A Science of Cities

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Key Themes

- We Stand at Threshold
- A Little History and a Puzzle
- Multiple Perspectives on Cities Across the Sciences
- The Fascination with Form
- Attempting to Explain Location, Place and Space

  Social Physics, Economics and Transportation
- Systems Models and the Transition to Complexity
- Enter Time: Generic Models, Agents, Cells, and Cities
- More General Theory: Scale, Size & Shape
- Attempting a Synthesis

We Stand at Threshold

We live in an age of cities. By the end of this century everyone will be living in cities of one form or another, many of them very large. When this occurs the very definition of the city will be under scrutiny

Just as we need a better science of society to figure out what we are doing in general, we need a science of cities for figuring out how we might best live in them.

You may think that this is what we have been doing for the last century or more and we have but this has been slow and painful progress. There is now some sense however of the sort of science that might be required.

What then will this science look like?

- Well it will be more abstract than the nature of science in this domain so far
- It will be based on big data, about how we all behave and react to change in cities, really big data much bigger than anything we have ever had hitherto
- It will be as much concerned with relationships – networks between us – than with locations or physical form – ***with connectedness***
- It will also look at the size and scale of places where we interact and come together – with ***growth and change*** in places and networks

What I intend to do this afternoon in being the first speaker in the symposium is tell you a little about how we got here –to sketch out some of this science as simply as possible so that it might provide a sense of direction.

To give you some sense of what this science might look like

It is very early days as yet and it has taken a very long time to reach the point where we are now in terms of our understanding of cities and I will elaborate on this.

But let me begin with a little bit of history and a puzzle…….

A Little History and a Puzzle

Cities have been talked about since classical times, since the written record began but only in the last 150 years since the industrial revolution has there been a widespread and sustained effort to intervene in their functioning.

This has largely been through planning which began in the west in the late 19th century.

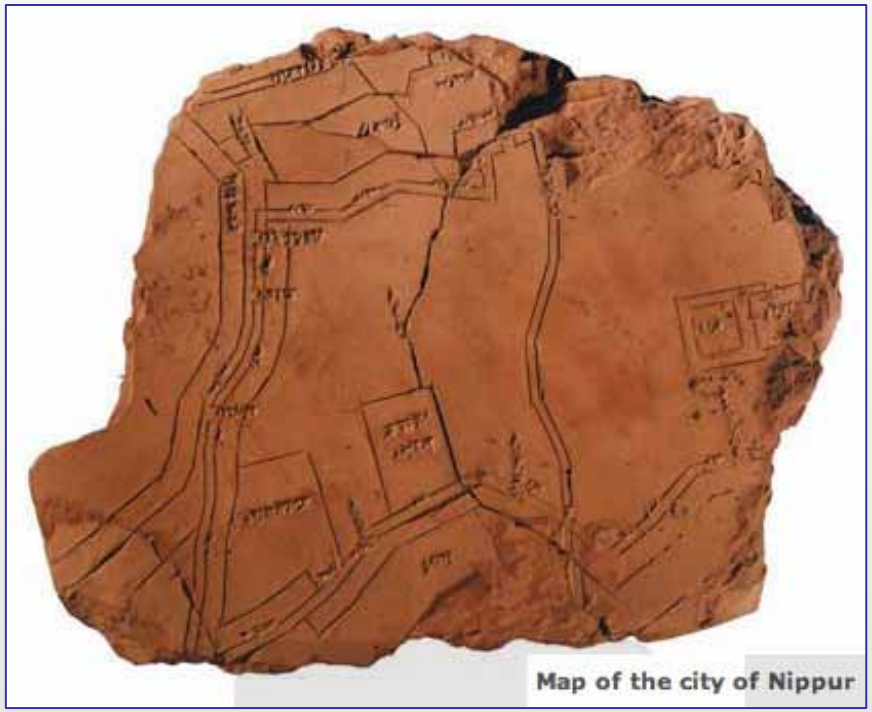
It now seems strange but there was enormous certainty that the evils of the industrial city were supposedly to be resolved by producing cleaner, greener versions of the same thing, but smaller, and away from the industrial city. A return to the countryside.

The puzzle now is that people thought they could do this with little understanding of the city. In fact they thought it did not need understanding and that all it needed was reorganisation. How can you have prediction or prescription before explanation? I guess in human affairs, it happens all the time.

Cities were physical as was their planning and the prevailing view was based on producing better cities through better physical plans.

The city was seen as a work of art more than a social mechanism or rather its planning was a work of art embodied in a strong physical order that assumed it would function a little better.

Here are some early – very early – examples



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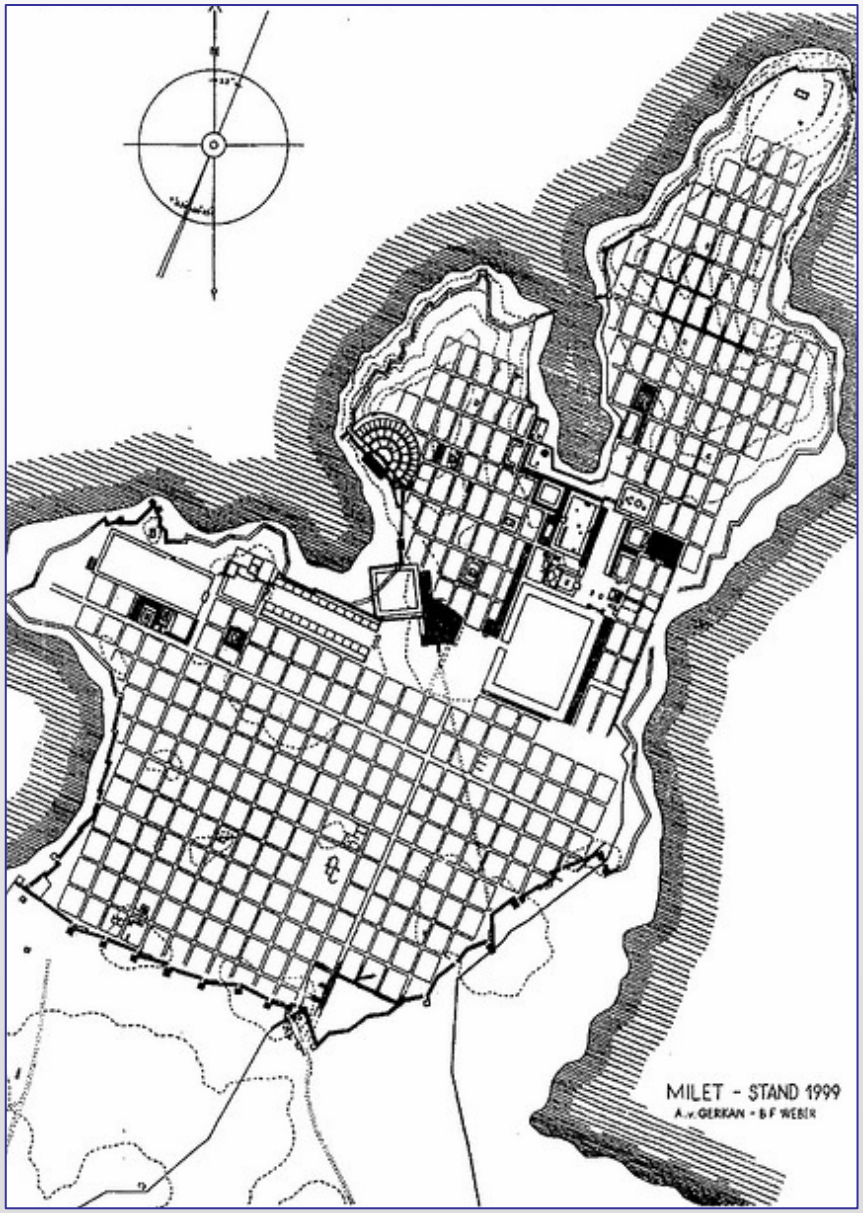

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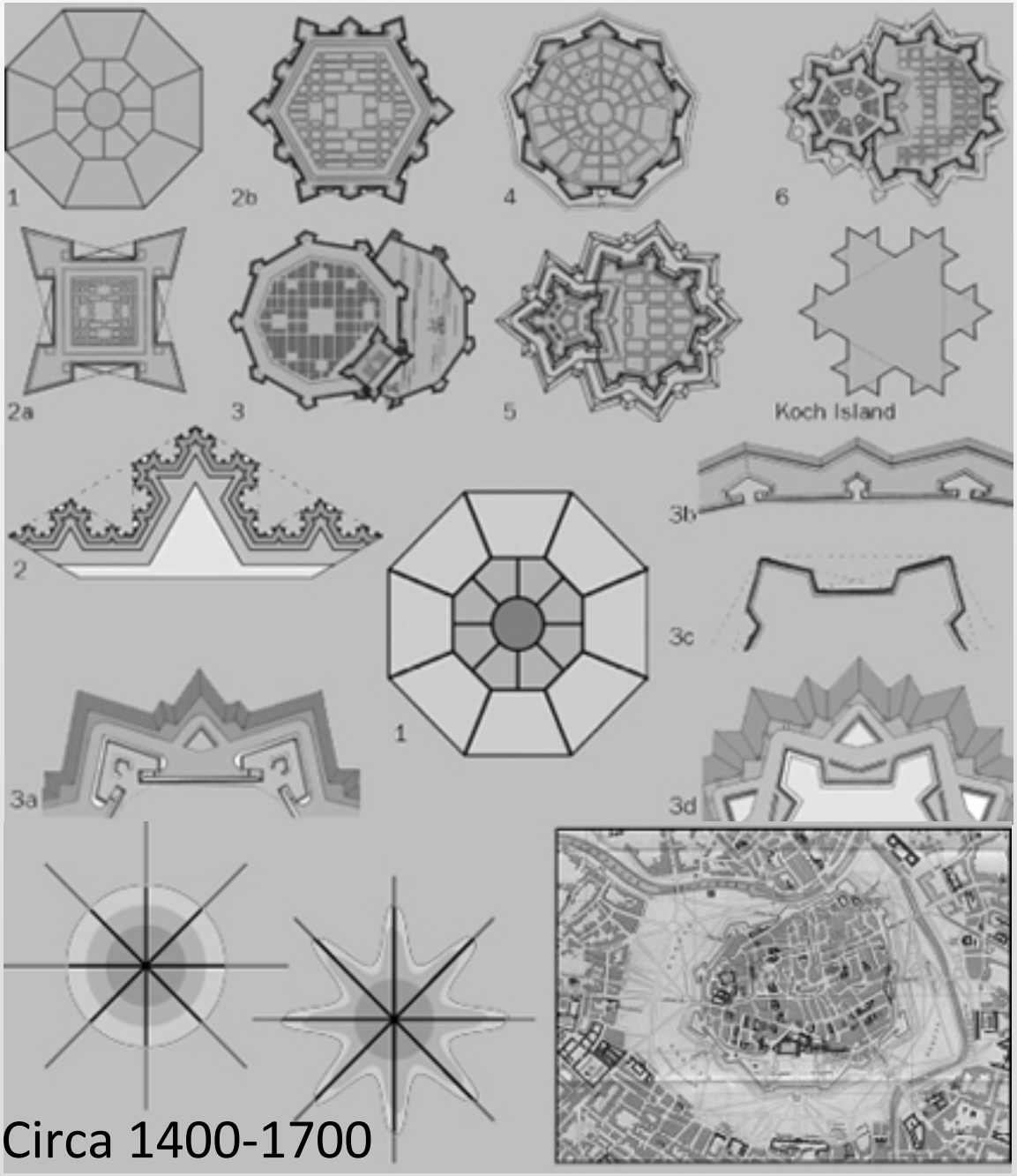
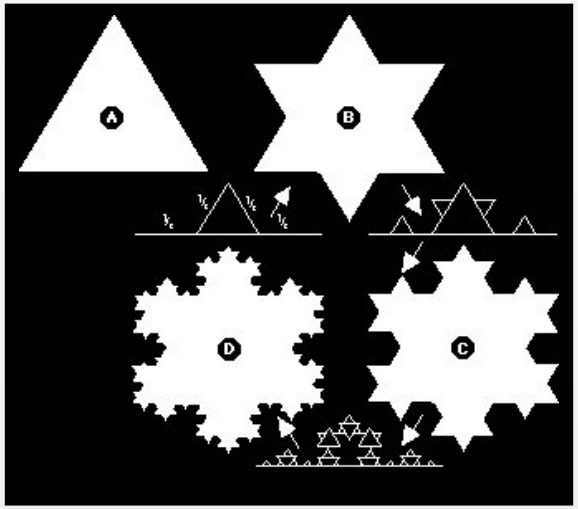
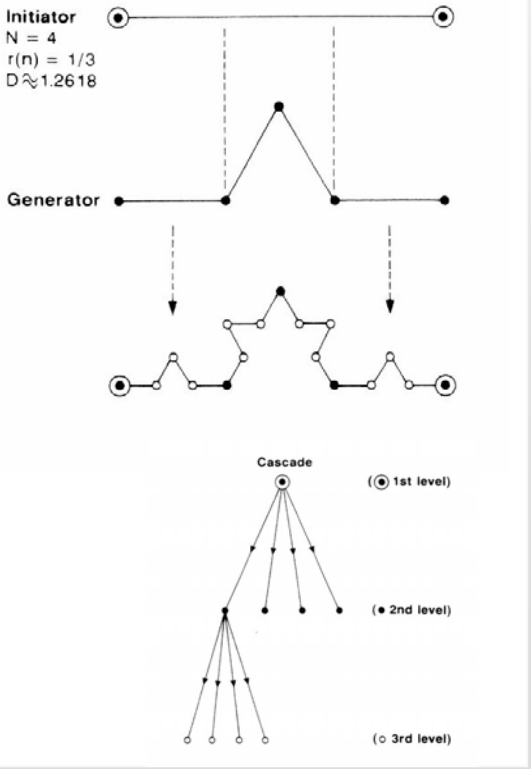
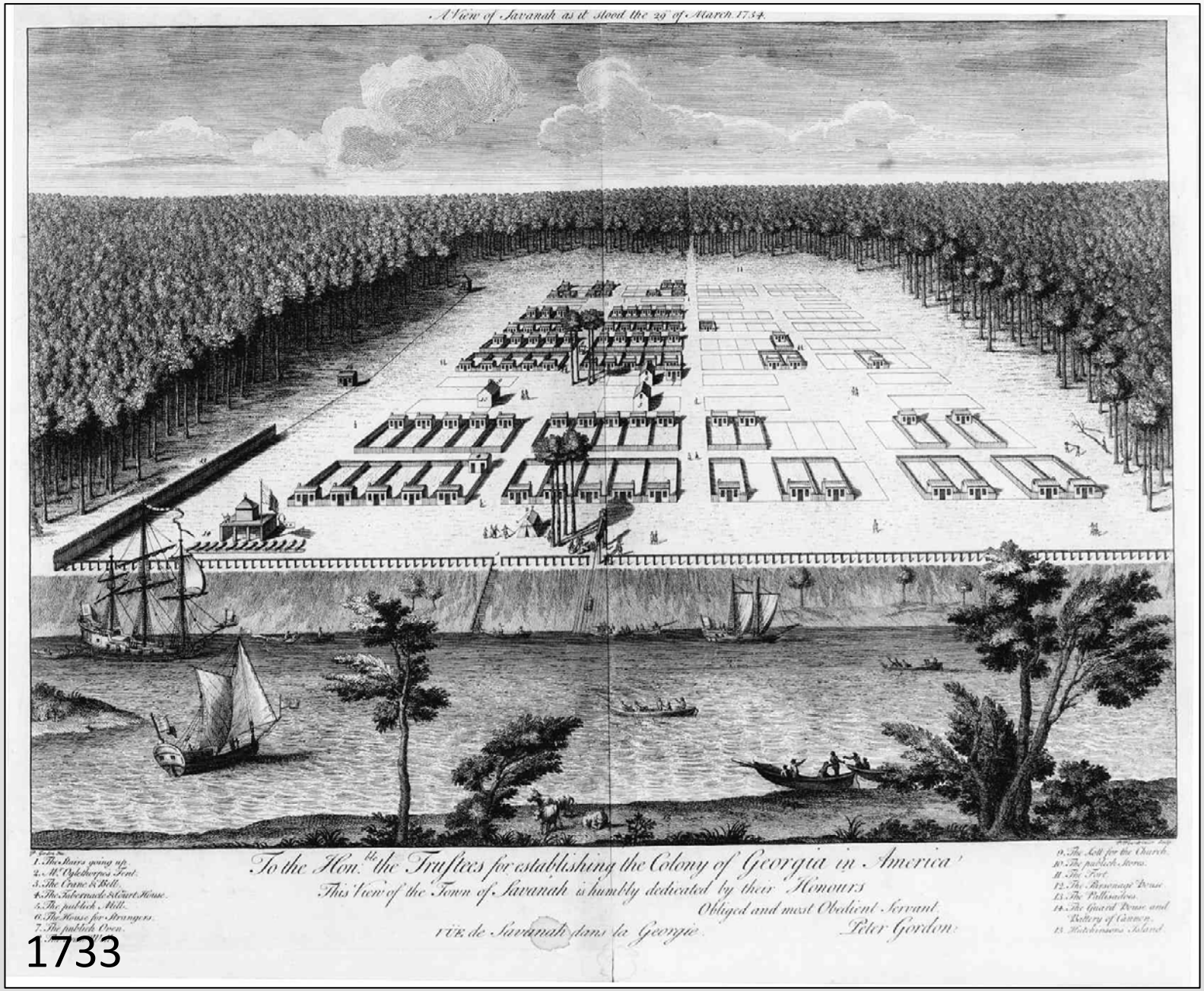


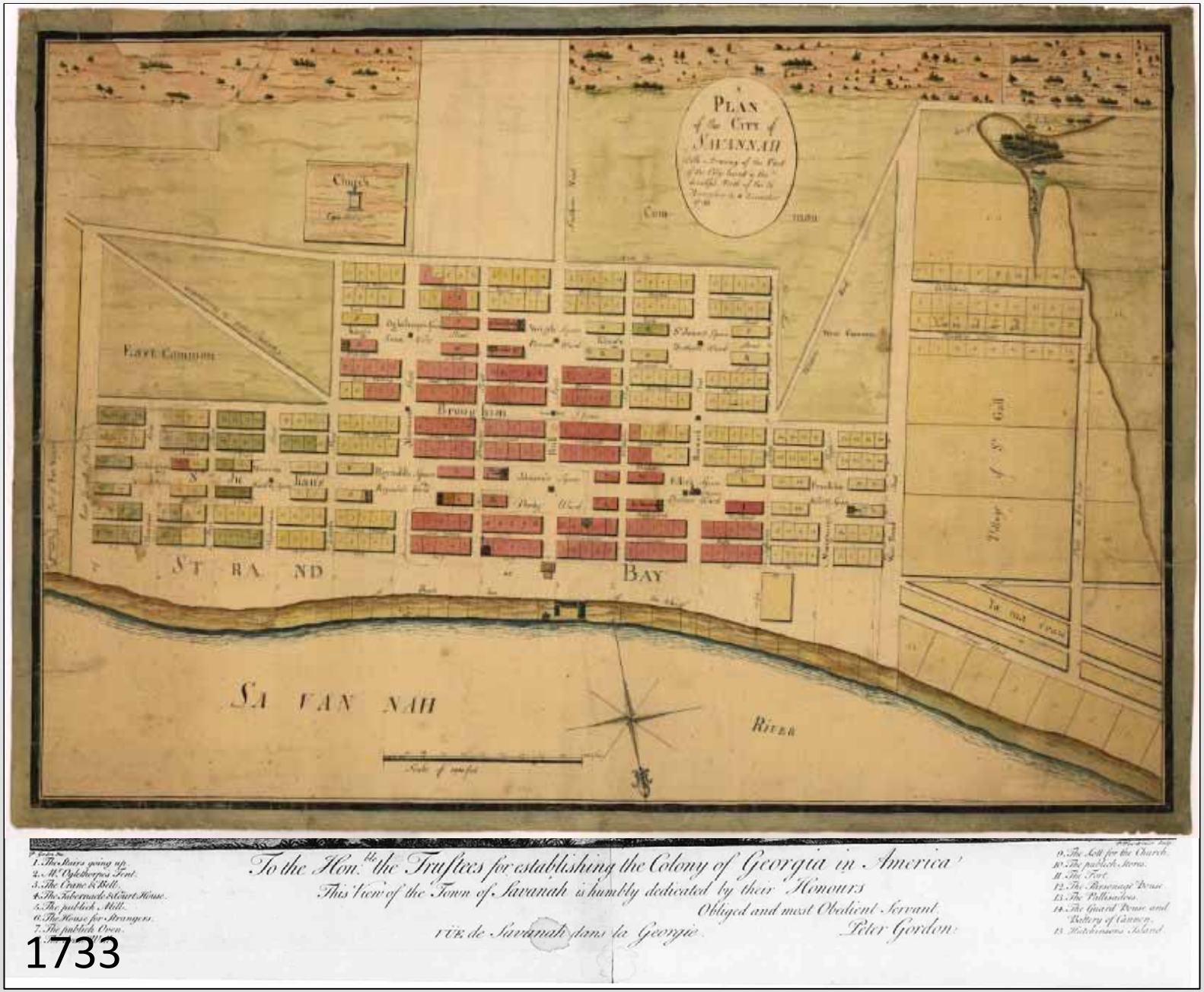
Circa 1400-1700






A View of Savanah as it Stood the 29 of March 1734.
To the Hon.ble the Trustees for establishing the Colony of Georgia in America
This View of the Town of Savanah is humbly dedicated by their Honours
Obliged and most Obedient Servant
Peter Gordon
VUE de Savanah dans la Georgie
1. The Stairs going up.
2. Mr Oglethorpes Tent.
3. The Crane & Bell.
4. The Tabernacle & Court House.
5. The publick Mill.
6. The House for Strangers.
7. The publick Oven.
9. The Lott for the Church.
10. The publick Stores.
11. The Fort.
12. The Parsonage House.
13. The Pallesadoes.
14. The Guard House and Battery of Cannon.
15. Hutchinsons Island.

1733


PLAN
of the CITY of
SAVANNAH
Church
EAST COMMON
BROUGHTON
ST RA ND
BAY
SA VAN NAH
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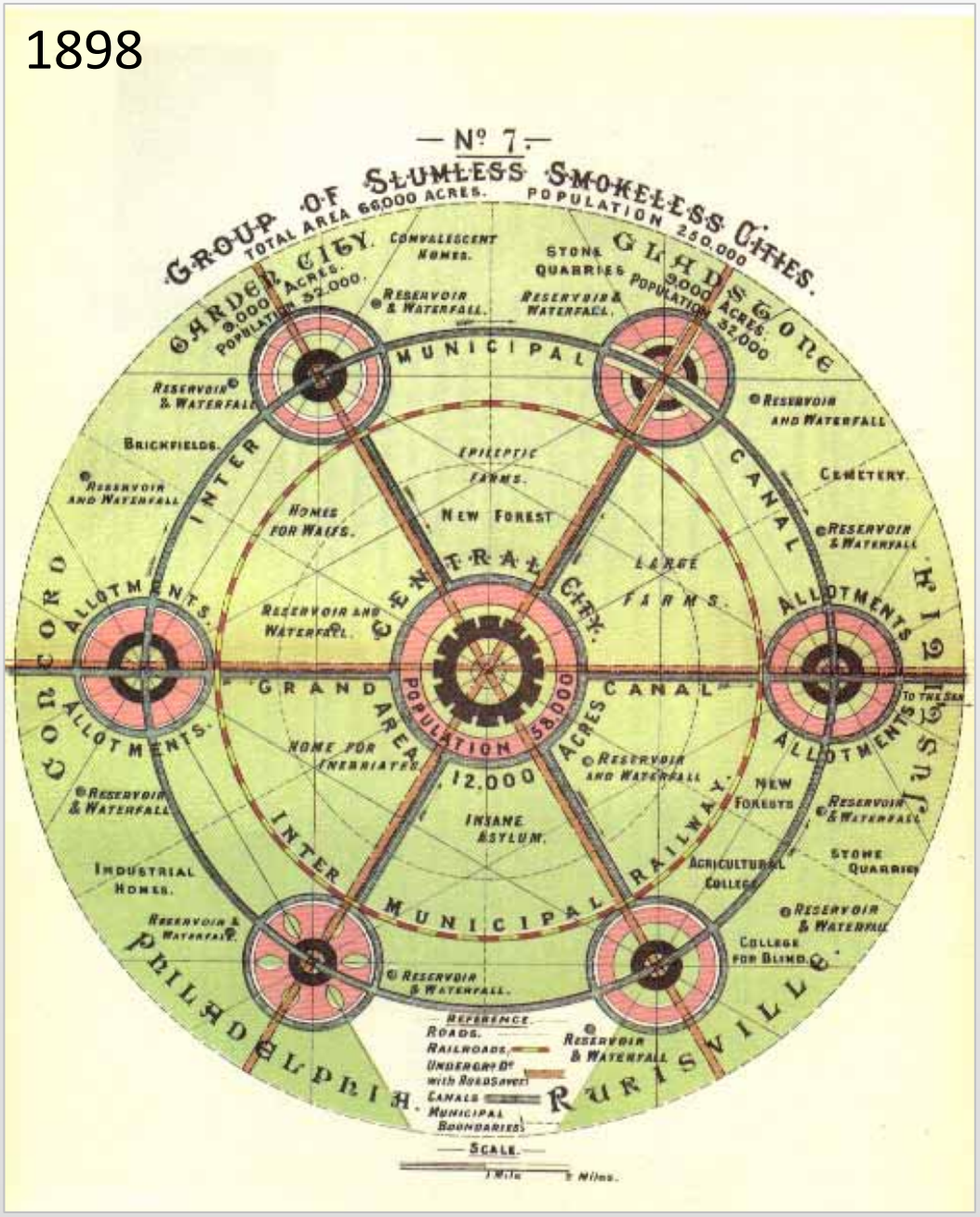
1733

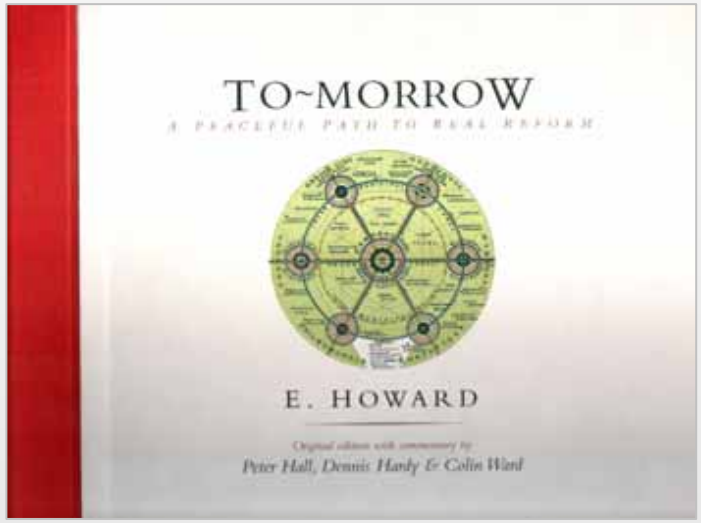
By the middle of the 19th century, the idea that the cities could be improved through top down physical planning gained momentum. By the early 20th C various institutional apparatus had been put in place to do something about it. The key issues were:

- Cities were regarded as something 'evil' to be managed
- The idea that the country should be moved back into the town was important
- Decentralisation, suburbanisation, counter-urbanisation was key to policy
- Managed 'sprawl' implicitly regarded as acceptable, what the Americans now call 'smart growth'.

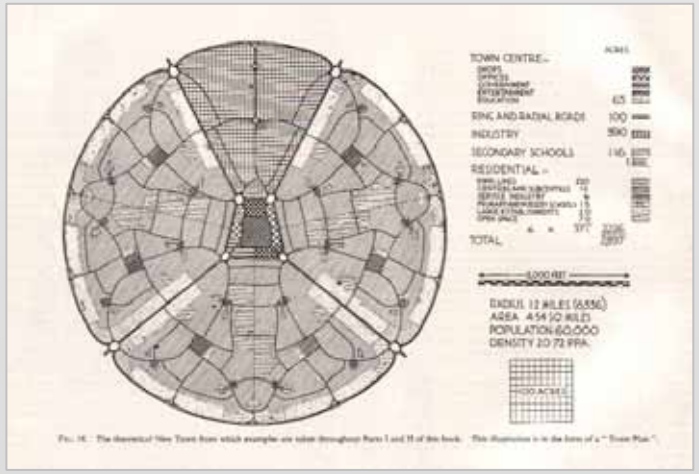
1898

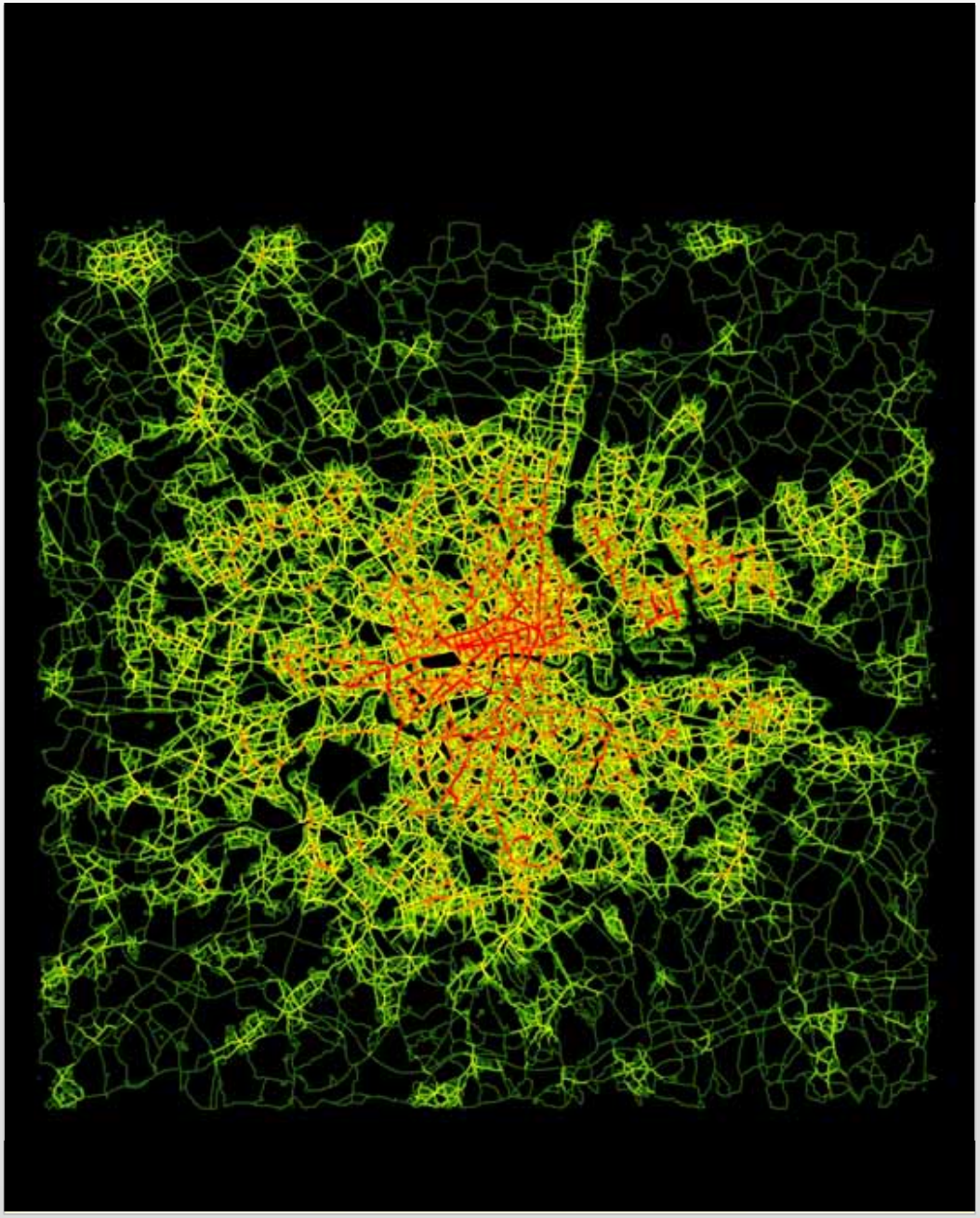


A System of Cities: The Inter-Urban



A City: The Intra-Urban





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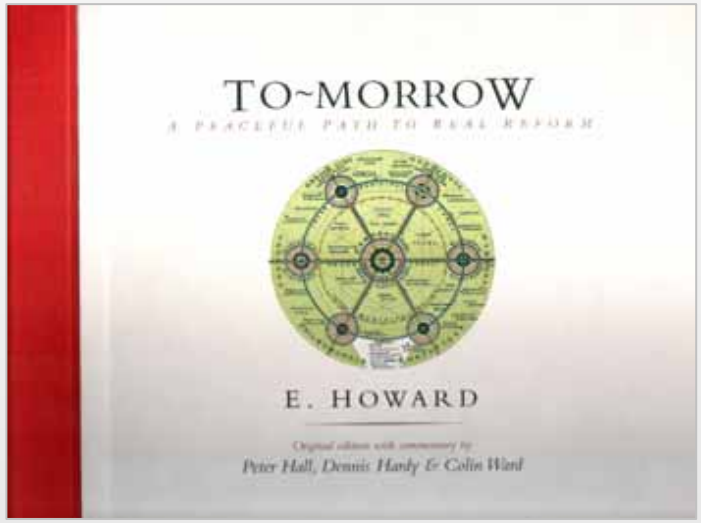

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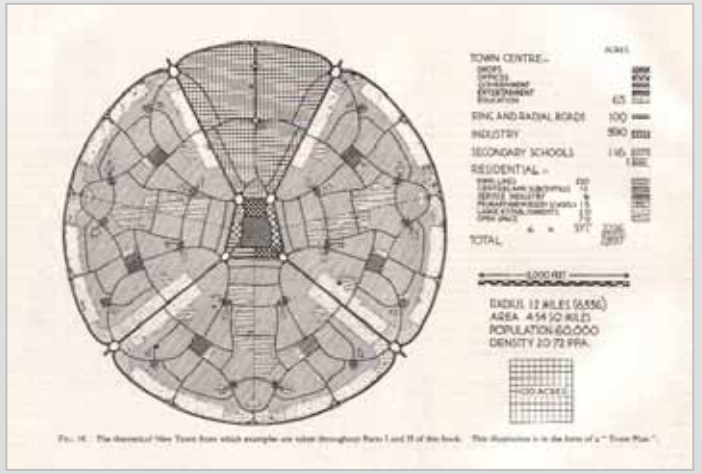


Multiple Perspectives on Cities Across the Sciences

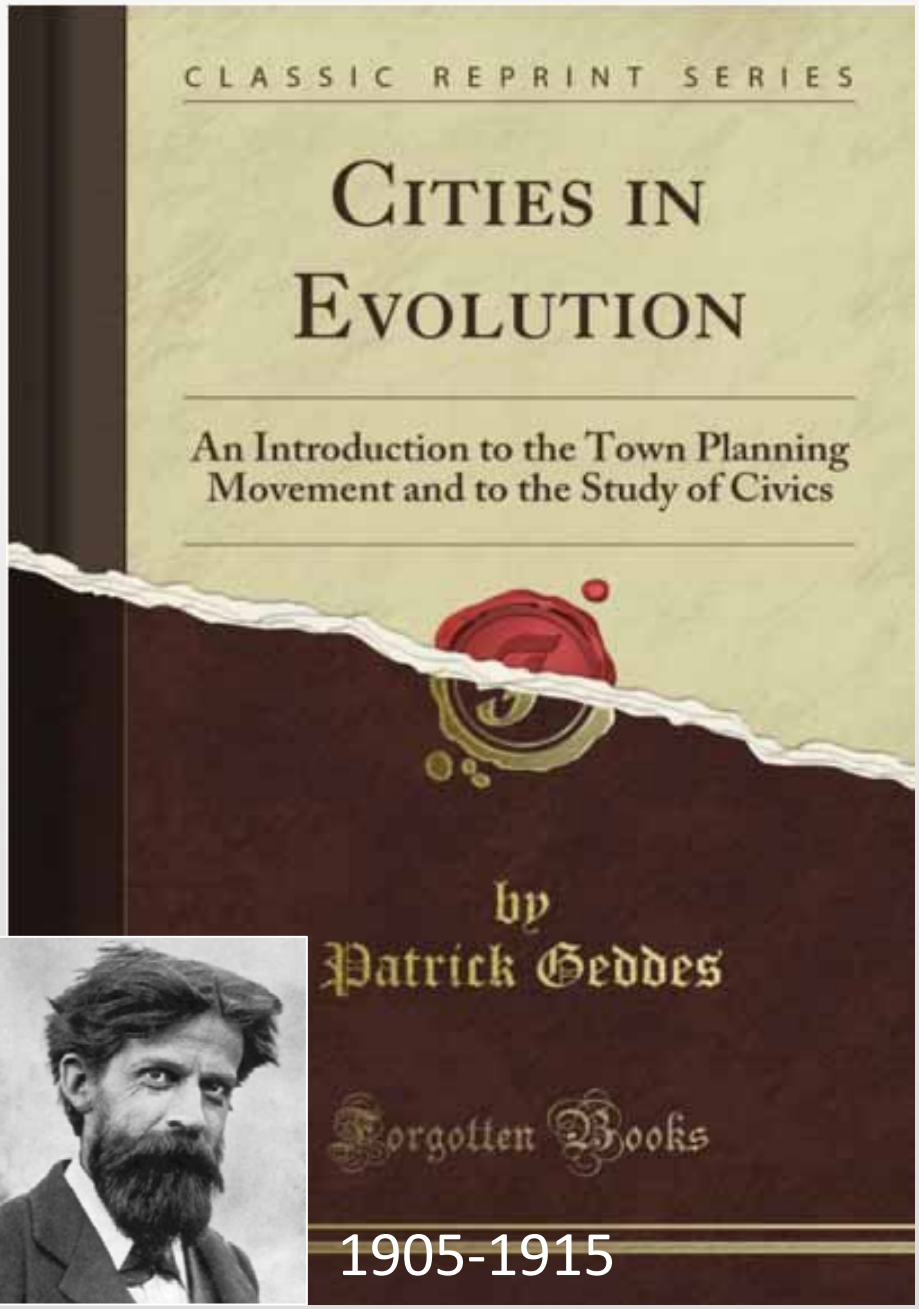
The 20th century saw the proliferation of ideas about the city in many intellectual domains

In the arts and humanities and the social sciences but also in engineering and more recently in physics

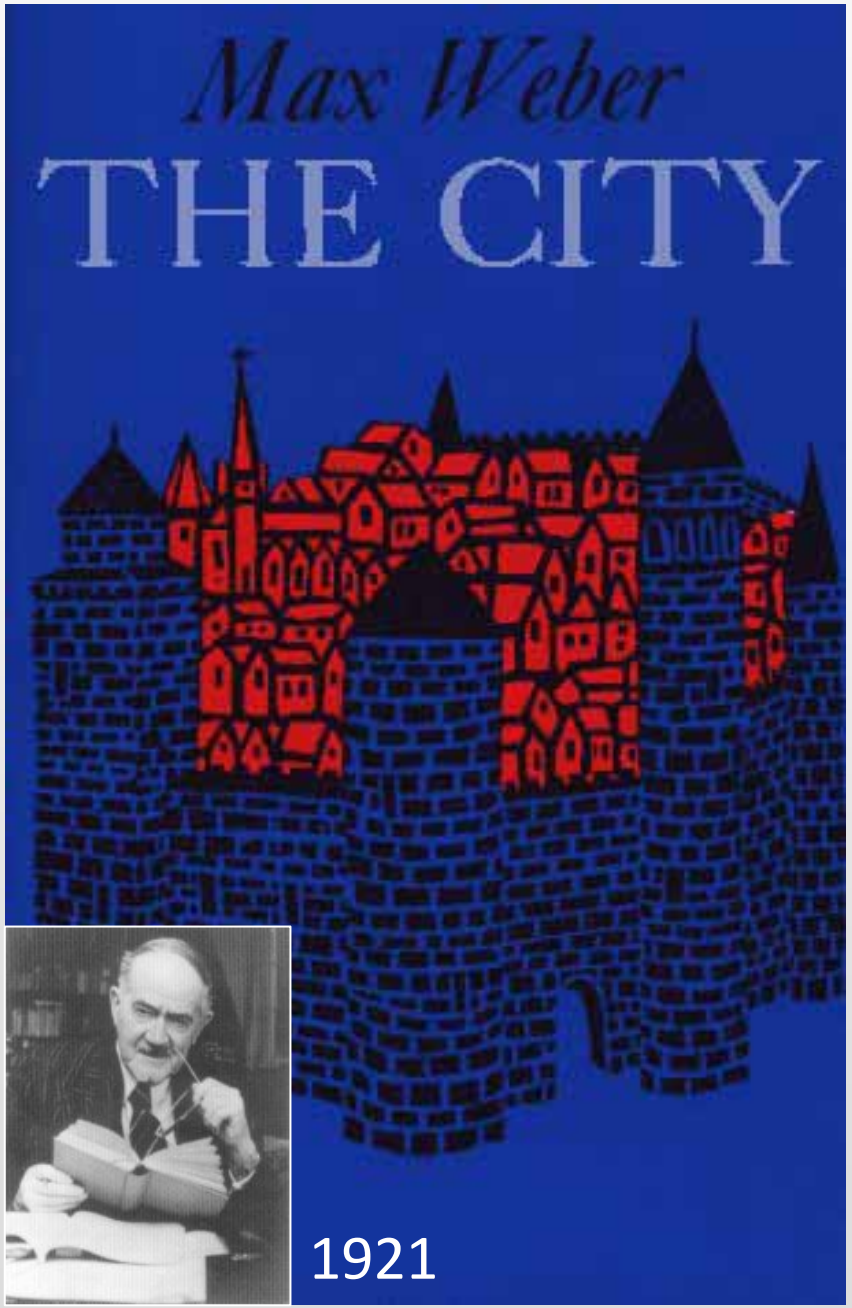
Each professing that they have the kernel of knowledge that will explain the key forces at work in the city

There is an enormous domain of 'urban studies' focusing on cities; and the professional and semi-academic domain of city planning and architecture

Two early books that focus on different perspectives imply a sense that there might be a science of cities



1905-1915



1921

I could show you a 100 books, perhaps a 1000, more,, which profess to explain the city but these two reflect an early concern with science – Geddes – and with politics – Weber.

Although a science of cities was largely not discussed, there were the seeds of a dawning recognition that cities could be understood more systematically

It is one purpose of this talk to try and build a bridge between those currents and what we are thinking about today.

The currents were primarily economic in focus – to explain the city as an economic mechanism although the dominant focus has been physical, and to a lesser extent social

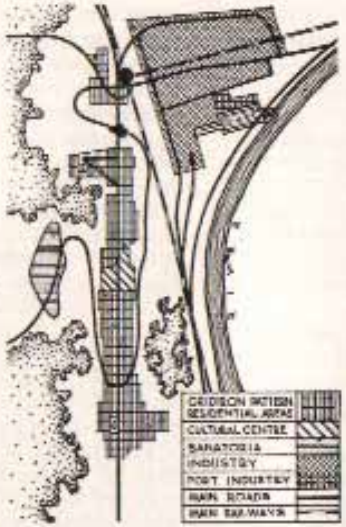
The Fascination with Form

As we have already seen, the city has always been articulated in terms of its physical form. I call the quest to explain how cities function through the lens of form *physicalism*

In fact planning cities was almost invariably physical in its manner during most of the 20th century for it was always believed that the efficient and equitable functioning of cities would manifest in urban form

You could see pollution, slums, deprivation, traffic congestion, green space, and so on and a lot was considered to be only surface deep, hence easily solvable.

(i)



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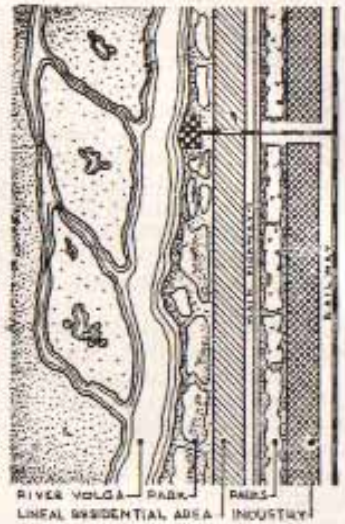

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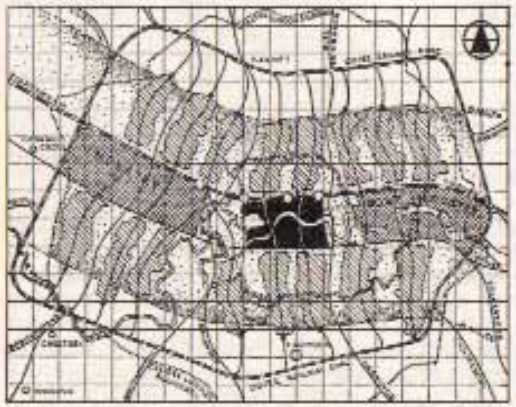

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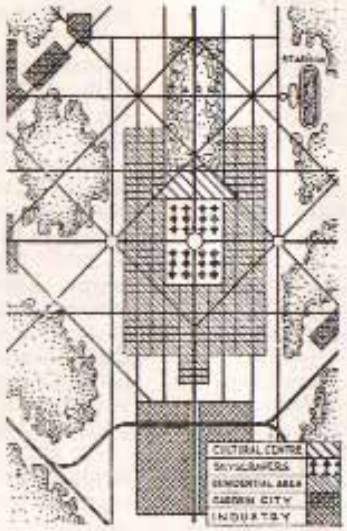
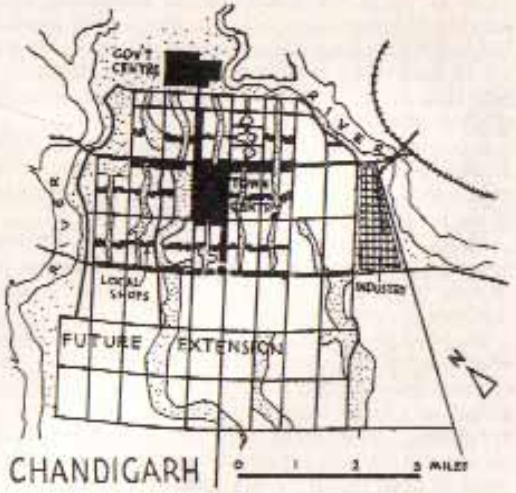


(v)

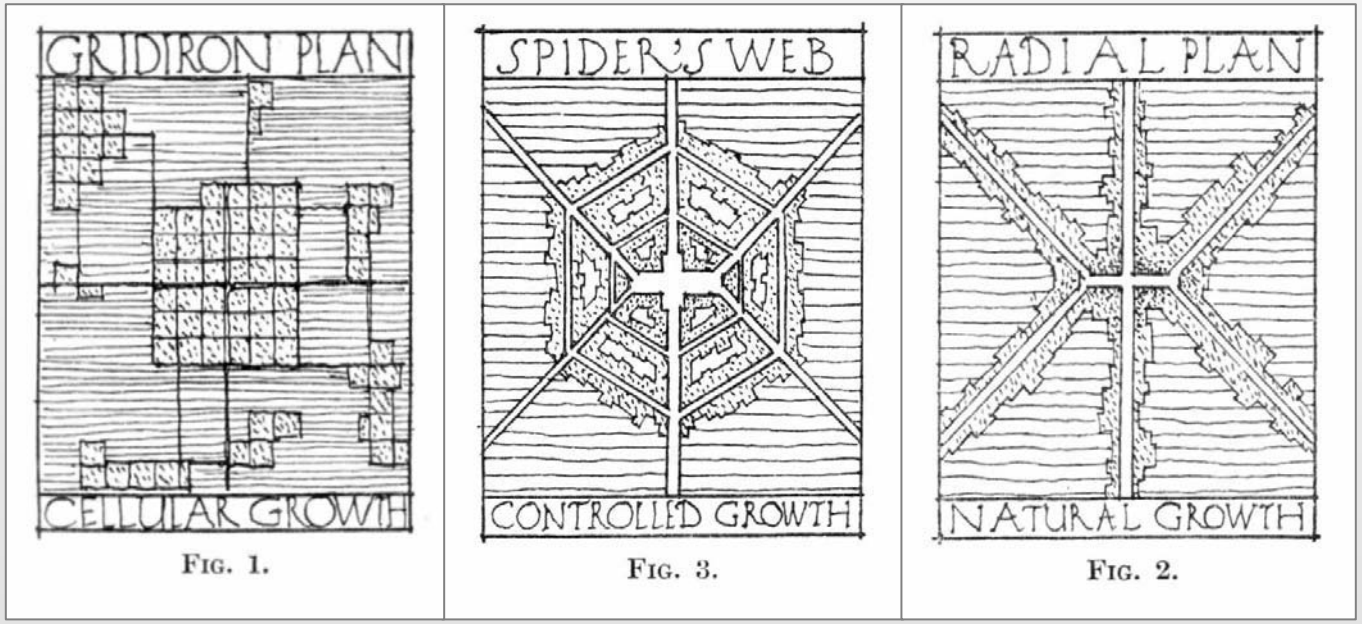


(vi)

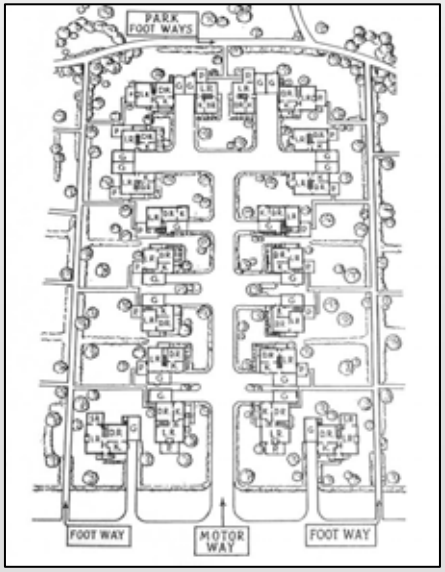
FIG. 17 PLANNING THEORIES

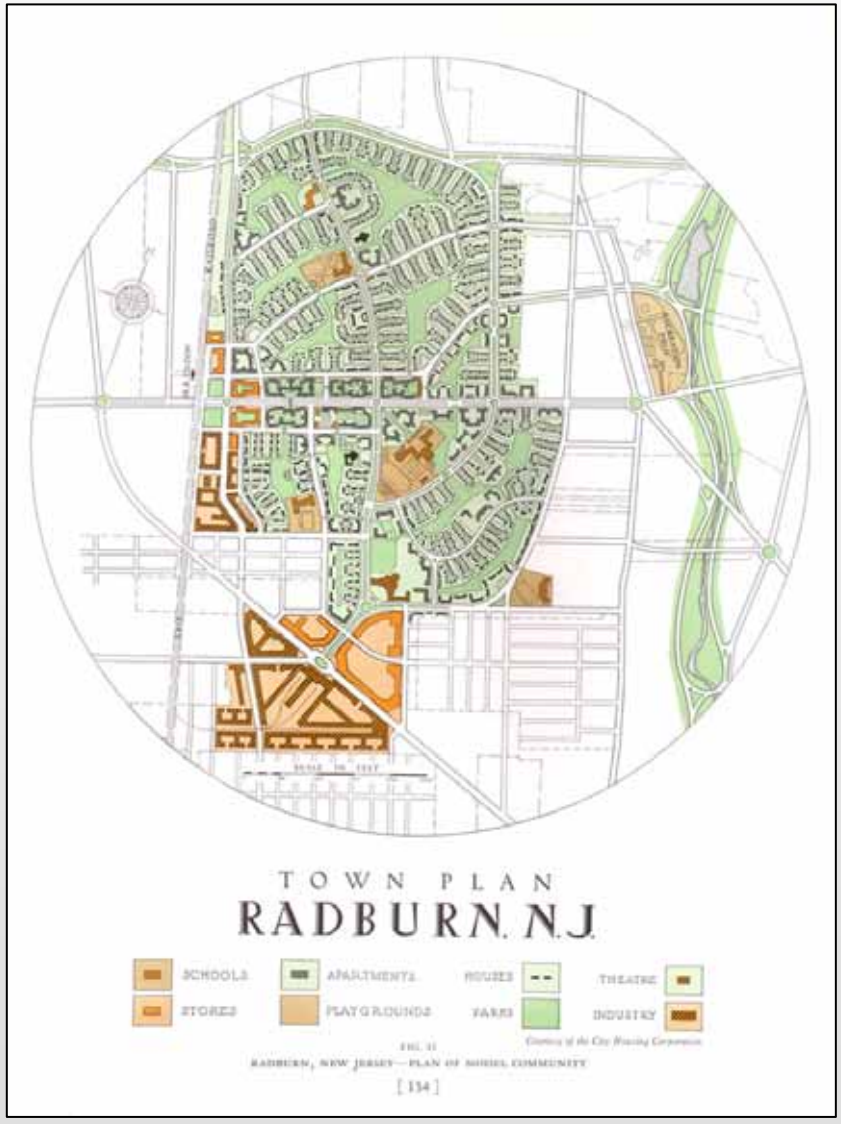
(i) The original Ciudad Lineal.
(ii) Garnier's " Cité industrielle ".
(iii) Part of a lineal plan for Stalingrad.
(iv) M.A.R.S. group Plan for a lineal London.
(v) Le Corbusier's " City of Tomorrow ".
(vi) Chandigarh.

Here are some idealised forms, which imply different degrees of planning – from Abercrombie's little book **Town and Country Planning** (1935)



Note that these forms are highly suggestive of generative models but let me digress briefly about the word 'city' and 'town' for one minute. I should perhaps digress about 'science' but that can wait.





Modular design: an early ‘new town’ RADBURN, NJ, 1920s

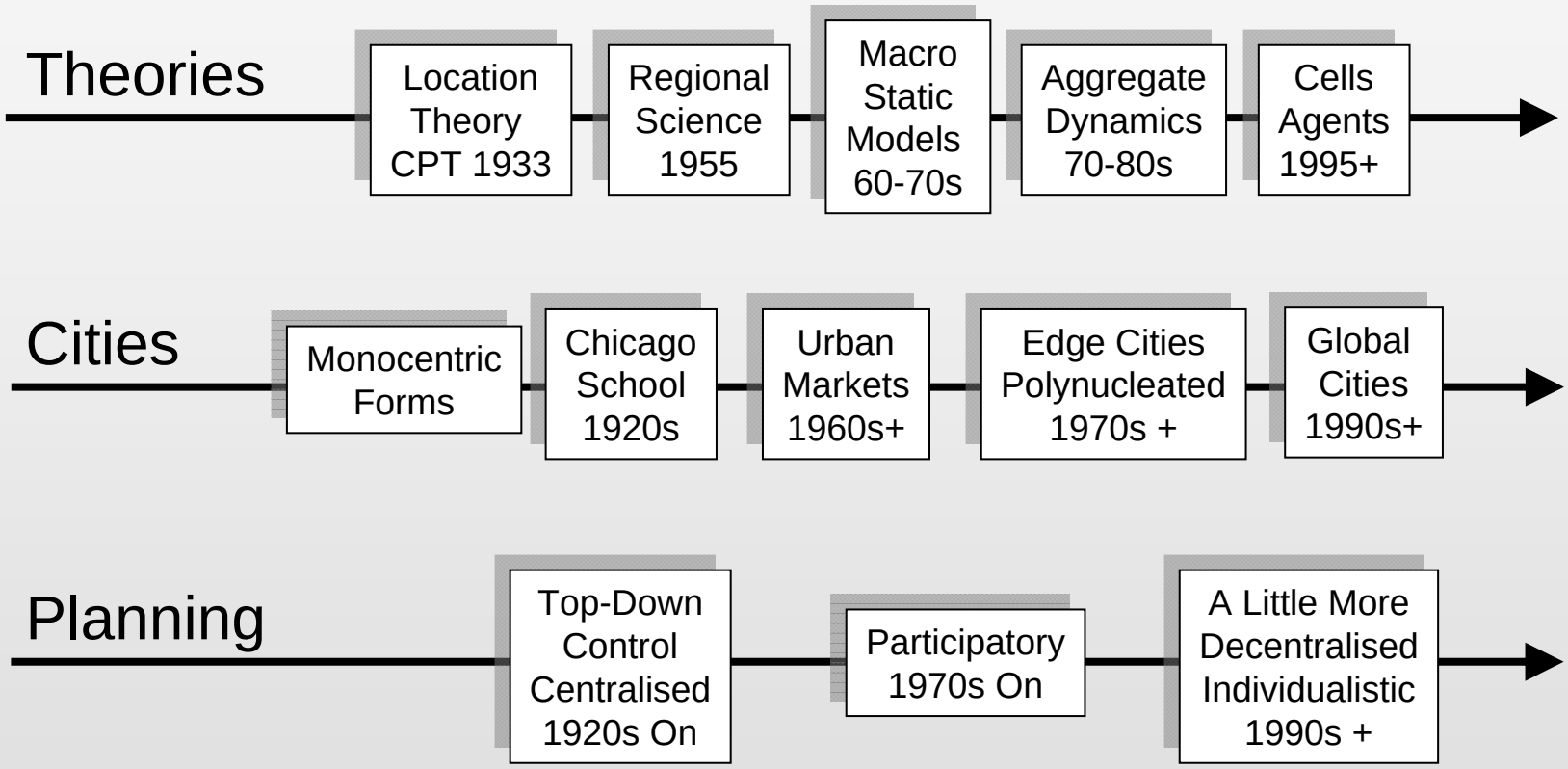
We are still fascinated by form today, as witnessed in more recent examples such as the planned developments in places like Dubai, arguably even more extreme than these more modest layouts of the early and mid 20th century

Attempting to Explain Location, Place and Space: *as Social Physics, Economics and Transportation*

Ok let me try to begin by sketching the various currents that began to fashion an understanding of cities as a science during the 20th century

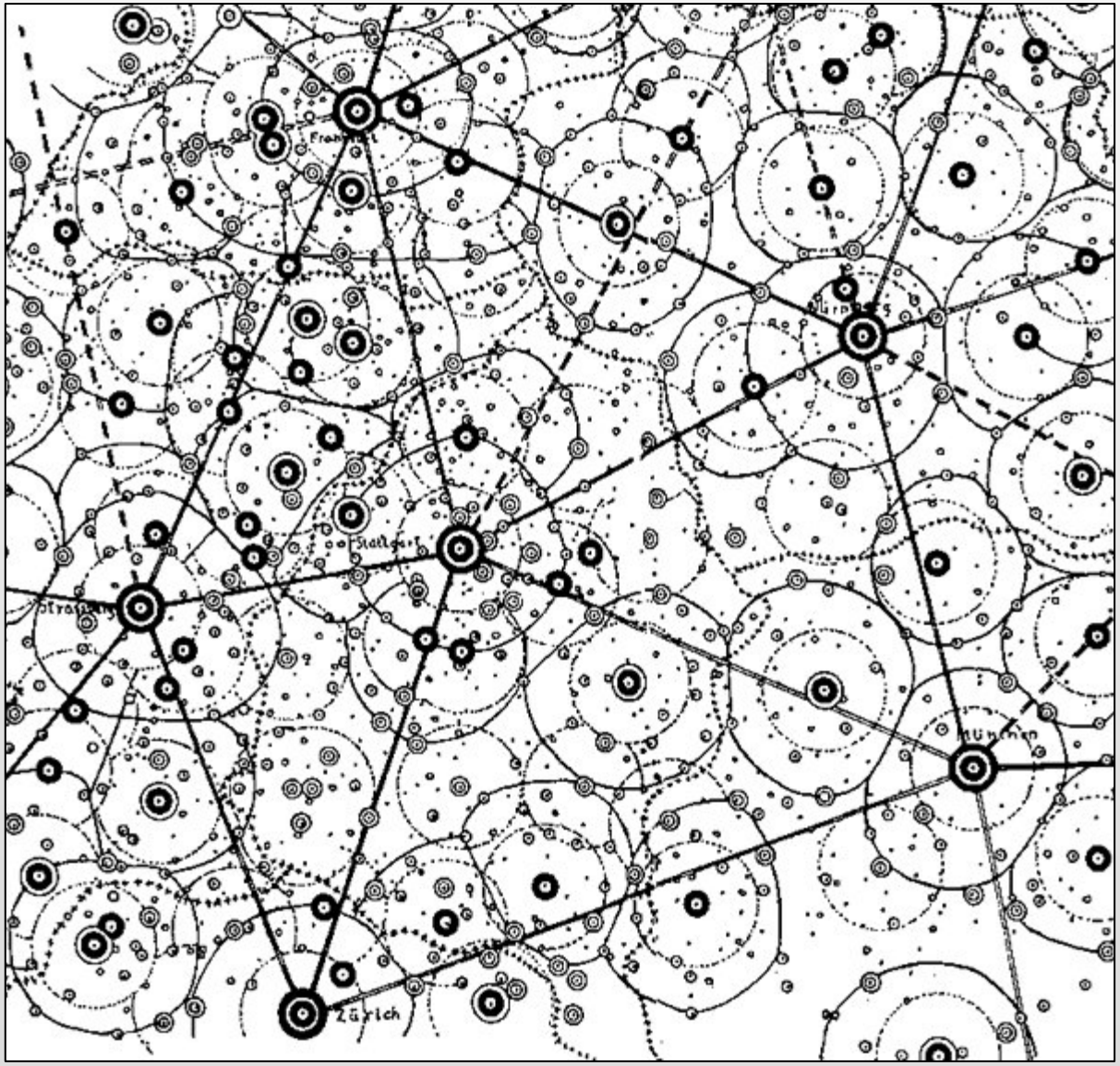
First I will sketch a chronology of ideas and then begin to sample them. It is a tall order to give you anything but a sample on such a wide canvas but I will try.

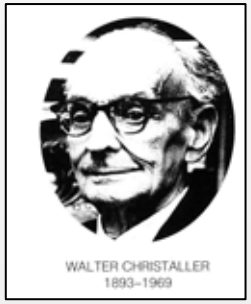
I will also attempt to see these in terms of ***size, scale, shape of location (actions) and interactions*** - watchwords for what a new science might be about



19th century industrial city …… 21st century global city

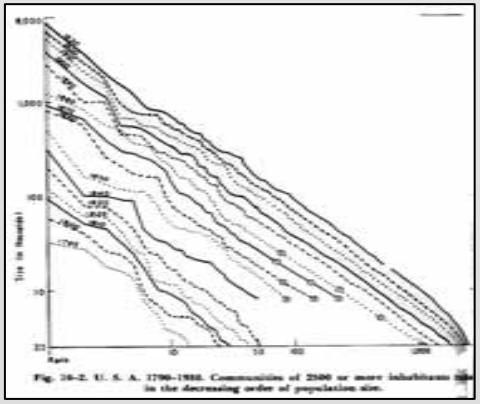
Economics between cities: Hierarchy, Size, Shape & Scale



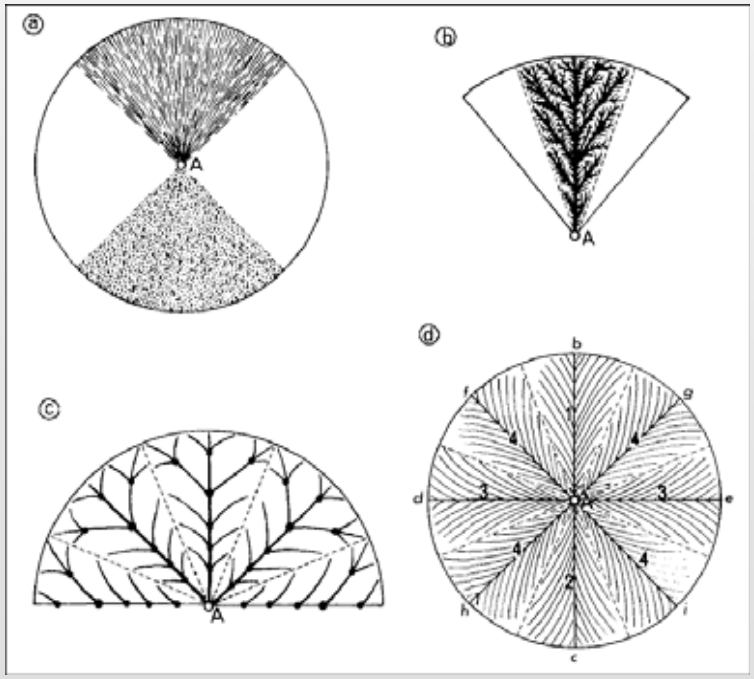


Losch

Zipf



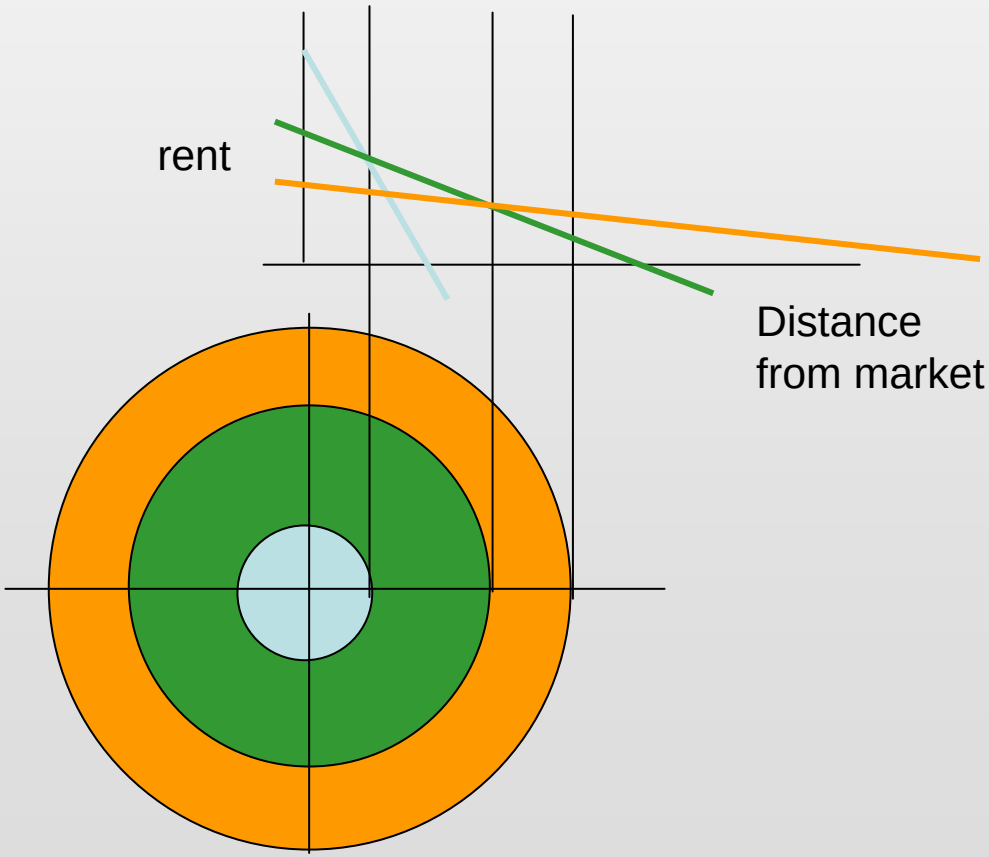
There were several much earlier statements in fact: Kohl (1841) *Traffic and Settlements of People with Regard to their Dependence on the Morphology of the Earth's Surface*



And in 1842 Jean Reynaud produced a version of Central Place Theory

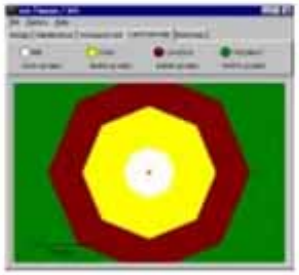
Economics within the cities: Price – Intra-urban, scale and size with shape implicit

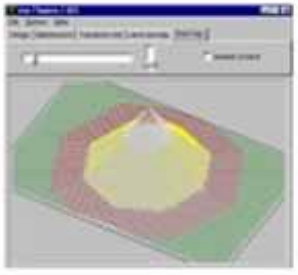
The best model I can show of urban economics in the mid to late 20th century is von Thunen's – of 1826



I have a little model to demonstrate this and it really contains everything we know about how accessibility shapes land use and how rent is determined. It relates a little to shape as well

Von Thunen



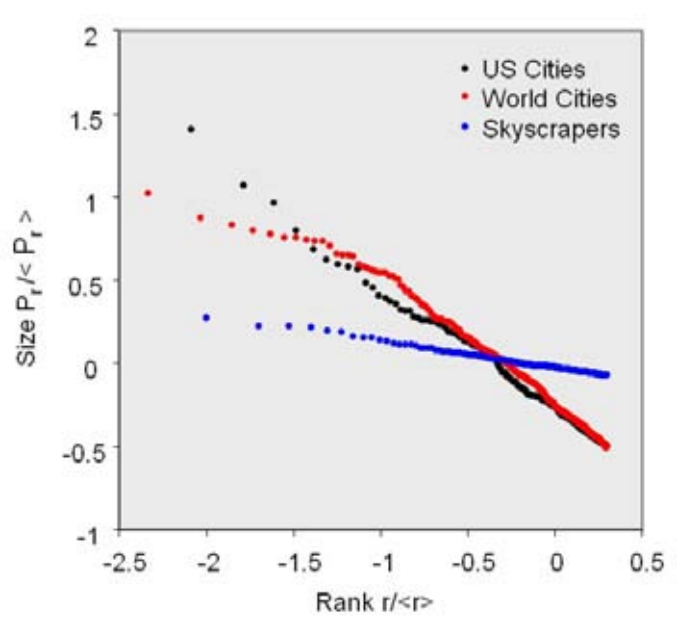


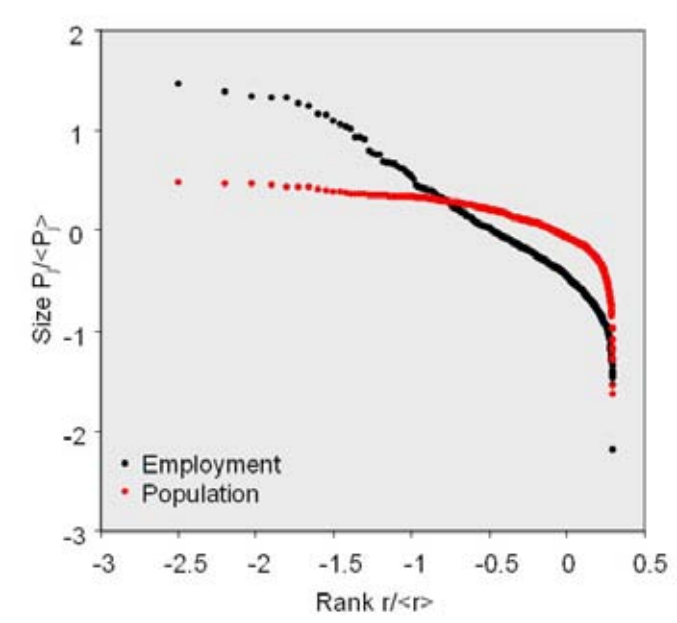
I will show you our little model built originally by Phil Steadman when he was at the Open University 20 years ago and you can download this from

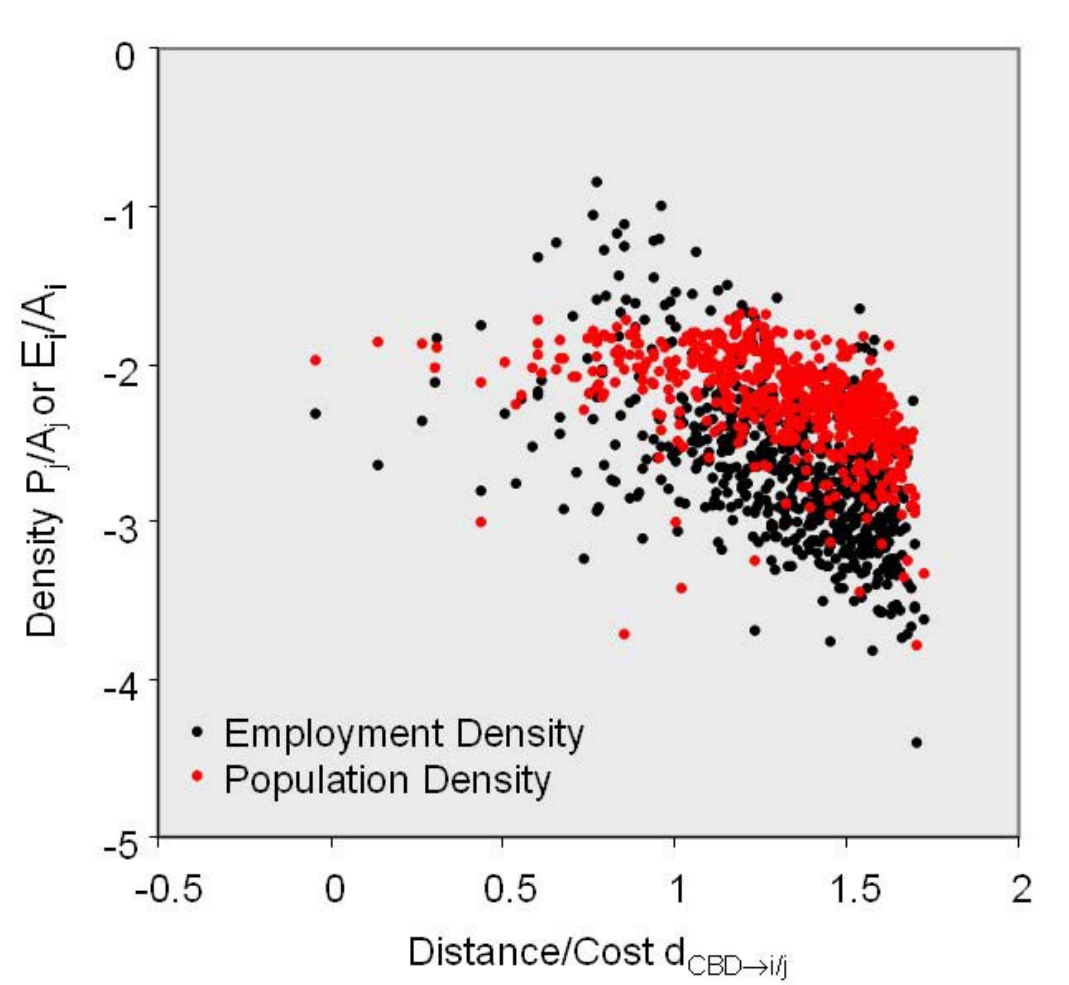
http://www.complexcity.info/media/software/von-thunens-model/

Spatial Interaction: A long history of application of the gravity model which treats distance as a scaling phenomena. I don't have time to go into this in detail but worth noting that the von Thunen monocentric city rent model is really a one dimensional spatial interaction model

Worth noting too that as yet a complete set of ideas about ***scale, size, shape, hierarchy*** for ***locations and interactions*** defining ***systems of cities*** (inter-urban) and the ***city system*** (intra-urban) has not been assembled but could be. Let me finish this brief section by pointing to the difficulties of fitting these kinds of idea to data and show some of these for London.


US Cities
World Cities
Skyscrapers
Size $P_r/<P_r>$
Rank r/<r>


Employment
Population
Size $P_j/<P_j>$
Rank r/<r>


Employment Density
Population Density
Density P_j/A_j or E_i/A_i
Distance/Cost $d_{CBD \rightarrow i/j}$

Systems Models and the Transition to Complexity

In the 1960s, there was some sense that we needed to underpin cities with comprehensive theory and the systems approach became popular. Systems conceived as being in equilibrium – another massive limitation of the emerging theories but fitting them rather well.

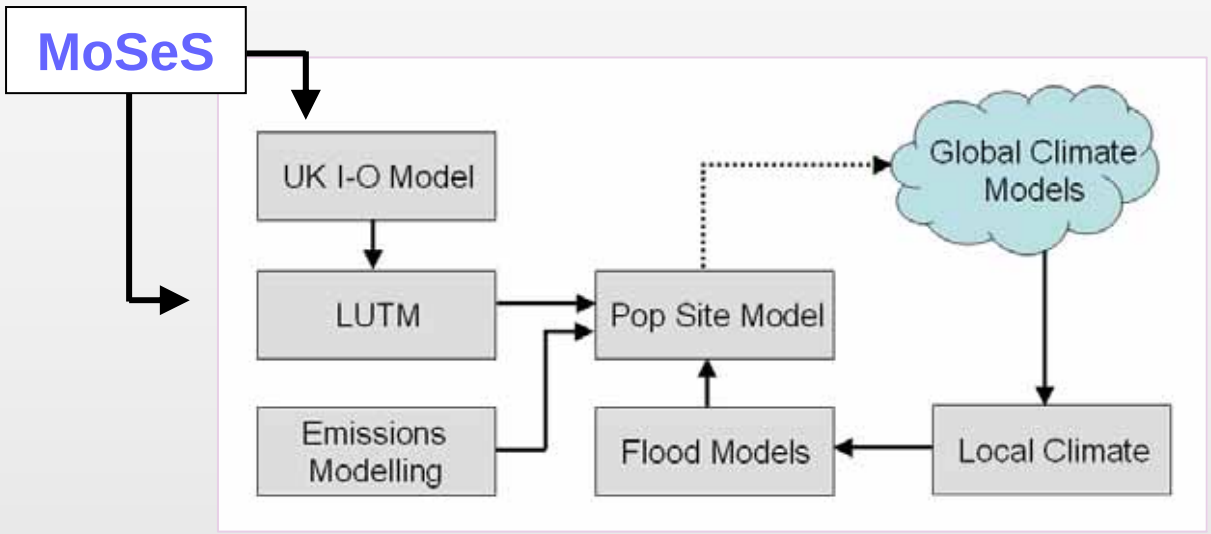
And top down in terms of their organisation – and control – fitting rather well the predominant model of planning that had become widely established since the end of the 19th century.

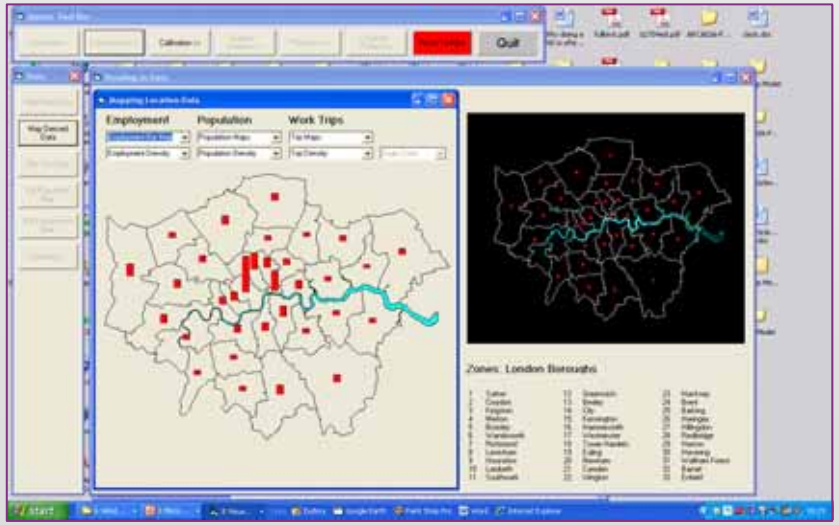
Onto this scene came aggregate, equilibrium, operational meaning empirically grounded in data and applicable for practical prediction, transport then land use-transport models.

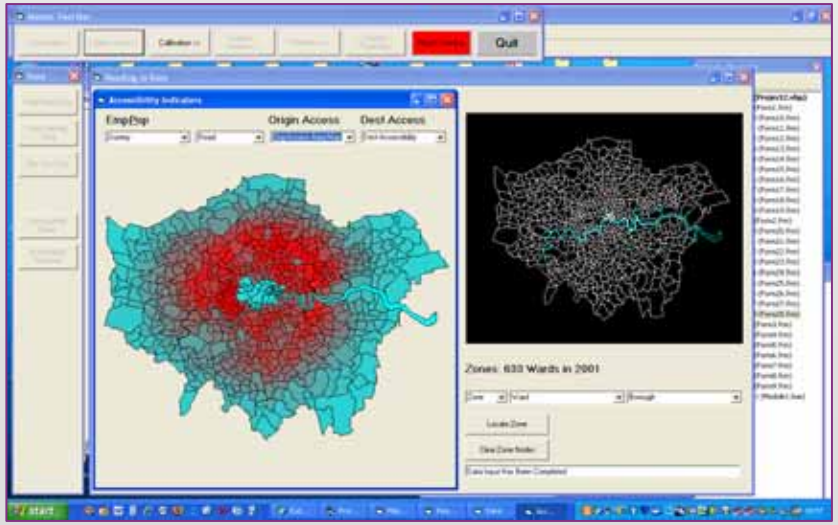
The heritage of these models largely built around spatial interaction and discrete choice theory in terms of travel demand are still with us today. These models are policy-orientated, large-scale, fit rather badly, and tend to be one-offs. And they persist …

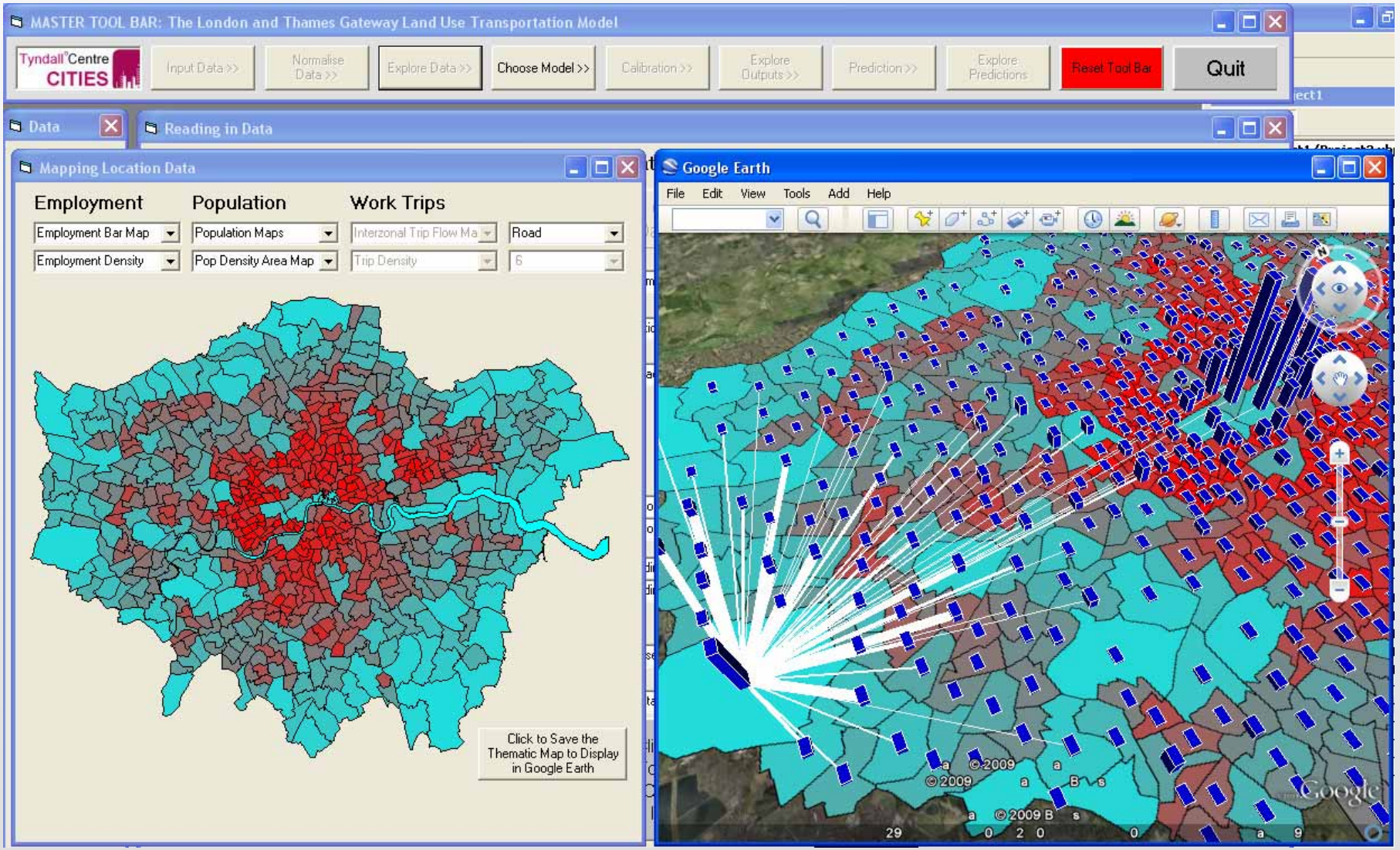
They are now much more disaggregate and some quite interesting developments from the TRANSIMs work at Los Alamos – in particular MATSIM and there are links to UrbanSim. Let me provide a sense of this kind of thinking from our own work in London

Let me first explain the Tyndall Cities Model for London









Exporting data and predictions to external software on the fly –

I would like to show you a movie of this as it represents some really rather powerful developments in software for planning support

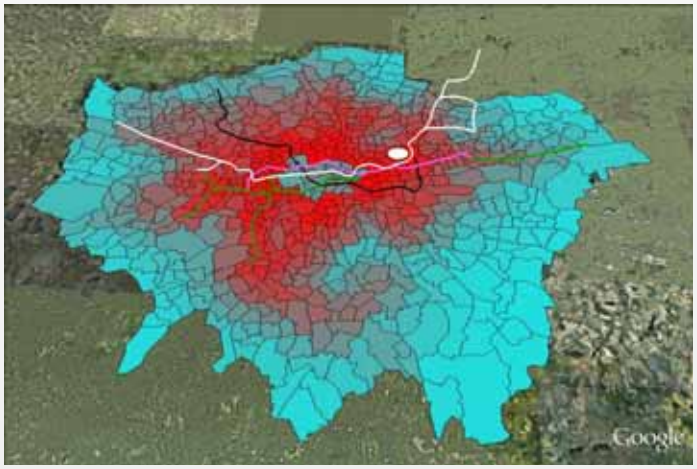
It is online at

http://www.casa.ucl.ac.uk/movies-weblog/googleEarth.mov

If I can't load it you can see it here – it shows how you can mesh desktop modelling software with 'free' resources such as Google Earth

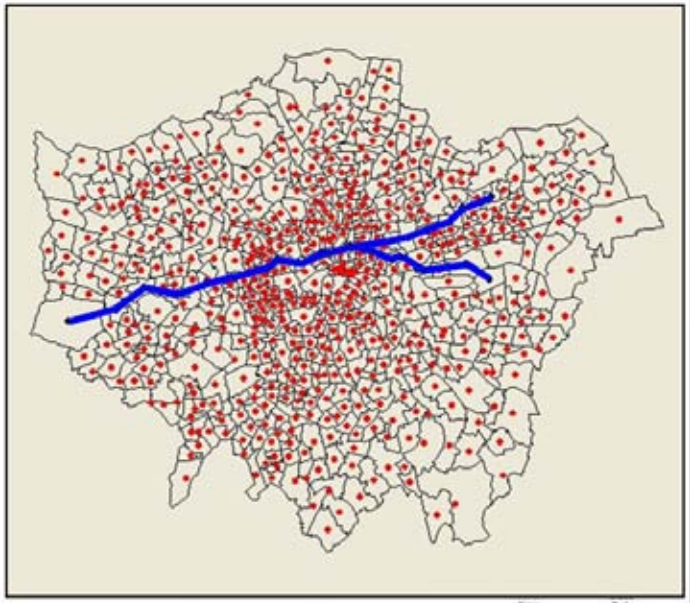
And to really indulge, I want to show you something that was made 31 years ago in the Architecture and Planning Building here at the Uni

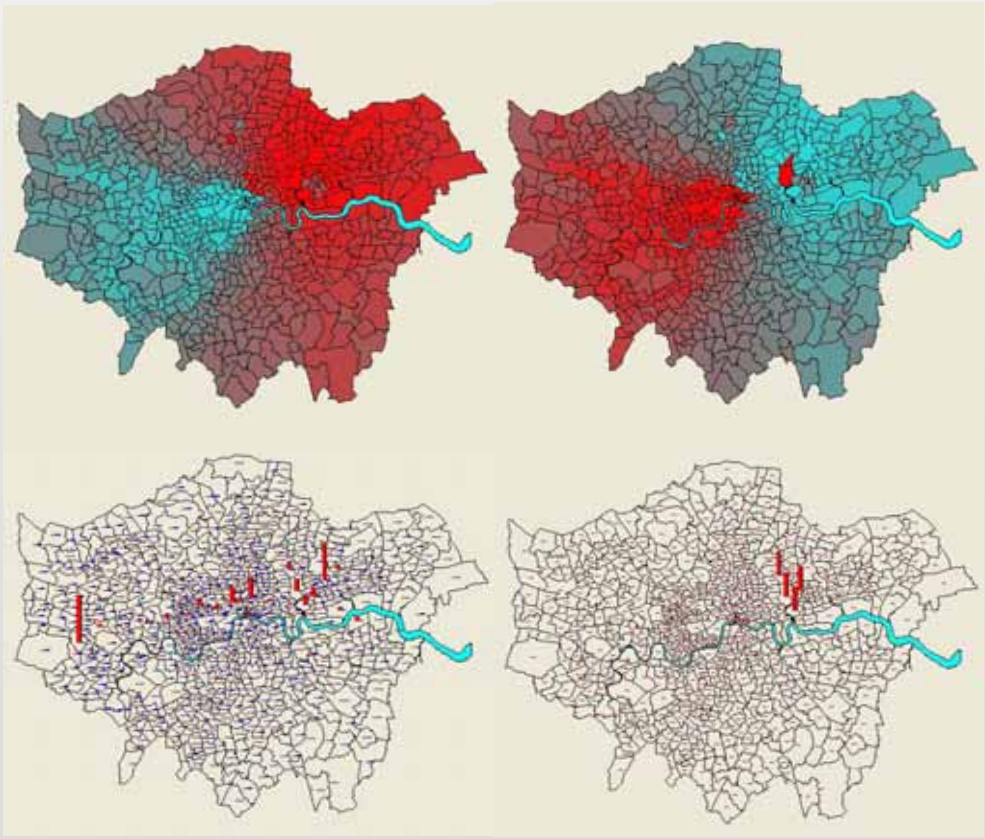
http://www.casa.ucl.ac.uk/movies-weblog/Melbourne-1982-Movie.mov

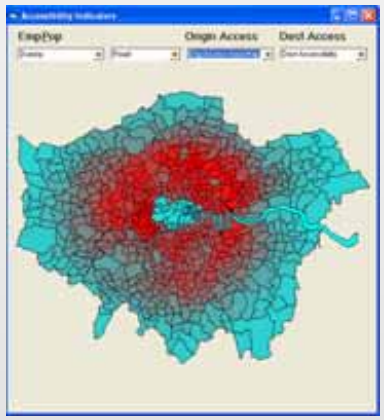


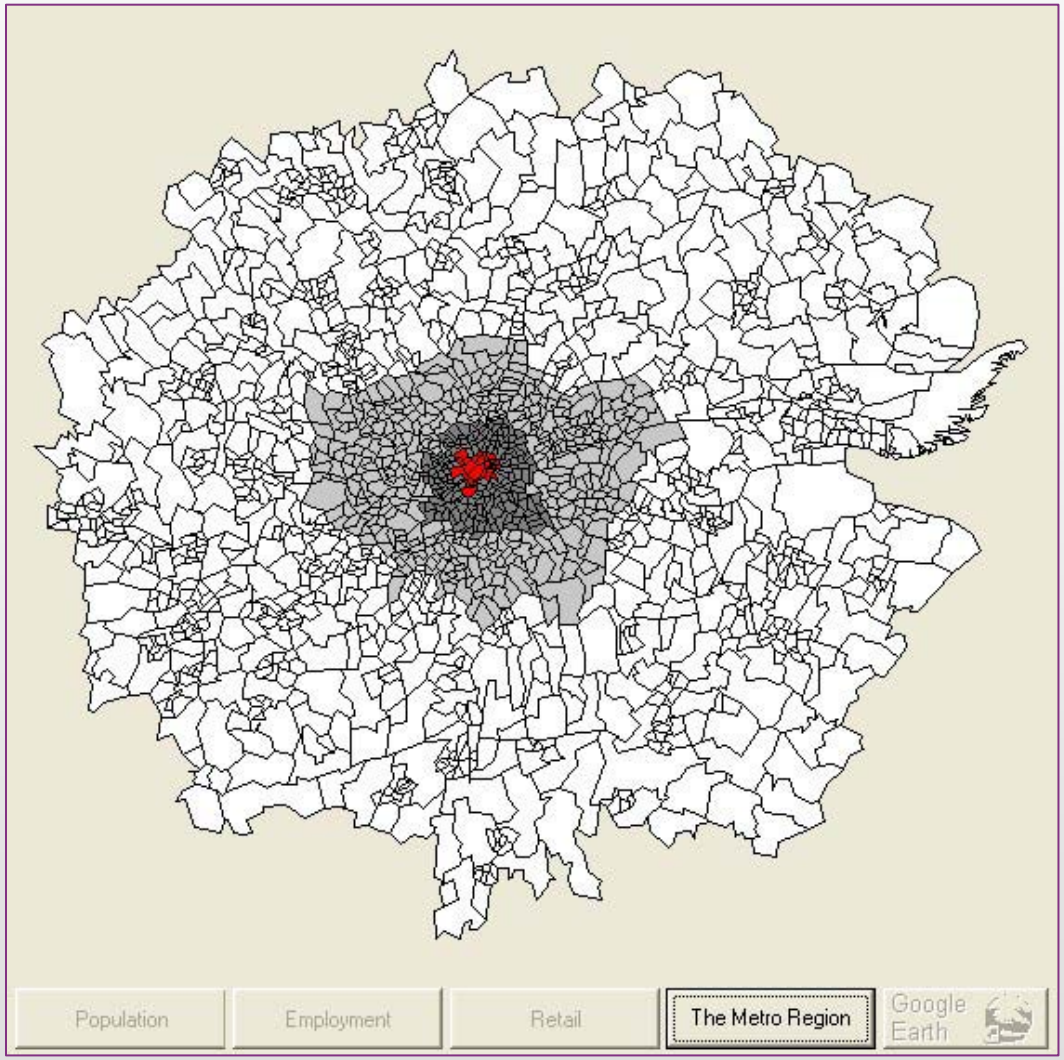
Let me look at some examples of how we are using these models.

The Olympics Site and the Impact of Cross-Rail









And extending the scale is important in this kind of modelling to embrace the wider spatial environment

Enter Time: Generic Models, Agents, Cells, and Cities

So far most of this science has been a timeless science, a world in equilibrium for obvious reasons. Cities look like they are in equilibrium physically because of the inertia of the built environment, temporal data is inordinately hard to get and so on.

In the 1970s, there were many flirtations with chaos and catastrophe theory, with bifurcation theory and some models were developed theoretically

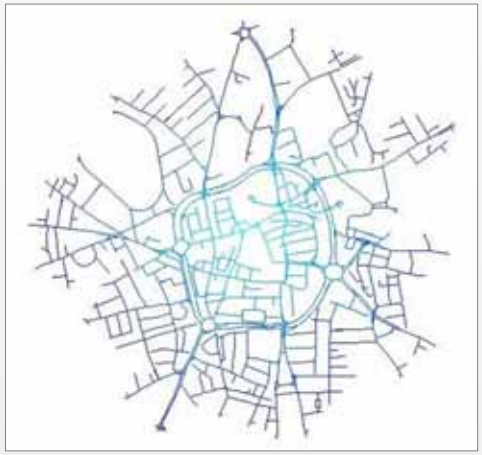
Progress was slow and probably the most significant is the embedding of interaction theory into predator prey models to simulate rapid growth

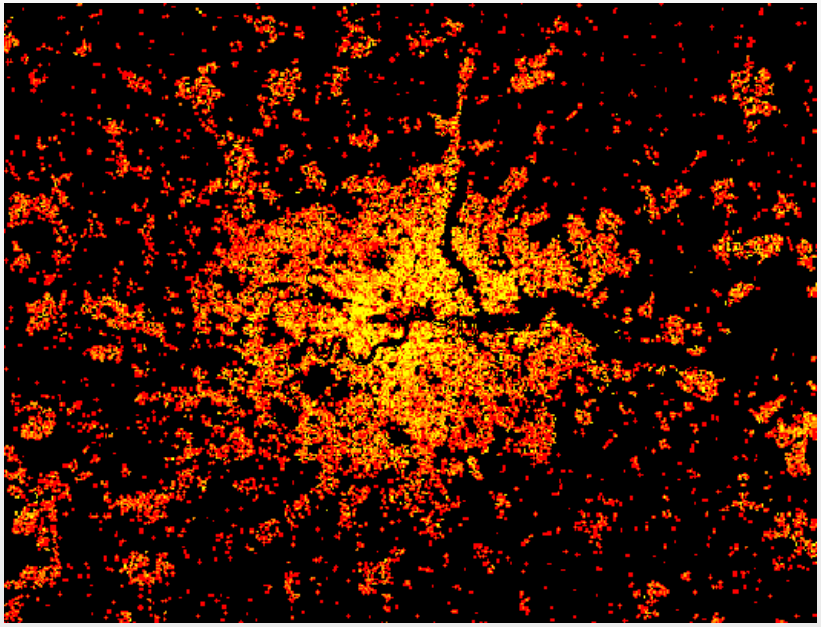
But by far the most significant were notions about how urban structures might be generated akin to the way fractal structures grow and this meant that the mantle of physicalism continued. Let me show some more pictures of what the focus was – explaining urban growth using fractal models

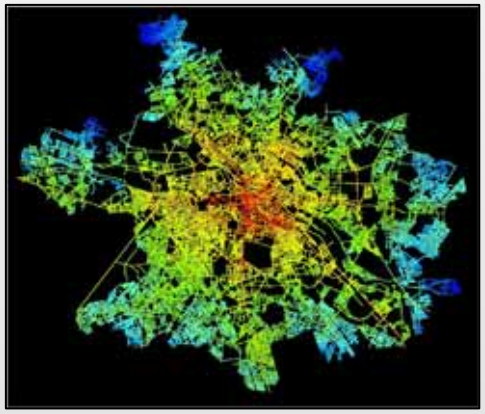
In fact a good deal of this was anticipated in the early quantitative geography movement beginning in the late 1950s where there was a concern for morphology.

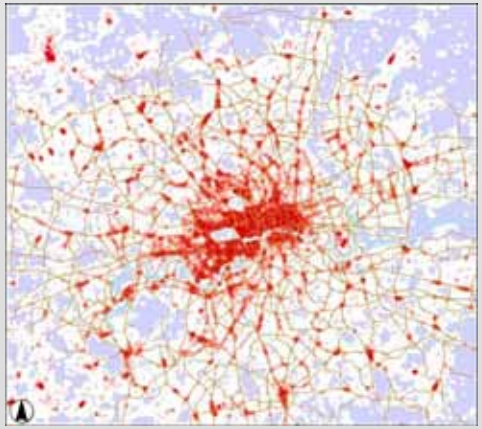
And the implementation of these ideas was generally based on cellular automata kinds of algorithm.

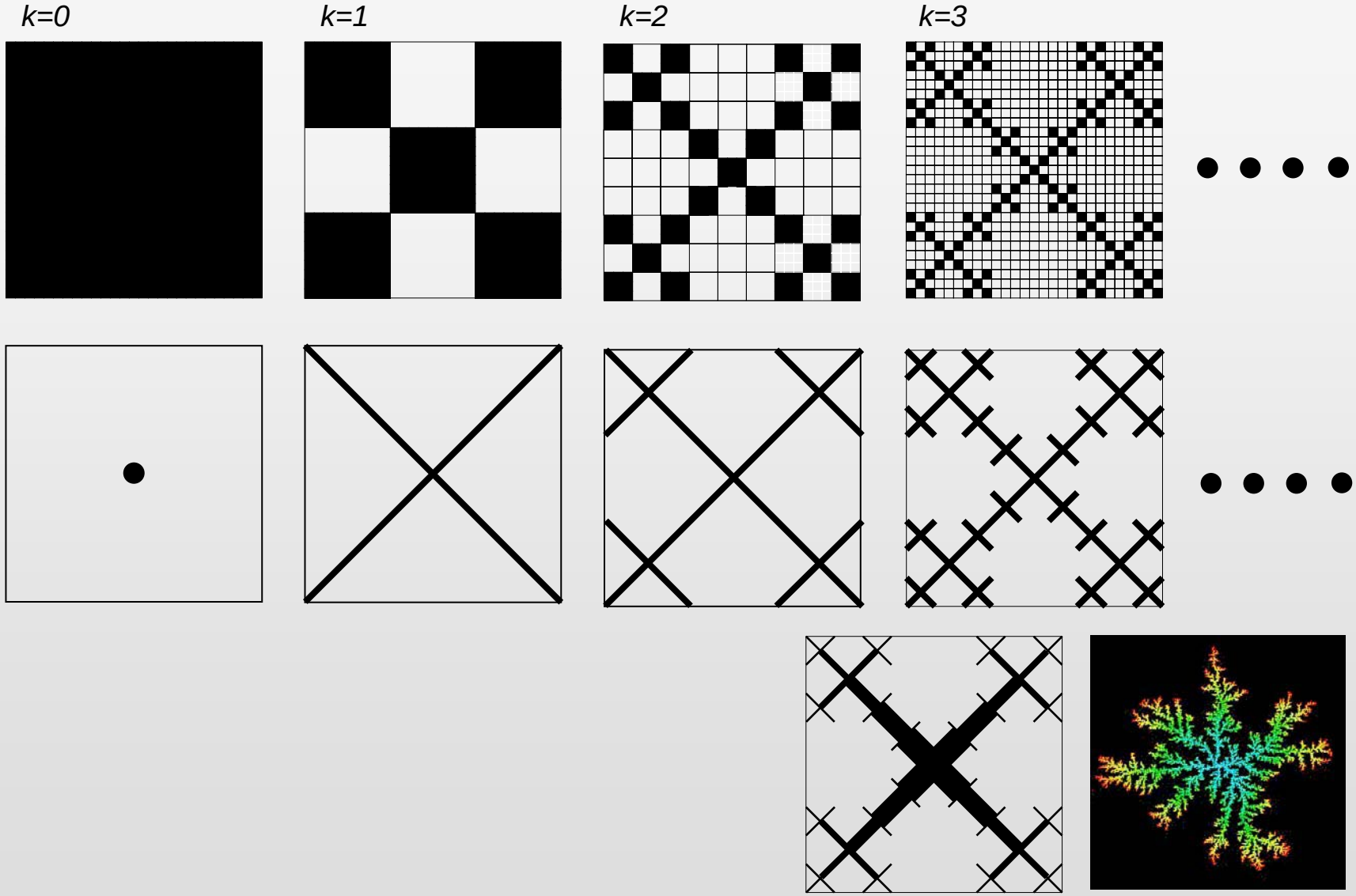
Let me show how these kinds of models might be built.










k=0
k=1
k=2
k=3

We can load these idealised network structures with traffic

Let me show you one glimpse of this new science from big data and the idea that we can think of flows in cities as the flow of energy – akin to blood flowing – the life blood of the city.

This is from our Oyster card data in London for the Tube – some 7 millions tap in and outs per day and a typical week in the life of

This of course opens up an entirely different dimension of smart cities and big data that is proceeding in parallel and drawing to an extent on this new science.

http://www.simulacra.info/

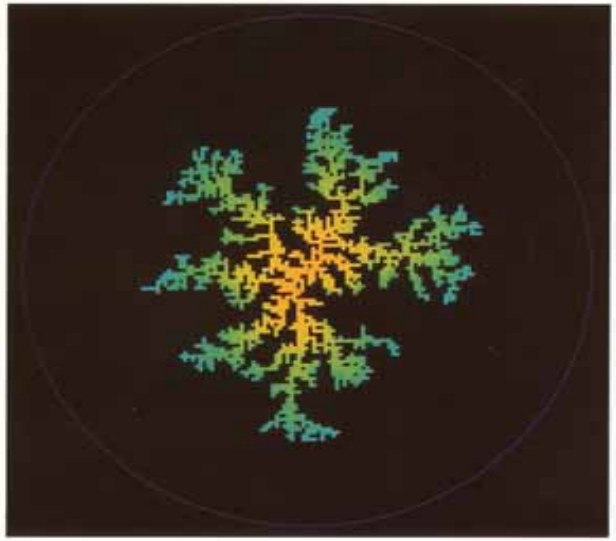
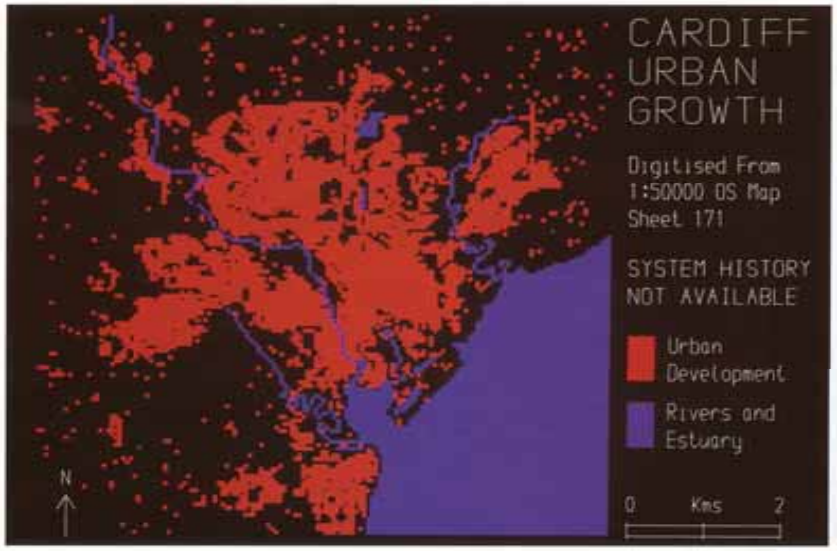


Plate 8.3 *(left)* The Baseline Simulation η =

Plate 8.5 *(below)* The Urban Area of Cardiff.



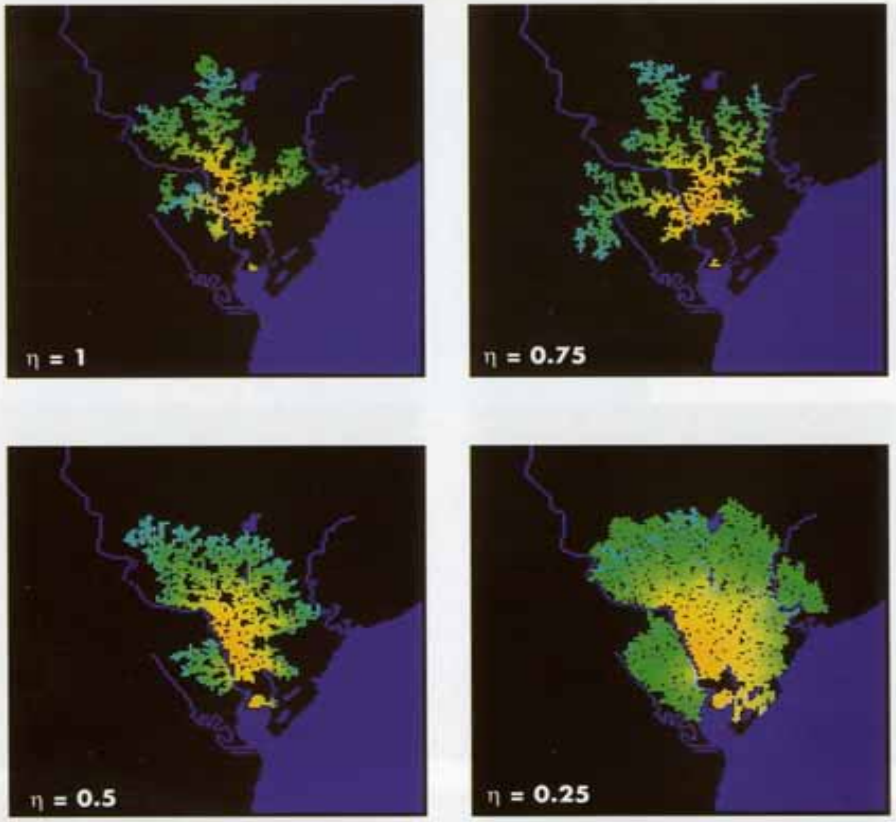
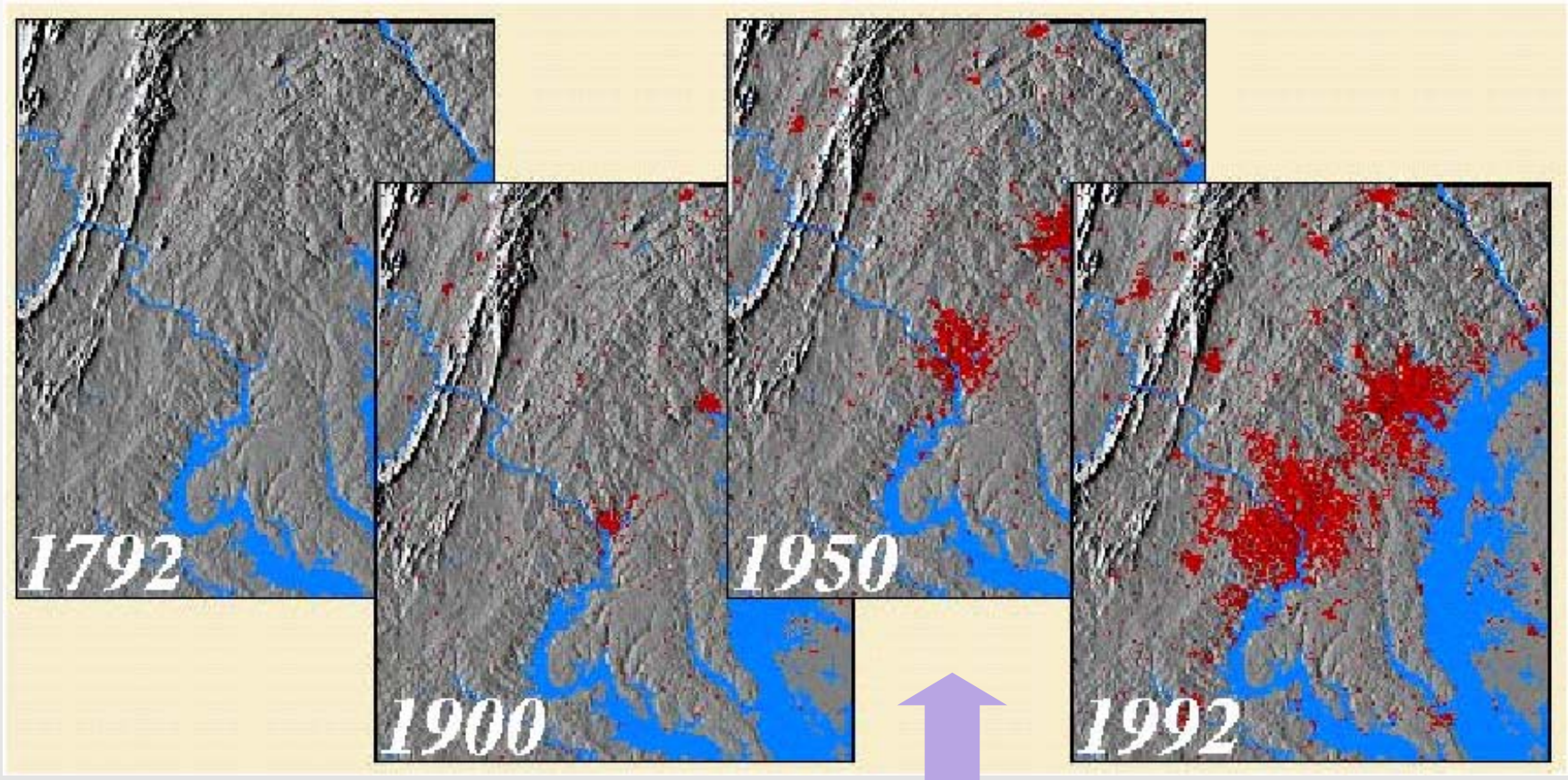
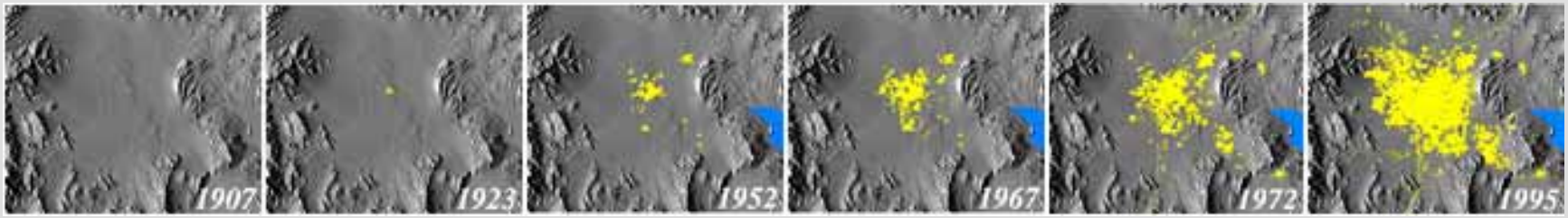
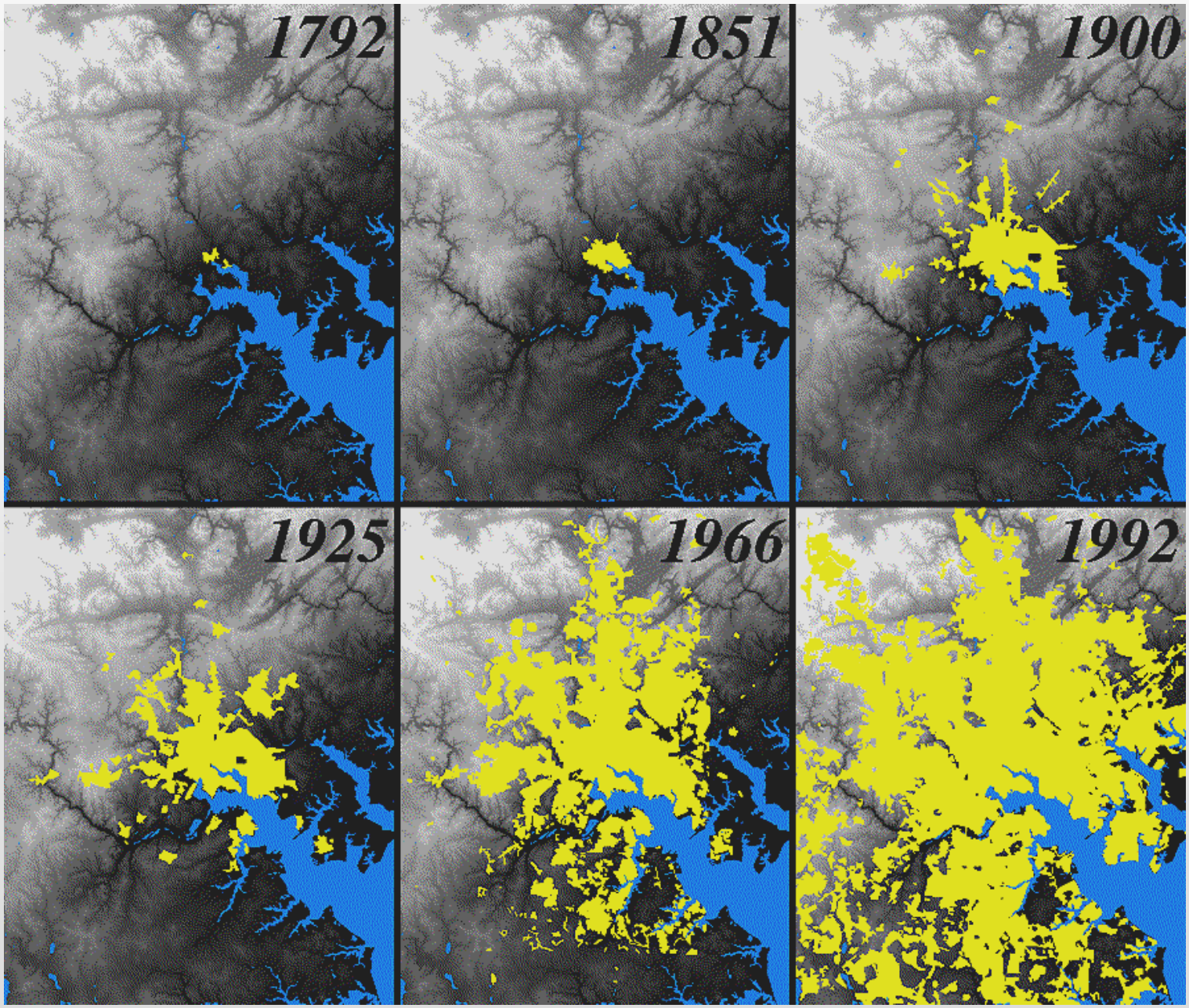


Plate 8.6 Simulating the Urban Growth of Cardiff



Growth through time: Washington DC-Baltimore Las Vegas




1792
1851
1900
1925
1966
1992

More General Theory: Scale, Size and Shape

There are some really key questions that dominate what we have said so far

None of this is integrated any more formally than the way I have sketched it and perhaps there is no need to do this because the focus is on many different aspects of the city and many different problems

There are lots of things that relate to cities and their analysis that I have not talked about – particularly at the fine scales and over short time periods

In so far as the kinds of things I have talked about are tested empirically and there is quite a lot of work on this, their goodness of fit – performance – is poor

In fact many of these models are not tested at all. These processes are rarely tested, their outcomes might be. But let me list some key problems:

- The level at which the system is considered – aggregation v. the individual – to what extent should we be searching for a theory that embraces both consistently. This has been impossible so far in economics ?
- Dynamics – the time horizons over which we need to observe cities functioning – the smart cities, big data focus is shortening these massively but with consequent changes in what we are interested in
- Equilibrium – do such models that we have seen have any place in a theory of cities?

- The extent to which our models should be tested and validated empirically? A place for models as thought experiments and as simulations of a range of outcomes – exploring the solution space.
- The role of prediction more generally in social systems is key, especially in the context of design and prescription
- To what extent should a science of cities embrace design? This raises the whole question of policy
- The age-old question of organically growing versus planned cities needs extensive scrutiny in the wider context of a science based on the evolution of cities
- I have talked about location but interaction is key

- The key focus to me is on ***scale***, ***size*** and ***shape*** applied to ***locations*** and ***interactions*** –which means on activities and actions in fixed places, and on interactions between places
- These can be accomplished at ***intra-*** or ***inter-urban*** scales and a good question is whether we should expect the same processes and structures and patterns to pertain to both
- I am conscious that my focus on morphology has played down interactions, networks, and although these have entered, all and more of what I have said here about locations apply to interactions that have their own morphology.

Attempting a Synthesis

The biggest question of all is should we attempt a synthesis of this science? Even if not, I am sure we need a big picture in which to anchor our efforts.

I realise this has been a rather general talk but I know that some of my colleagues who study cities would consider it to be rather narrow. That is also a paradox

And last but not least “Sustainability” the focus of this meeting. I have not addressed this directly but it is implicit in that to an extent, all cities are inevitably sustainable but the big questions are “what kind of sustainability?” – these of course are beyond science in the domain of our beliefs.

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