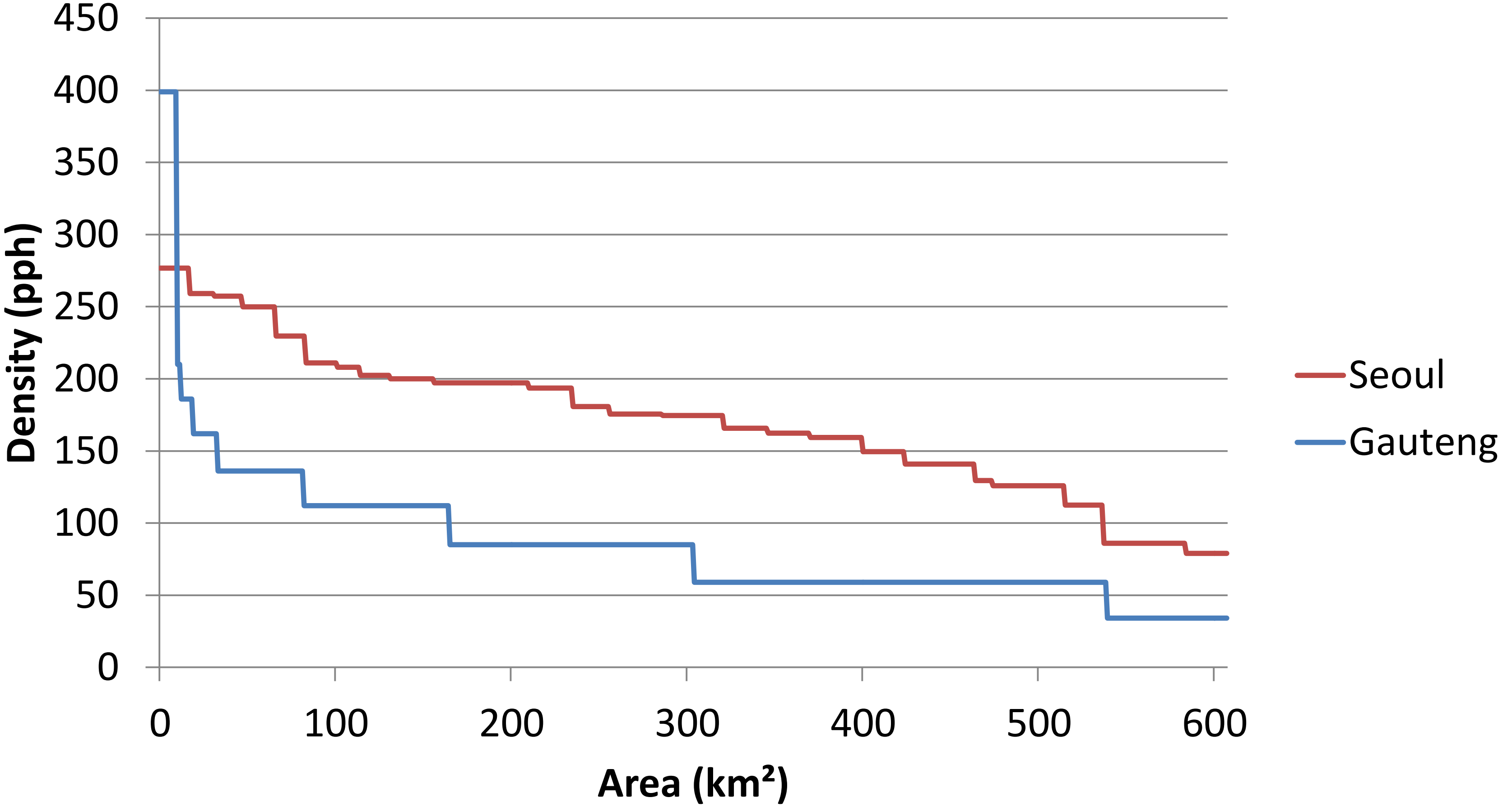
Tswahne density map (census 2001)



Density distribution in the 1000 densest km² of Gauteng, out of 16,000 km² in total



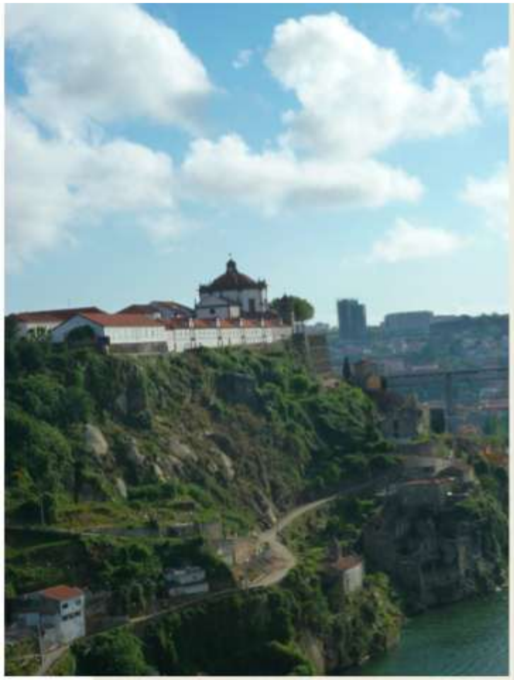
Comparison of Seoul (South Korea) and Gauteng in the densest 600 km². The densest 600 km² in Seoul host 2 times more people (10 million people) than Gauteng (5 million people)



Morphogenesis in historical cities

MORPHOGENESIS: Historical cities construct fractal landscapes through the encounter of men fractal patterns of enclosure and movement with fractal topography - PORTO





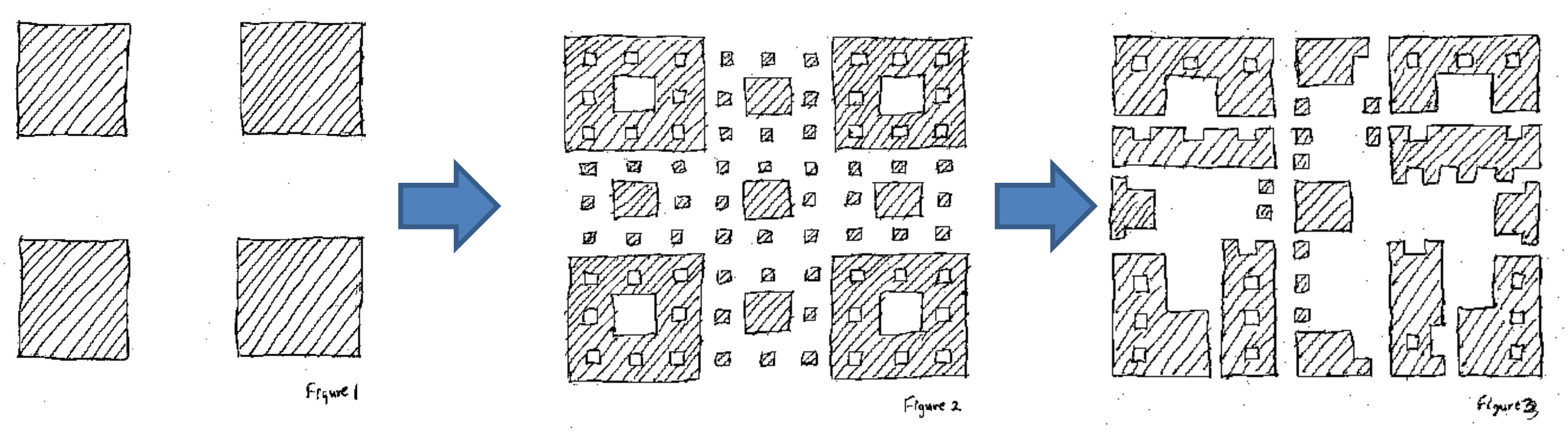


TOLETVM

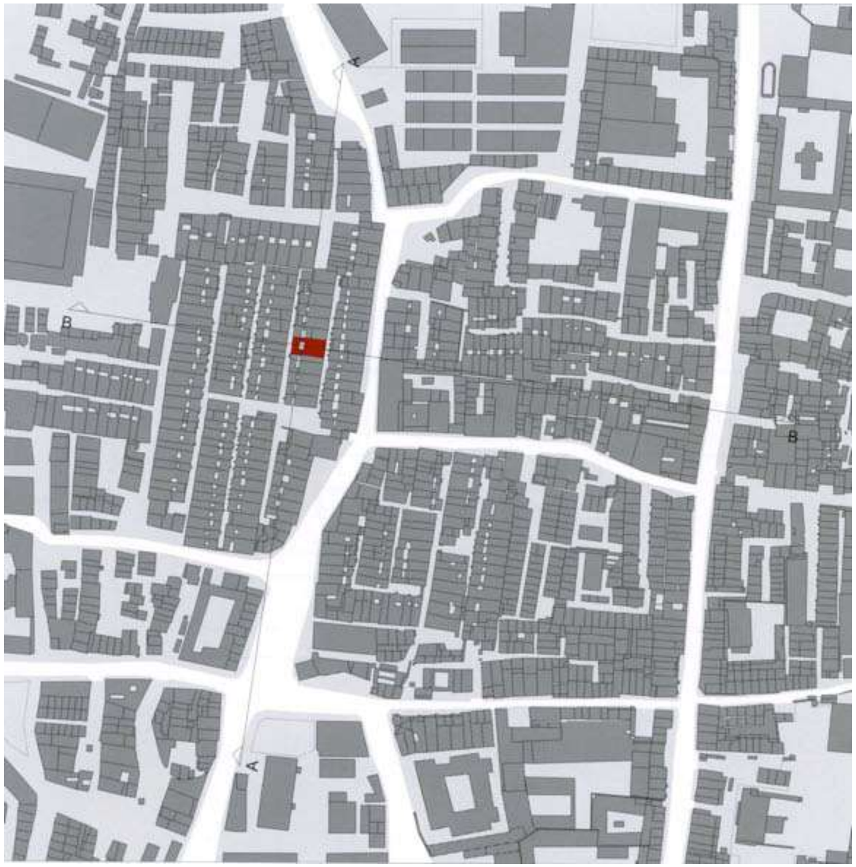
N. Salingaros

From simple urban tissues to complex fractal geometries

(from auto similarity to auto affinity)



Ahmedabad







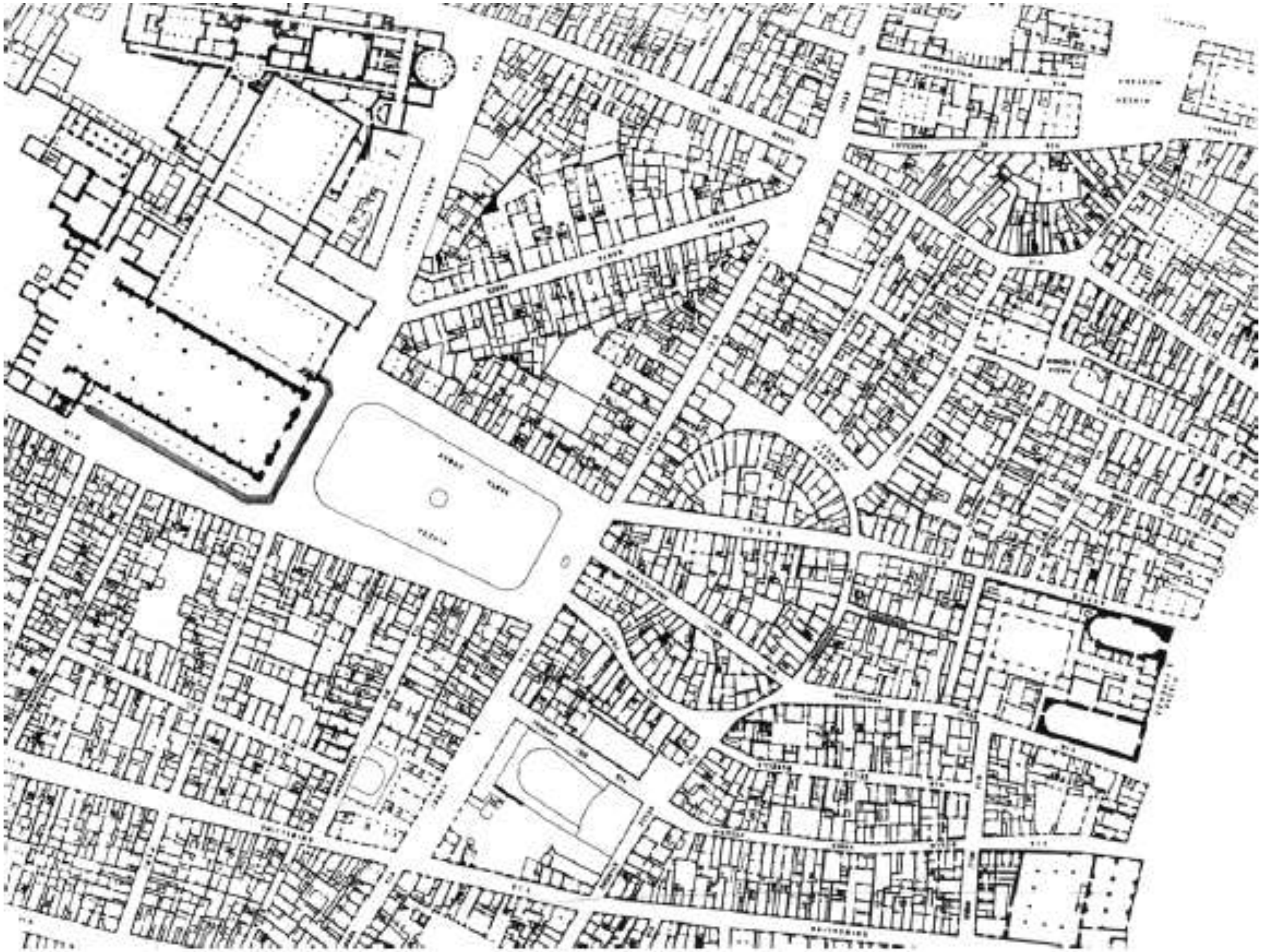


History and adaptive resilience: complex stratification versus modernist simplification

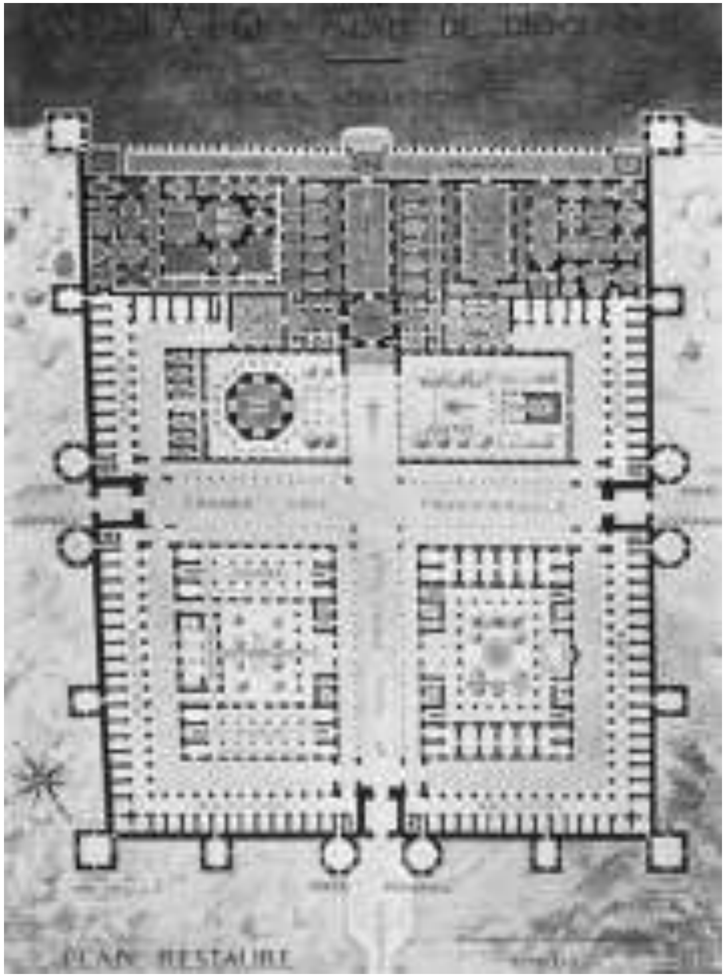
- Interaction of graph (street pattern) and map (built form) is not enough to describe the historical urban form.
- In historical urban form positive and negative space are intertwined
- Both the historical street patterns and built forms present high adaptive resilience and grow through becoming more complex even when starting from regular patterns
- Orthogonal grids can be free scale (thus fractal)


DI ROMA
TAVOLA
Porta del Popolo
Villa Borghese
Porta Pinciana
Porta Salara
Porta Pia
Porta Angelica

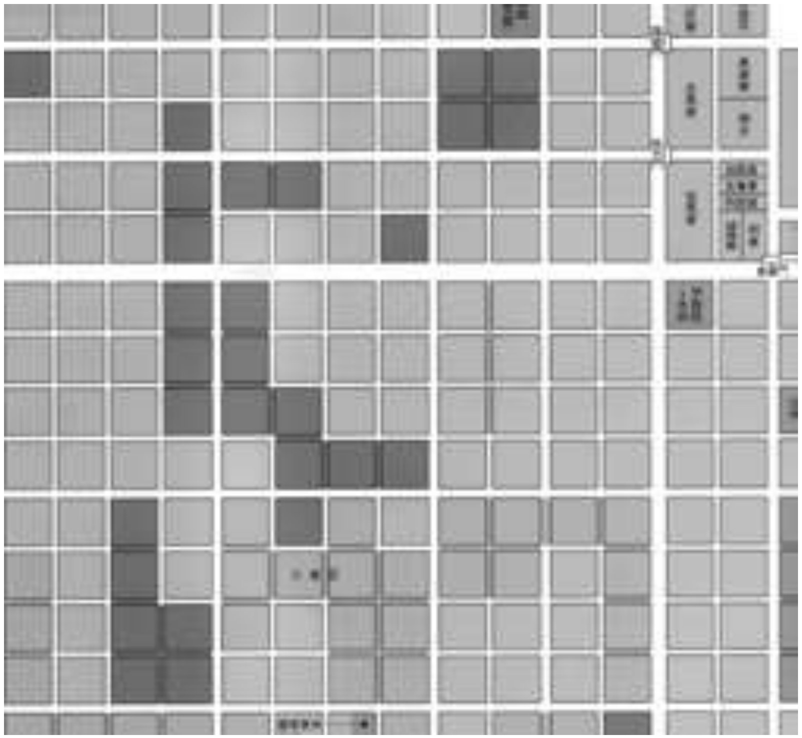
Public space in Roma is continuous, presents a high level of scale hierarchy (squares, courtyards, and building interiors
and a scale free connectedness



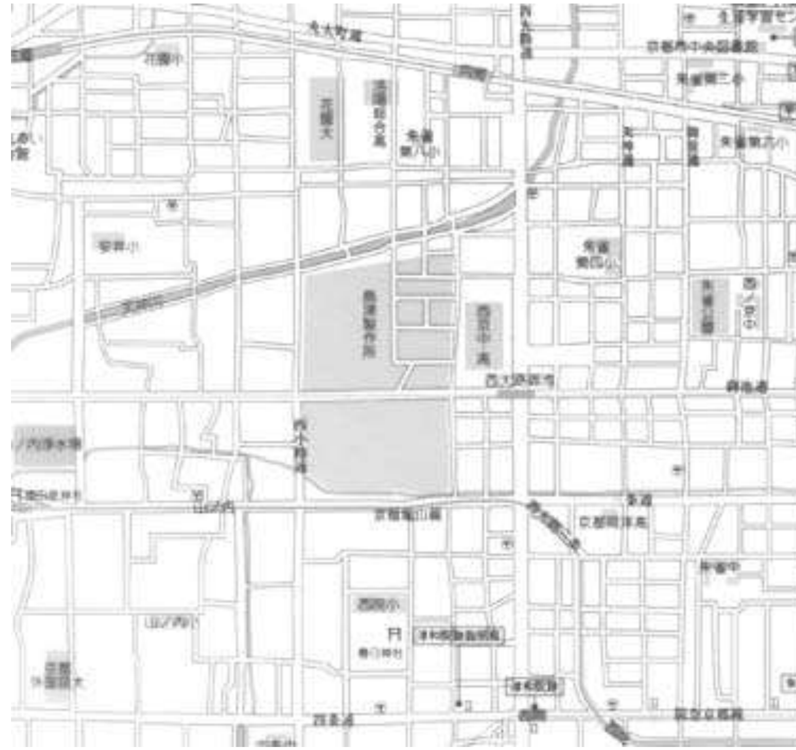
Florence, typological plan of the Santa Croce district, with the buildings constructed on the site of the Roman Amphitheater. Renaissance and medieval Florence can be read in present day Florence urban fabric, which became more complex without effacing the traces, still visible here, of a Roman Amphitheater



Spalato, Palace of Diocletian. Reconstitution of the ancient plan and the plan today. From a complex Euclidean pattern (H. Simon Chinese boxes) to a fractal pattern

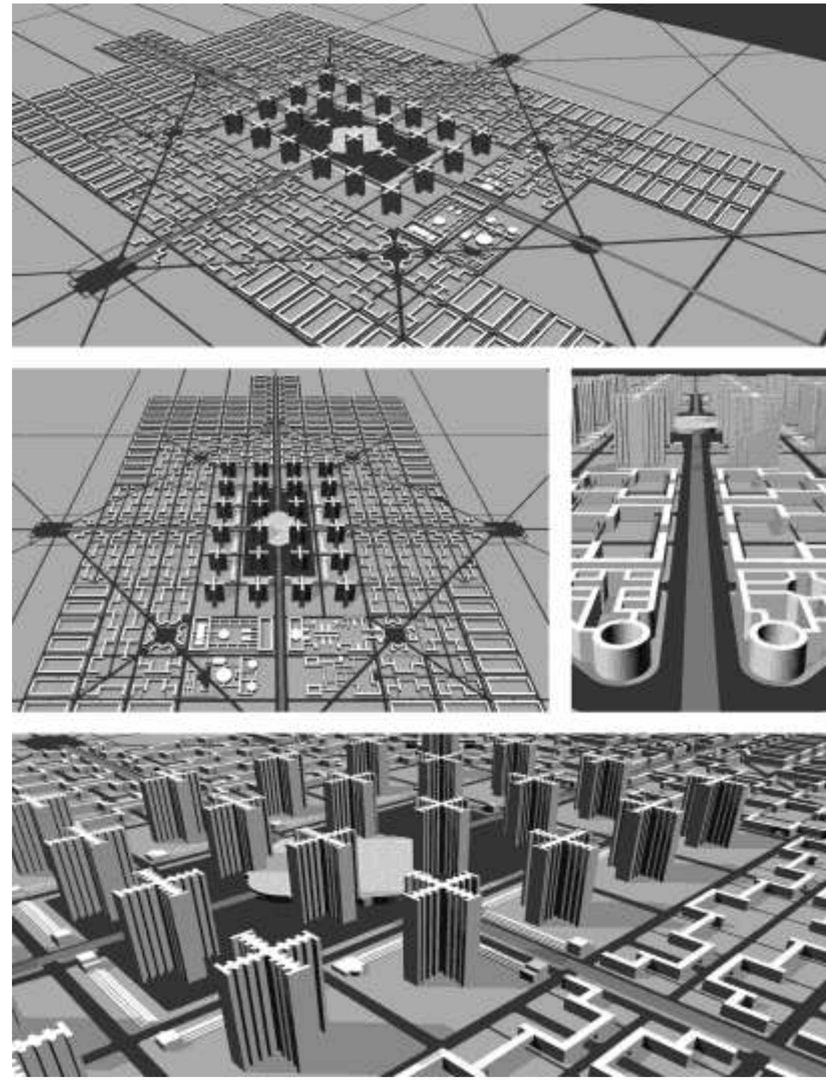


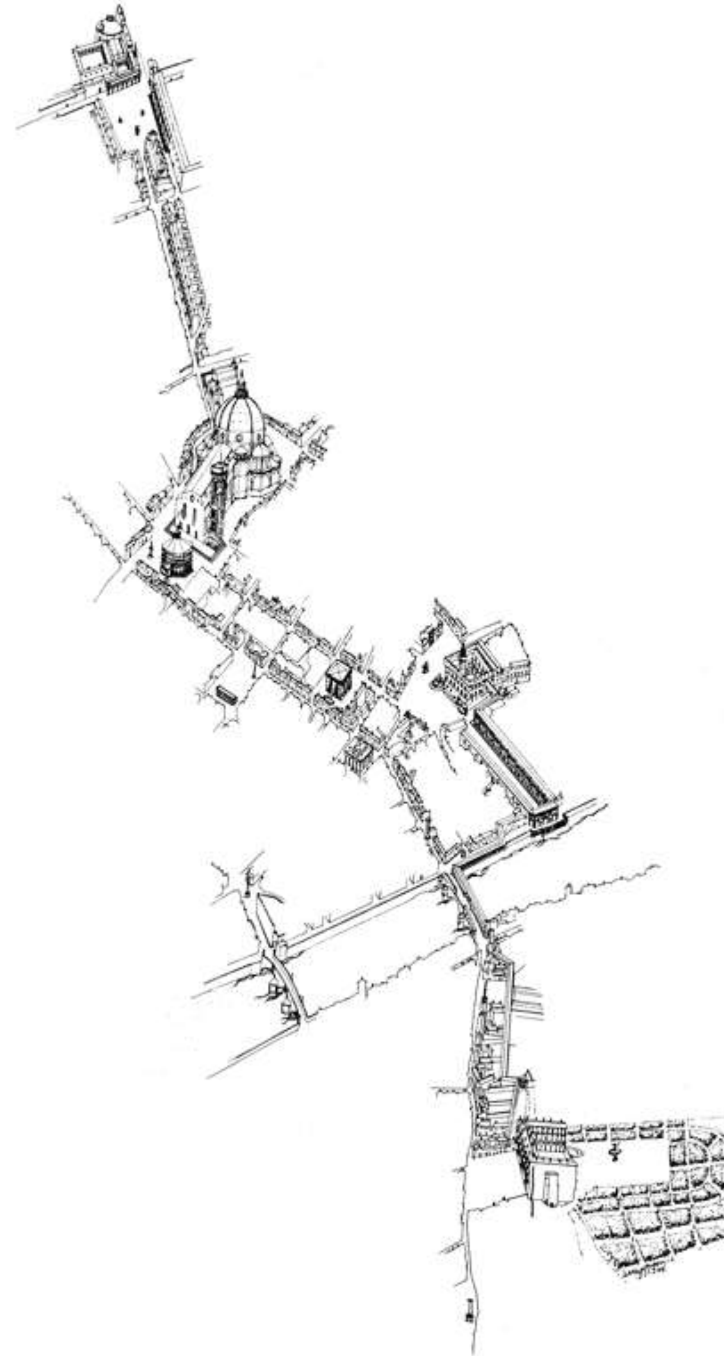
From Heiankyo

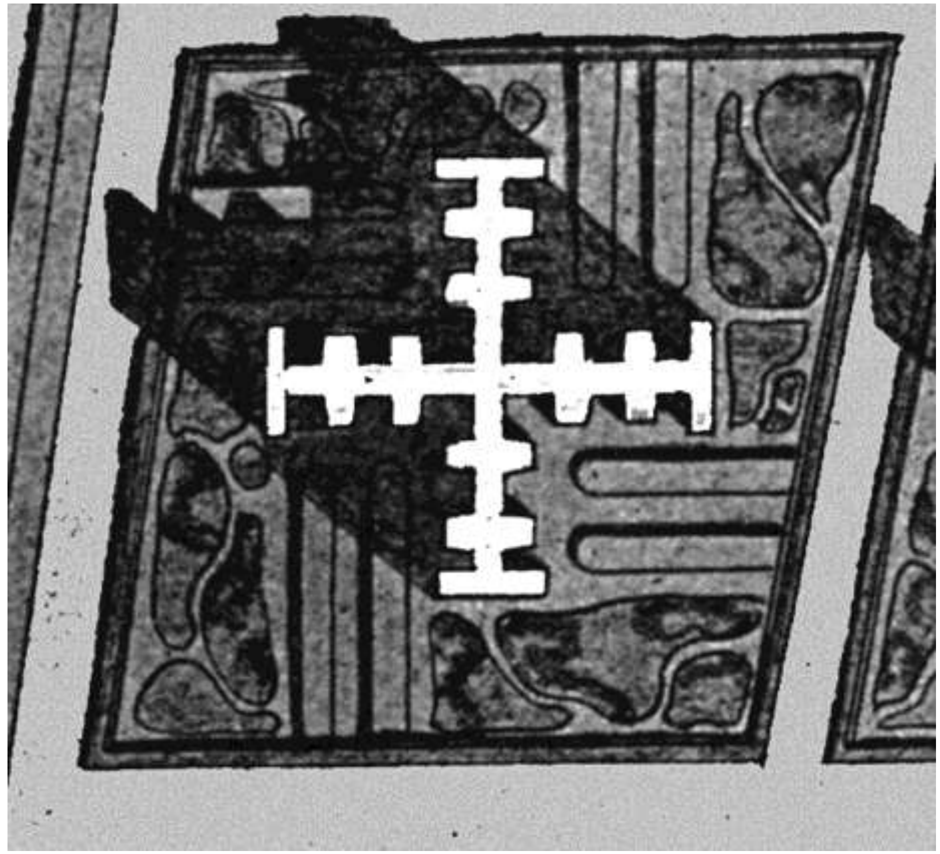


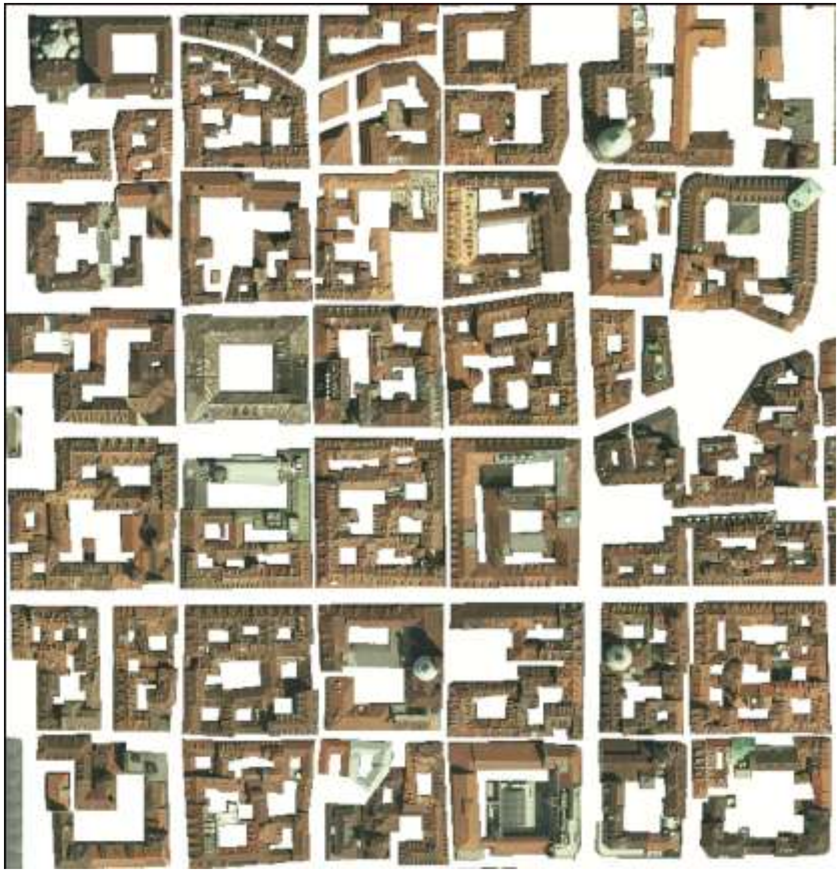
to Kyoto

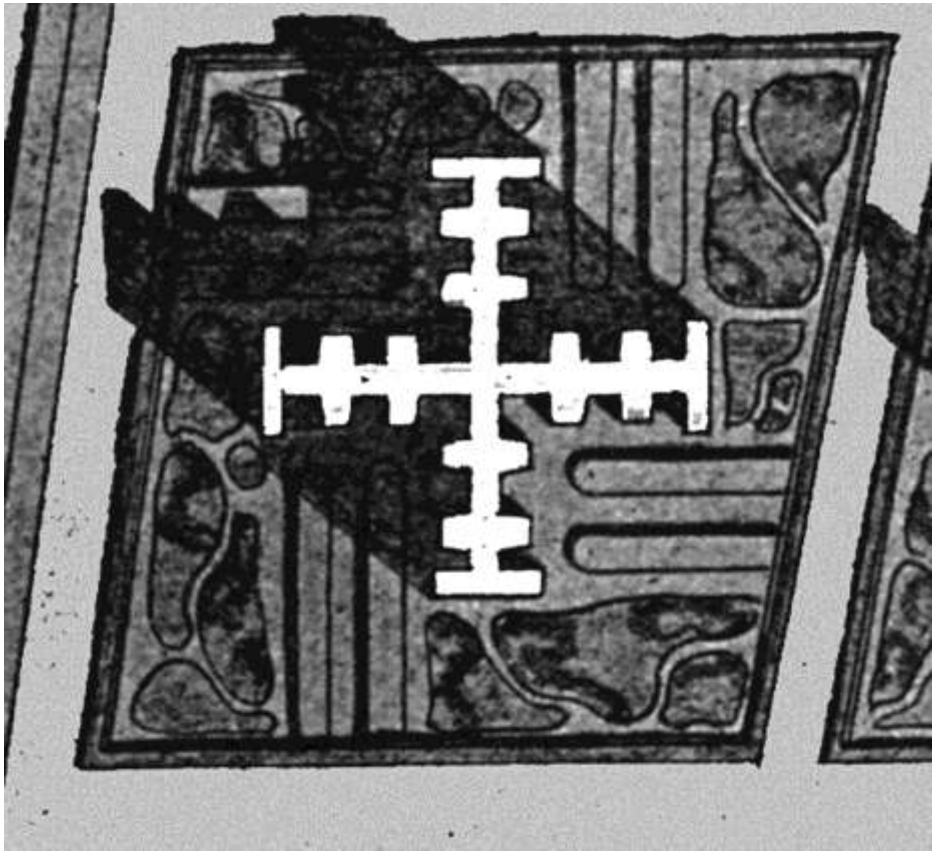
Modernism turned its back to fractals and to the resilience of all evolutionary structures



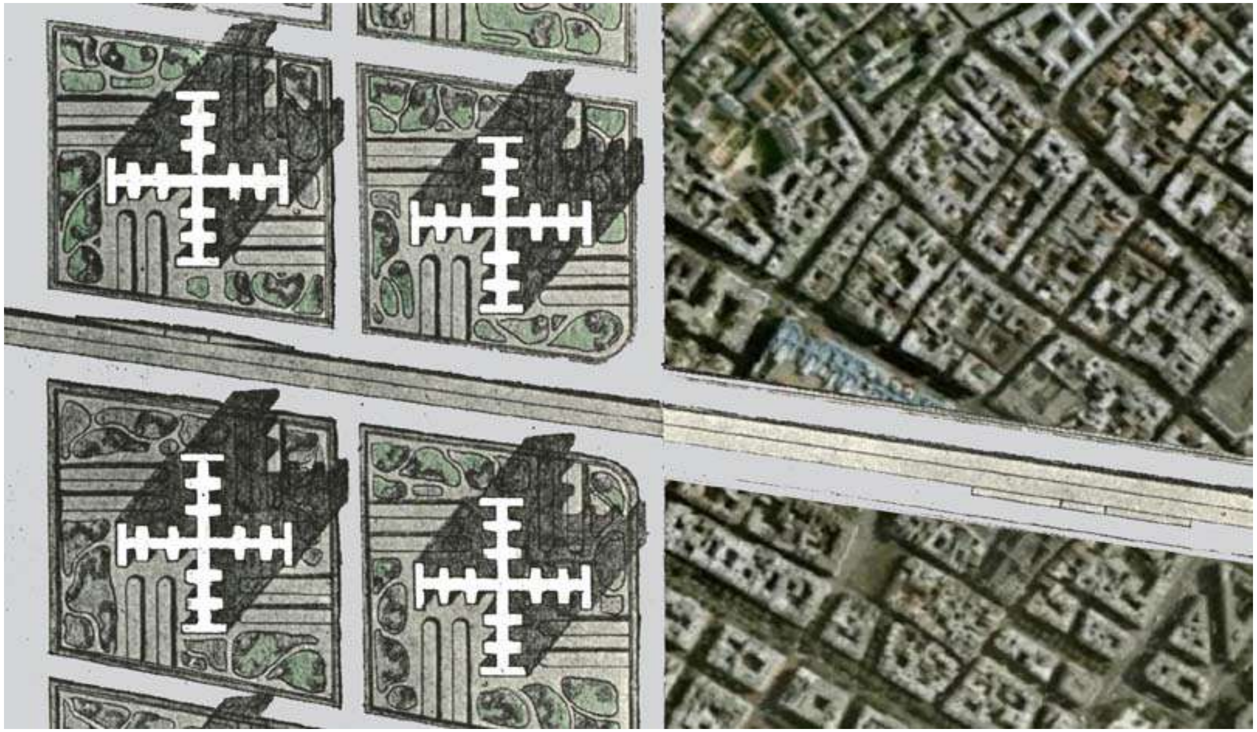




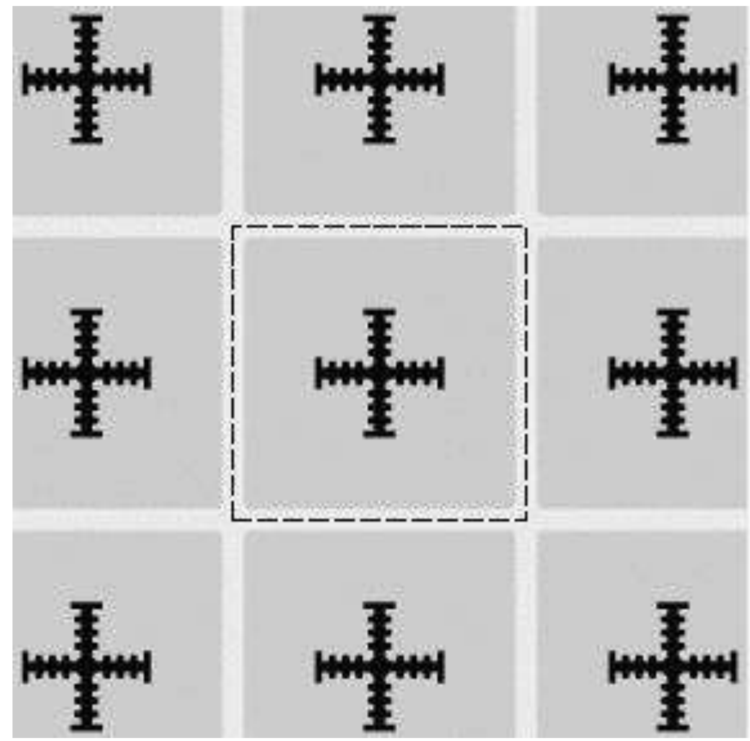


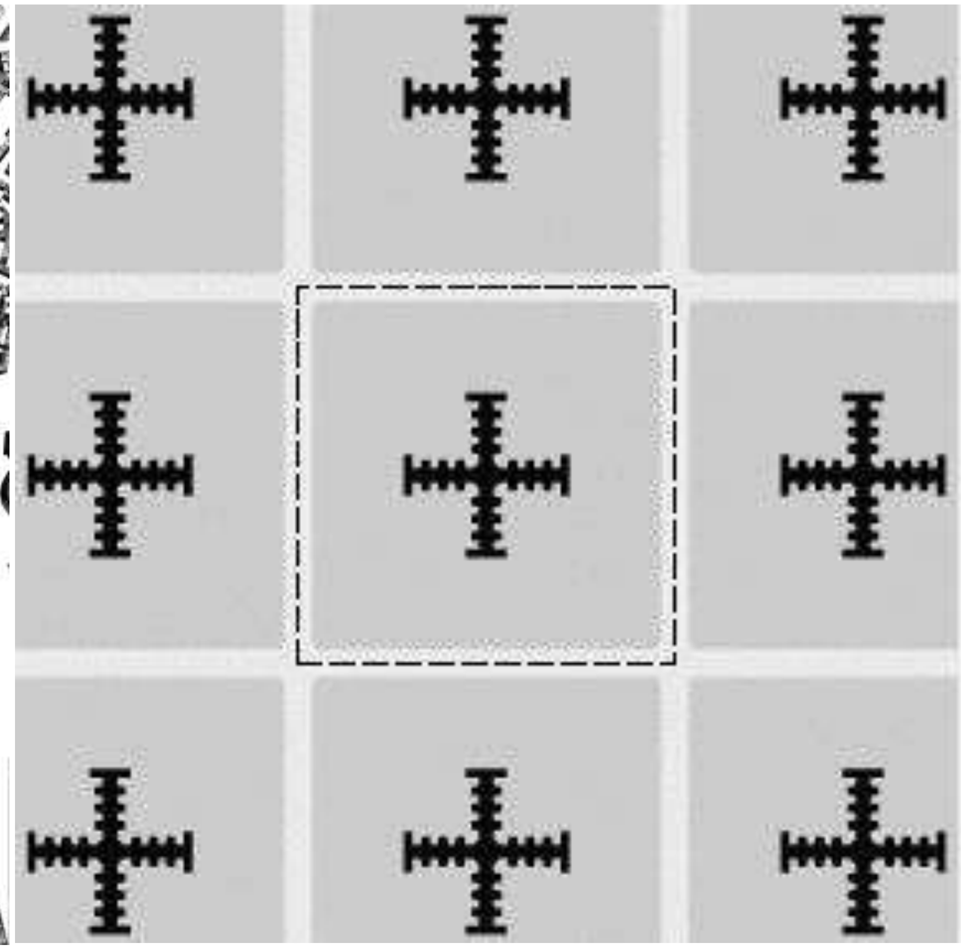


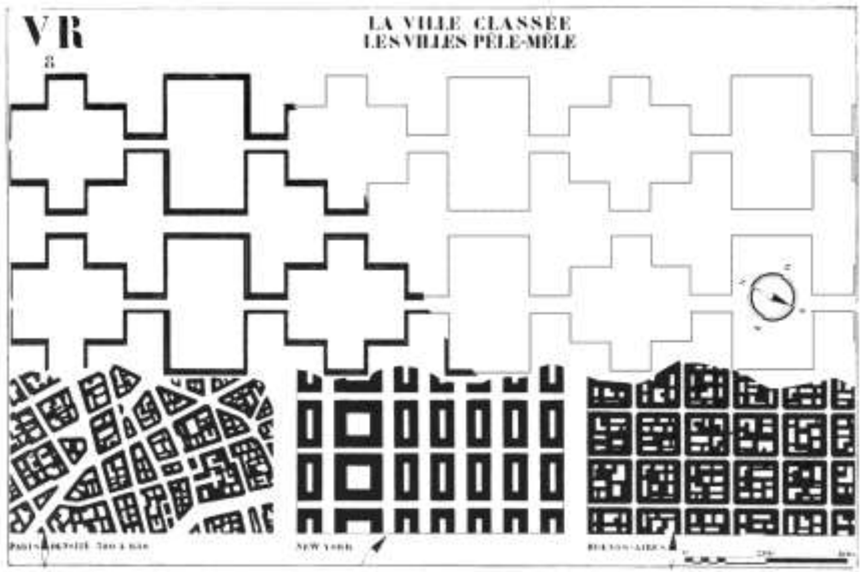
The 20th century modernist movement has simplified the city

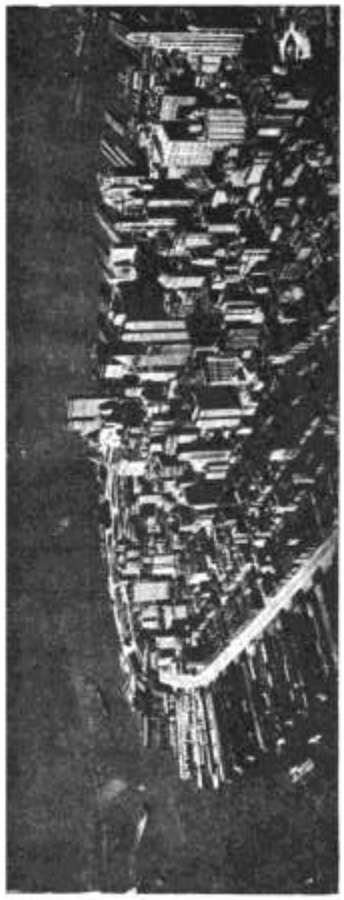


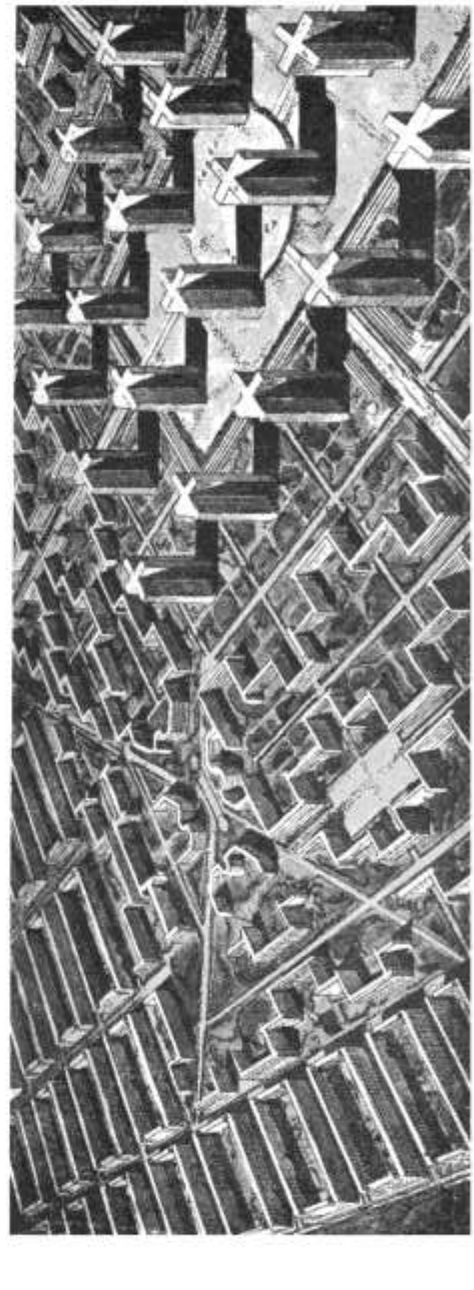
Non resilient Corbusean structure versus resilient Paris urban fabric




VR
8
LA VILLE CLASSÉE
LES VILLES PÊLE-MÊLE
NEW YORK



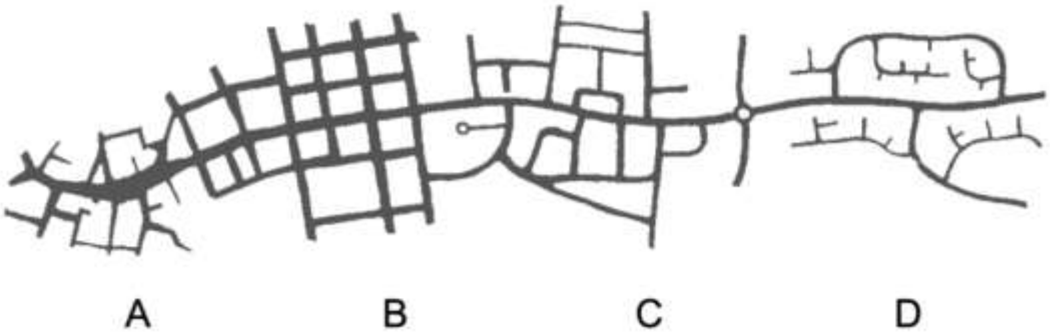


A la même échelle et sous un même angle, vue de la *Cité* de New-York et de la Cité de la « Ville contemporaine ». Le contraste est saisissant.

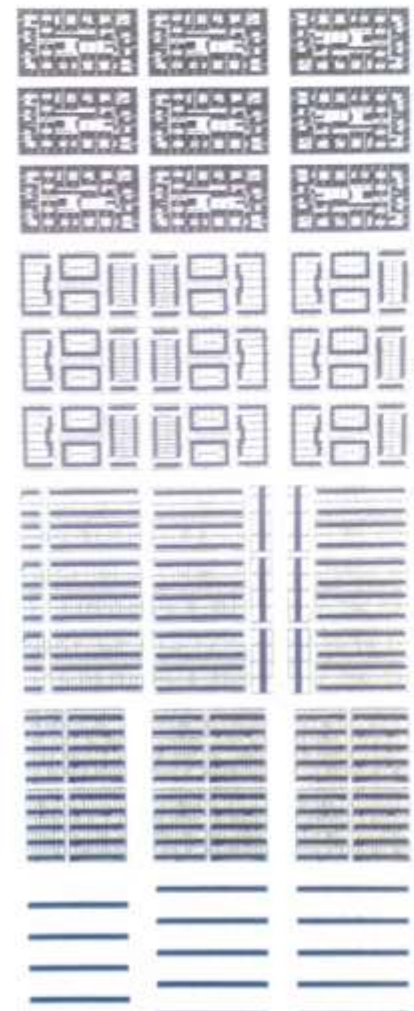
A double loss: of connectedness of street patterns, of scale hierarchy of the urban block

La ville et ses formes

Evolution des morphologies urbaines:
De l'îlot à la barre et à l'urban sprawl...



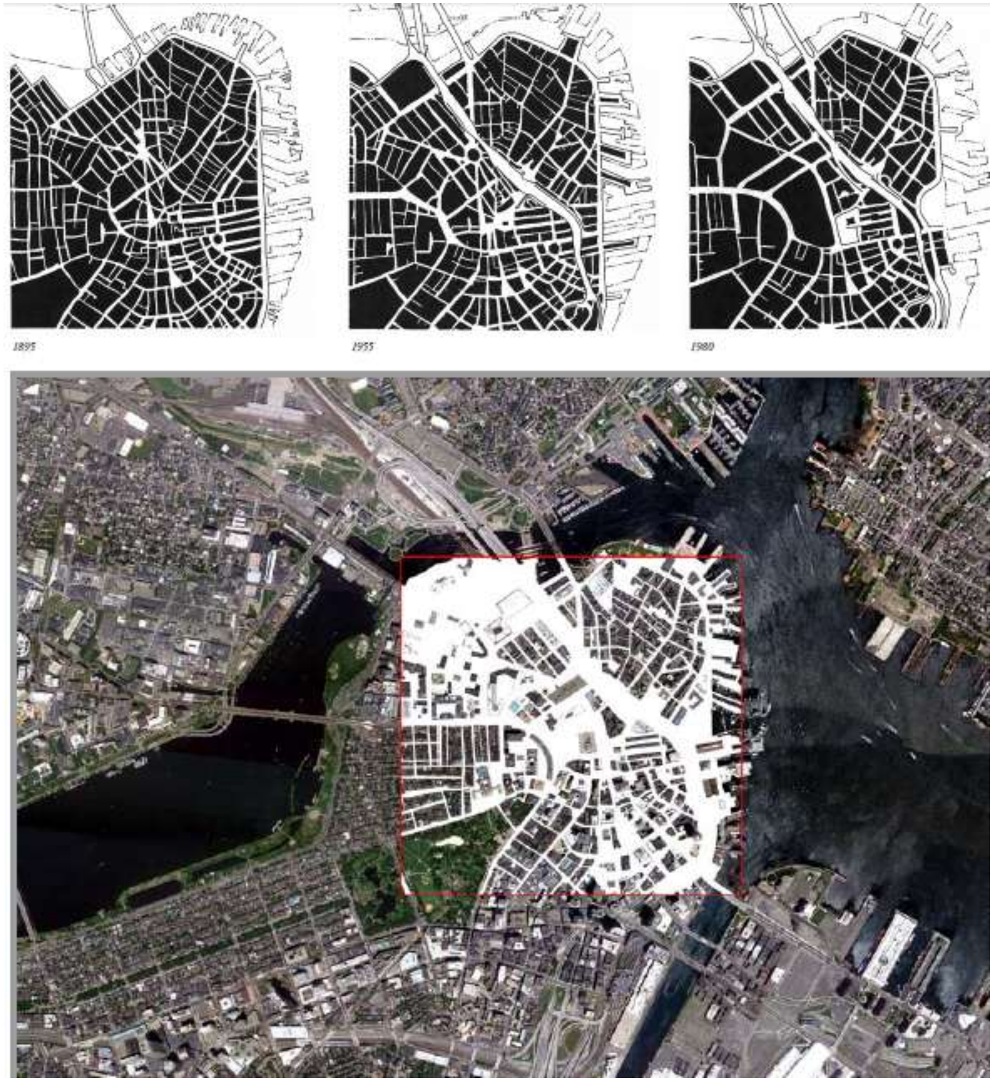
Evolution des motifs de rues et des tissus urbains, Source: S. Marshall, Streets & patterns



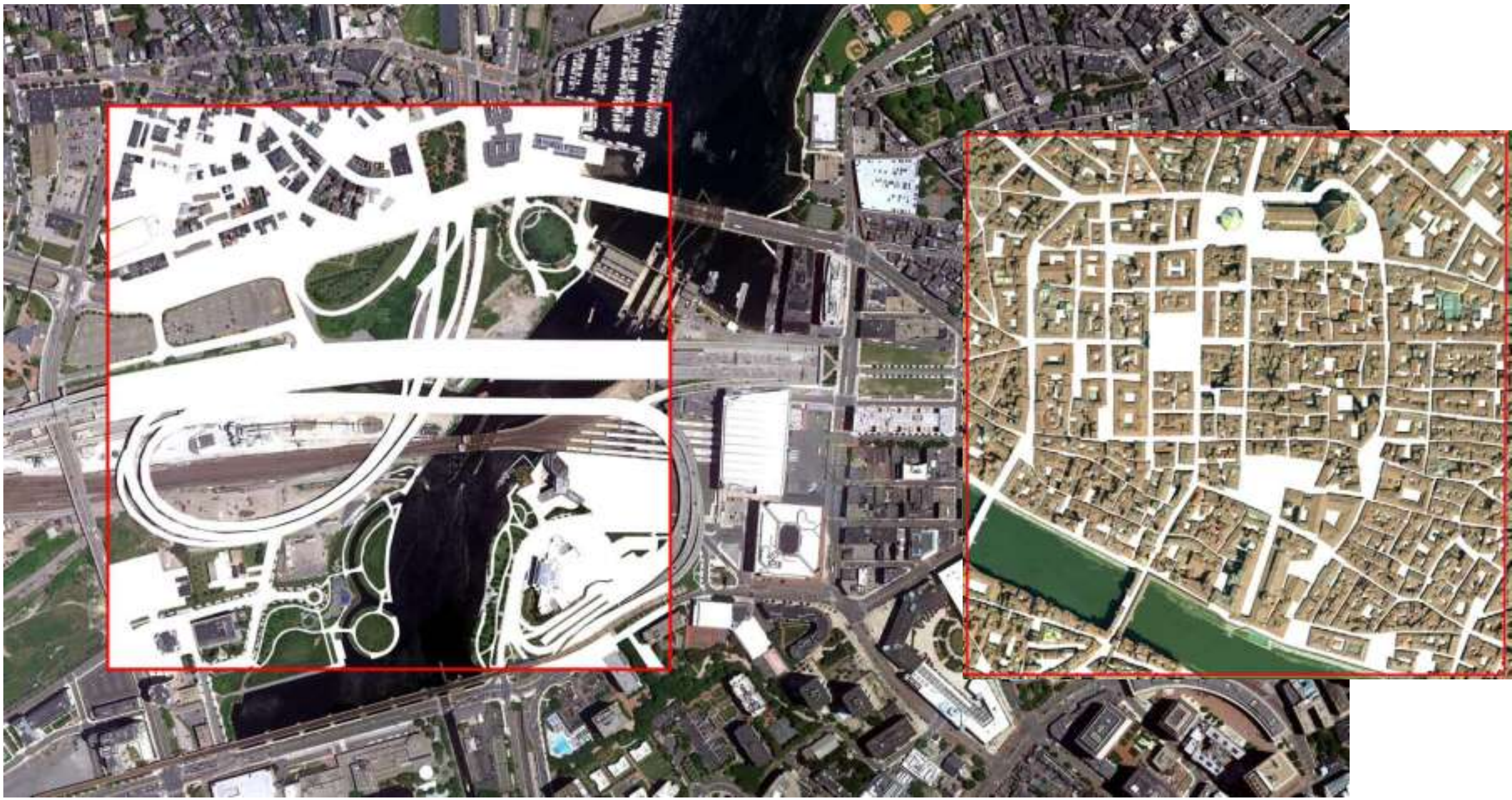
Evolution des formes bâties, Source: P. Panerai, J.C. Depaule, J. Castex de l'ilot à la Barre

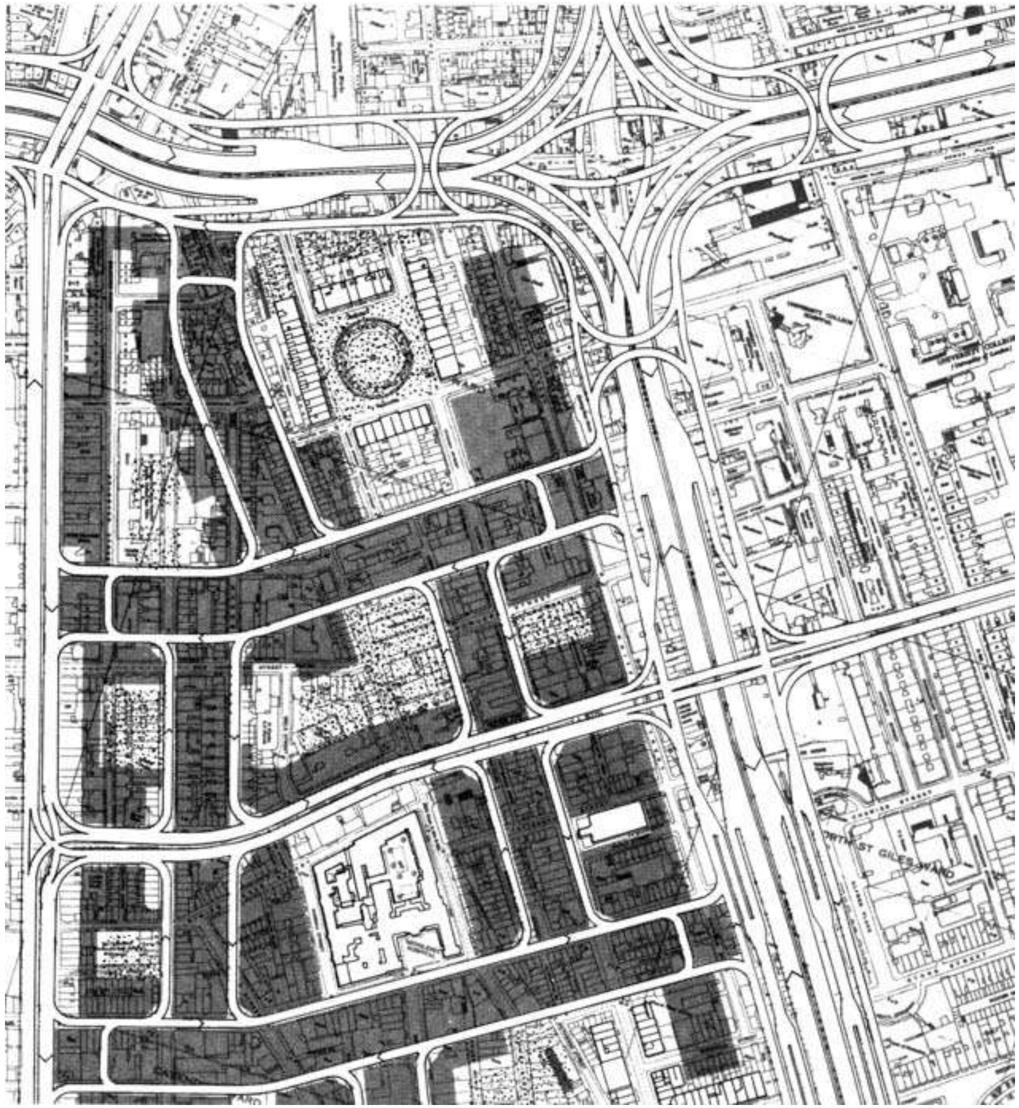
The modernist Corbusean city is not resilient because of its lack of connectedness. It is a discontinuous set of isolated elements in rigidly connected transport infrastructures.

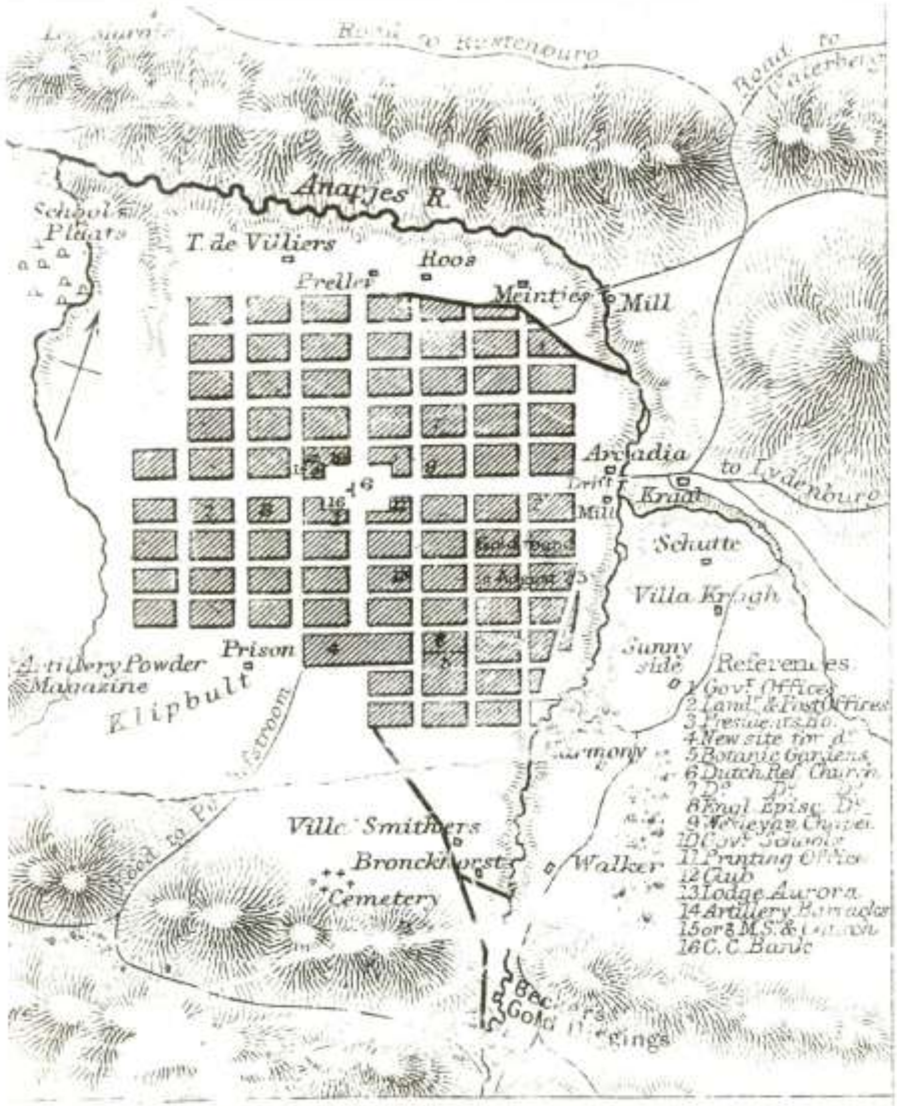
On the Contrary, Parma has a high continuity and connectedness of positive and negative space in the urban fabric and a high scale hierarchy.



The loss of connective resilience of American cities during the 20th century: Boston center urban texture and its evolution between 1885, 1955, 1980 and 2010

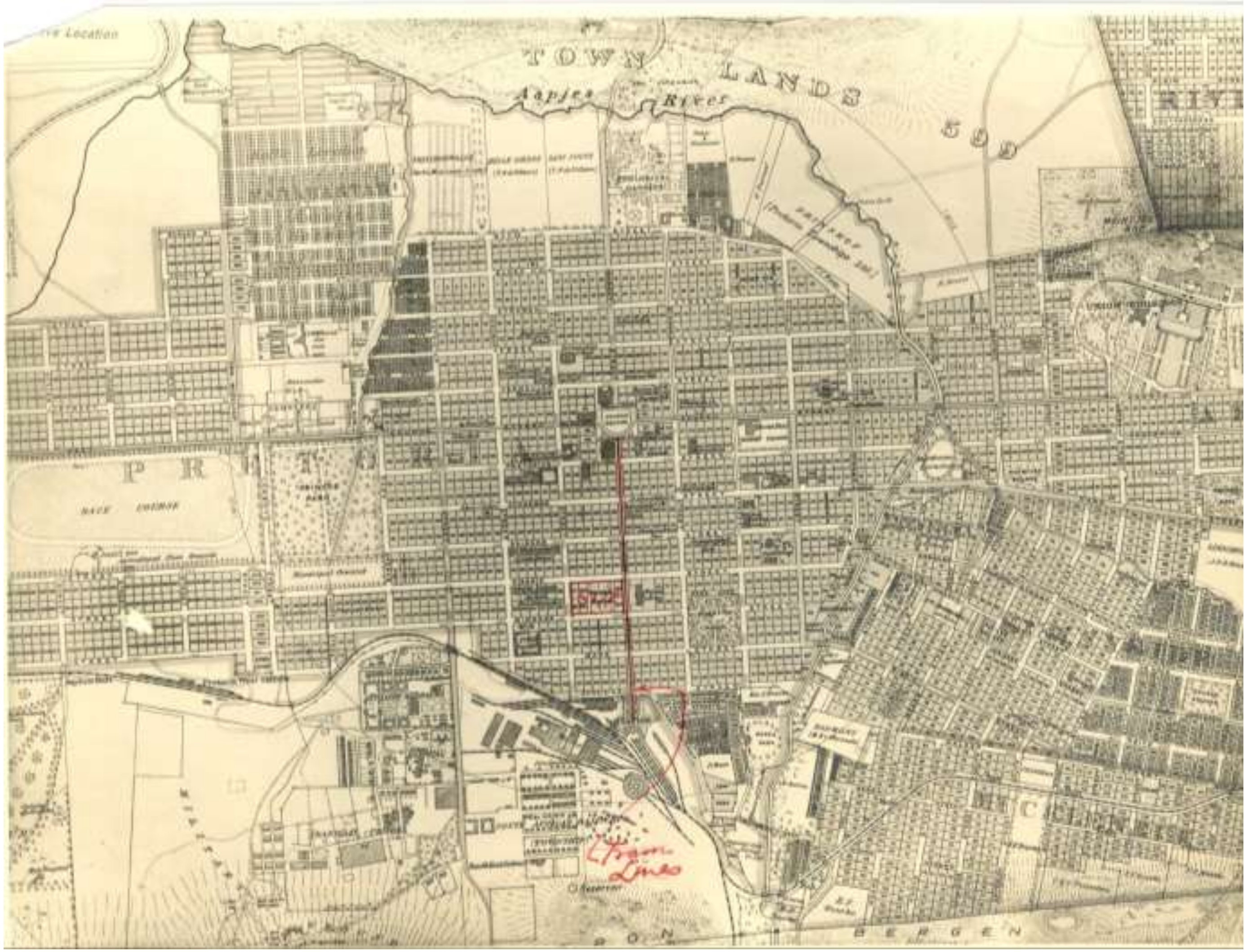


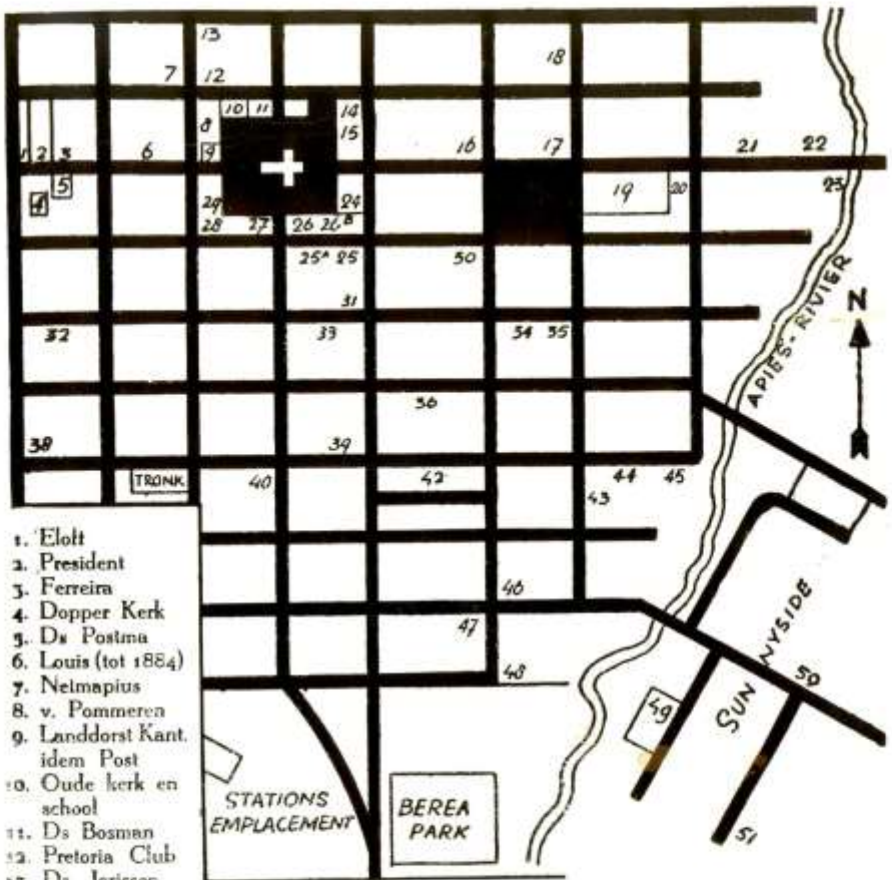




PLAN OF PRETORIA

1878


TOWN LANDS
599
Aapjes River
RACE COURSE
Tram Lines
BERGEN



1. Eloff
2. President
3. Ferreira
4. Dopper Kerk
5. Ds Postma
6. Louis (tot 1884)
7. Nelmapius
8. v. Pommeren
9. Landdorst Kant. idem Post
10. Oude kerk en school
11. Ds Bosman
12. Pretoria Club
13. Dr Jorissen
14. Bibliotheek
15. Stegman & Esselen
16. T. W. Becket
17. De Waal
18. Van der Goes
19. Louis (van 1883)
20. Jeppe
21. Bell
22. S. P. Meintjes
23. Meintjes Se Gat
24. Gerechtshof
25. Transvaal Hotel
25a. Kant. Komm.-Gen.
25b. Boeren winkel
26. Grand Hotel
27. Volksraads Geb. later Gouvts. Geb.
28. European Hotel
29. Pretoria Hotel
30. Dr Leyds (1886)
31. De Nijssen
32. Kock
33. Eng. Kerk
34. Ds Spoelstra
35. Minnaar
36. Gen. Smit
37. Fockens
38. Wolmarans
39. Ned. Consul
40. Ds Godefroy
41. Kotze
42. Landdrost Smit
43. Dr Leyds (1896)
43. Dr Hummel
45. Wagner
46. Boeschoten
47. Kleyn
48. Dewildt
49. Mevr. v. Warmelo
50. Henry Cloete
51. Bosman

Pretoria - 1939

Pretoria - 1958

Pretoria - 1976

Pretoria - 1991

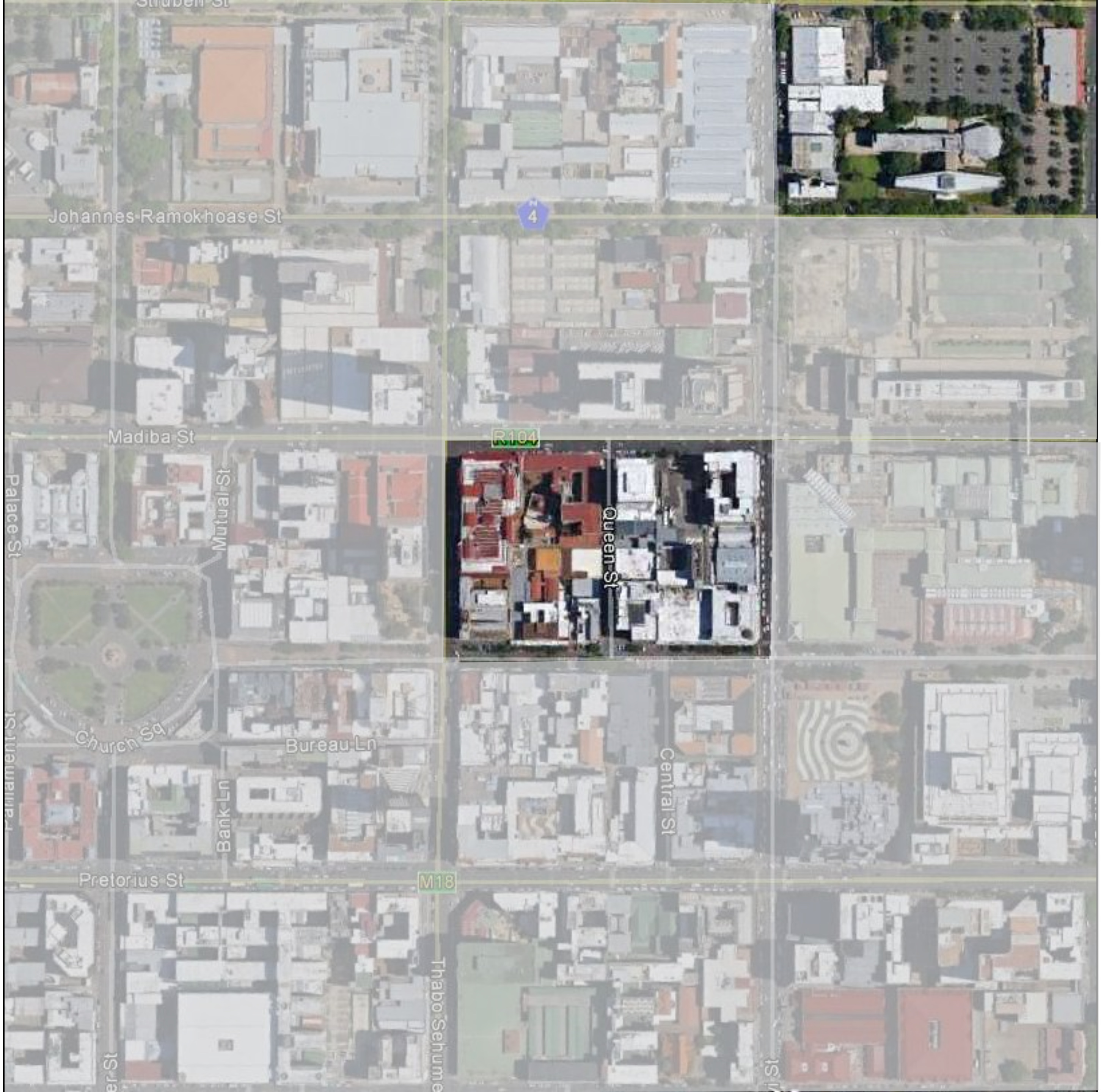
Pretoria - 2013

Inner city Blocks

Key scales for urban sustainability

City scale	Community scale	Block scale
• Compact • Connected	• Walkable • Accessible	• Mixed use • Diversified

800mX800m area


Johannes Ramokhoase St
Madiba St
R104
Queen St
Palace St
Mutual St
Church Sq
Bureau Ln
Central St
Bank Ln
Pretorius St
M18

The Contrast between interface and use

LEGEND
- Informal Trader
- Convenience Store
- Individual Shop
- Mobile Street Trader
- Wholesale
- Speciality Retail
- Chain Store/National Retailer
- Arcade/Shopping centre route

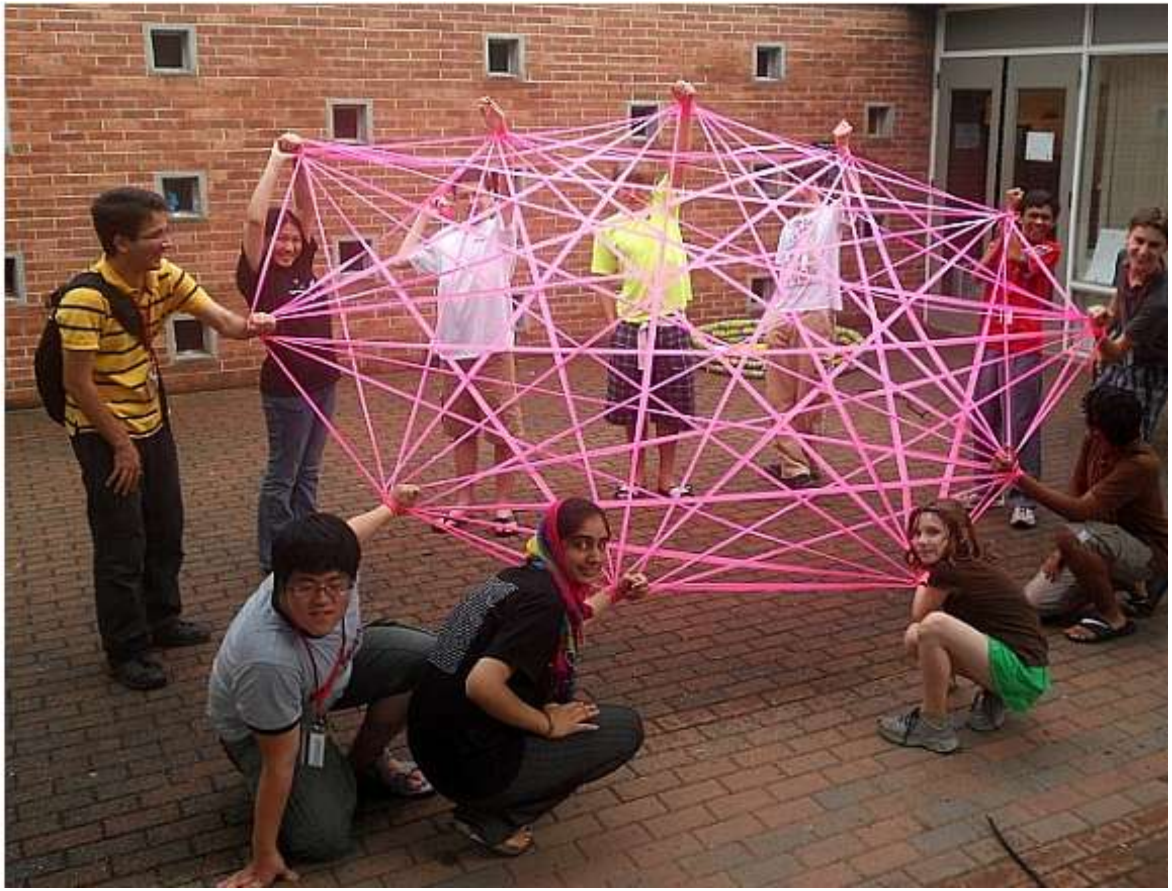
Small Blocks with subdivisions and mixed uses

LEGEND

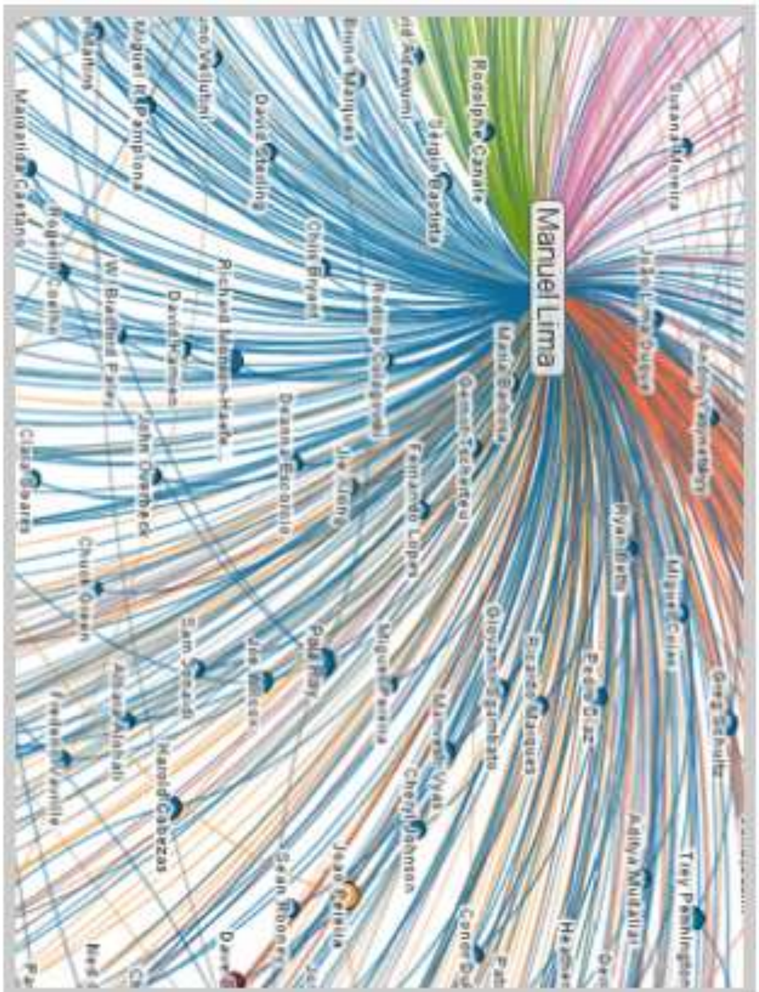
- Informal Trader
- Convenience Store
- Individual Shop
- Mobile Street Trader
- Wholesale
- Speciality Retail
- Chain Store/National Retailer
- Arcade/Shopping centre route

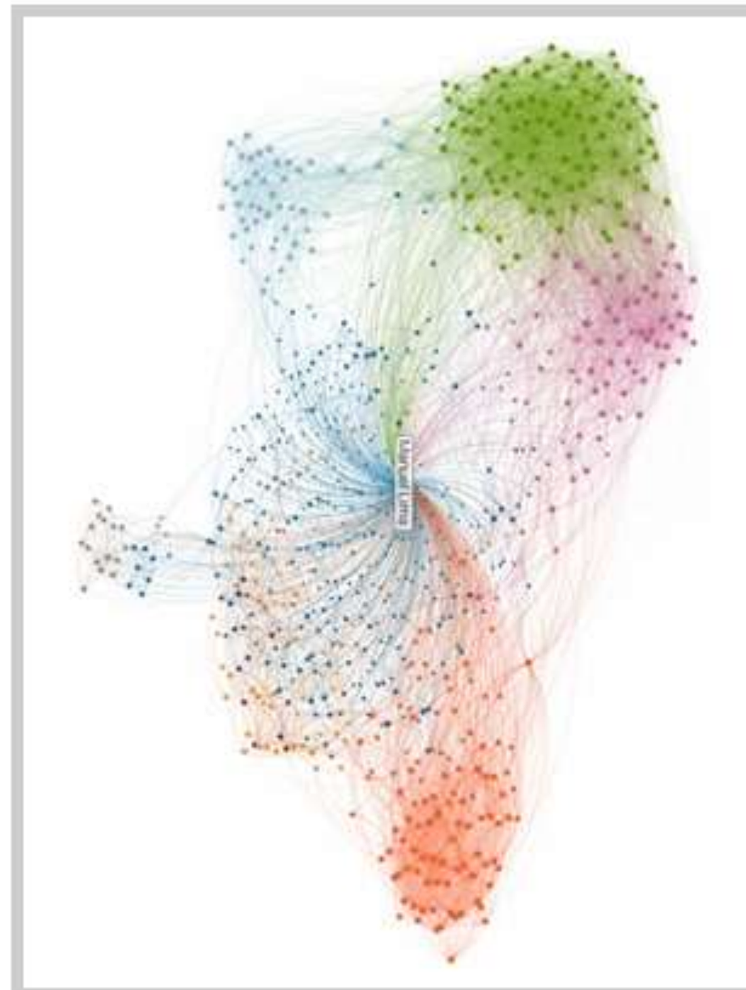
Graph theory, small worlds and clustering

Cities are above all networks of interacting people



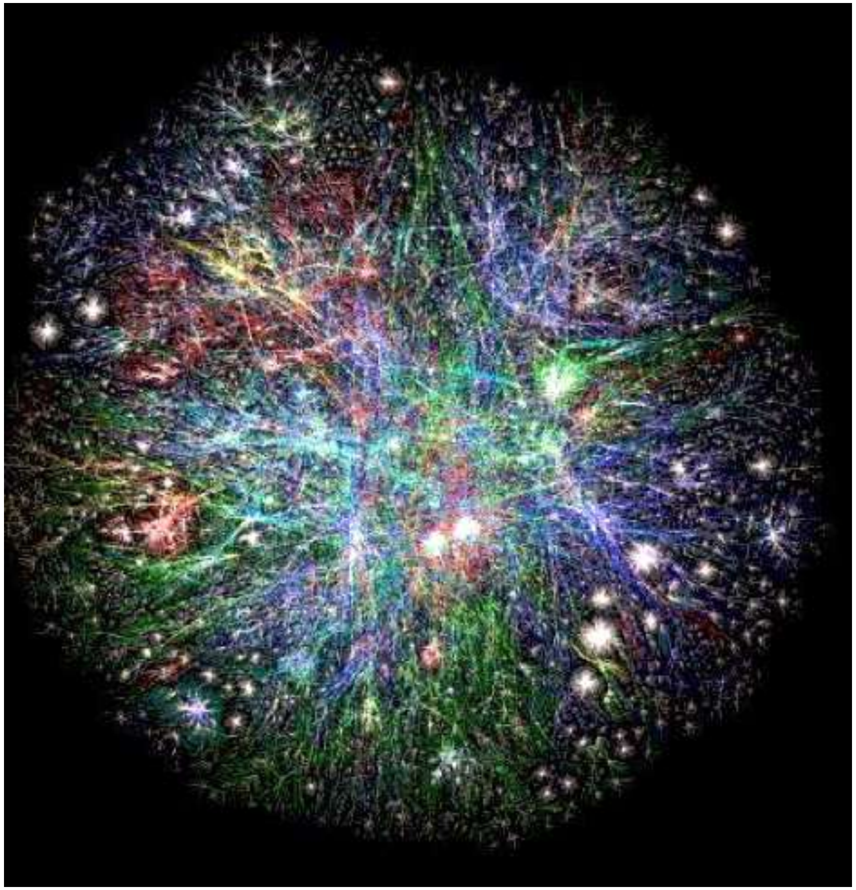
How do human beings interact ?
The structure of Linkedin

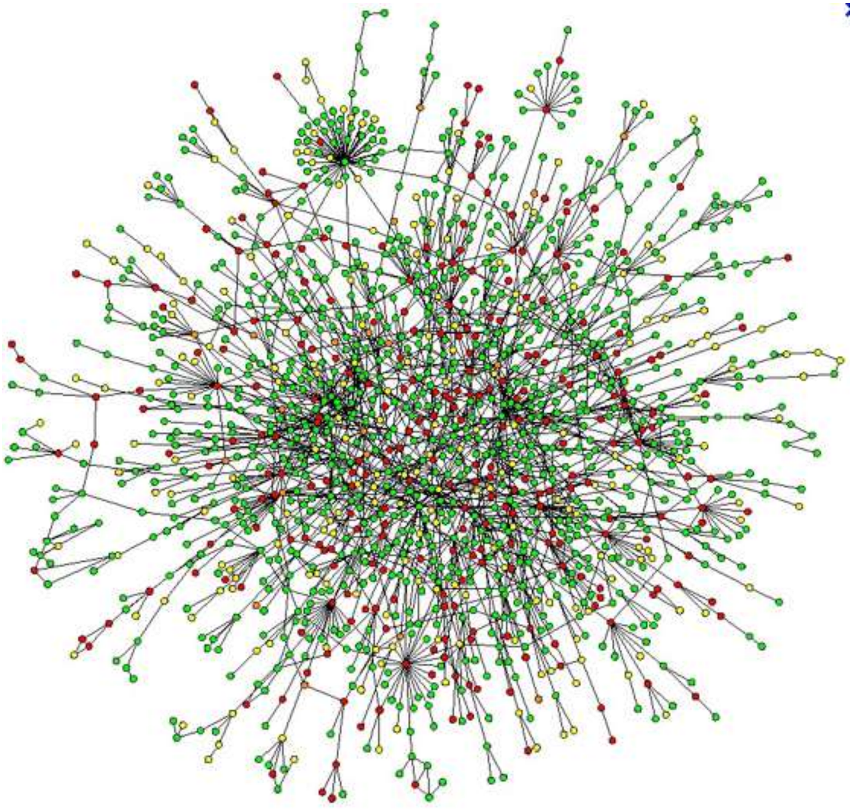




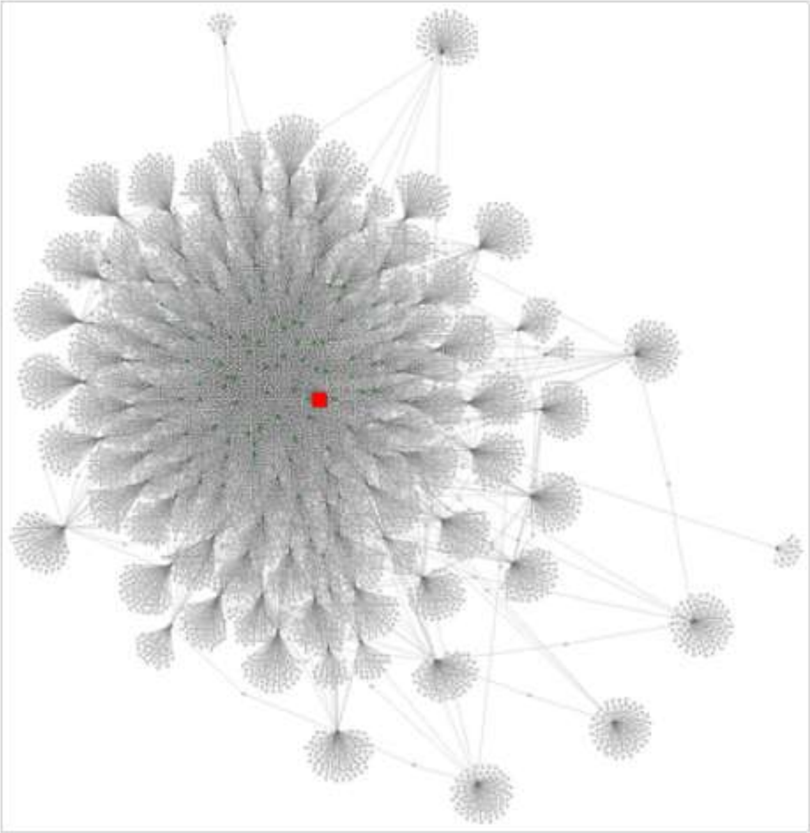
The map of fa

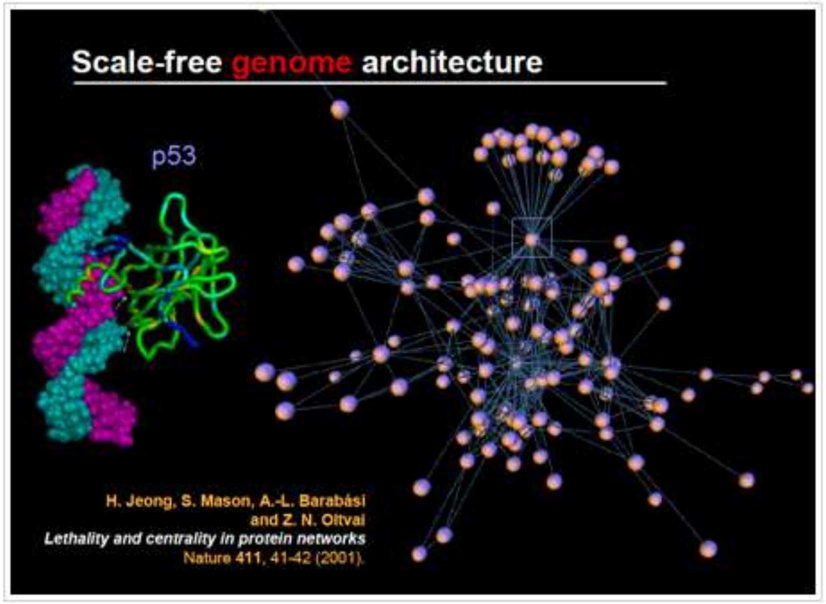
World Wide Web (left) and protein interaction network (right) are similar



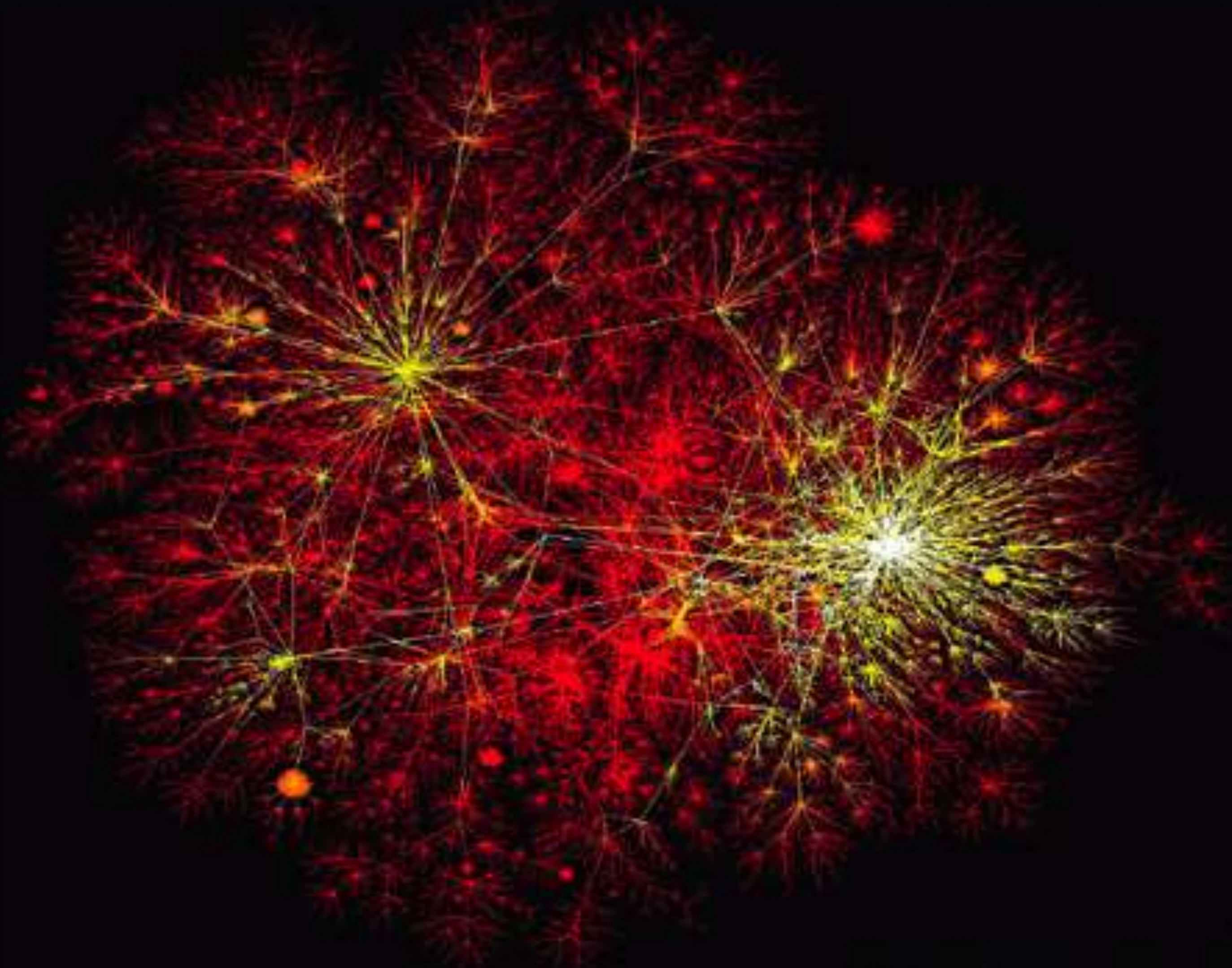


Social networks (left) and genome architecture (right) are similar

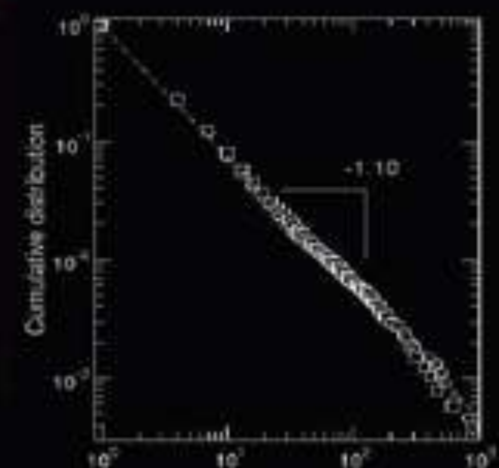




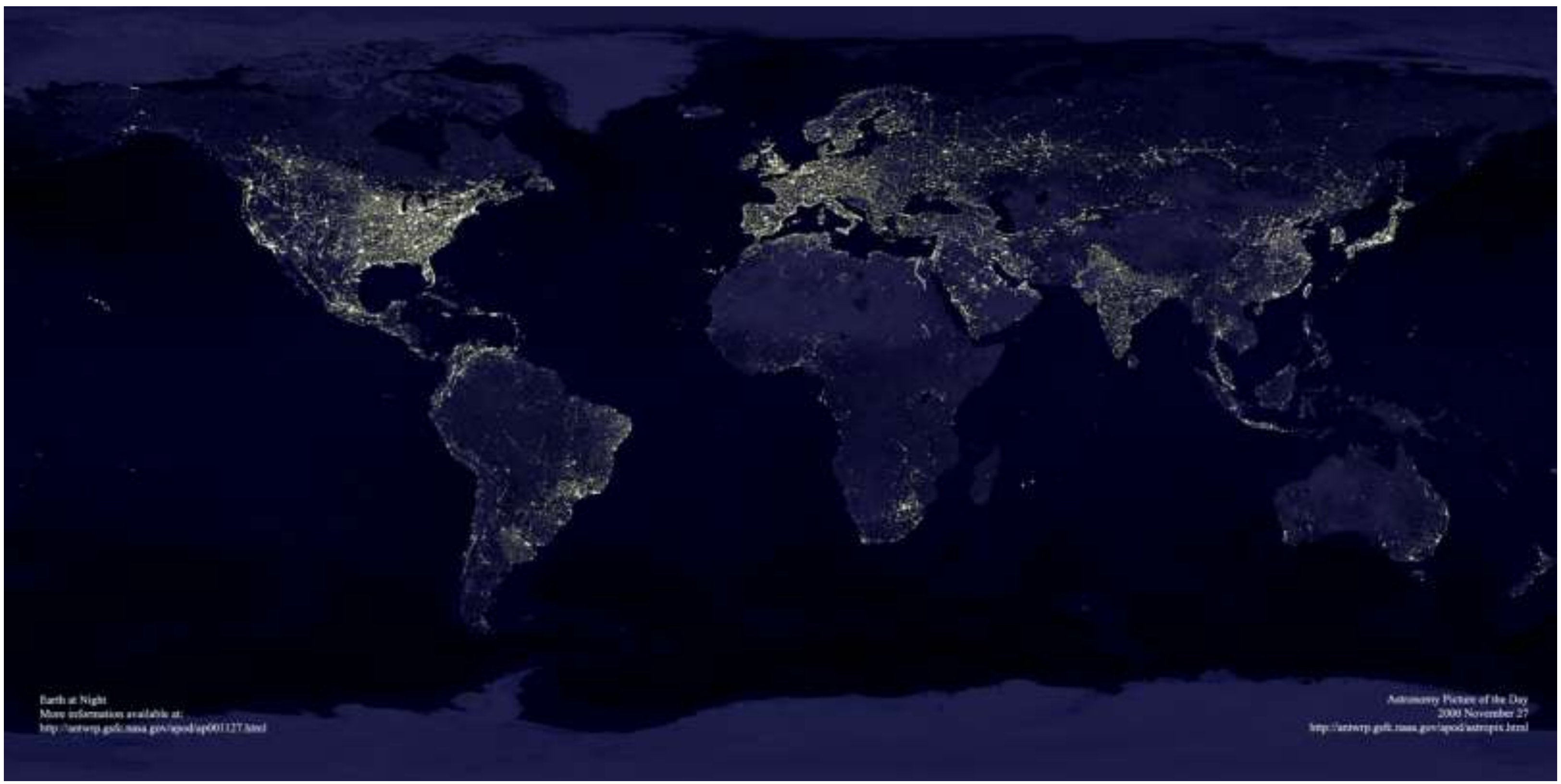
Complex networks are scale-free



$$P(k) \sim k^{-\gamma} \phi(k/\xi)$$

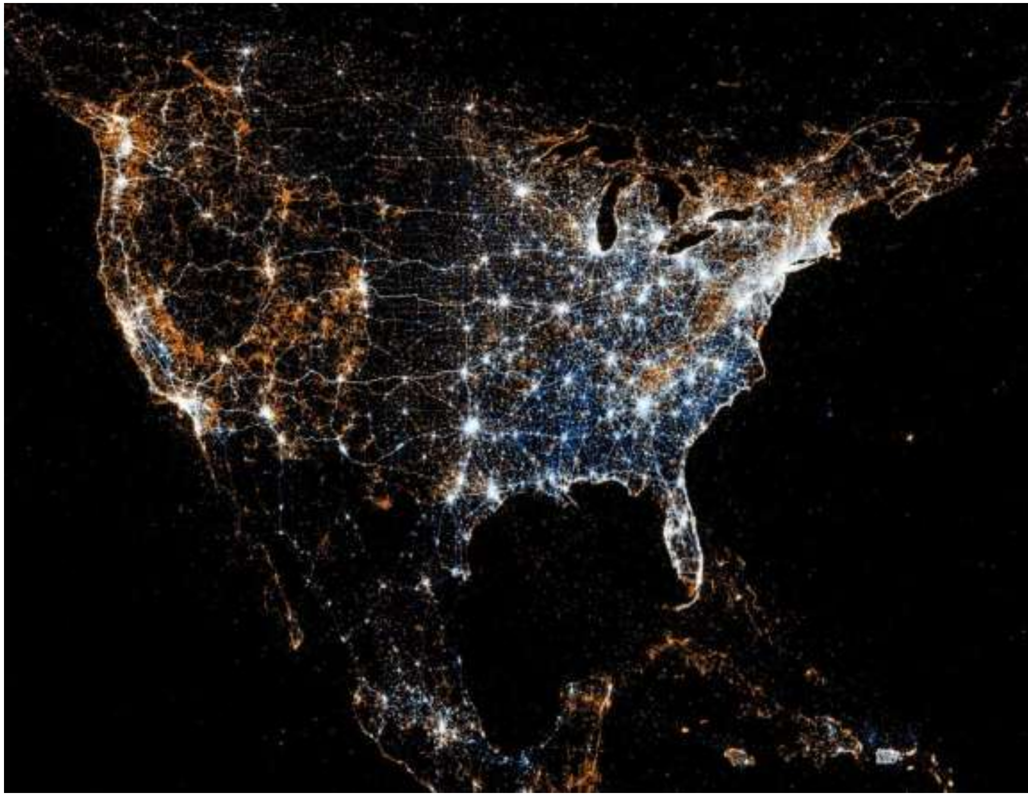


The graph of the WWW is scale free and the map of planet earth world wide urban system is fractal



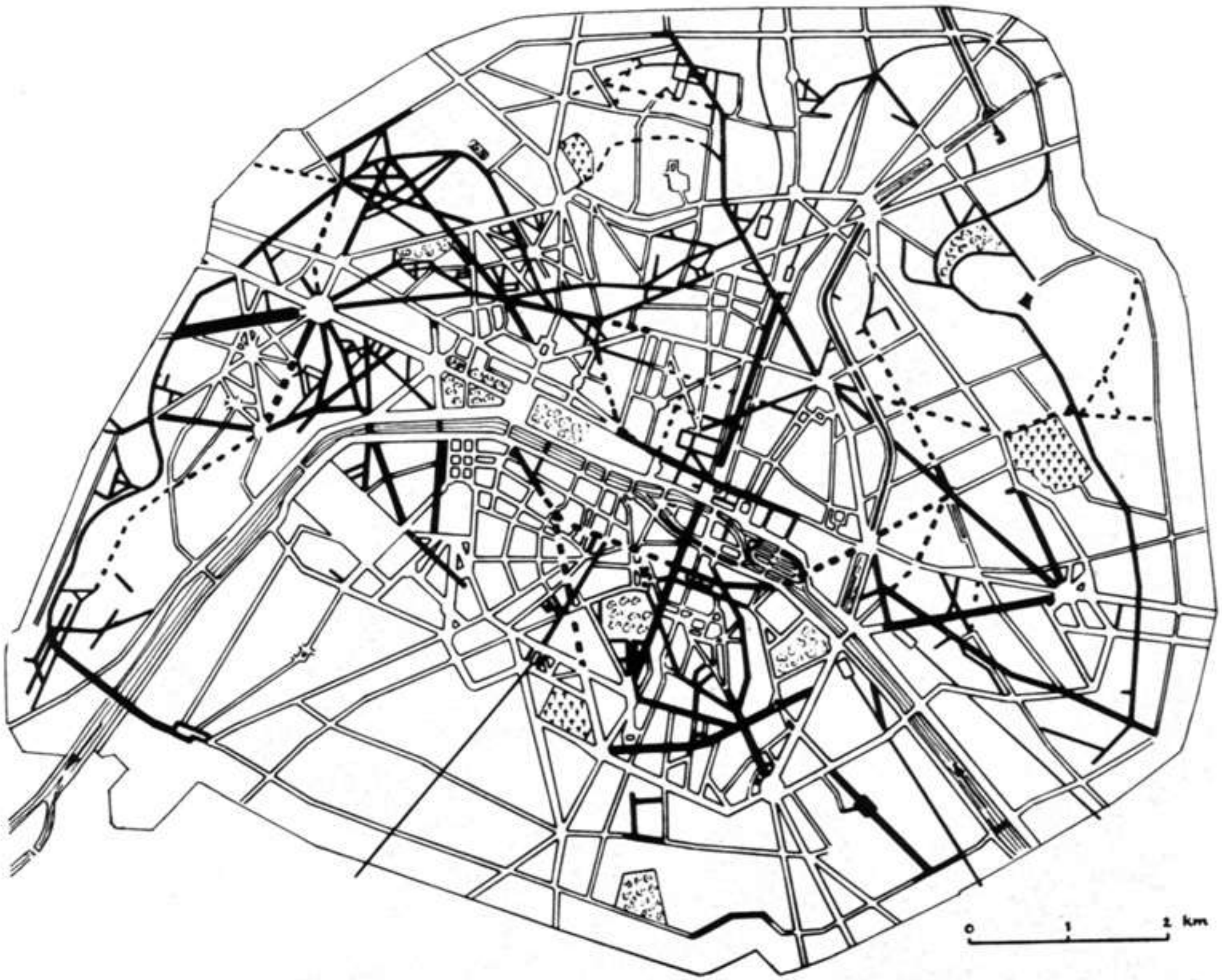
There is a correspondence between scale free graphs (topology) and scale free maps (geography). The World wide information system is a scale free network (graph of facebook)

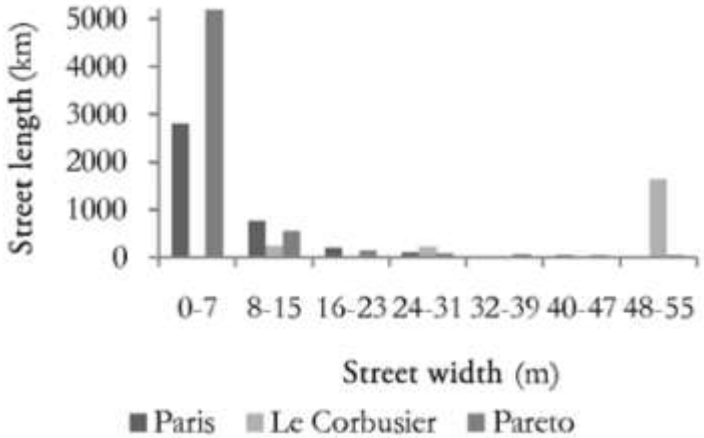
The graph of facebook and the map of urban North America at night



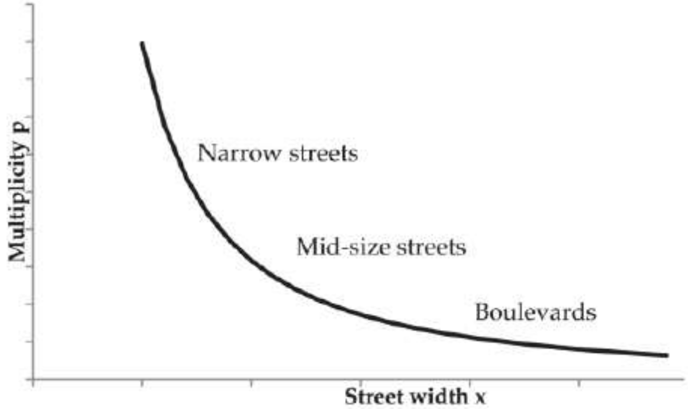
Paris

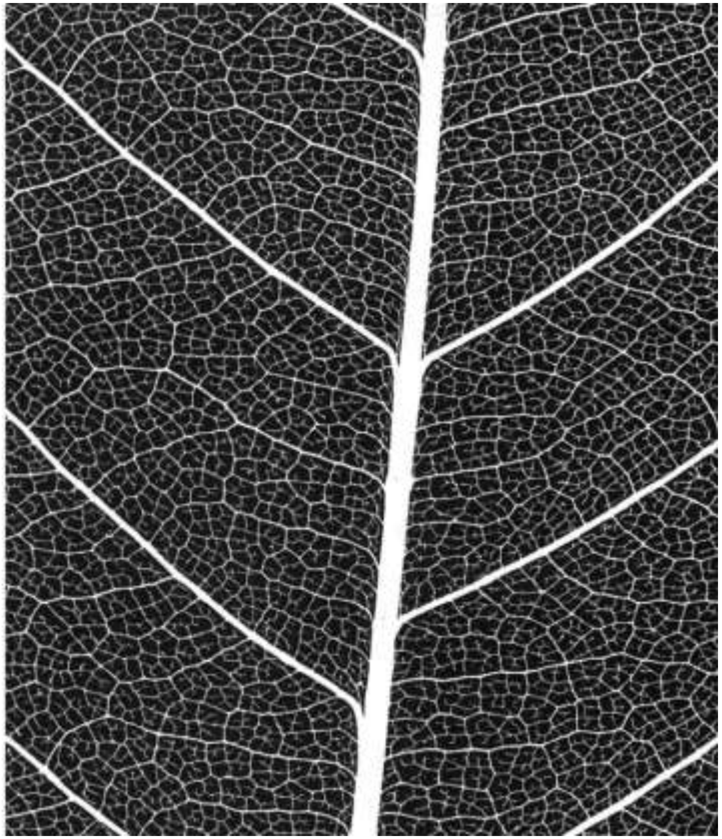
Street, Patterns & Haussmann



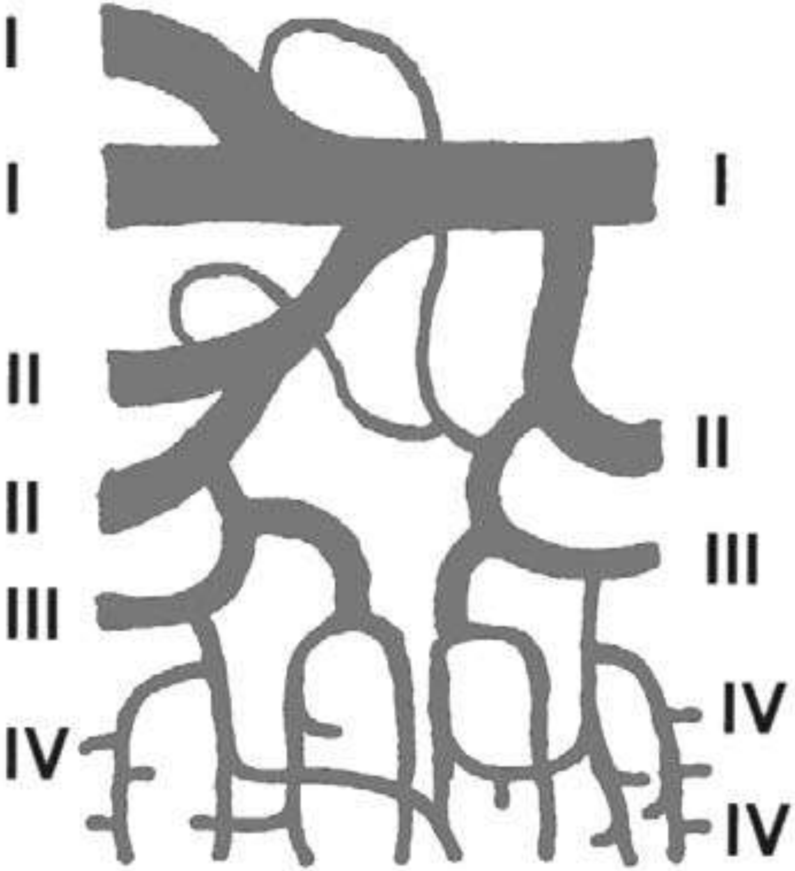


Paris road network
Pareto exponent = 1.23





A leaf structure



A Transit oriented arteriality scheme

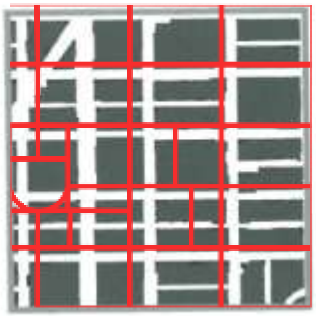
Morphological Typology in the City of Tshwane

<u>Case study areas</u>

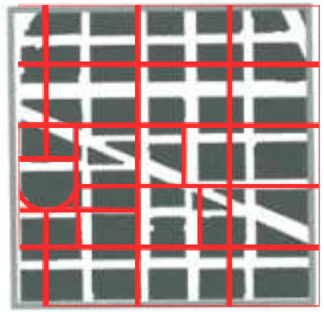
- Inner city of Pretoria Tshwane
  - Grid model
  - Fine grain grid
- Suburban
  - Classic Open
  - Enclosed and Gated communities
- Township
  - Informal
  - “RDP”
- Rural

New York Manhattan

Washington Center



Washington Center



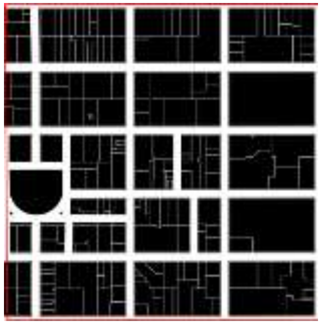
New York Periphery

Washington Periphery

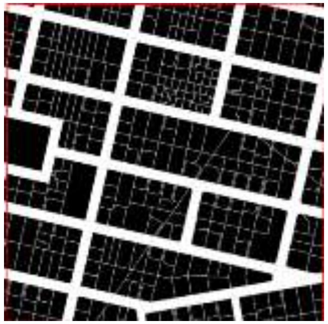
Menlyn Maine

Attridgeville

CBD

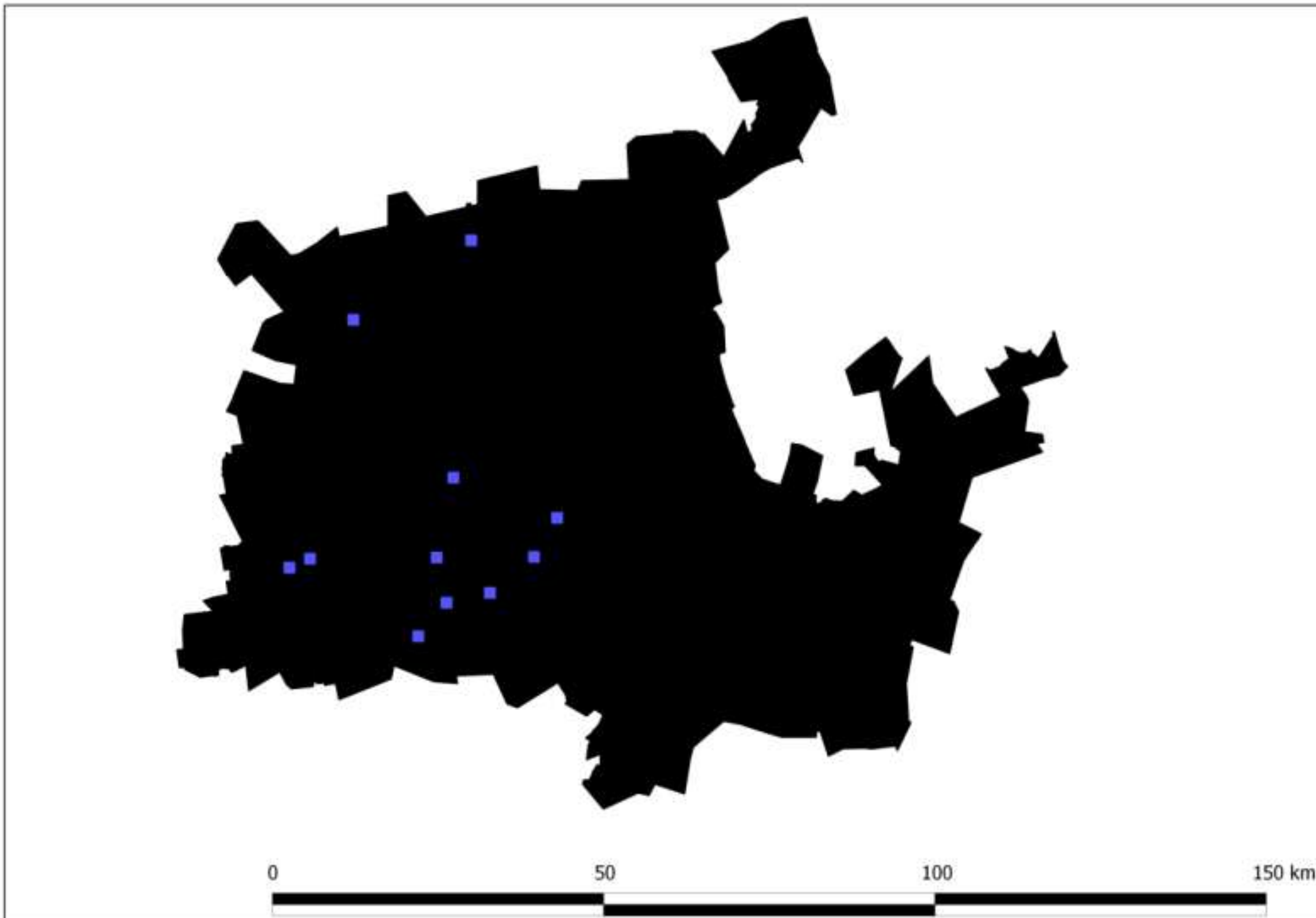


Brooklyn



Zambezi Estate

Case study Areas



1 square mile selection

Woodhill

Brooklyn

Attridgeville

Hammanskraal

CDB

Zambezi

Irene

Mamelodi

Ahmedabad: 2700 intersections

Hammanskraal

Ahmedabad: 2700 intersections

Mamelodi


Solomon Mahlangu Drive
© 2013 Google
Google earth

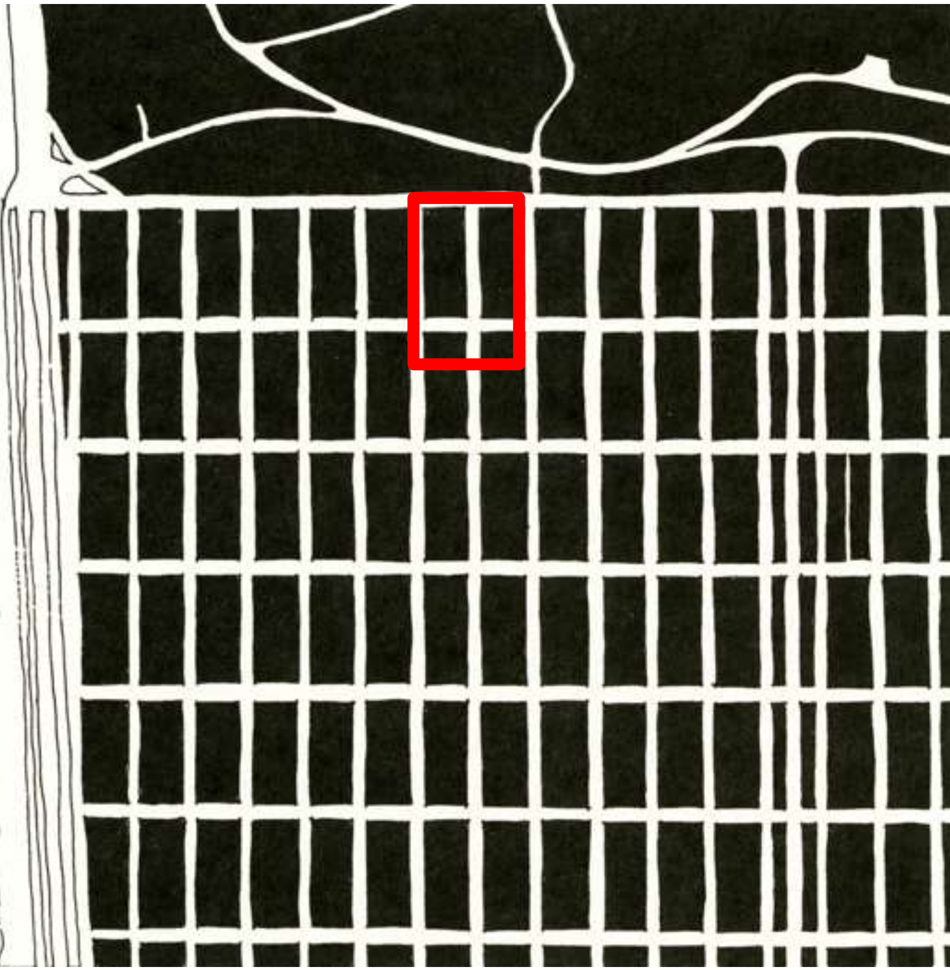

Google earth

Marabastad

Pretoria Central

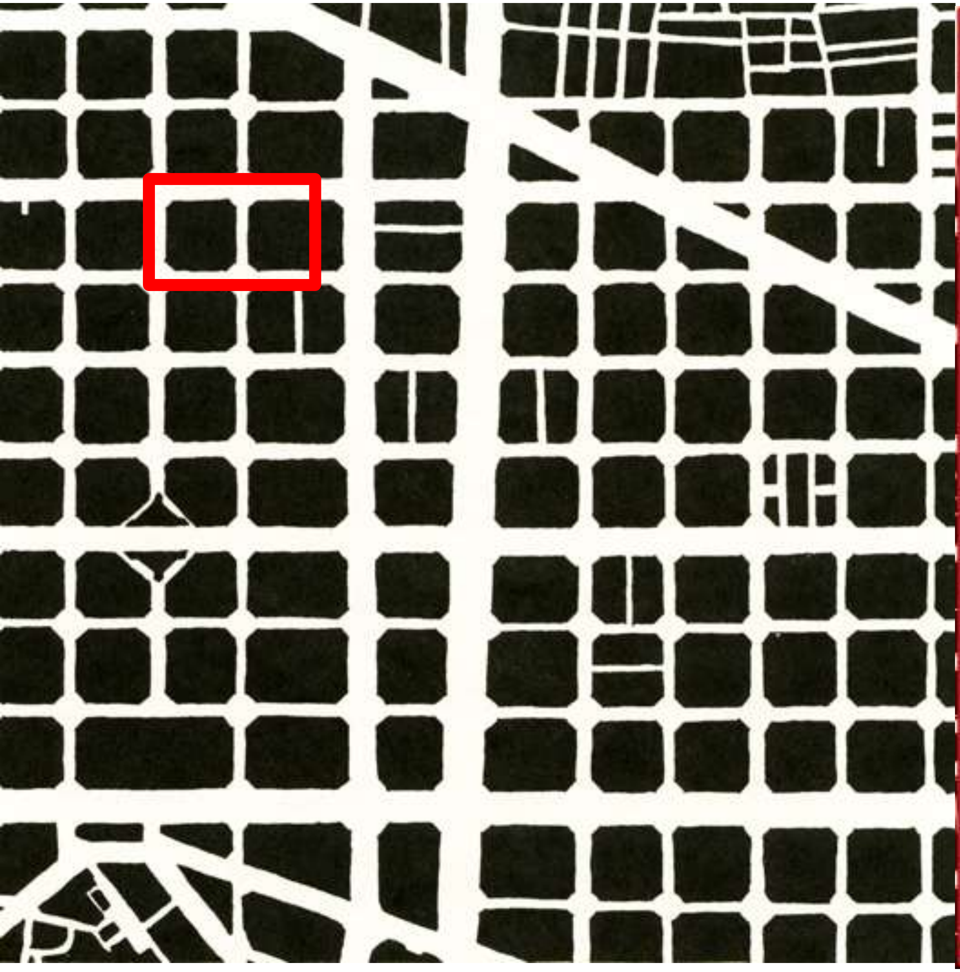
New York

CBD of Tshwane

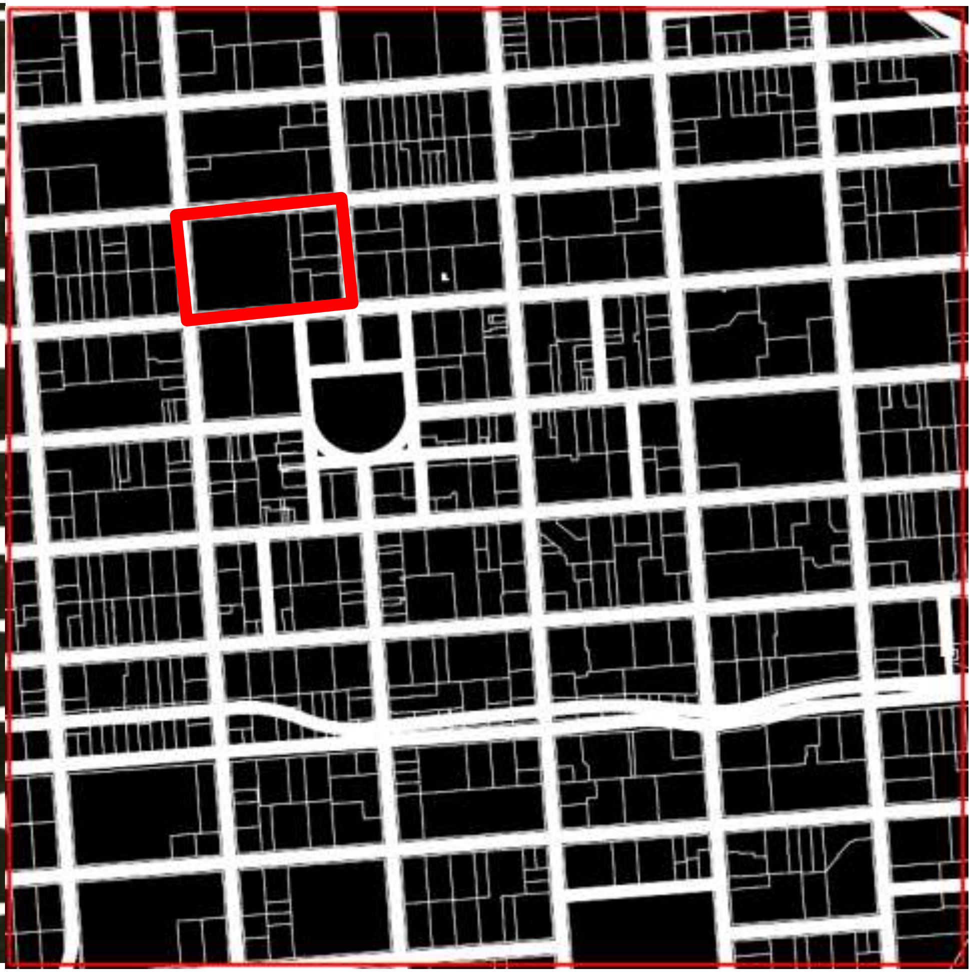


San Francisco: 137 intersections

CBD of Tshwane: 86 intersections

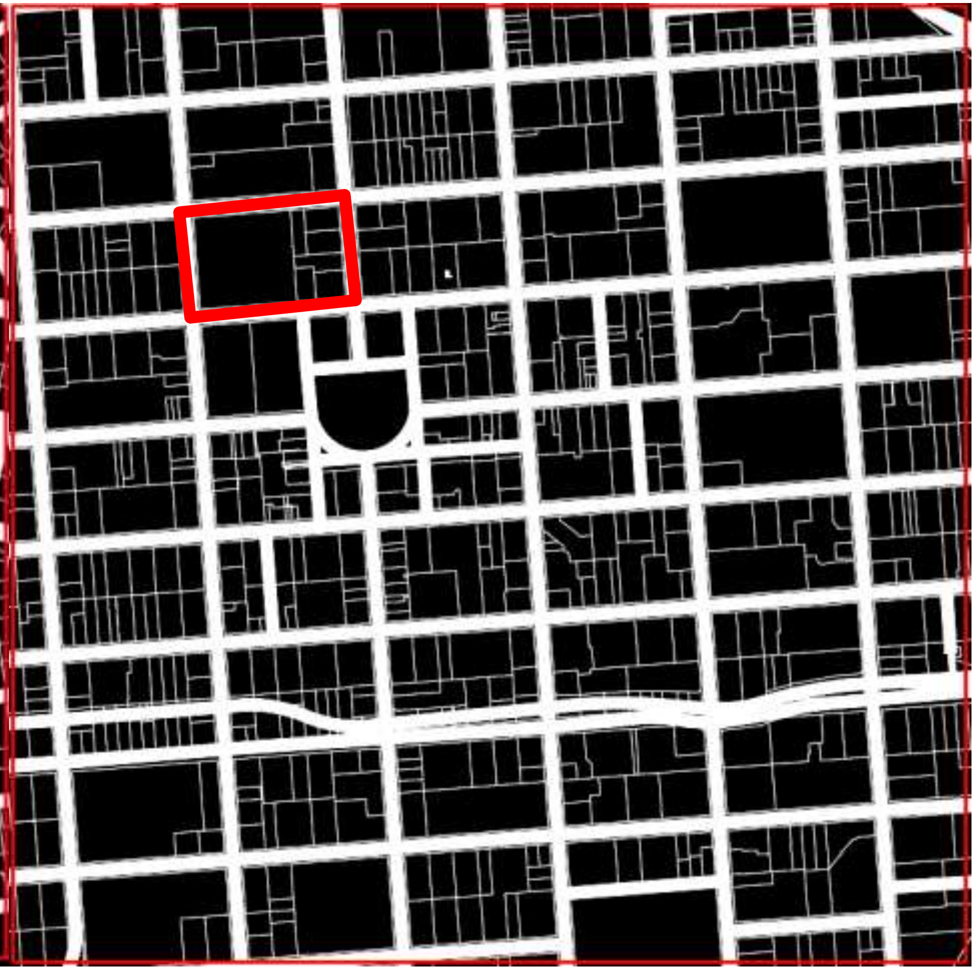


Barcelona: 168 intersections



CBD of Tshwane : 86 intersections

Brooklyn



CBD of Tshwane : 86 intersections

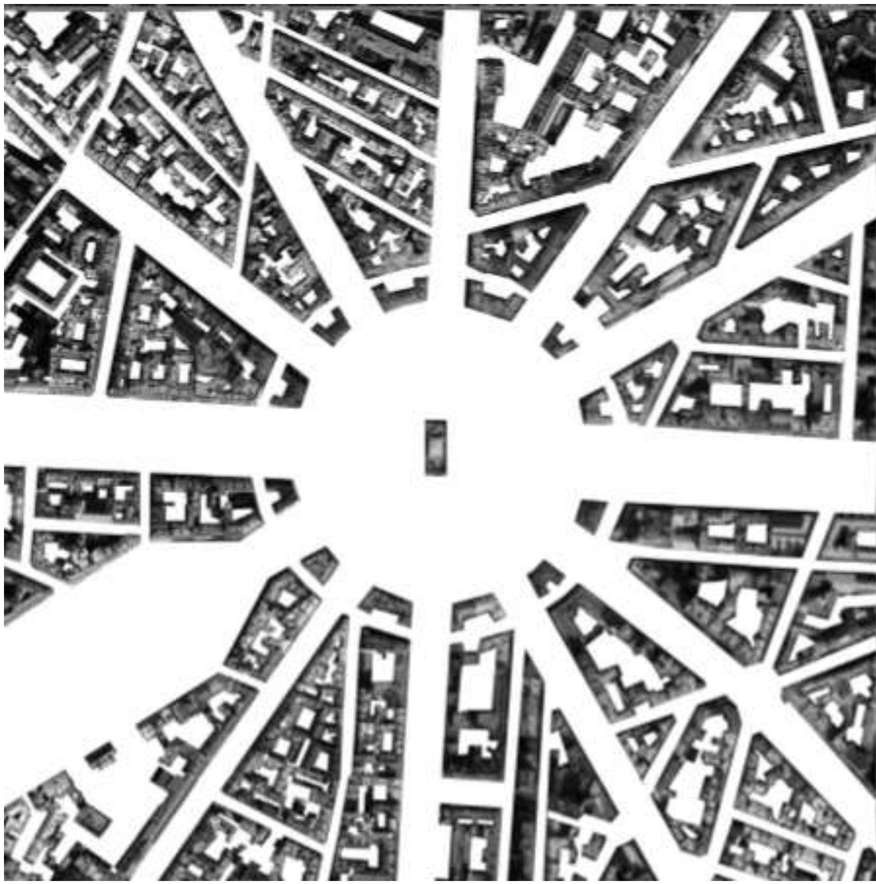
Marabastad

CBD of Tshwane

+73 000
PLAY AREAS,
MANICURED LAWN
PHASE 4
ZAMBEZI 21
X 40
N
E
S
W
ABSA
DevCo
Uys & White
(Pty) Ltd
Zambezi
COUNTRY ESTATE

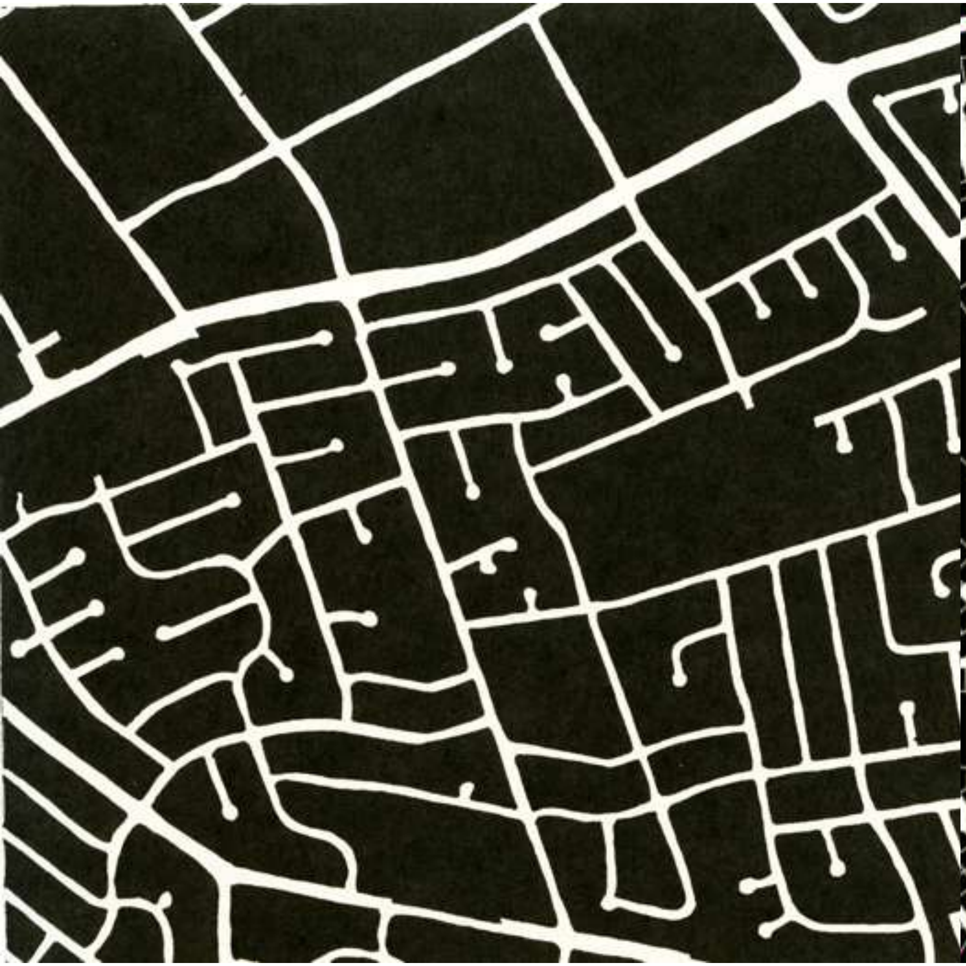
Walnut Creek: 107 intersections

Zambezi Country Estate 42 intersections



Paris

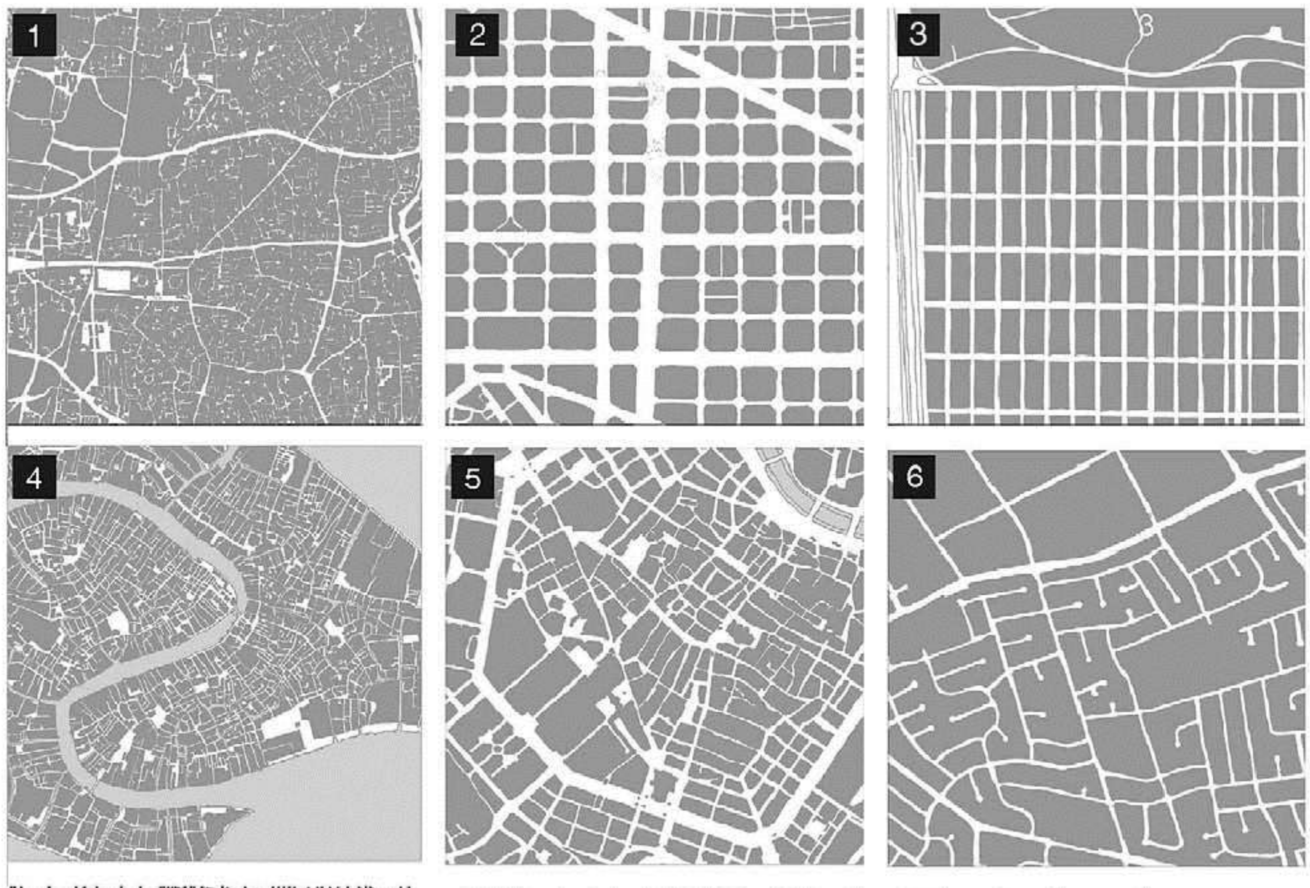
Attridgeville



Walnut Creek: 107 intersections

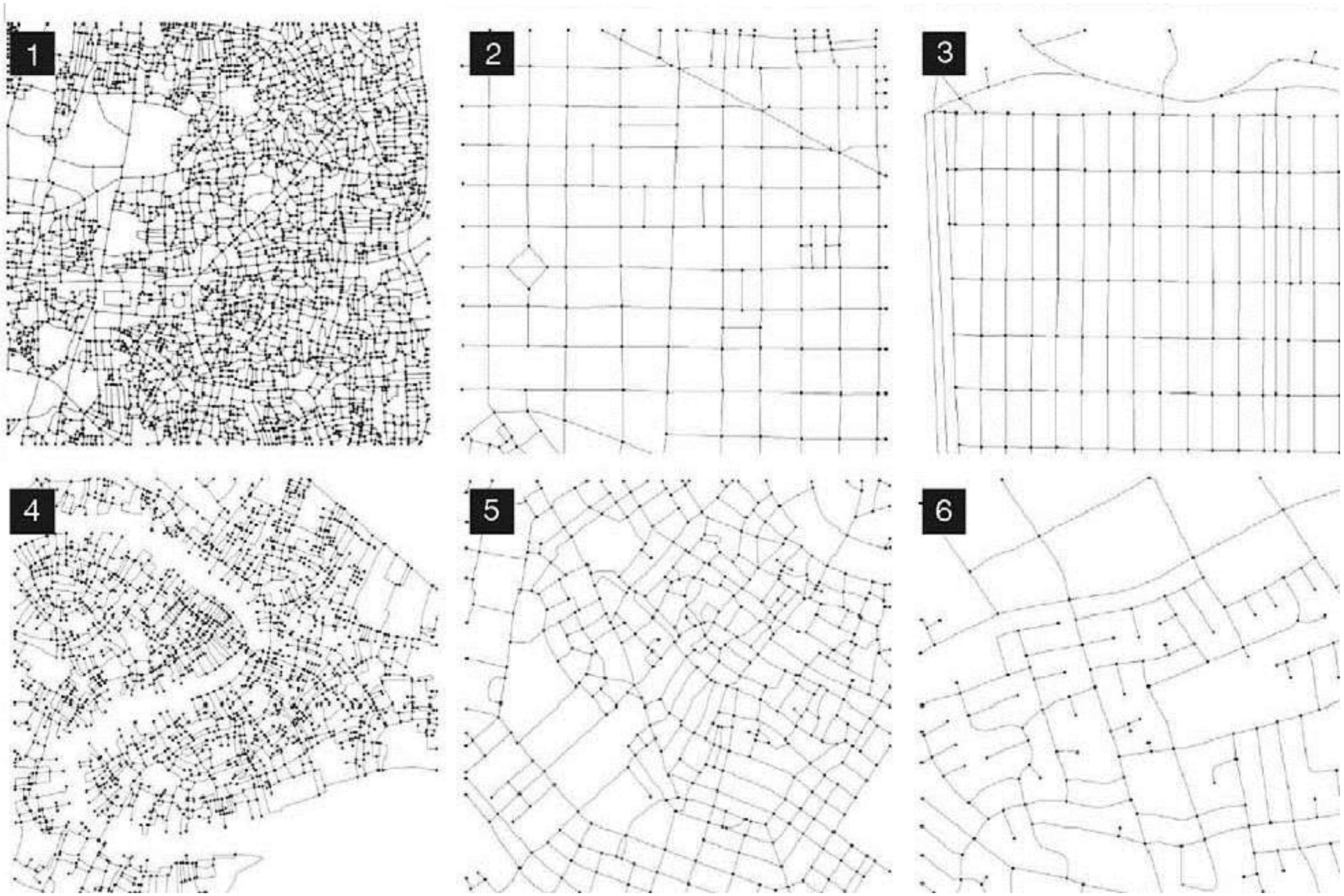
Woodhill estate: 44 intersections

Graph analysis: a dual approach



1.	Ahmedabad
2.	Barcelone
3.	San Francisco
4.	Venise
5.	Vienne
6.	Walnut Creek

Graph analysis: a dual approach



1.	Ahmedabad
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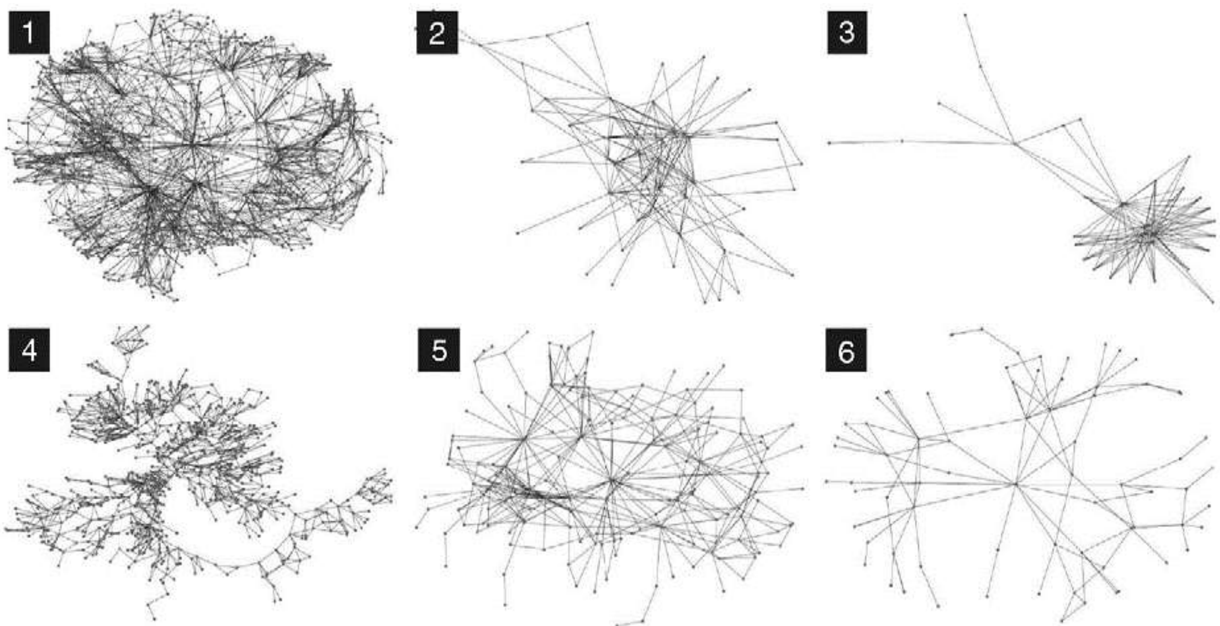
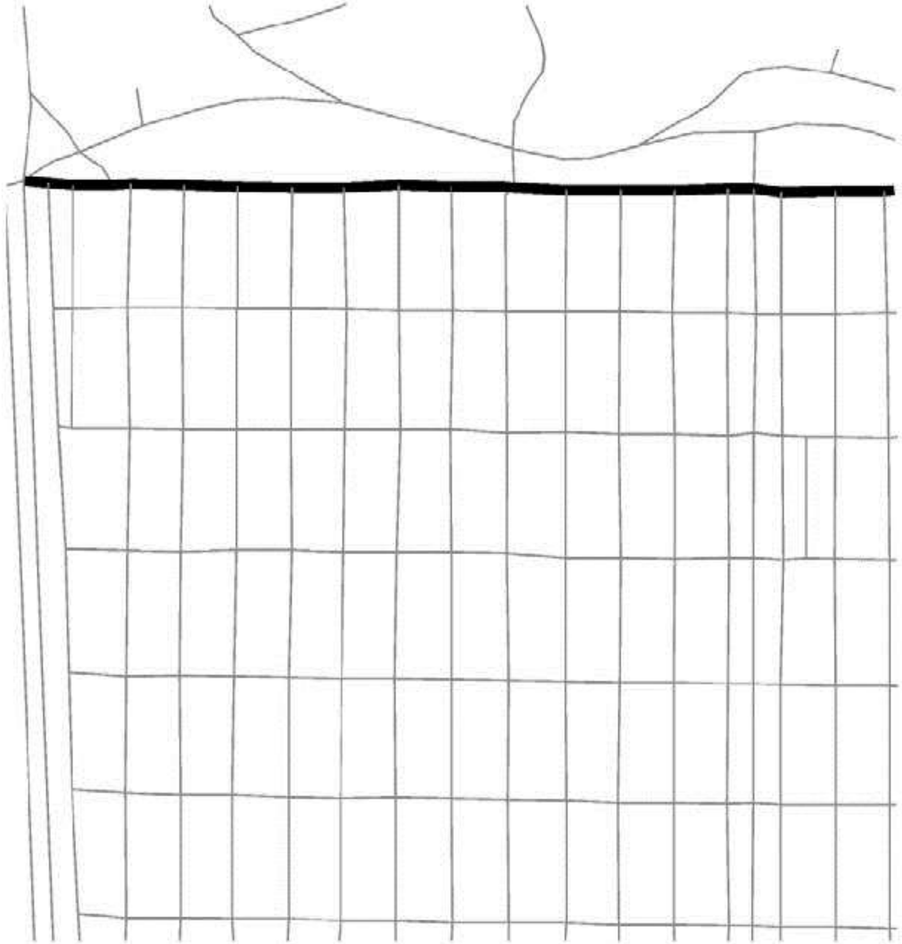
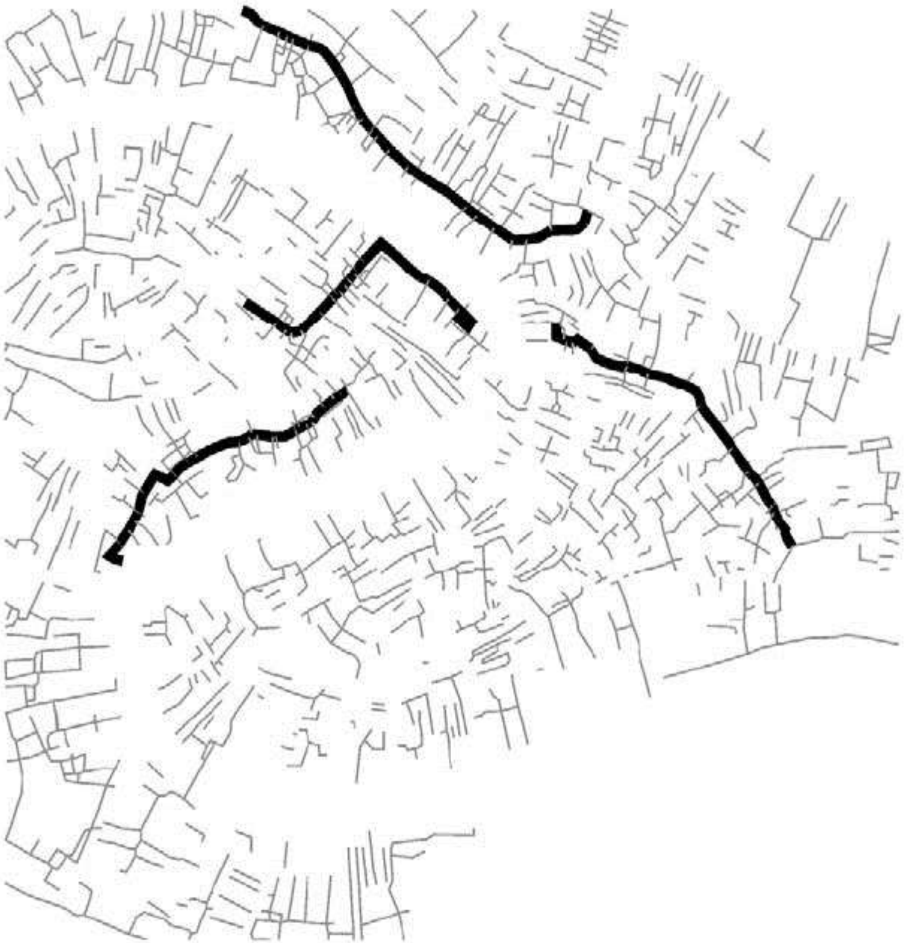
Graph analysis: a dual approach



1.	Ahmedabad
2.	Barcelone
3.	San Francisco
4.	Venise
5.	Vienne
6.	Walnut Creek





	Number of streets	Nb of intersections	Nb of intersections by street	Maximum degree
	N	K	$\langle k \rangle$	K_{MAX}
1. Ahmedabad	1239	2709	4.37	68
2. Barcelone	53	168	6.34	15
3. San Francisco	34	137	8.06	21
4. Venise	783	1312	3.35	29
5. Vienne	170	395	4.65	35
6. Walnut Creek	78	107	2.74	13

Small worlds et clustering

Case	*Coeff. de clustering* *C*	*Coeff de clustering pour le réseau eq. aléatoire* *C rand*	*C / C rand*
Ahmedabad	0,250	0,003	83
Venise	0,174	0,004	43
Vienne	0,175	0,025	7
Walnut Creek	0,062	0,026	2,4

$$C(G) = \langle C_i \rangle = \frac{1}{N} \sum_{i \in G} C_i,$$

$$C_i = \frac{2e_i}{k_i(k_i - 1)}$$

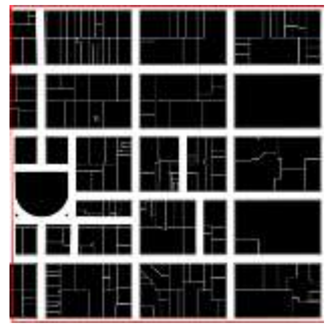
	E_{glob}	$(E_{glob})_{rand}$	E_{loc}	$(E_{loc})_{rand}$
1. Ahmedabad	0.21	0.21	0.281	0.003
2. Barcelone	0.45	0.49	0.144	0.154
3. San Francisco	0.57	0.60	0.070	0.400
4. Venise	0.15	0.18	0.191	0.004
5. Vienne	0.33	0.32	0.206	0.026
6. Walnut Creek	0.30	0.25	0.067	0.026

$$E_{loc}(G) = \frac{1}{N} \sum_{i \in G} E(G_i); \quad E(G_i) = \frac{1}{k_i(k_i - 1)} \sum_{l,m \in G, l \neq m} \frac{1}{d'_{lm}}$$

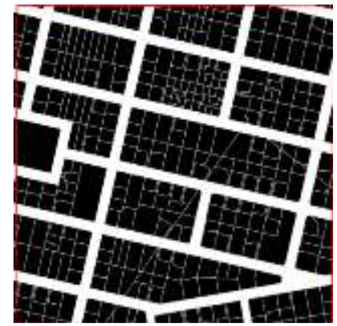
Menlyn Maine

Attridgeville

CBD



Brooklyn

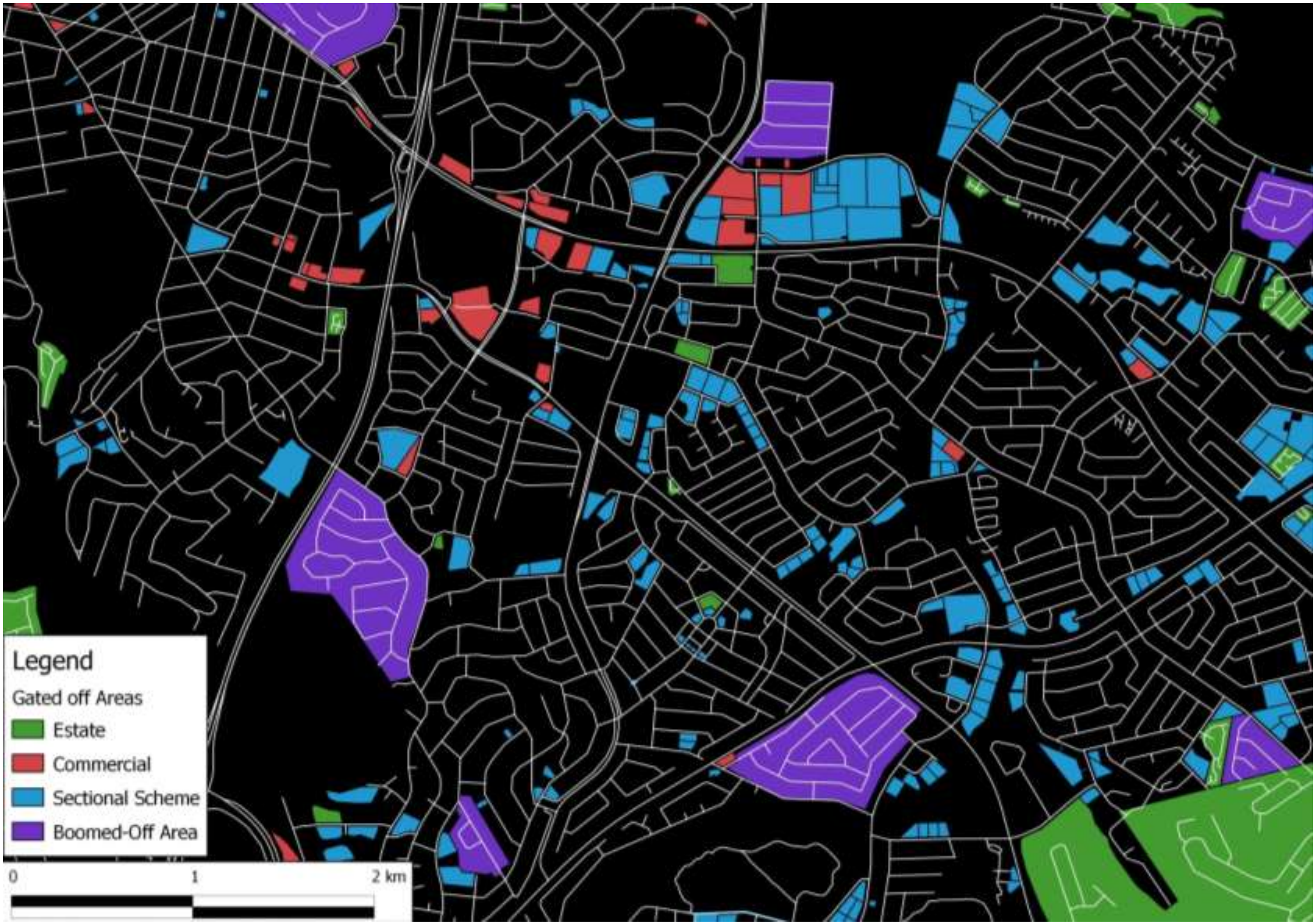


Zambezi Estate

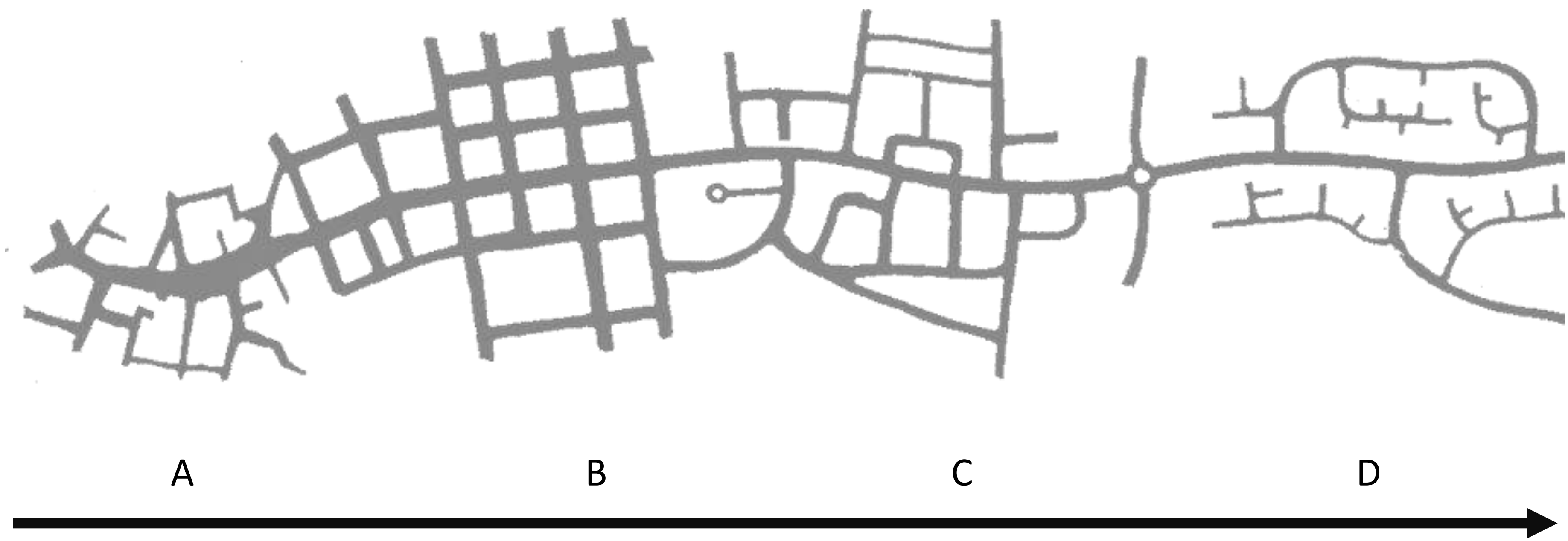
On going work…

Neighbourhood Analysis

Most of Pretoria east: suburban layout

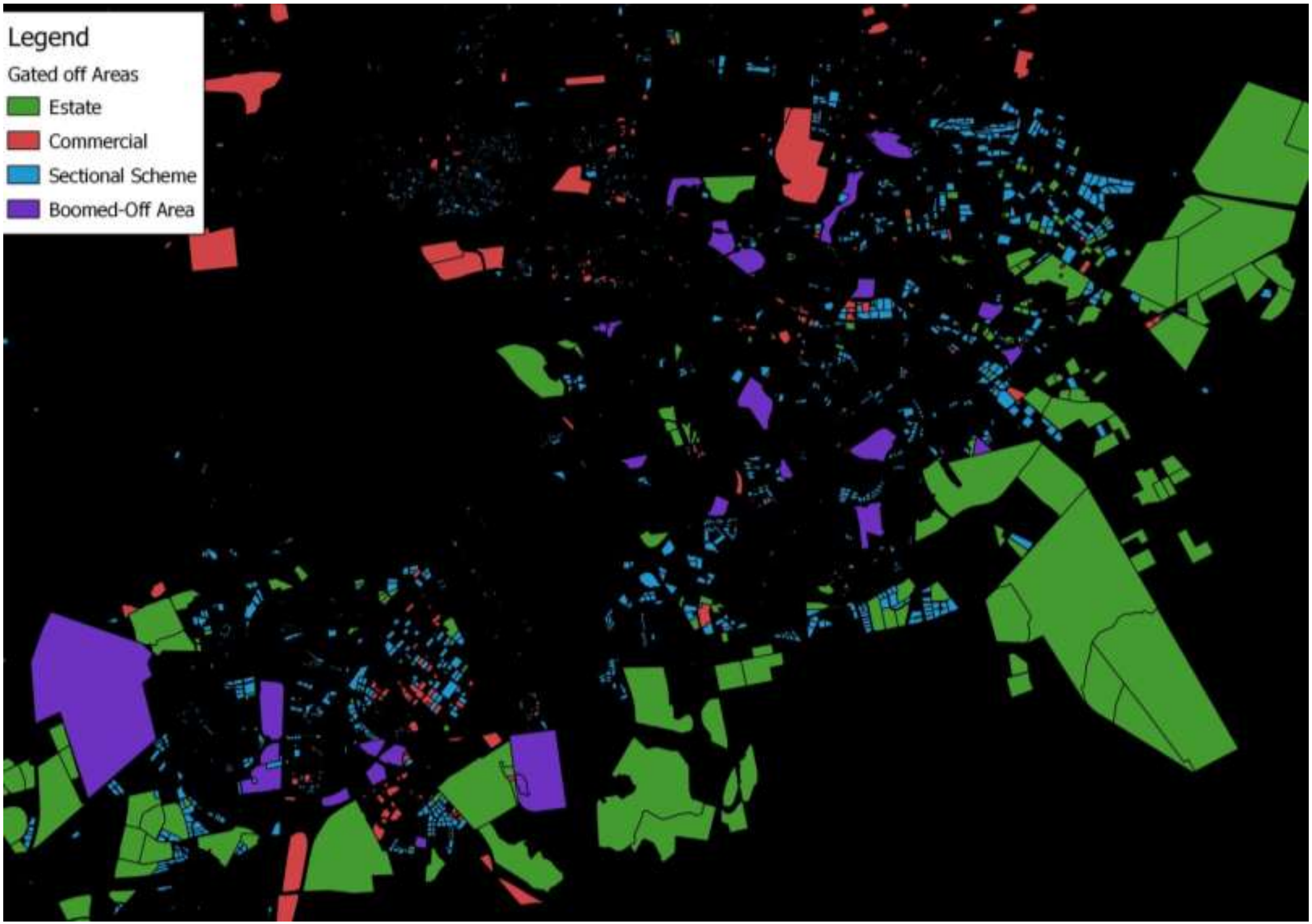


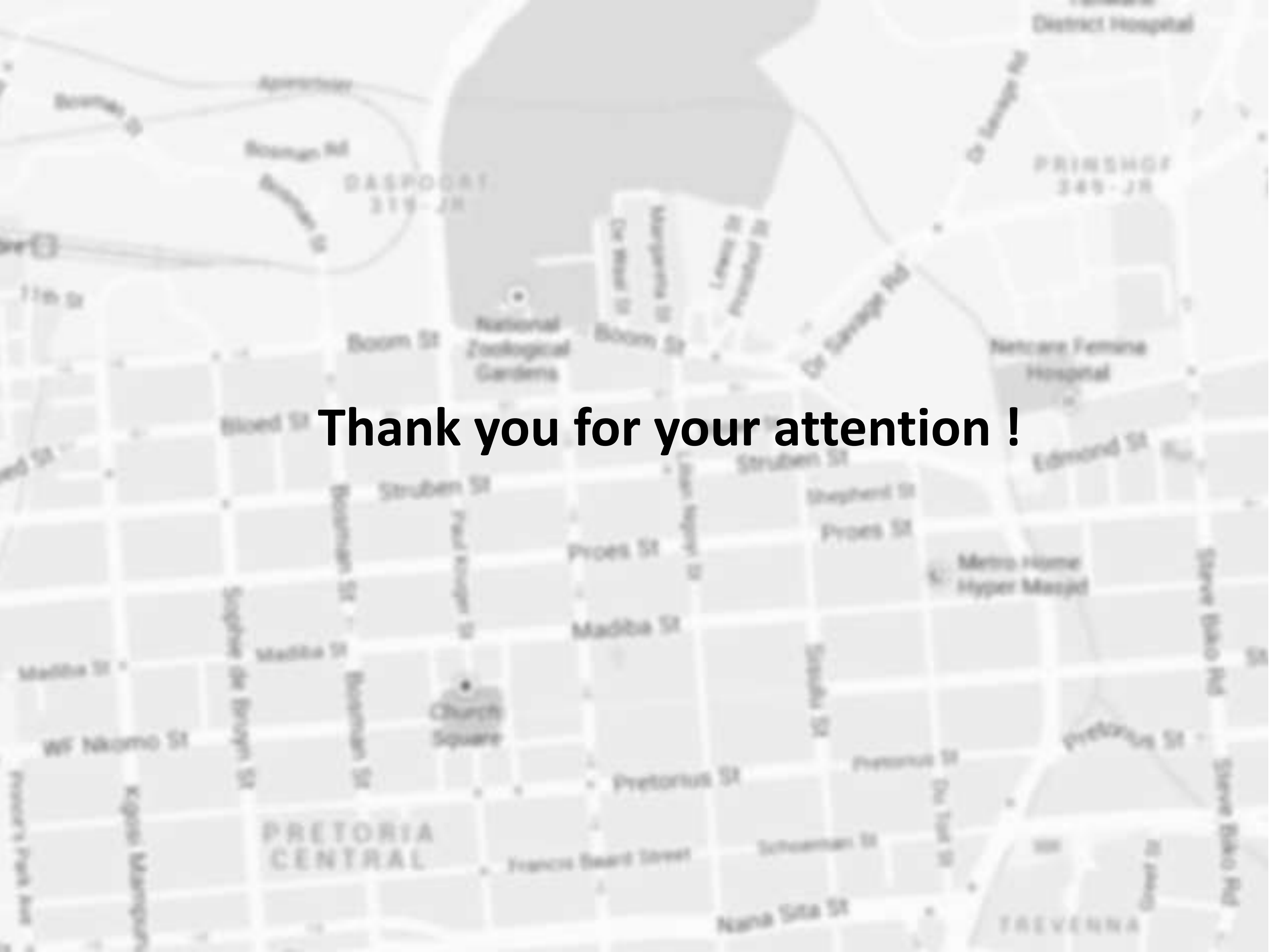
The evolution of the suburban tree



Salat (2012)

Concentration of different types





Thank you for your attention !