RITSUMEIKAN UNIVERSITY SCHOOL OF GEOGRAPHY

Lecture 1:
What are Models:

The Scientific Context: Definitions of Model and Theory: The Model-Building Process, Data Analysis to Calibration to Prediction

Outline

- What are Models? Relationships to Theory
- Definitions of Models
- A Classification: Icons, Analogs, Symbols,
- Aggregate viz Disaggregate Modelling
- Statics viz Dynamics
- The Paradigm Shift: Aggregates to Agents
- The Model-Building Process
- Facts and Theories, Factoids and Stylized Facts
- Verification, Validation, Goodness of Fit
- Calibration and Estimation

What are Models? Relationships to Theory

A theory is an *abstraction* of some phenomena, usually '*real*' but sometimes imagined in a form that makes the *simplification* or abstraction clear. A model is a simplification of *reality* which takes the theoretical abstractions and puts it into a form that we can manipulate. Simulation is often used to characterise this process of implementation.

In everything we do, we theorise, and more and more frequently we build models to demonstrate theory.

This is all fairly obvious – but the focus on theory is important because theory can be implicit as well as explicit. In fact in our growing quest describe the world through models, theory is tending to become part and parcel of models.

The main reason for beginning with theory is that the conventional wisdom of science begins with theory and then *tests* theory against observations – data. It is impossible to approach the world without prior theory and without getting involved in where theory comes from, let us assume that whenever we model a phenomena we have in mind theory.

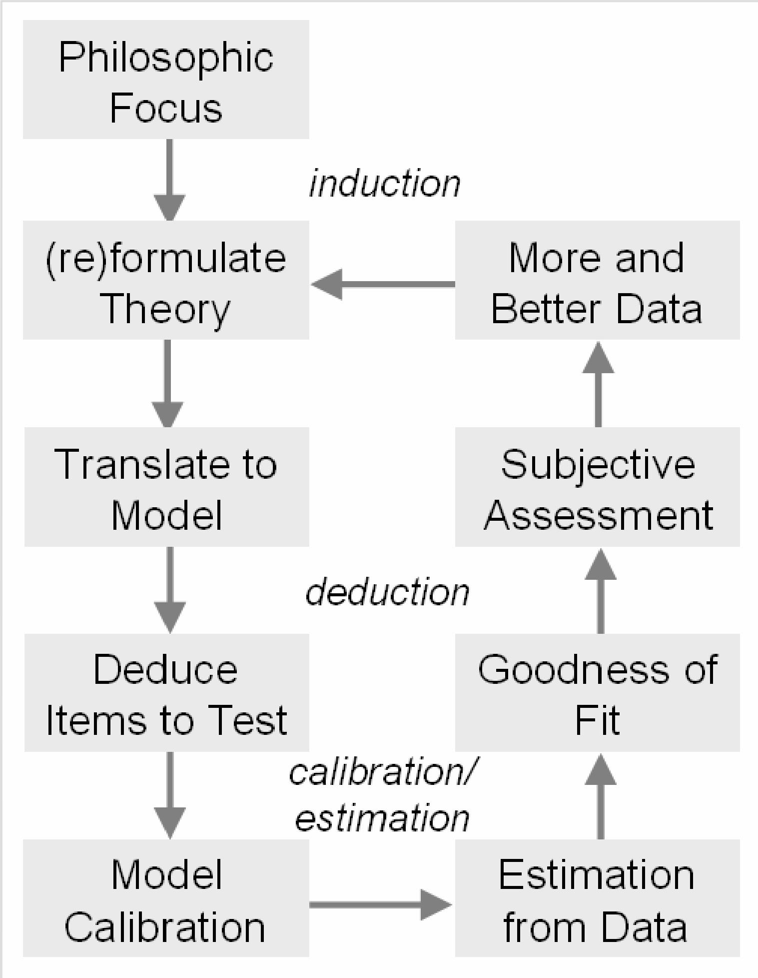
Thus the model- building process is really part and parcel of the scientific process – the scientific method where the current wisdom is that science tests theory by assembling data about reality which is designed to '*falsify*' the theory.

This is scientific method a la Popper and it suggests that data or observations is the ultimate arbiter of what is good theory. The method implies that this process of testing takes place in systems which are controllable in some science, are not volatile, as in experimental lab contexts. In fact as science has progressed, these conditions appear to be increasingly unlikely.

Hence the need for models – for theories in a form other than in the laboratory, where we can perform good testing.

The new form of the laboratory is the computer and instead of experimentation there is simulation. We could and perhaps we should spend time talking about this issue – for by no means all models are simulation models and all science is not based on computers. But increasingly science is intrinsically about computation and this is changing science itself. I also use the term ‘ science’ advisedly, in its most catholic sense ….. another debate perhaps later

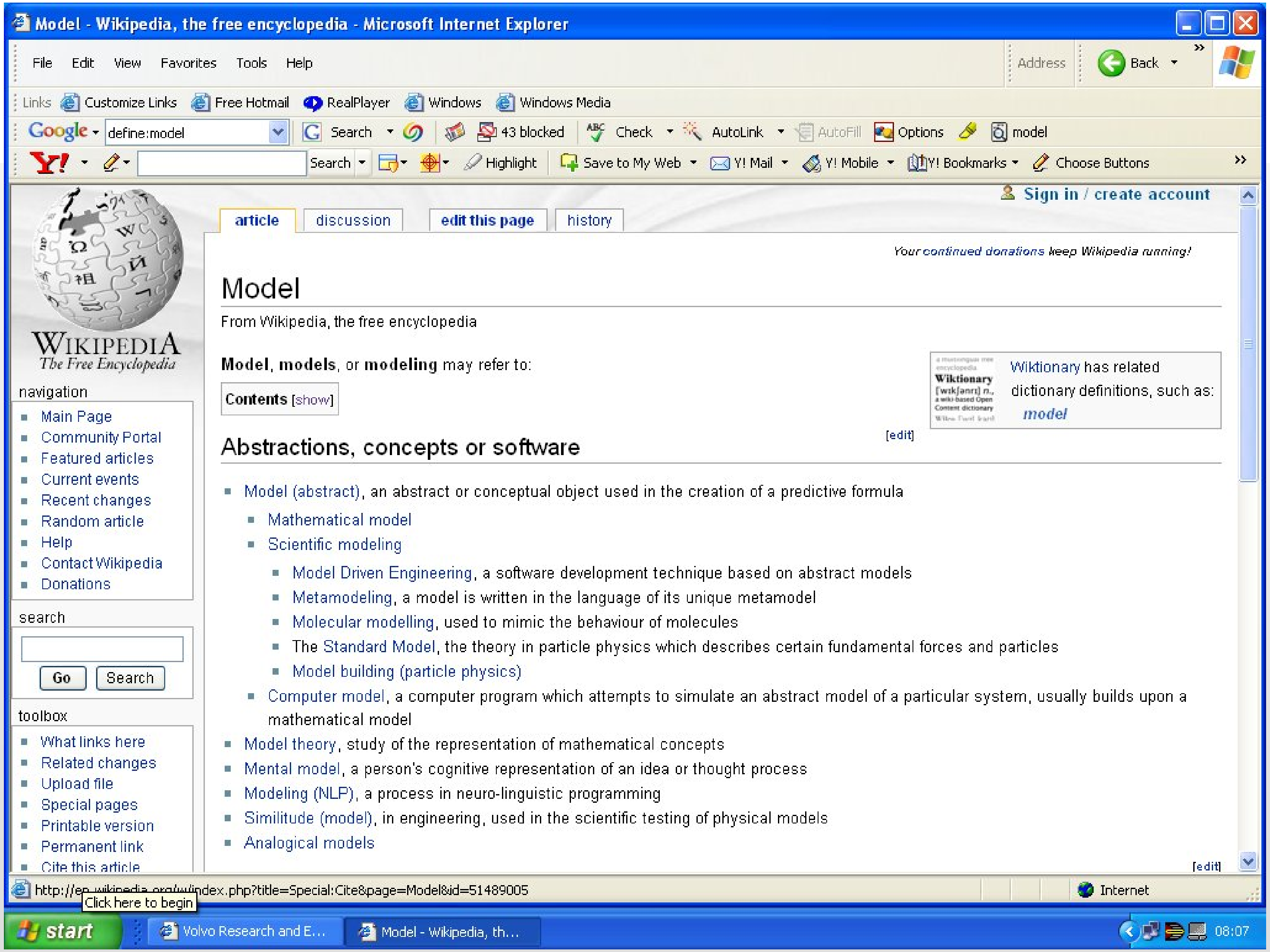
Let me get some more terms out of the way – and to do this here is a simple picture of the scientific method.



Definitions of Models

There are of course many types of models and although you may think that here we are only going to deal with mathematical or symbolic models, nothing could be further from the truth. Lowry's paper that I recommended you read classifies models, and we will draw loosely on his scheme.

There seem to be three or perhaps four different generic ways of abstraction – iconic, analog, symbolic and logic and these categories are not mutually exclusive.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Model, models, or modeling may refer to:
Contents [show]
Wiktionary has related dictionary definitions, such as: model
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Abstractions, concepts or software
Model (abstract), an abstract or conceptual object used in the creation of a predictive formula
Mathematical model
Scientific modeling
Model Driven Engineering, a software development technique based on abstract models
Metamodeling, a model is written in the language of its unique metamodel
Molecular modelling, used to mimic the behaviour of molecules
The Standard Model, the theory in particle physics which describes certain fundamental forces and particles
Model building (particle physics)
Computer model, a computer program which attempts to simulate an abstract model of a particular system, usually builds upon a mathematical model
Model theory, study of the representation of mathematical concepts
Mental model, a person's cognitive representation of an idea or thought process
Modeling (NLP), a process in neuro-linguistic programming
Similitude (model), in engineering, used in the scientific testing of physical models
Analogical models
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A Classification: Icons, Analogs, Symbols

Iconic models are representations that visually convey what the real things looks like – maps are the classic example – these are largely representations – they may have some symbology but they are scaled down versions of the real thing.

Symbolic models represents system in terms of the way they functions, often through time and over space – these models are invariably mathematical.

Analog models are a half way house between iconic and symbolic. The key issue is that they take a representational and/or functional form of one system and apply it to another.

e.g. analogies between physical and human systems – the flow of blood in analogy to hydrodynamics developed for models of the atmosphere, traffic flow as an analog of an electrical network, and so on.

Logical models are symbolic in a sense but are based on causal connections composed of rules. We can mix, of course, any of these four types.

The reason why the term model has become so significant is that computers are increasingly being used as the ‘container’ or ‘media’ for many models as our world becomes digital.

Computers mean that iconic, analog, symbolic and logical models merge into one another, so for example we can have iconic models but built of mathematical structures as in GIS

And computer models are being generalised to all sorts of other things that we never used to call models – to plans, to processes of participation etc.

Aggregate viz Disaggregate Modelling

50 years ago when models first became identifiable as a distinct activity in science, and as the social sciences embraced them, they were usually statistical summaries or aggregations of elemental units.

Good examples were economic models based on macro economics, e.g. Keynesian models, econometric models

Population models, models based on social physics

There has always been a quest however to disaggregate – meaning that the model needs to be specified in more detail. Let me take an example – models of retail systems, called shopping models

Shopping trips = f (Population, Floorspace, Distance)

Shopping trips	Population	Floorspace	Distance
from zone i where people live to zone j where they shop	zone i where people live	zone j where people shop	from zone i to zone j

We might want to disaggregate the data into detailed types of population and detailed types of shopping, different transport networks and so on.

As computers have become ever faster and larger in terms of processing power, such models have become more and more disaggregate – in principle although data remains a constraints.

In fact as disaggregation has proceeded, models have changed in focus and a new stream of model where the fundamental elements themselves can be represented have become popular.

These are based on objects – or agents – where every element can be simulated – and we will say a lot more about these later in the week.

Statics viz Dynamics

In passing, it would be remiss not to make the distinction between statics and dynamics. Models in social systems have tended to be static – comparative static or cross sectional as they are called in economics – with assumptions about that systems tend towards equilibrium.
In the last 20 years, all this has been thrown up in the air and dynamics has come onto the agenda in a big way. This has important implications for spatial systems where time has not been a popular feature of representations and models.

The Paradigm Shift: Aggregates to Agents

I am not going to talk this morning about this paradigm shift but will do so this afternoon, but just to flag these ideas, we will build

- temporally dynamic models on fine scale spaces called cellular automata or CA models
- temporally dynamics models where individuals or objects move in space – agent-based models ABM or multi-agent models MAS

The Model-Building Process

In later talks and discussions, we will return to the model building process and examine processes for defining a problem, theorising about the problem, formulating a model, operationalising the model, confronting the model with data, calibrating the model to the data, testing the model's fit, taking the model elsewhere to truly test it, improving the model by extending the theory, and reiterating the process in this way. But here we need to say something about facts and how we fit models to facts

Facts and Theories, Factoids & Stylized Facts

- Generally observations of the system being modelled or simulated are assembled and the model's predictions are compared against these 'facts'
- Facts are publicly agreed sets of observations over which there is 'no' disagreement
- Facts can range in quality from well defined observations to highly speculative pieces of data.
- Factoids and stylized facts are two types of observation that are sometimes used in testing a model's predictive abilities

Factoids

1. A piece of unverified or inaccurate information that is presented in the press as factual, often as part of a publicity effort, and that is then accepted as true because of frequent repetition.
2. combining the word "fact" and the ending "-oid" to mean "like a fact".
3. Factoid has since developed a second meaning, that of a brief, somewhat interesting fact, that might better have been called a ‘factette’.
4. A 'factlet' is a fact that is tiny and trivial, and also correct.

Stylized Fact

In social sciences, especially economics, a stylized fact is a simplified presentation of an empirical finding. While results in statistics can only be shown to be highly probable, in a stylized fact, they are presented as true.

A stylized fact is often a broad generalisation, which although essentially true may have inaccuracies in the detail.

Highly applicable to the assumptions of agent-based models which may not be verifiable but plausible

Verification (a model matches its design)

To check, confirm or prove the truth of something.
To establish, prove, substantiate, attest, corroborate, support, confirm.

Validation (a model matches the data)

To meet some criterion/criteria associated with the model and or the data/observations. In general, validation is the process of checking if something satisfies a certain criterion. Examples would be: checking if a statement is true, if an appliance works as intended, if a computer system is secure, or if computer data is compliant with an open standard. This should not be confused with verification.

Goodness of Fit

A well defined measure of how the model's predictions match the known observations of facts, typically some measure of difference between predictions and observations.

Predictions are any outcome of the model, past, present or future

Calibration and Estimation

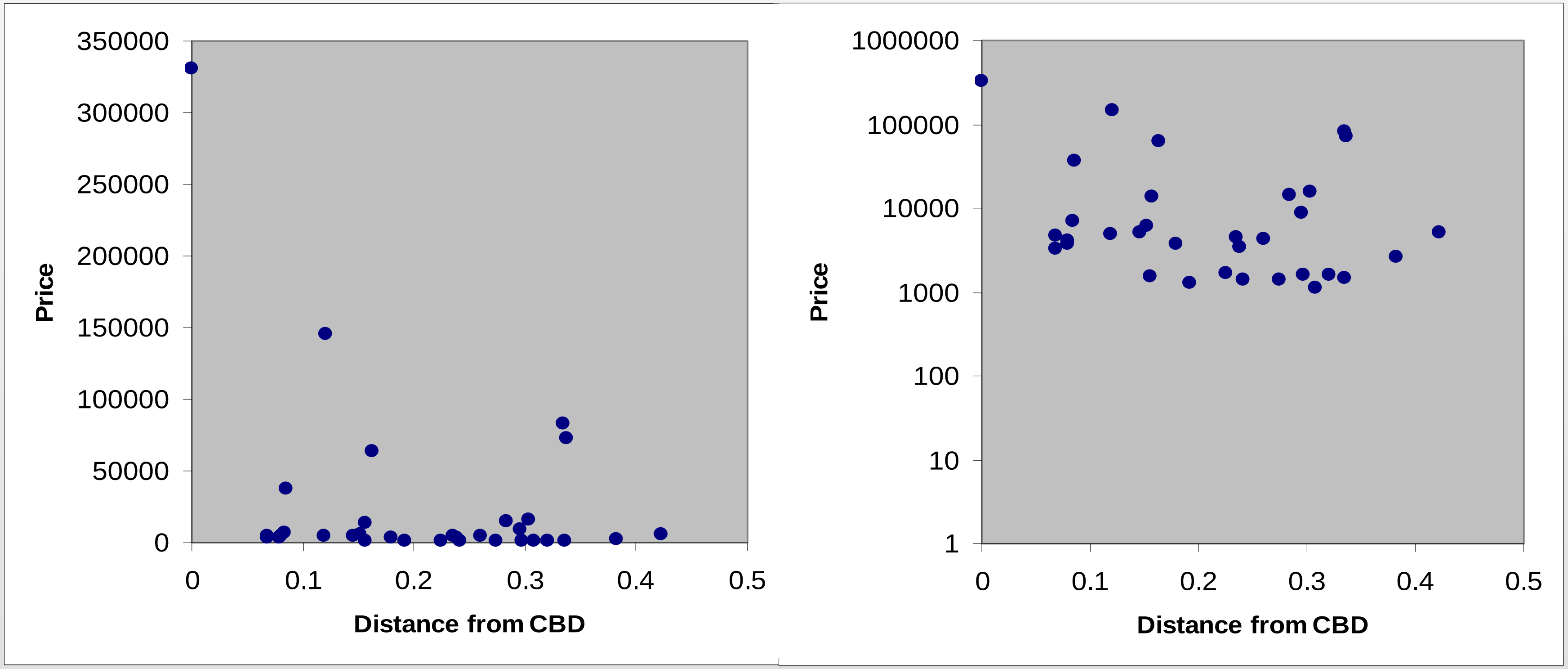
Calibration is the generic process of validation and verification. Estimation is the process or method of generating a precise estimate of some parameter characterising the model.

Anticipating Goodness of Fit and Calibration or Estimation

First we need a model so let us choose one that is quite basic to this course – how an activity in a city varies with distance

Let us take rent (or house prices) versus distance – in fact this is a key idea in urban economics

Let us postulate that rent per unit of space falls with distance and from past observations, then we might expect something like this


350000
300000
250000
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Price
0
0.1
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Distance from CBD
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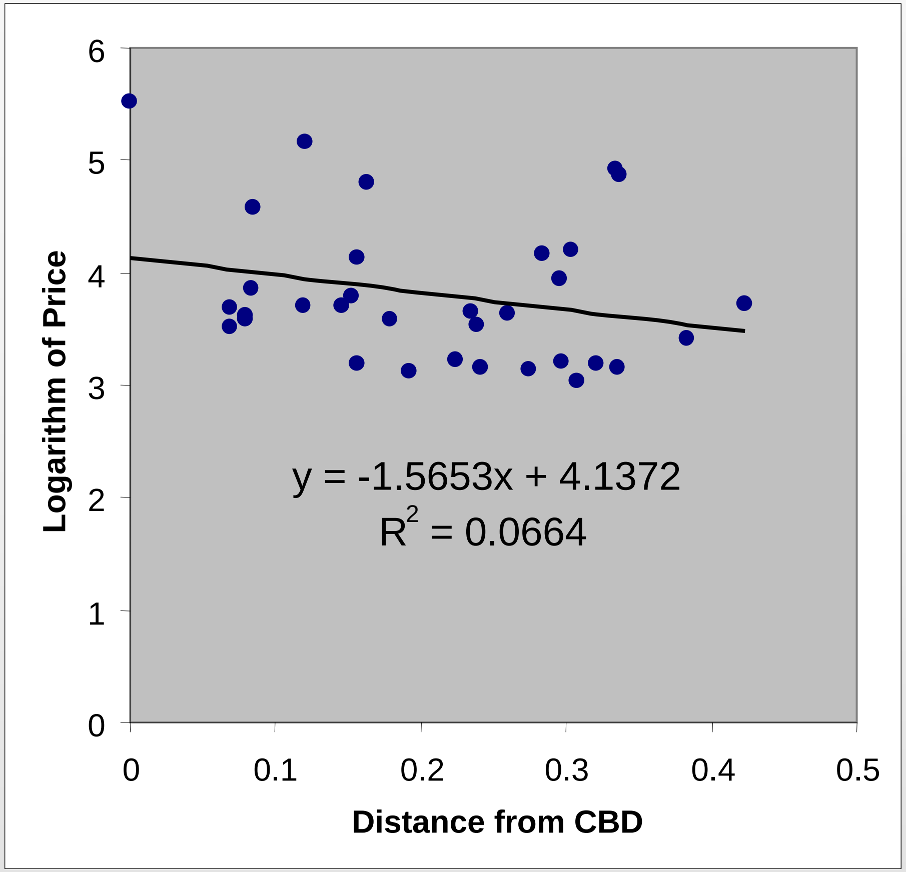
Distance from CBD



Note how the goodness of fit is rather poor but one would not reject the fact that price varies inversely with distance – can any guess what sort of equation we are fitting here??

Other Issues

consistency and reliability –with reliability is the consistency of your measurement,

I don't think there is a coherent discussion of all these issues *per se* as they are pieced together from multiple sources.

Sensitivity Testing
Process Modelling
Parsimony v richness
Scale, aggregation …. Space and time

Background Reading

I will out this material up on the web tomorrow but there are five papers worth looking at

Batty, M. (2009) Urban Modeling, in R. Kitchin and N. Thrift (Eds) **International Encyclopedia of Human Geography**, Volume 12, Elsevier, Oxford, 51–58.

Batty, M. (2008) Spatial Interaction, in K. K. Kemp (Editor) **International Encyclopedia of Geographic Information Science**, Sage. Los Angeles, CA, 416-418.

Batty, M. and Torrens, P. (2005) Modelling and Prediction in a Complex World, **Futures**, **37** (7), 745-766.

Lowry, I. S. (1965) A Short Course in Model Design, **Journal of the American Institute of Planners**, **31**, 158-165.

Vanderleeuw, S. E. (2004) Why Model? **Cybernetics and Systems: An International Journal**, **35**, 117-128

And if you want some old background you can download my book Urban Modelling (1976) from our web site at www.casa.ucl.ac.uk/urbanmodelling/

Questions?