Urban Modelling: A Progress Report

The Paradigm Shifts Yet Again

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My Key Topics

- The Beginnings: At the Dawn of Digital Computation
- Aggregate Statics: Comparative Statics, Early Dynamics
- Berry's Data Cube: Space, Time, Sector
- Aggregate Dynamics: Chaos, Catastrophe, Bifurcation
- Disaggregation: Discrete Choice, Microsimulation
- New Generations of Urban Models: Disaggregate Dynamics

  Cellular Automata Models of Land Development: Visualisation

  Generic Modelling Types: ABM and Microsimulation: Computation

  Large Scale Modular Extendable Simulation Models
- The Switch from Models to Data: Big Data
- A Switch in Time Horizons, in How We Think About Cities
- Future Models: Short Term, Immediate, Data Driven?

The Beginnings: At the Dawn of Digital Computation

I think we stand at a threshold in thinking about how we build an understanding of cities that is relevant to their planning

This is much *more about cities* than it is *about the methods* we use to understand and model them; it is in fact largely about *technologies* in the most general sense and the way these are changing our behaviour.

In fact, it is my contention that the basic ideas about what we want to understand in cities and the way we think we should understand them have not changed much since the earliest urban models, at the dawn of computing in the mid 1950s. But they appear to be changing faster now than ever before.

Right from the beginning we had a concern for three key issues:

space, _time_ and _sectors/activities_ that define the city.

These were phrased in terms of representing space and sectors first as aggregates because we had no real data on individual behaviours and even if we had – and occasionally we had, then we could do little about this for computation was primitive, remote and slow.

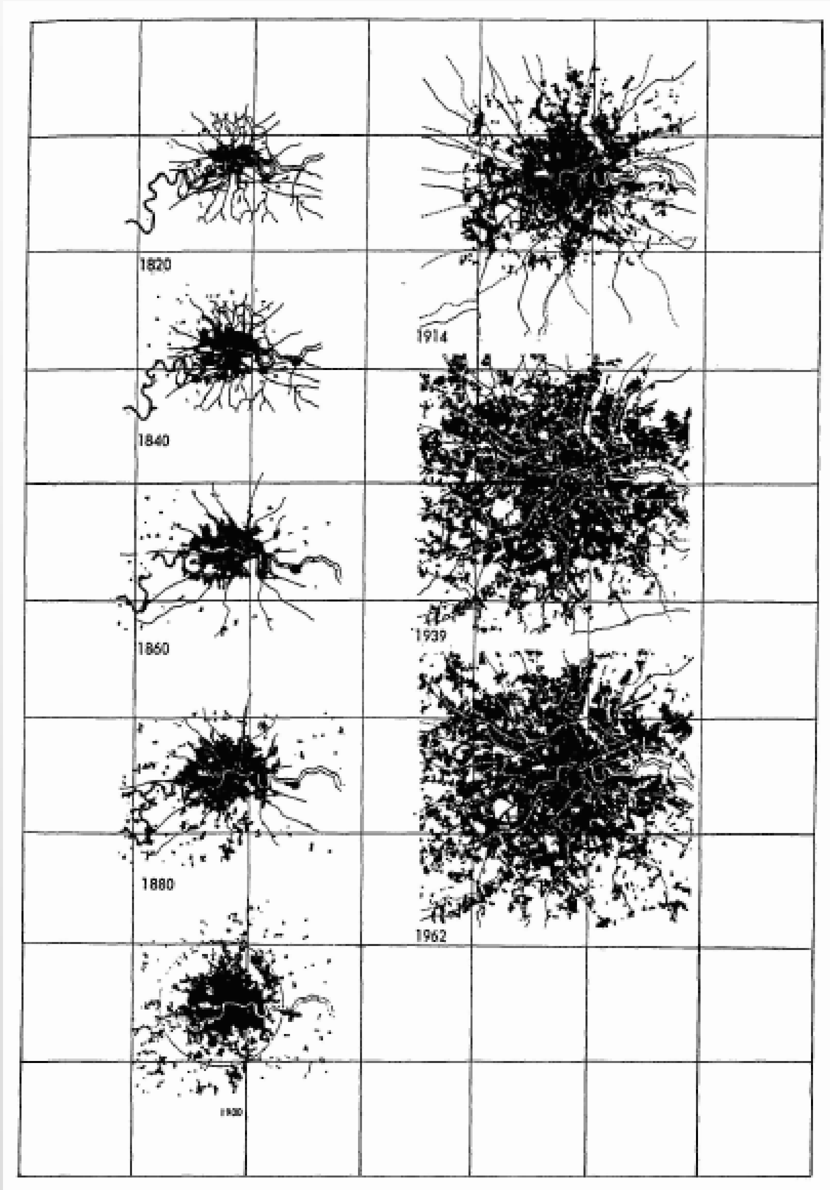
Yet from the beginning, aggregation-disaggregation were key points in terms of the resolution of space, time and activities.

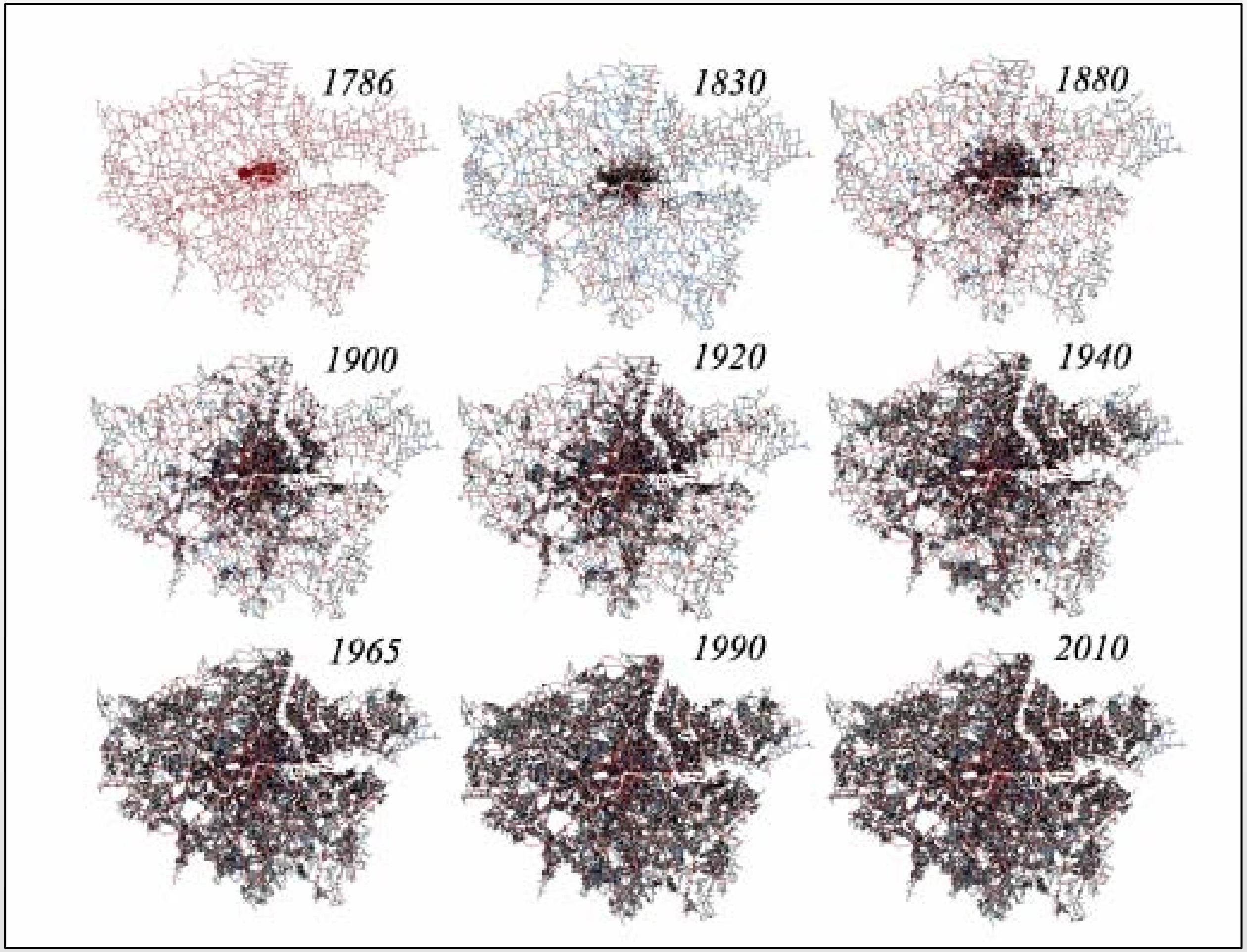
What emerged in the first instance were aggregate static models constrained by limits on computation and data, yet it must be acknowledged that we also thought the world was _more in equilibrium than out_. Amazing seeing that in the 20 years prior to the first computer and models, the world was in turmoil – the great depression and world war 2.

Of course our conception of cities as being in equilibrium is very strong – they look the same from decade to decade in terms of their form and structures

Not their functions though and not the populations that they contain.

But at the level of form, they do seem similar. Look at London.





A. Paolo Masucci, Kiril Stanilov, & Michael Batty (2013) Limited Urban Growth: London's Street Network Dynamics from the 18th Century, ***PLoS One***, forthcoming

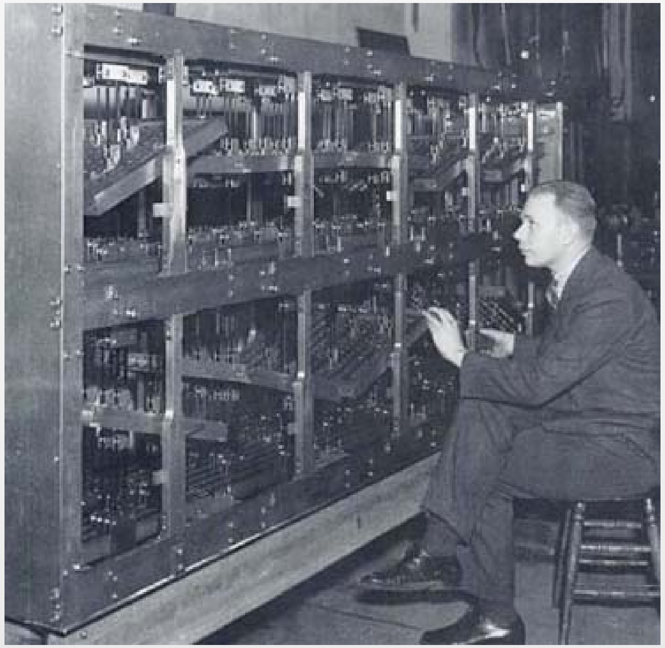
Aggregate Statics: Comparative Statics, Early Dynamics

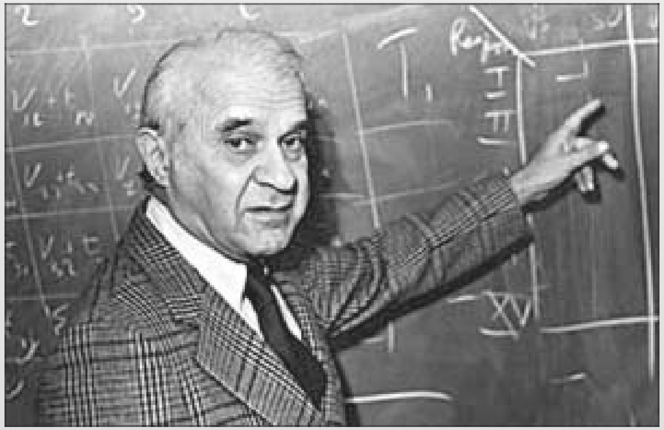
Let me return to the beginning and say something about how we got started. Right from the beginning, researchers decided to build static models with a sense that what was being modelled could indeed be plausibly related to statics

Yet right from the beginning, there was a sense of dynamics, if only making the statics comparative.

There is wonderful example relating to Leontief whose first computable input-output model in the late 1930s made use of Wilbur's Simultaneous Equation Solver, a mechanical, not digital device at MIT.

The story is so good that it bears repeating and let me sketch the context





Leontief who invented I-O nearly 90 years ago before he came to the US, reduced his model to a 10 sector, 10 equation form and used Wilbur’s machine which could handle 9 equations and 9 unknowns.

Leontief was well aware of stability in I-O models and also the idea of comparative statics. His 10 sector model would have required 450,000 multiplications or as he reckoned it at 120 multiplications per hour, two years to compute. So he was driven to use the Wilbur machine at MIT.

"Made of tilting plates (representing the unknowns) and steel tapes (representing the equations to be solved), the machine could solve nine simultaneous equations.

Leontief recalls: *"You could really change the coefficients slightly by simply sitting on the frames, and if they did not give too much, this meant that the solution was relatively stable"* "

Early sensitivity testing which is comparative statics. Dynamics was there from the beginning.

Let me throw onto the agenda, two more forays into dynamics that show that this debate has been alive from the beginning. First Alan Schmitt's simulation of 100 or more years of development in East Lansing, MI in 1967.

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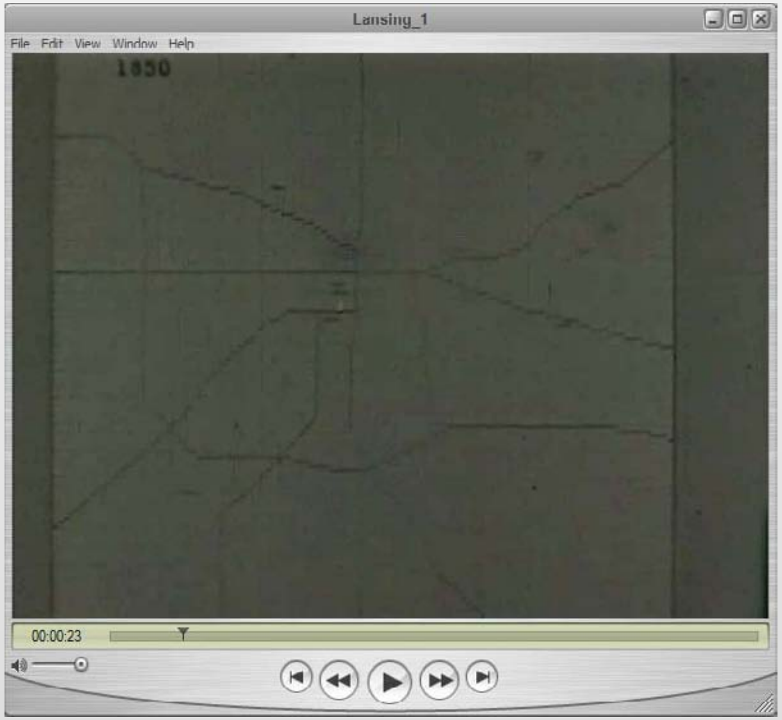

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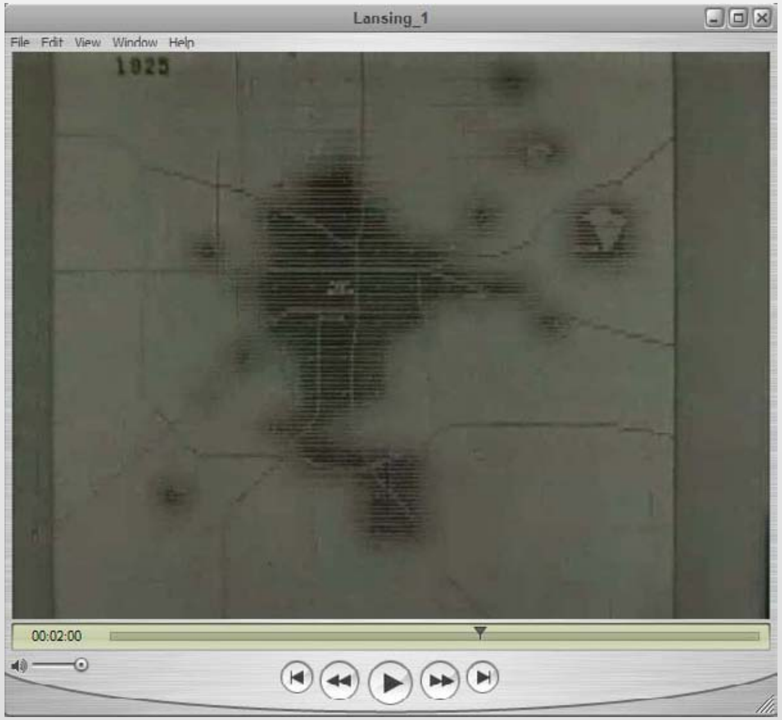

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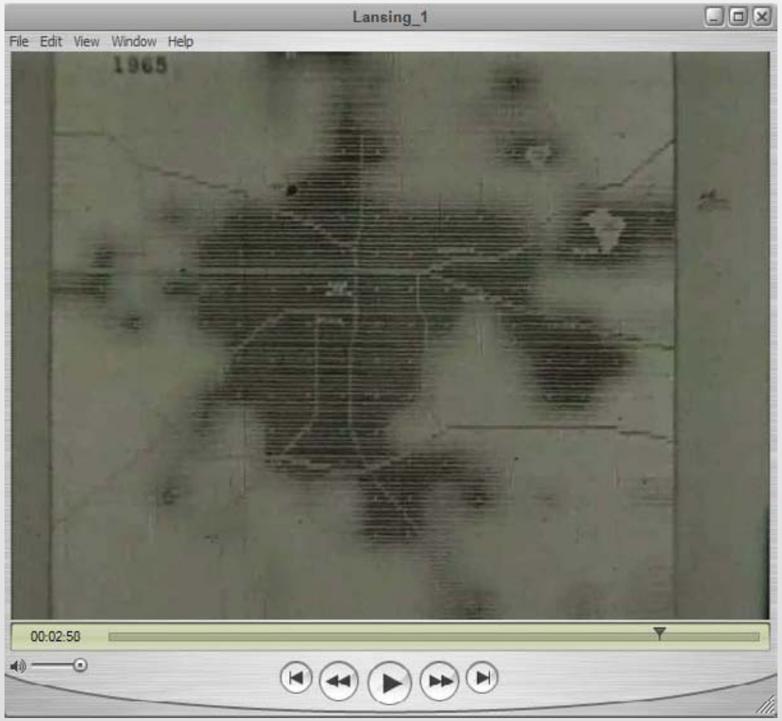

And last but not least in 1969, onto the scene came an explicitly dynamic model – Forrester's Urban Dynamics – we had our own version linked to a semi-dynamic Lowry model at Reading in 1970. Here are some snaps:

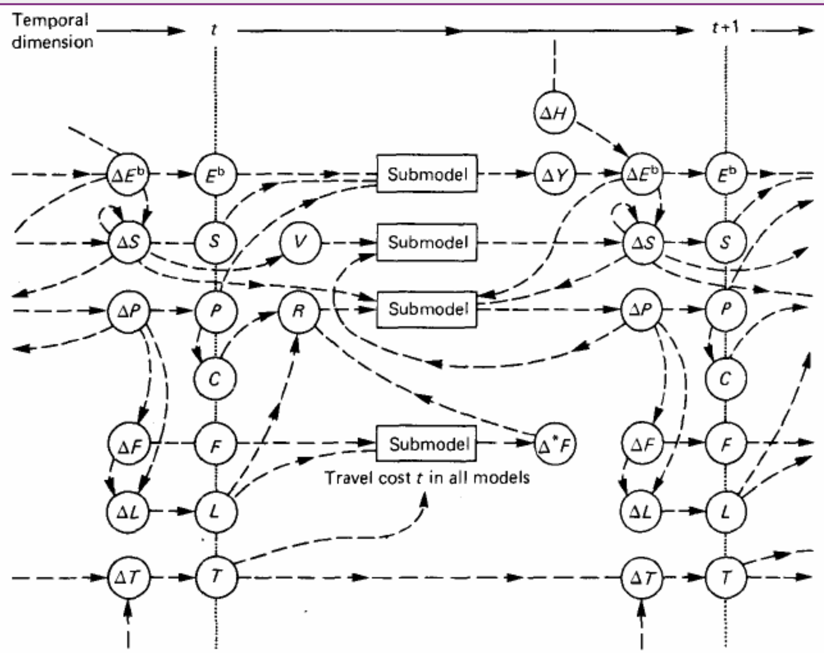

Fig. 12.4. Linkages between model variables in and between time periods.

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Dynamic simulation 349

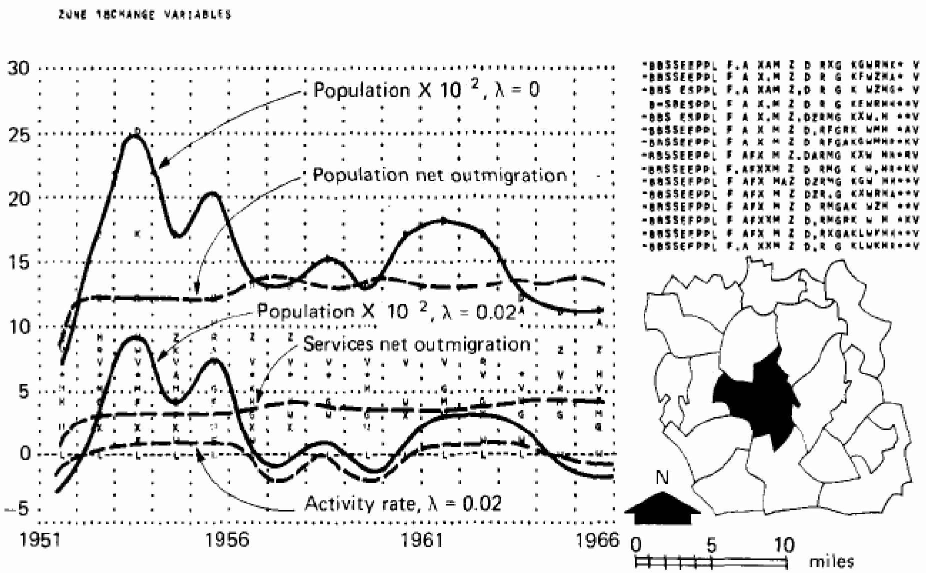


Fig. 12.15. Sensitivity of the mover pool ratio π in Reading zone 1.

Berry’s Data Cube: Space, Time, Sector

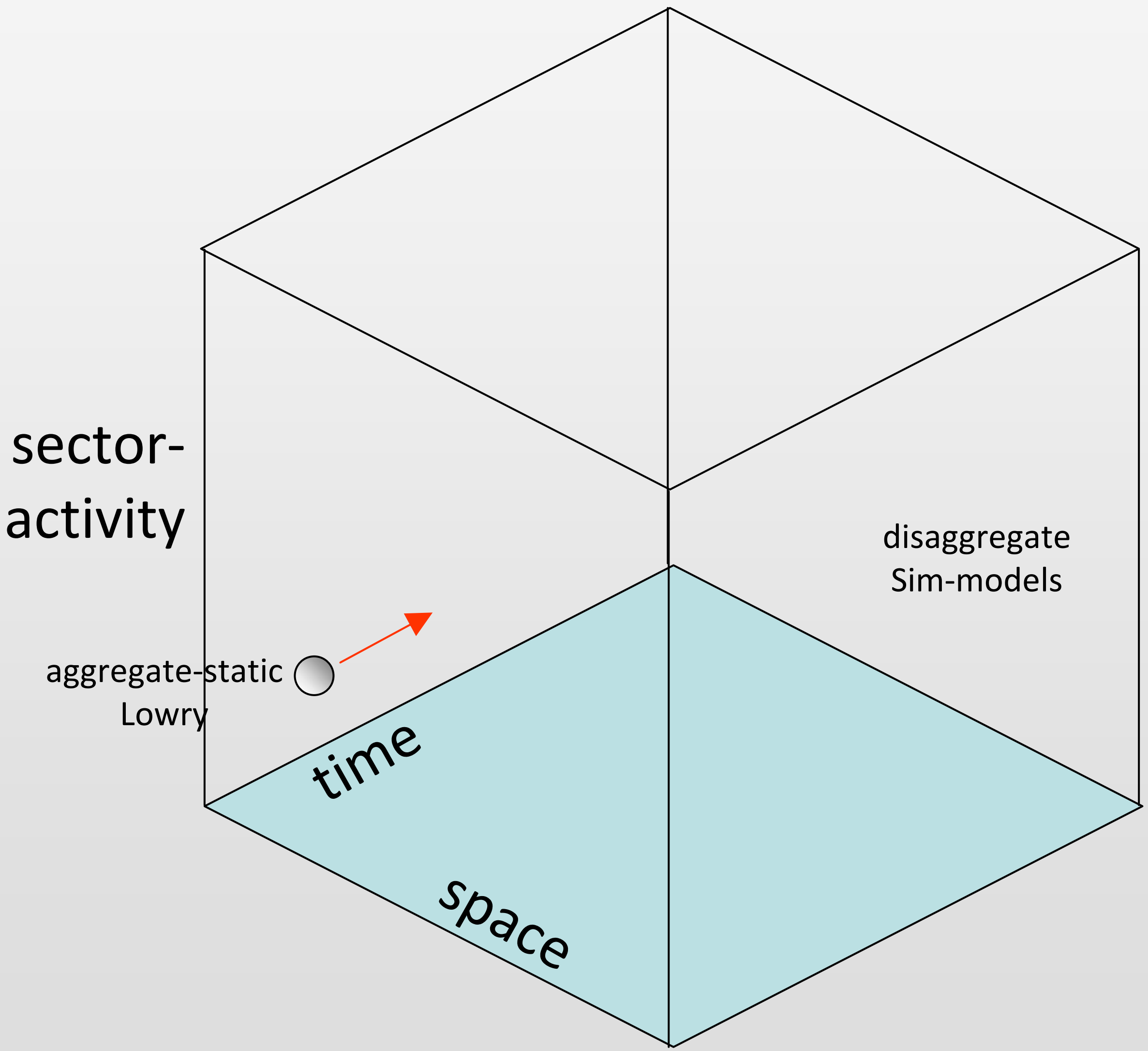
A really nice way of putting all this together and tracing the trajectories though time in terms of

- Spatial Aggregation → Spatial Disaggregation
- Statics (Temporal Aggregation) → Dynamics (Temporal Disaggregation)
- Activities Aggregation → Activities Disaggregation

These three themes are woven together inextricably through the development of urban modelling with a move from aggregative to disaggregative, the key force over the last 40 years.

In fact I can’t find the reference to Berry’s work – I think it is his chapter in *Spatial Analysis* (1968) but my copy is missing !

Anyway here is what I think the data cube is



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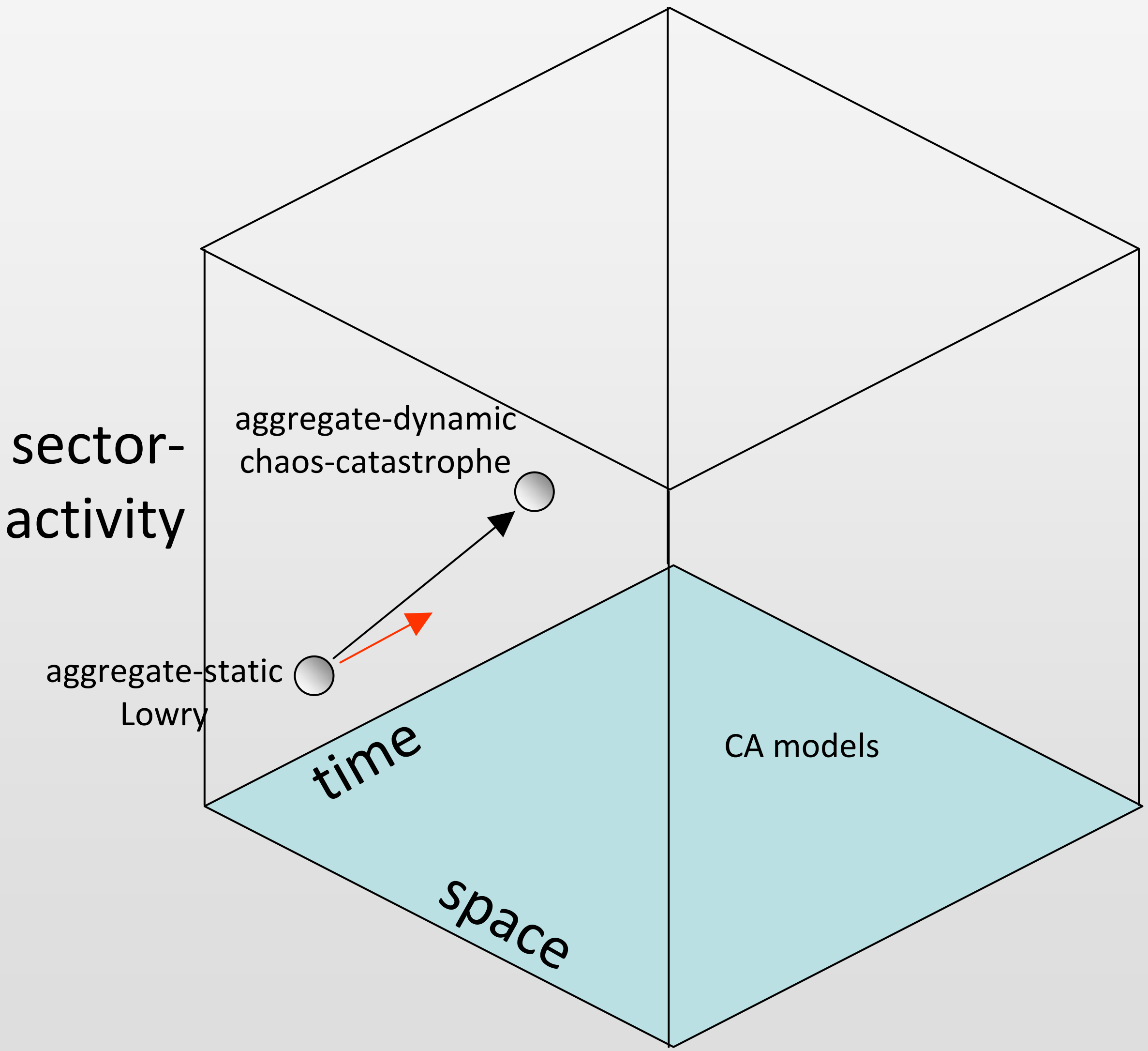

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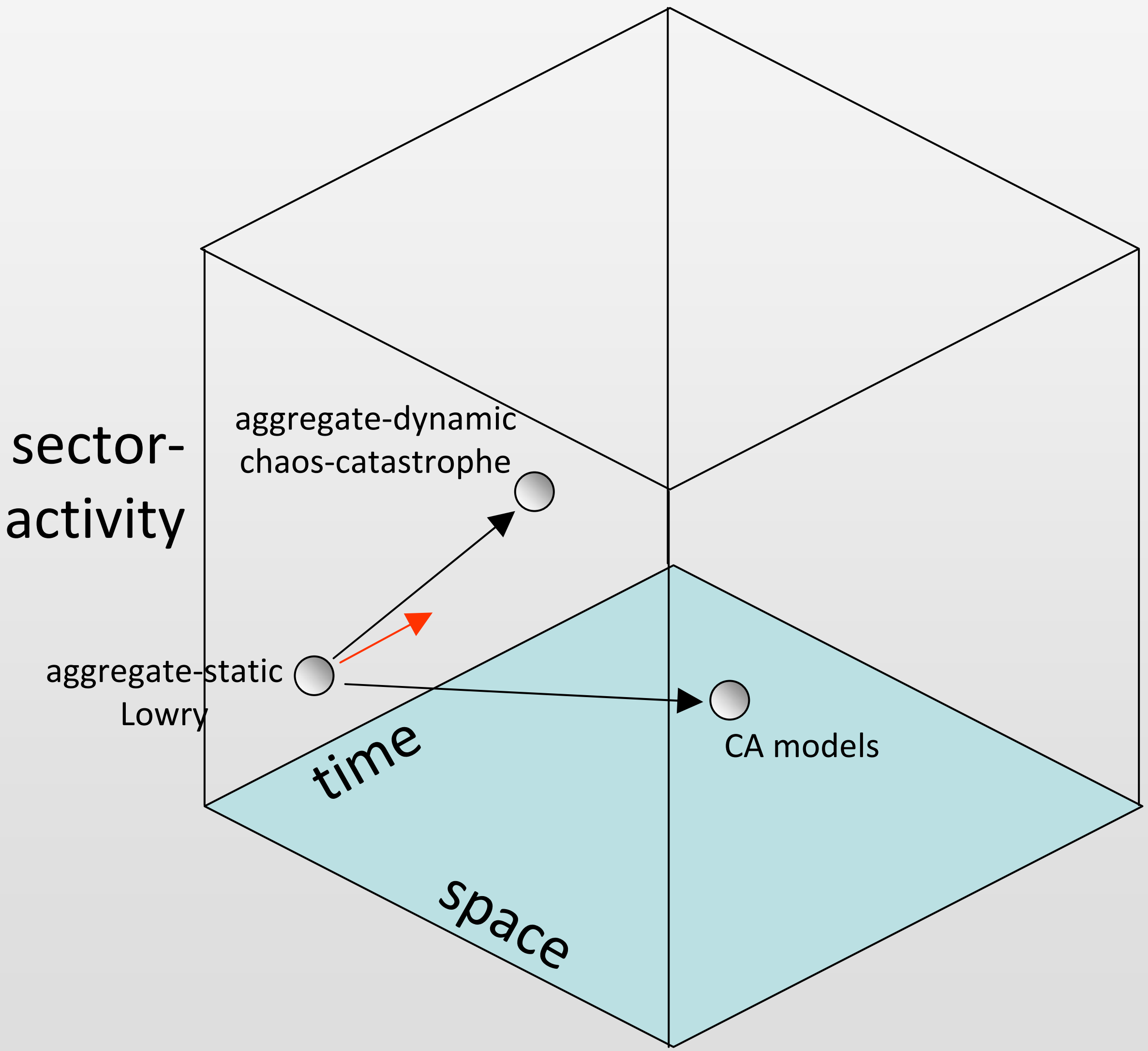

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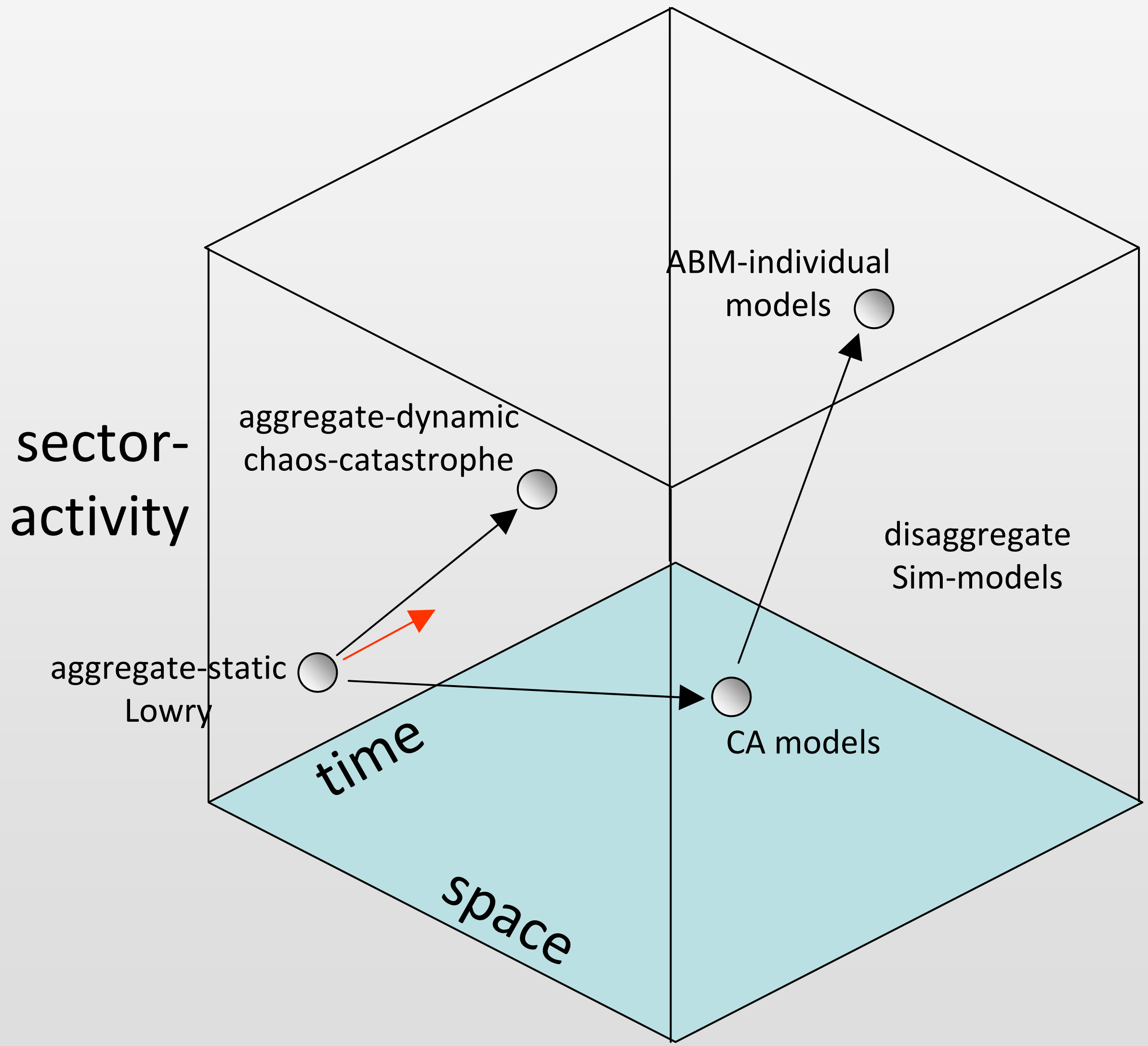

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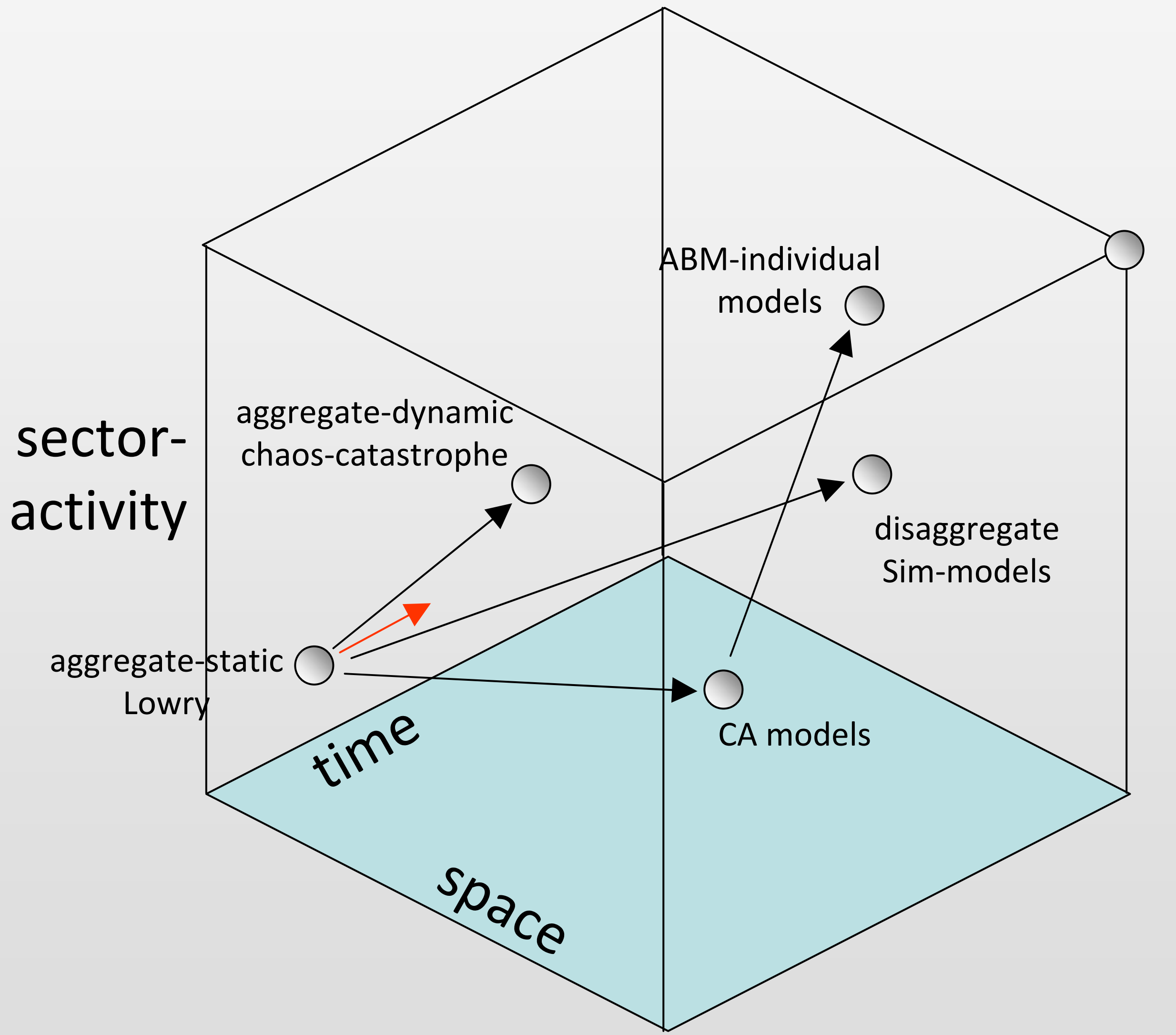

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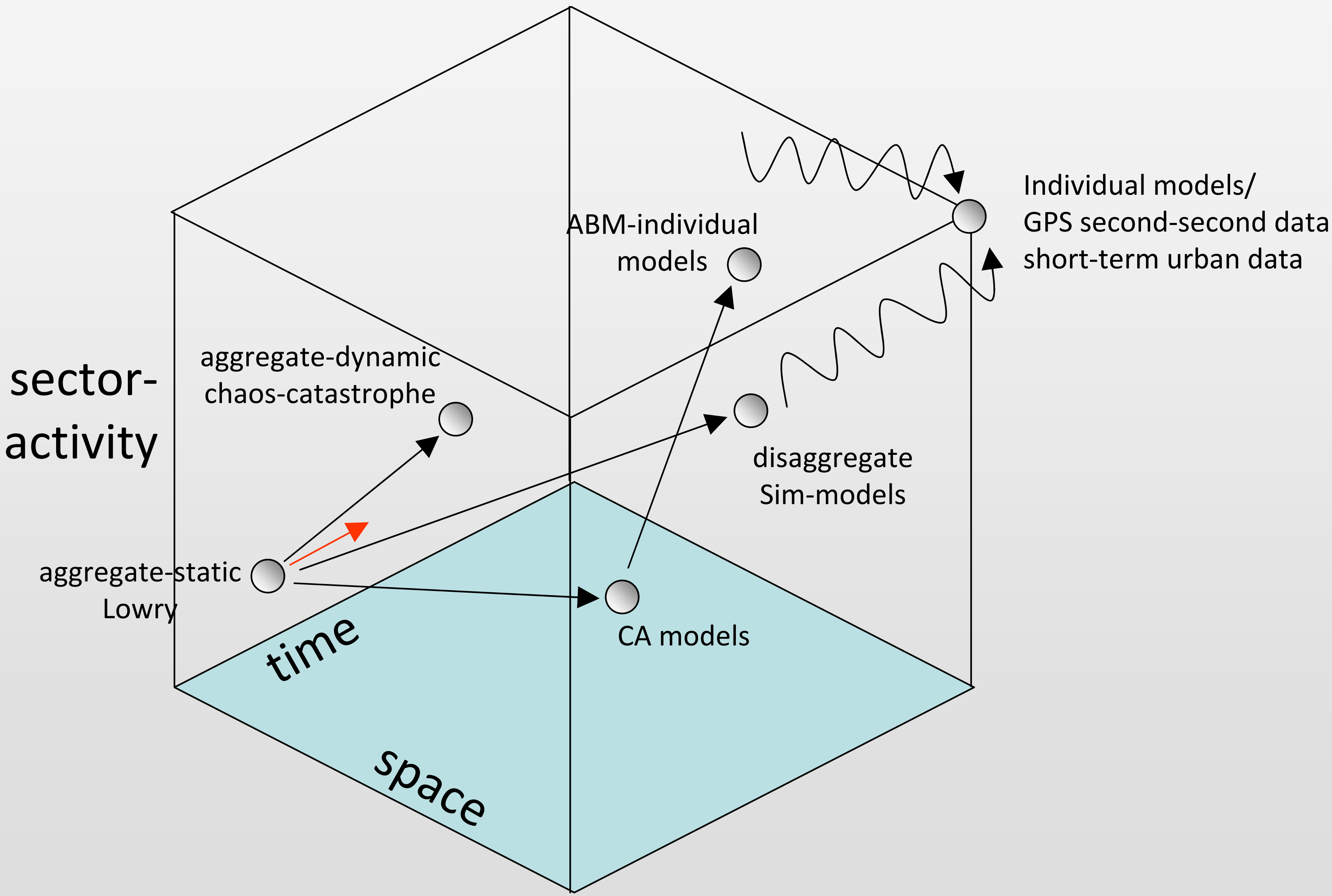

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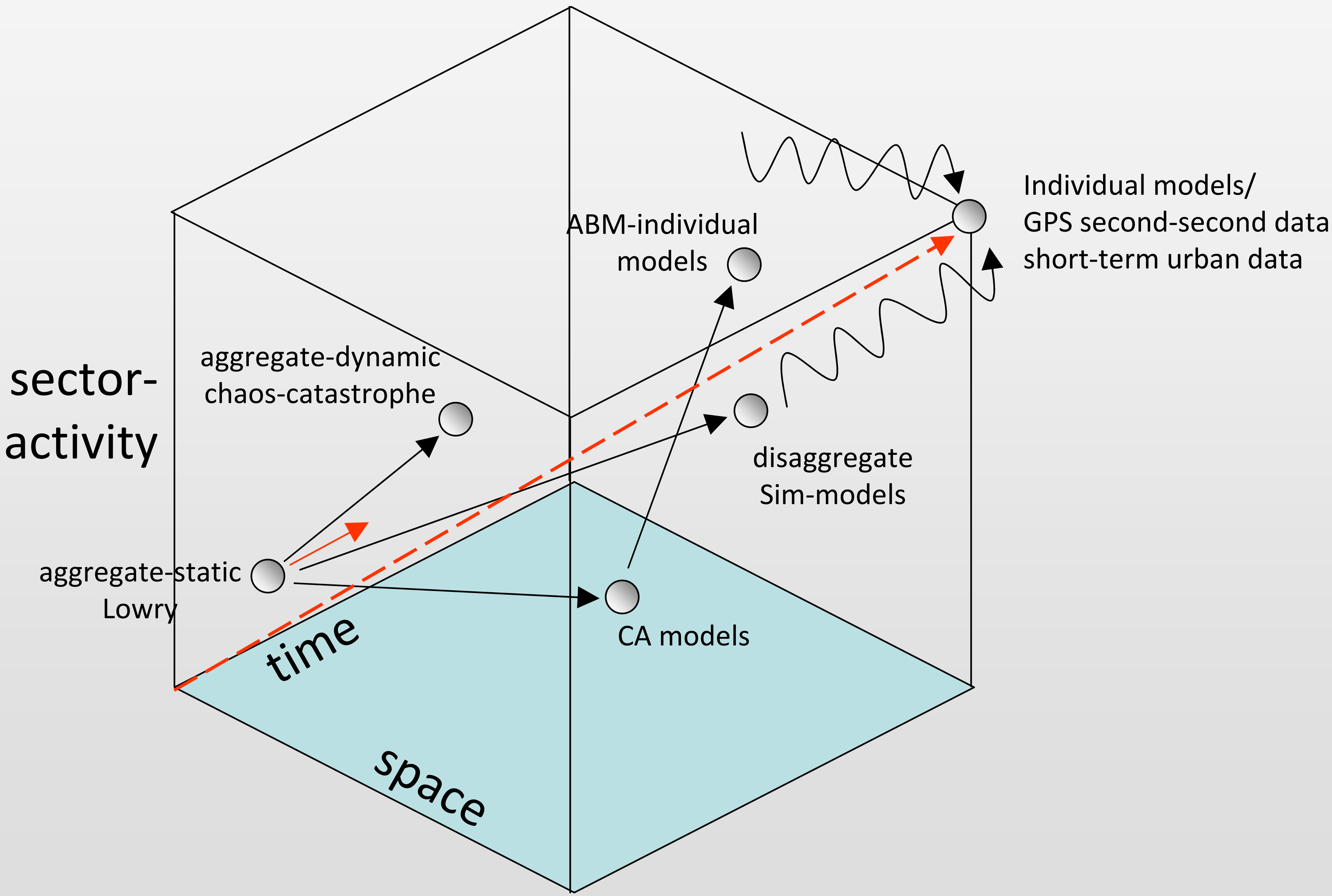

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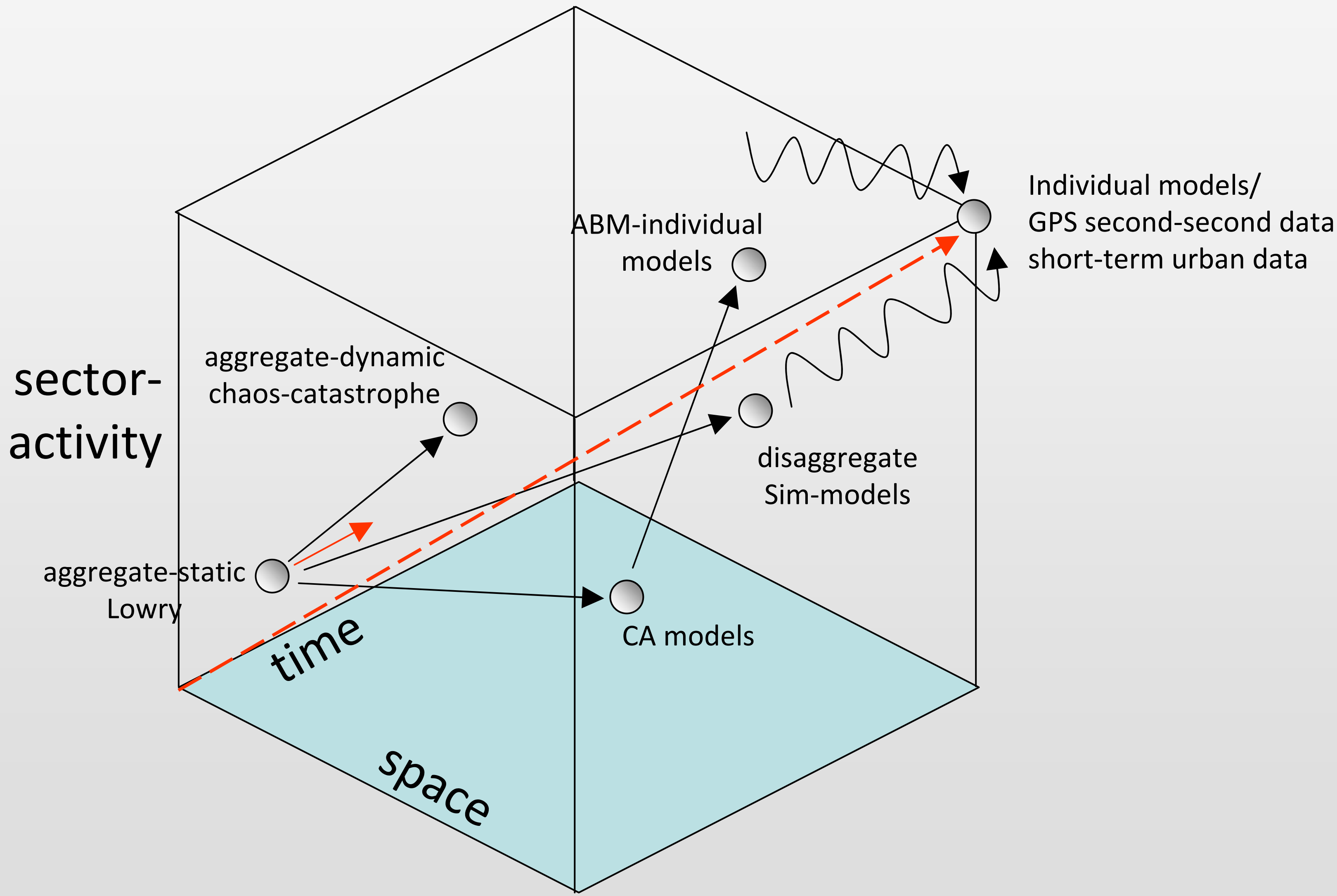
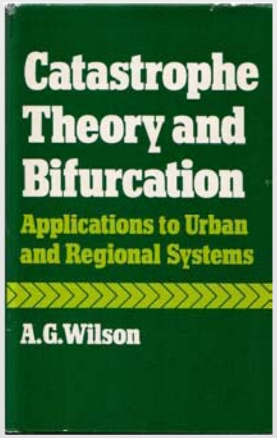
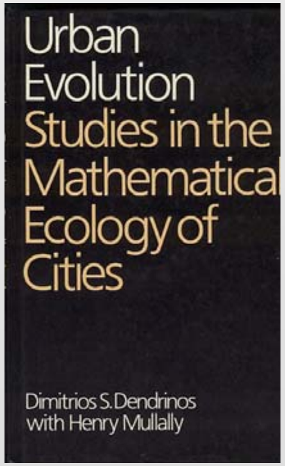
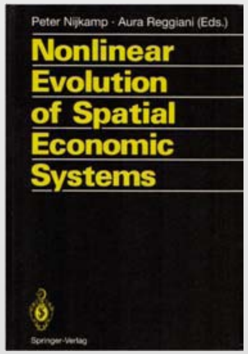


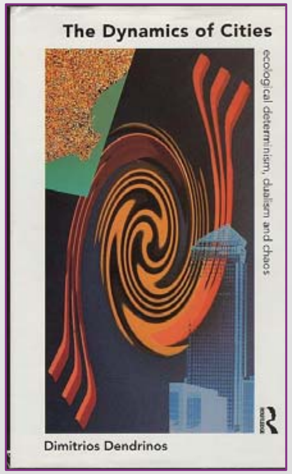
Aggregate Dynamics: Chaos, Catastrophe, Bifurcation

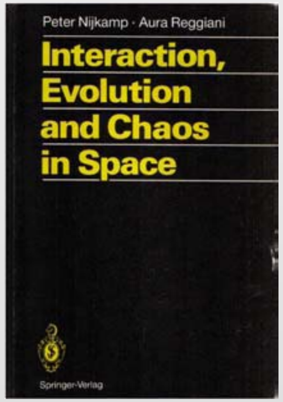
When I gave my paper on 50 years of urban modelling about 8 years ago in Ascona (several of us were there), I rapidly sketched the development of the field throwing onto the canvas the key statements from the key books. Let me repeat this again as it races us through the last 30 years.

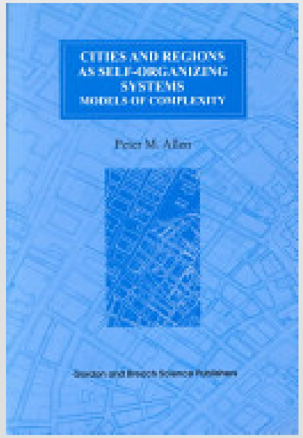




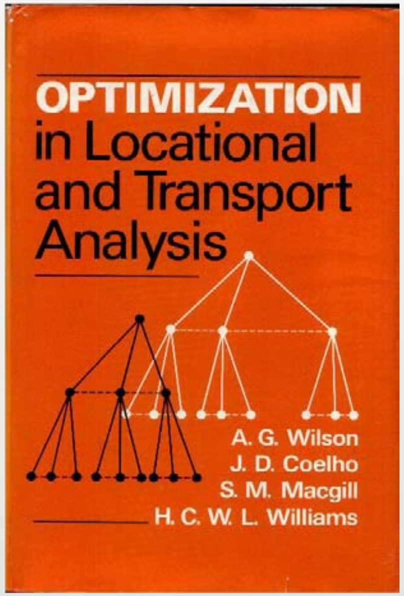


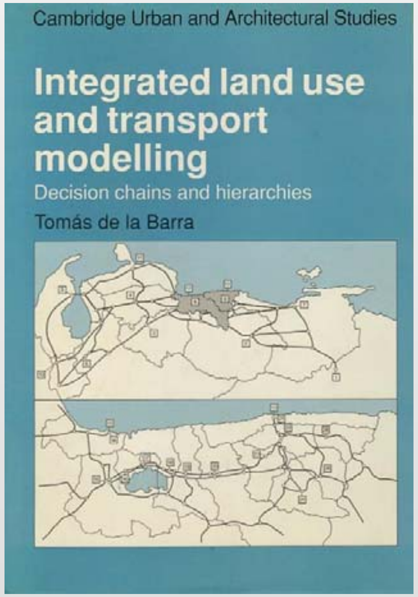


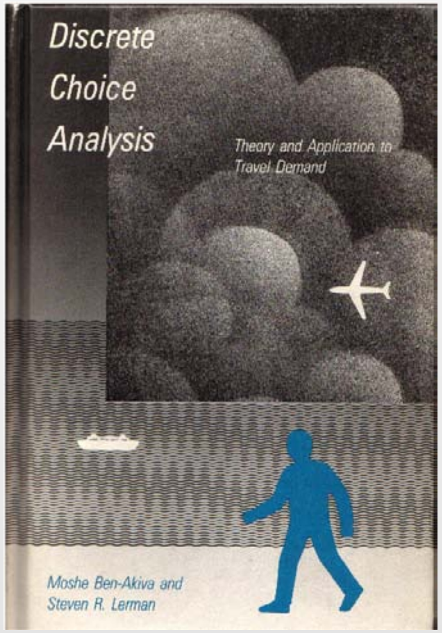


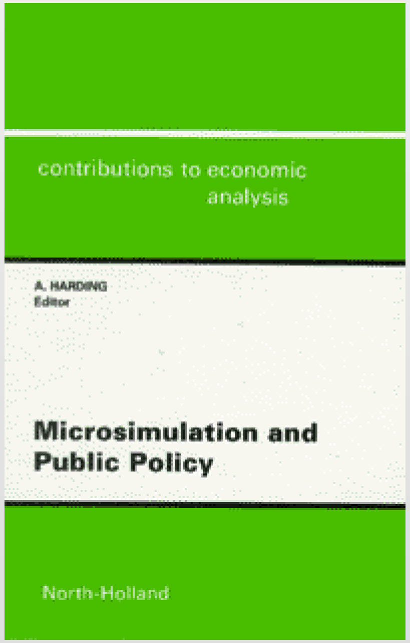


Disaggregation: Discrete Choice, Microsimulation









New Generations of Urban Models

Cellular Automata Models of Land Development

I could spend a lot of time outlining these models but they are intrinsically dynamic, tend to be aggregative, are linked strongly to GIS and remote sensing but also to fractals and complexity

Although their application in practice is quite pragmatic. They tend to be spatially fine scale but they treat the transport system in very low detail

They are in principle process driven but there is little emphasis on developing these processes and a strong reliance on physical fitting. Visualisation is key to these models.

They are not widely developed for policy because they are essentially qualitative, visual and non-numeric.

New Generations of Urban Models

Generic Modelling Types: ABM and Microsimulation: Computation

ABM is a style of modelling – it is generic and as such there are no real examples of ABM per se – it is a method used on various models to simulate individual actions.

It is essentially like discrete choice modelling sampling from a distribution and then using these samples as generic individuals but exhausting the population by scaling up.

Microsimulation is closely related as this is also a sampling style. Applications tend to be policy driven.

Computation has made ABM possible; microsimulation tends to be a tool developed for earlier data – ABM tends to be more relevant to big data

But these models were developed prior to the big data era

New Generations of Urban Models

Large Scale Modular Extendable Simulation Models

The largest scale urban models build on many traditions – microsimulation, ABM but more on aggregate static structures in terms of the plugging together of many different approaches

These models like UrbanSim, Matsim, Transim, ILUTE maybe … maybe even PECAS … tend to be very large scale but also disaggregate but based on temporal processes which are quite ad hoc. In this sense, I tend to think they are more like the old aggregate models rather than the truly ABM models in other social science areas.

These models unlike CA tend to represent transport in detail and are much more relevant to policy making. They represent the cutting edge of the field and are closest to big data.

The Switch from Models to Data: Big Data

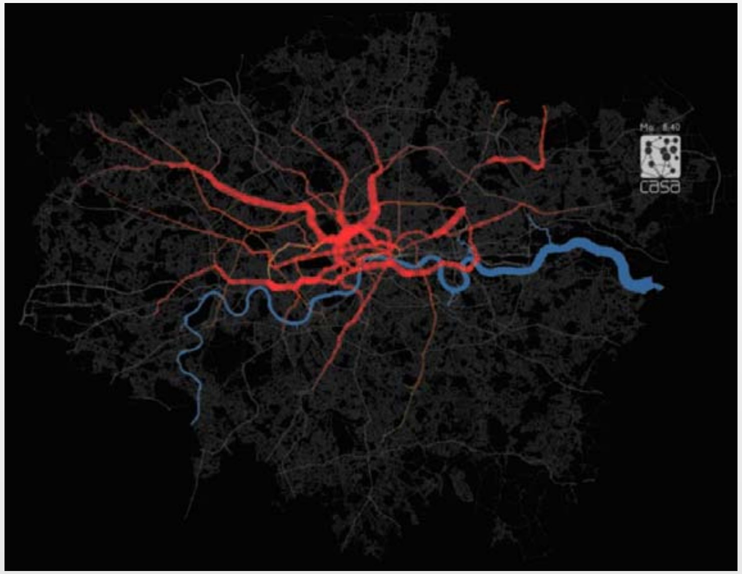
The biggest transition which is stretching our abilities involves the rise of big data; this is data that essentially is streamed from sensors being embedded in the environment but it also includes new open data and traditionally collected data which is large in extent.

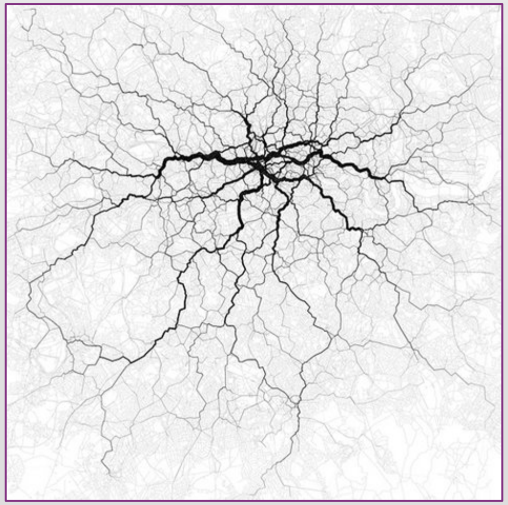
The biggest difference for this data is that it tends to be highly decentralised – spatial precise at geo-coordinates, individually based for populations, and temporally precise. In short this pushes the focus to an extreme corner point of the data cube.

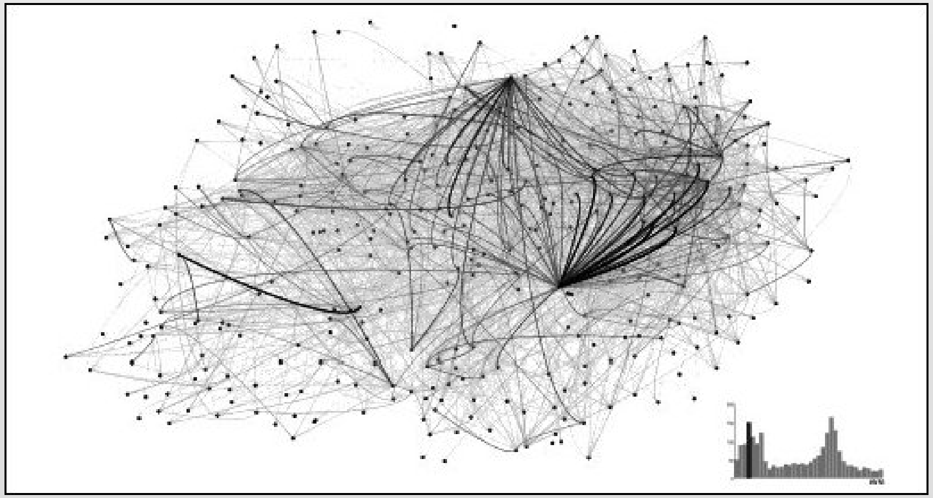
To show some of this data let us simply throw out three examples from our own work in CASA – the Oyster card data, the bikes data, data on social media – all in Greater London.

And this is changing our perception of the city – maybe not ours?

Here are some examples of this kind of data and processes







The focus on flows is key – and this in fact coincides with our focus on networks – to date in our models there has been little explanation of networks – networks have assumed to be part of the context, the background, not something to be simulated.

But this focus is changing. There is also now the focus on energy and how materials, people and information constitute changes in energy. The maps of flows represent the life blood of the city – this is an age old analogy I know but it is being fast resurrected.

Data is everything then. But its quality is problematic. And new models are strongly data driven.

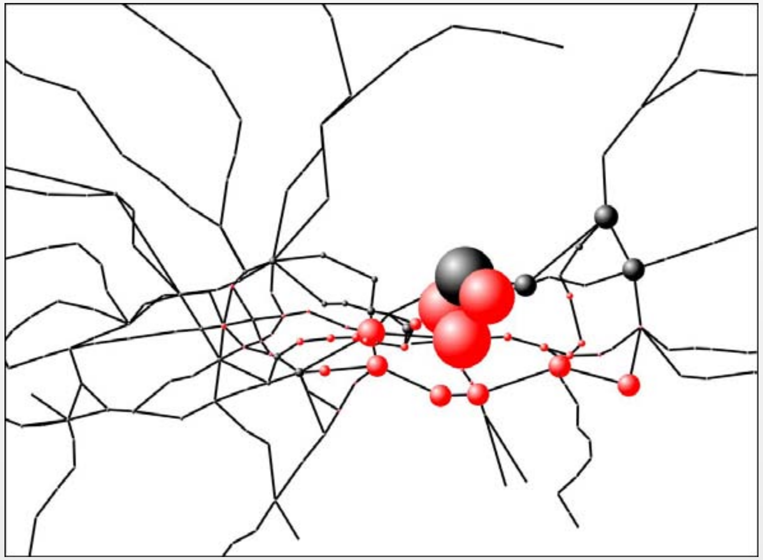
There are some issues in all this. Anderson's paper about the end of theory is worrying.

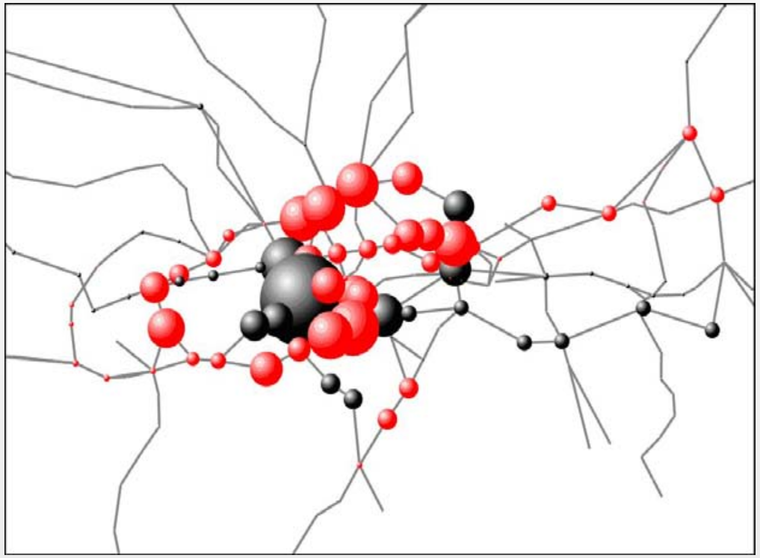
It is worth saying something about the problems that all this is raising – how good is all this data?

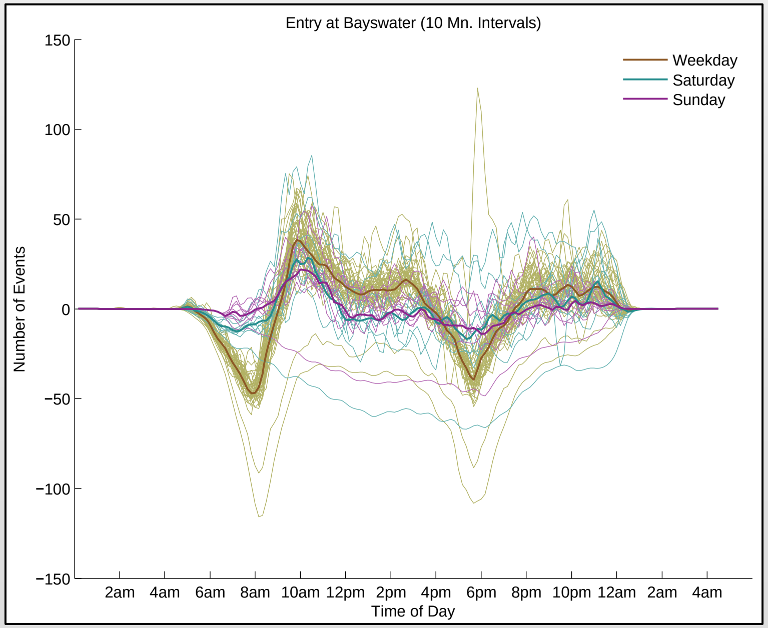
Let me say something about our Oyster card set, something about its incompleteness; this is a data set about demand for travel from one point to another. It is hard, if not impossible to match up to supply that is the first problem. The second is that it is incomplete in that large chunks are missing: we only have 85% of travellers; don't have those who tap in, not out

What does the data tell us? It says little about traditional concerns relating to origins and destinations of travel. It is hard to relate to locations in the most generic sense – land uses and activities.

It is much more useful for sensing disruptions than for sensing how the city is functioning as a comprehensive system; E. G.






Entry at Bayswater (10 Mn. Intervals)
Weekday
Saturday
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150
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Number of Events
2am 4am 6am 8am 10am 12pm 2pm 4pm 6pm 8pm 10pm 12am 2am 4am
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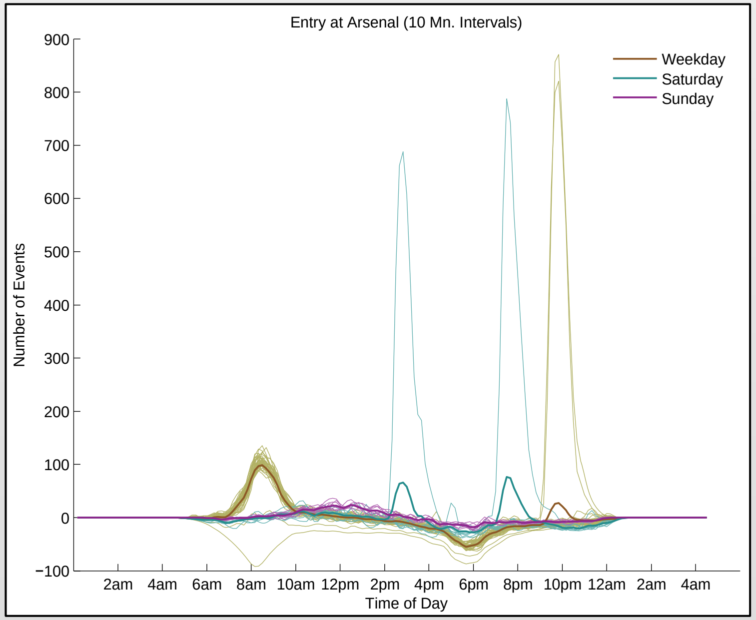
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A Switch in Time Horizons, in How We Think About Cities

The switch that is being occasioned in all this is a focus on the very short term, the immediate – how cities change in the next 5 minutes, the next hour, the next day, not the next year, or 5 or 10 or 50 years.

This shift in our attention span is problematic largely because many who are being attracted to think about cities, only see them in terms of the very short term.

However the power of big data is that if collected for long enough then the longer term will emerge from the short term. At the moment these data are about what happens in the short term, but over ten years or longer we will have a unique focus on the longer term – in fact we will have a snapshot of urban dynamics which is unprecedented.

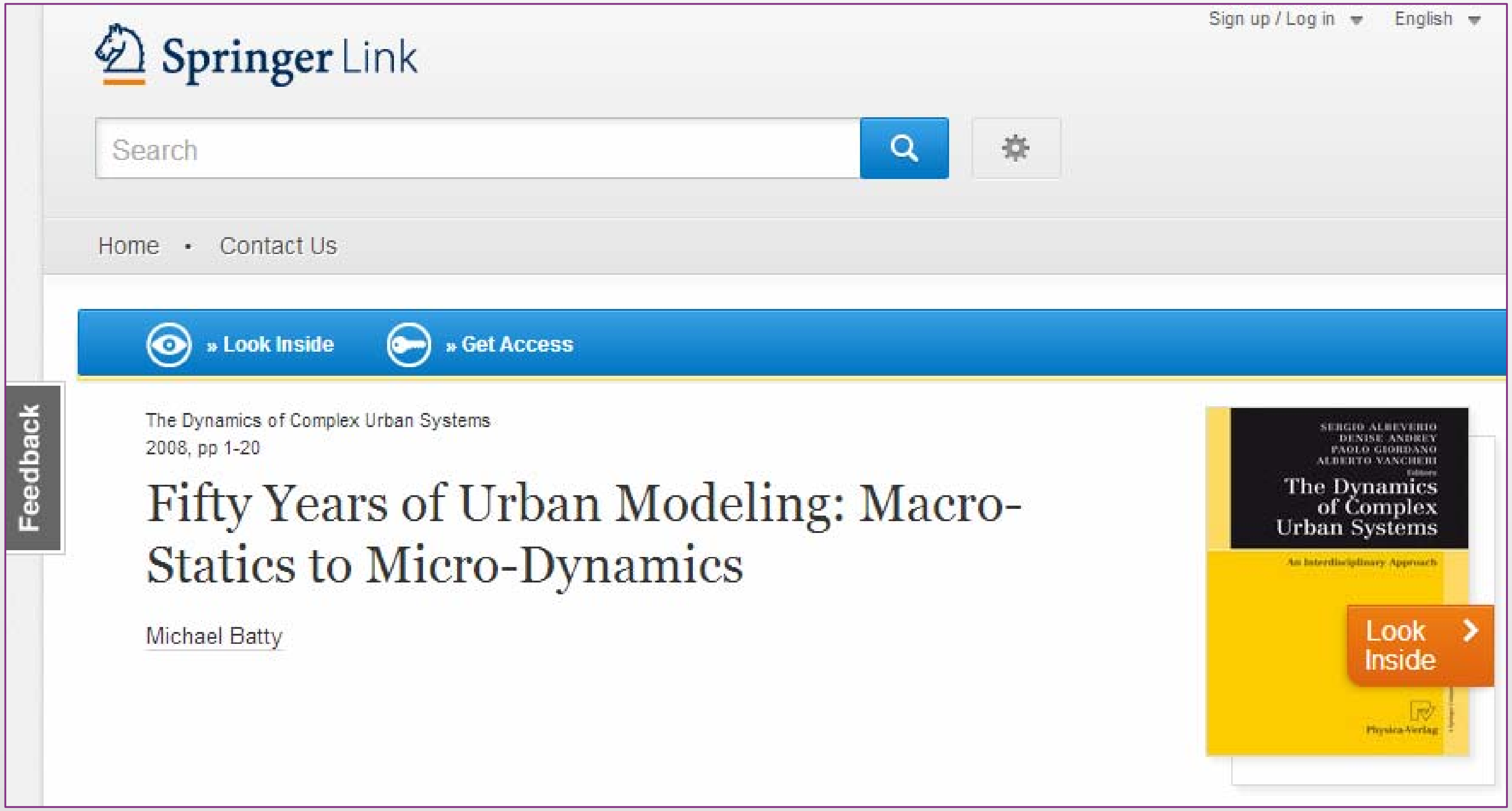
Future Models: Short Term, Immediate, Data Driven?

What kinds of models? It depends on what we want to understand and predict and my view is that this is changing more radically now than at any time in the last 50 years.

I think echoes of this will reverberate around this conference. In short it is not simply about LUTI models, CA, ABM and so on but it is more about short term and long term dynamics, about networks, how we handle disruptions, one off events

But the big challenges remain and the question of what models we use is as urgent as ever. I think the contemporary SIM models are key to this but so are many partial models and data driven models

I am not sure that there is any longer a consensus about this but I am sure that this issues will preoccupy us here.



You can download this chapter from my blog www.spatialcomplexity.info or from www.complexcity.info, I think

I am not sure we have time for questions

But some of these themes may be raised in sessions over the next three days.