Using AI and Digital Twins in Public Participation

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An Outline of the Talk

- What Is Artificial Intelligence? The Computable City
- AI As It Has Emerged Today
- The Meaning of a Digital Twin: Many Models, Big Data
- Communicating Plans: Maps as Twins
- Stakeholders, Non-Digital and Mixed Digital Twins
- Different Scales of Similar Models in the Same Location

  VR and A + 3D City Models: Smart Buildings + BIMS: ABM Transport Models in Real Time: Long Term Urban Change + QUANT
- A Digital Twin for Britain: Scale: The **Quant** Model
- Can We Devise a Template for AI Applications in Cities as Digital Twins

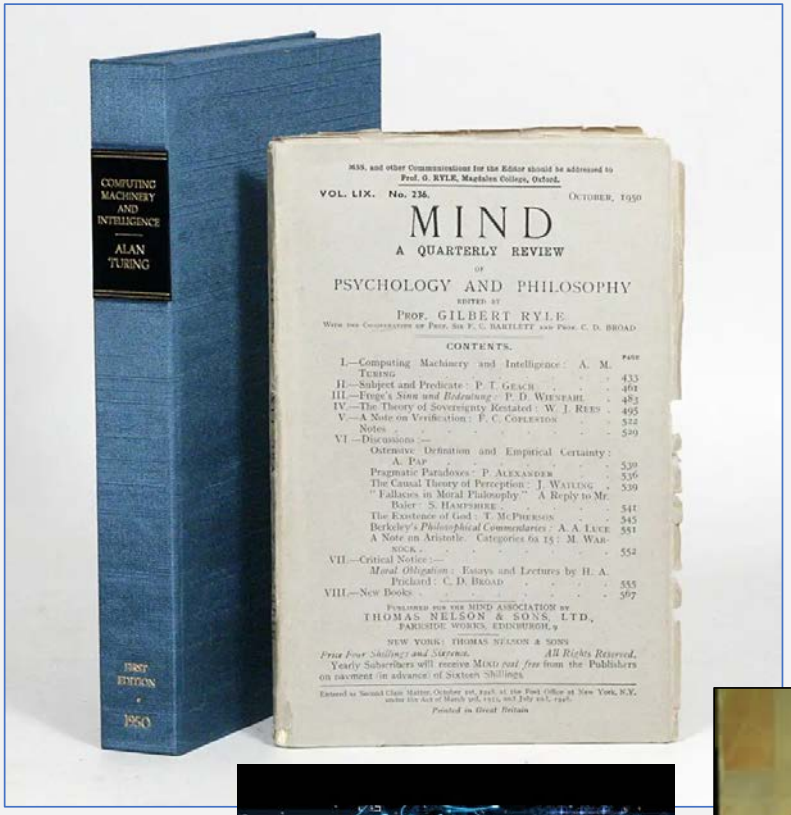
- **What Is Artificial Intelligence? The Computable City**

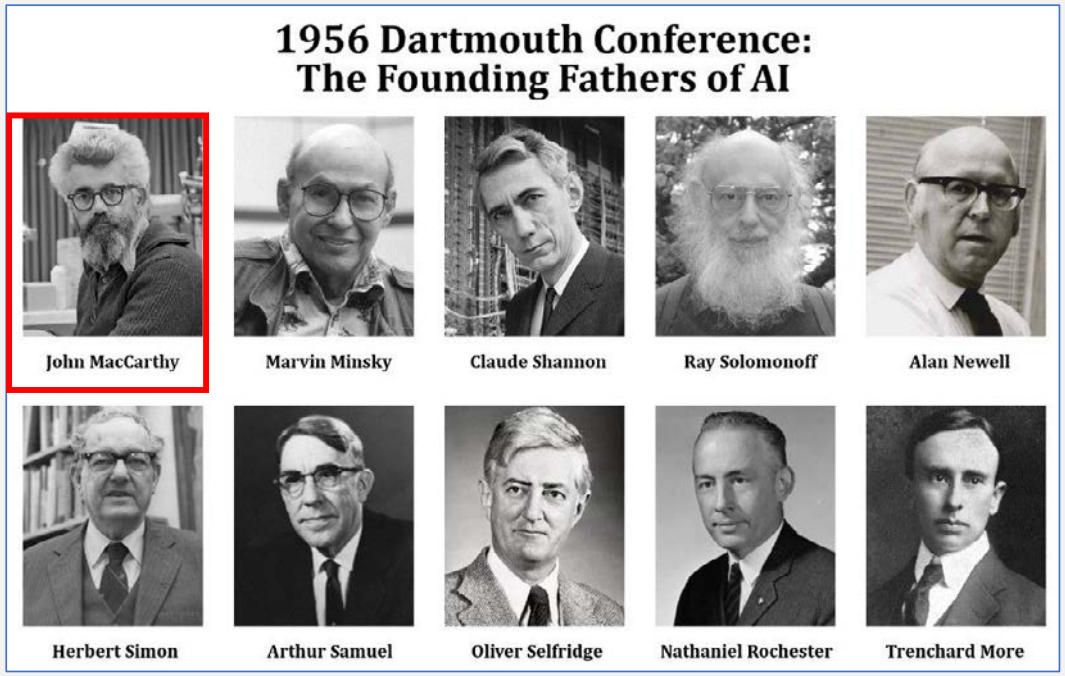
- *What Is AI?*
- The fact we don't have any kind of template of applications for AI seems to cover everything where you can explore intelligent procedures and methods. It has great generality. Cave and Dihal (2023) in their book ***Imagining AI*** say AI is

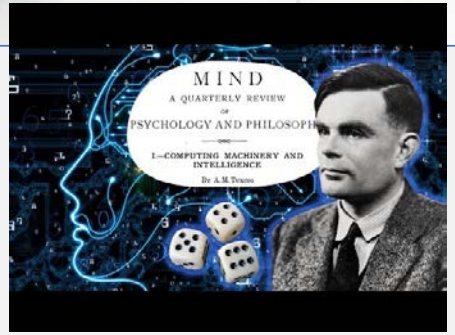
  "…a really vague concept that can expand endlessly to encompass all kinds of ideas …"

- I dare you to define it. Doubtless we can use it to improve our methods and applications and in this sense we can make our social and economic life more efficient and equitable. It is like all IT.

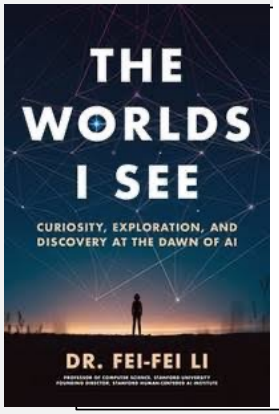
- *Where Did AI Come From?*
- As soon as the digital computer emerged during World War 2, the pioneers speculated that the ***computer was a universal machine*** – anything that could be reduced to the binary code could be computable, and that ***computers could be used to make intelligent decisions***
- The term ***AI*** came mainly from Turing and the idea that computers were like brains – networks of processing units – emerged
- ***AI*** was from the beginning a set of methods, it was not and never will be substantive theory– there is no template of applications
- ***AI*** is maths and logic– prior to AI, there was statistics – from empirical apps – from biology – Fisher, Pearson, Galton, Haldane, Huxley ……
- Much of ***AI*** now is statistics – machine learning is really linear modelling

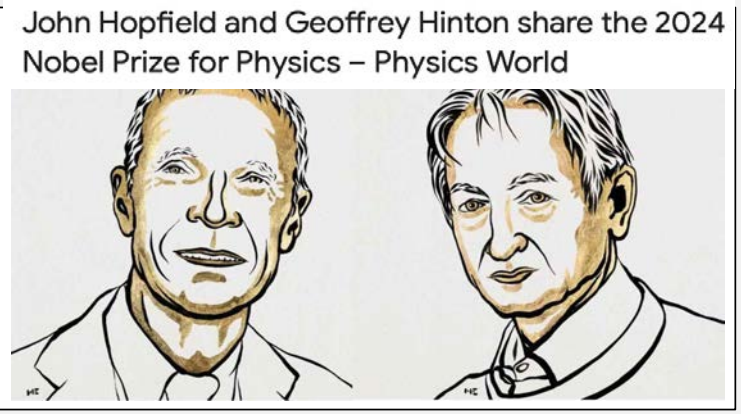







Fei-Fei Li





Using AI and Digital Twins in Public Participation

- *A Potted History from 1945*
- The brain and its network of processing units was the nearest to a generic template – the network – which embodied the notion of problem-solving. A template for processes not outcomes.
- The simplest neural net – the perceptron was there at the beginning as was the design and optimization – in the work of Simon et al.
- You can see that the notion of the city as an artefact for design was there but progress was very slow and AI entered its nuclear winter –
- More modest processes emerged – expert systems
- A period of slow but sure improvement began and the perceptron was resurrected –the neural net – connectionism
- Machines got ever faster and bigger. big data, sensors, search, the smart city emerged - machine learning – Hinton, Hassabis, Fei-Fei Li

AI As It Has Emerged Today

- There is quite a strong disconnect between all these ideas about networks and the kind of AI dependent on big data that has emerged recently which is more based on intelligent and generative search than machine learning: search v learning
- Foundation models - Large Language Models – LLM have rapidly emerged and it appears that ***we can apply them to any problem*** for which we can identify a large data base from which we can extract meaning. ***But who constructs the data bases?***
- The fact we don't have a template of applications is due to the great generality of the area. Cave and Dihal (2023) in their book ***Imagining AI*** say AI is "…a really vague concept that can expand endlessly to encompass all kinds of ideas …" We urgently need a debate about this in our field …following Susskind's recent book

- **The Meaning of a Digital Twin: Many Models, Big Data**

- Let us digress –I will begin with some basics about digital twins. DTs as the name suggests are a copy or replica of a real system. But a copy were some of the real system is inevitably missing? How close can the DT be to the PT – the physical twin

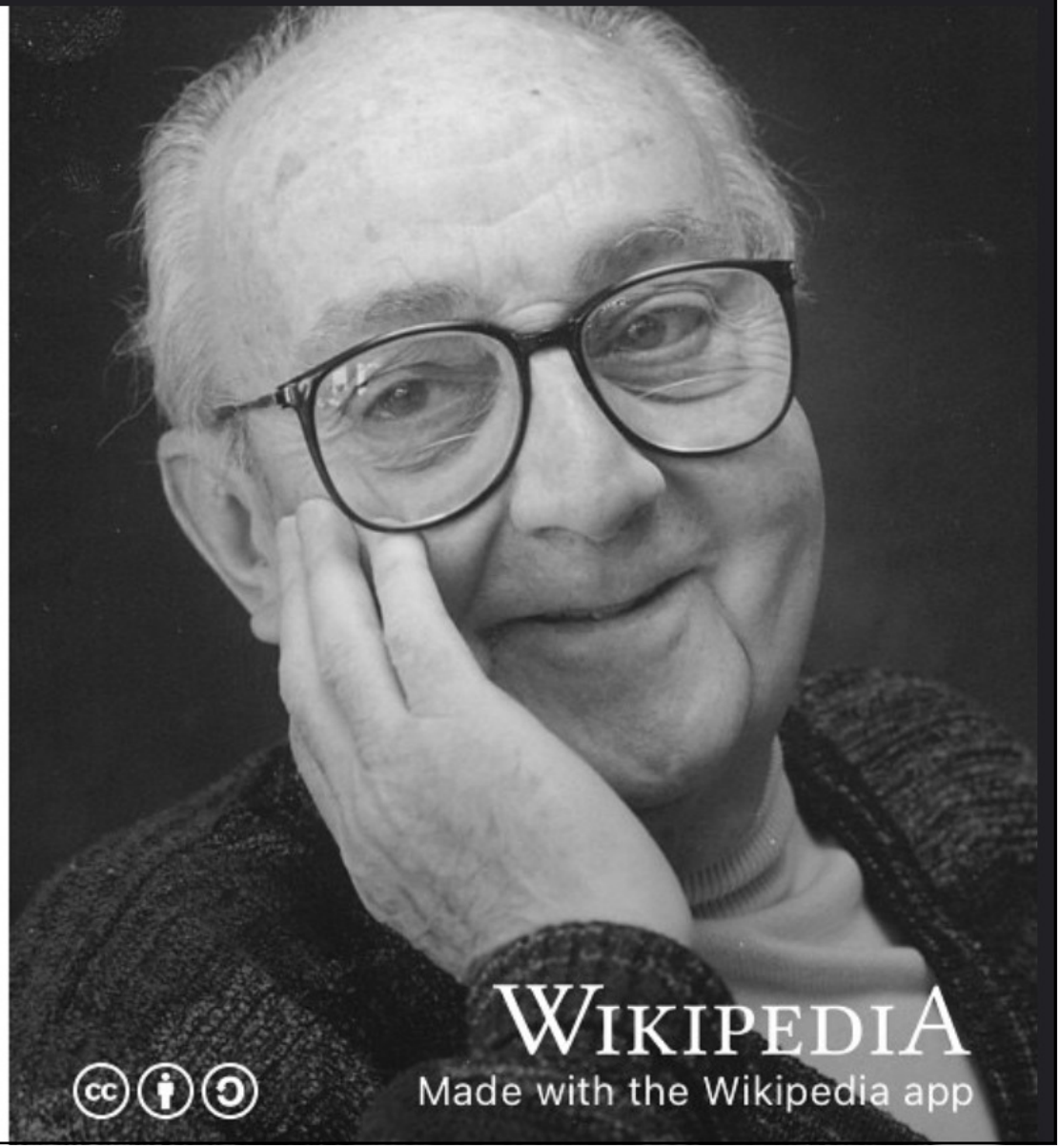
- This is my definition of a model. "A model is an abstraction or simplification of the real thing, where the model-builder throws away most of the real thing leaving only its essence".

- A model must be for some purpose and thus every model has a specific function; it is likely that if I build a model, and then you try to build the same model, they would be different.

- They would not be **identical twins** mainly because their designers or model builders have different expertise. In some minor detail, they would always be different. In essence this depends on setting up experiments that can never be exactly replicable ….
- In this sense, no model can reproduce the real system. Indeed the whole idea of a model is not to reproduce the real system but only some element or some process that the system has.
- However we are all still conditioned by the magic of science for we assume that when we build a model, we need to see how close we can come to the real thing. But we know conceptually that we can never reproduce the real thing. So why do we try?
- The answer is contained in George Box's great mantra ……

All Models are wrong, but some are useful

We need to build models so that we deal with counterfactuals – these are scenarios – plans that will always fall short of what we want - inevitably



- *Where do Digital Twins Come From?*
- The term appears to have been first coined in the early 2000s by Michael Grieves (2014) whose expertise in product design initially rooted the concept in production engineering.
- In this sense, one can see the twin as being very close to the real thing especially as production systems are being continually automated and this automation is largely digital. A twin links to its real system through feedback loops of various kinds.
- The closest in our world are the components of the built environment that make up the city – buildings, utilities, physical infrastructures – BIMS – it is no surprise that in this perspective of the smart city, this is where the idea is getting a lot of mileage

Communicating Plans: Maps as Twins: Maps as Analogies: A Digression

- The most evocative metaphors relate to maps – for maps are simplifications and there are many stories that suggest that the level of simplification is problematic. In fact there is a famous paper that some of us know by Benoit Mandelbrot called 'How Long is the Coast of Britain? ***Science*** in 1967. The answer is – the length is infinite but the real answer is 'it depends'

- But the best digital twin story I have ever heard is the one from Lewis Carroll who in his last work ***Silvie and Bruno Concluded*** (1893) tells of a conversation between himself and a German gentleman about making a map close to the real thing

Let me read it out. The conversation goes like this: between ME and Mein Herr (MH)

ME: 'What a useful thing a pocket-map is!' I remarked.

MH: 'That's another thing we've learned from your Nation', said Mein Herr, 'map-making. But we've carried it much further than you. What do you consider the largest map that would be really useful?'

ME: 'About six inches to the mile'.

MH: 'Only six inches!' exclaimed Mein Herr. 'We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to the mile!'

ME: 'Have you used it much?' I enquired.

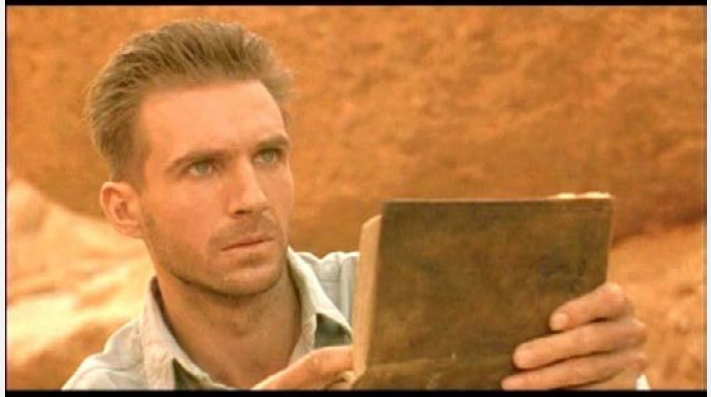
MH: 'It has never been spread out, yet', said Mein Herr: 'the farmers objected: they said it would cover the whole country, and shut out the sunlight! So, we now use the country itself, as its own map, and I assure you it does nearly as well'. (Carroll, 1893 [1982])

This notion of the map being the same as the territory has been explored by others, by Jorges Luis Borges, Gregory Bateson, Joan Robinson, Braudrillard, Gerlenter. Even D. H Lawrence said that "the map appears to us more real than the land" (1925)

- Somewhat later, Jorge Luis Borges (1946) in his essay ***'On Exactitude in Science'*** more or less tells the same story of cartographers so obsessed with their art that they decided to produce the most detailed map of their Empire that they could make at a scale of 1 to 1. The next generations less enamoured of cartography than those who made the map had little use for it but Borges concludes by saying *'In the Deserts of the West, still today, there are Tattered Ruins of that Map',*

- Conjuring up images from the movie ***The English Patient***. I wonder if the same fate awaits the digital twin: possibly in terms of terminology but the power of simulation and the prospect of getting better and better simulations shows no sign of stopping. …… We will see.

The English Patient with his 'map'



Herodotus's ***The Histories***

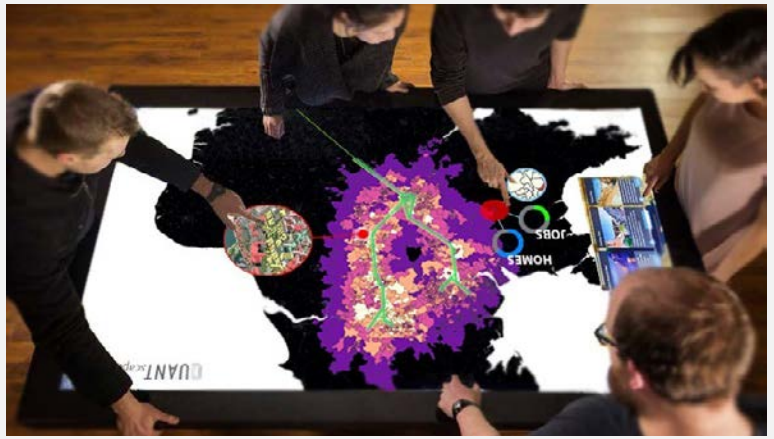
Non-Digital and Mixed Digital Twins, The System and Its Twin

- Where the semantics of the digital twin are most developed in various kinds of engineering, it is possible to imagine at least that one could build a model of a mechanical or electrical system close the real thing. But for cities in the way we conceive them as social systems, this seems unlikely.

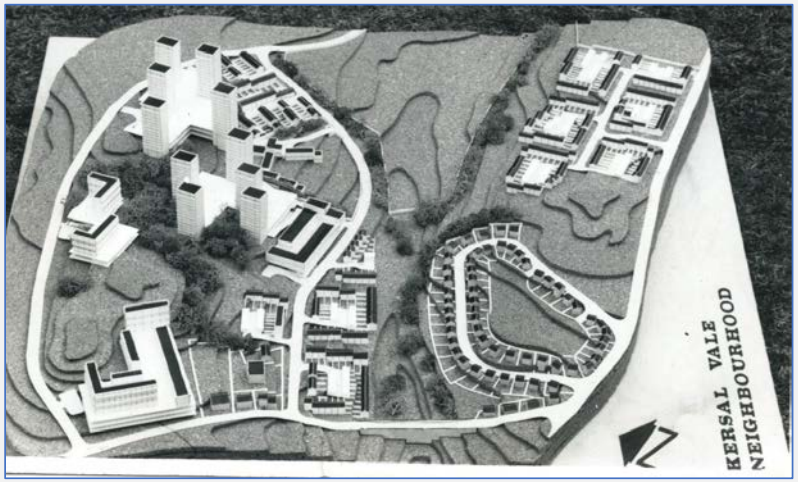
- This is as much because our systems are never stable, they are always changing, always evolving and in this sense, they are getting ever more complex: thus even if our models were exact copies, they would always be out of date.

- Models can represent the actual **physical system** or they can be a **conceptual or mathematical version** of the system or they can be a scaled down superficial replica, sometimes called an analogue model.

- In fact, they may be a mix of the non-digital, physical and the digital. When the human is explicitly in the loop, the model is semi-digital. Let me show you



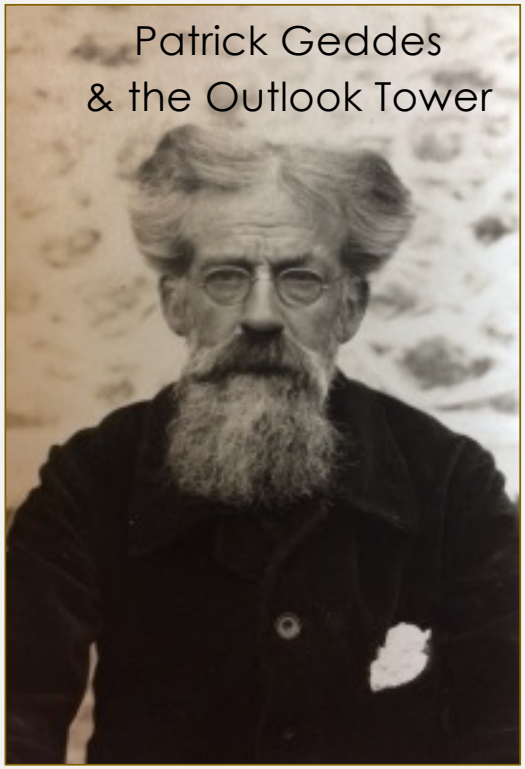
Analog Twins: Manchester 1960s, CASA 2010 Bartlett Architecture 2023

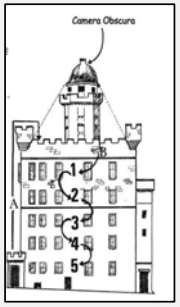


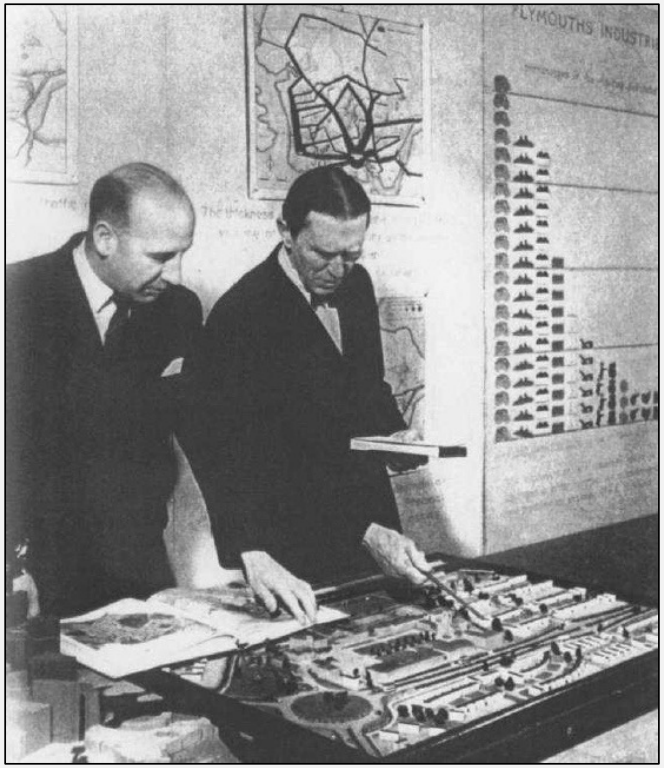
Analog Models: Digital Twins & PP

- **Stakeholders, Non-Digital and Mixed Digital Twins**

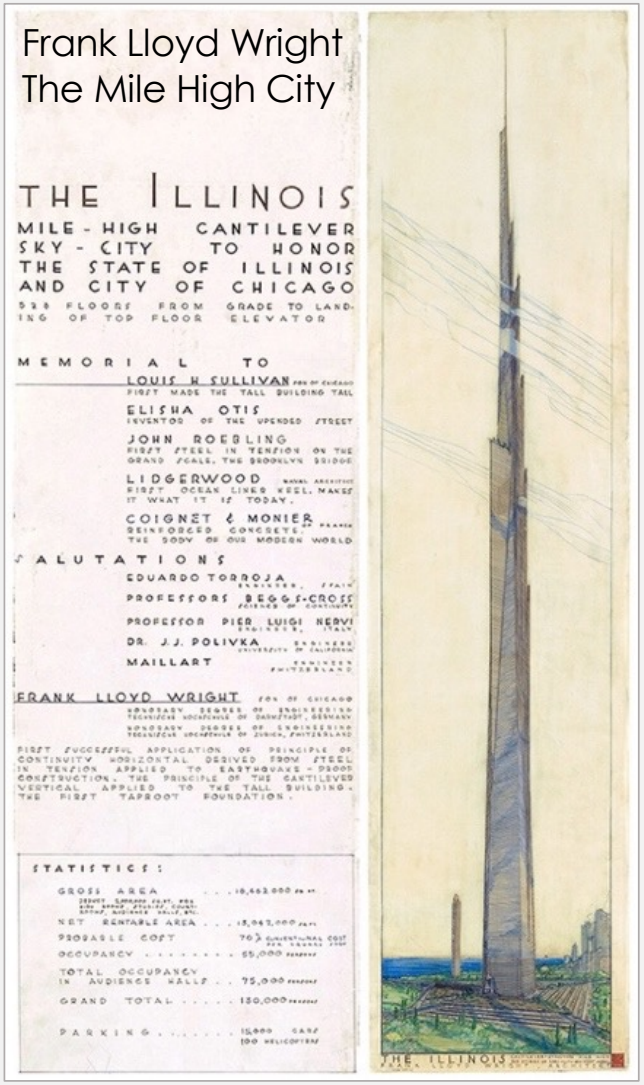
  Many different kinds of stakeholders – experts from technical to policy, the public-at-large of different types, and so on







Frank Lloyd Wright
The Mile High City



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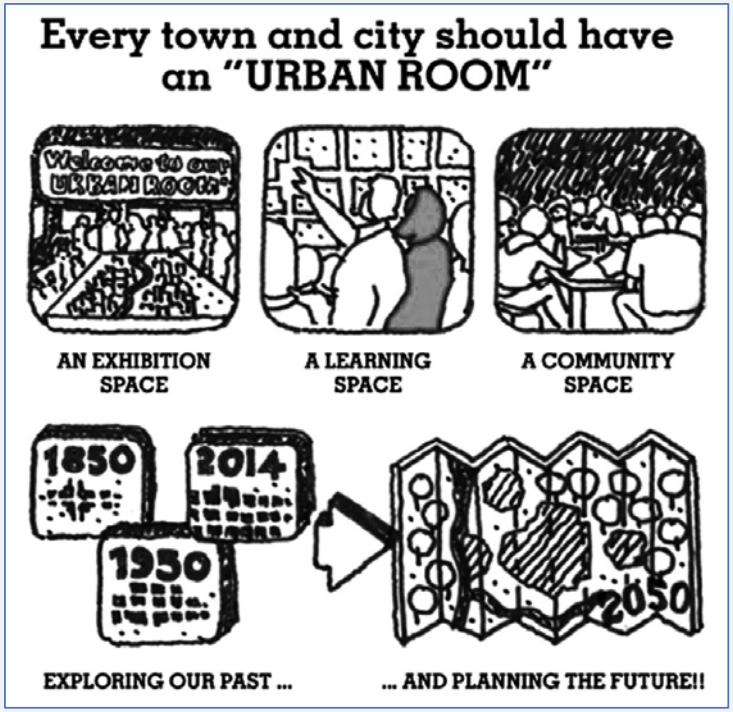
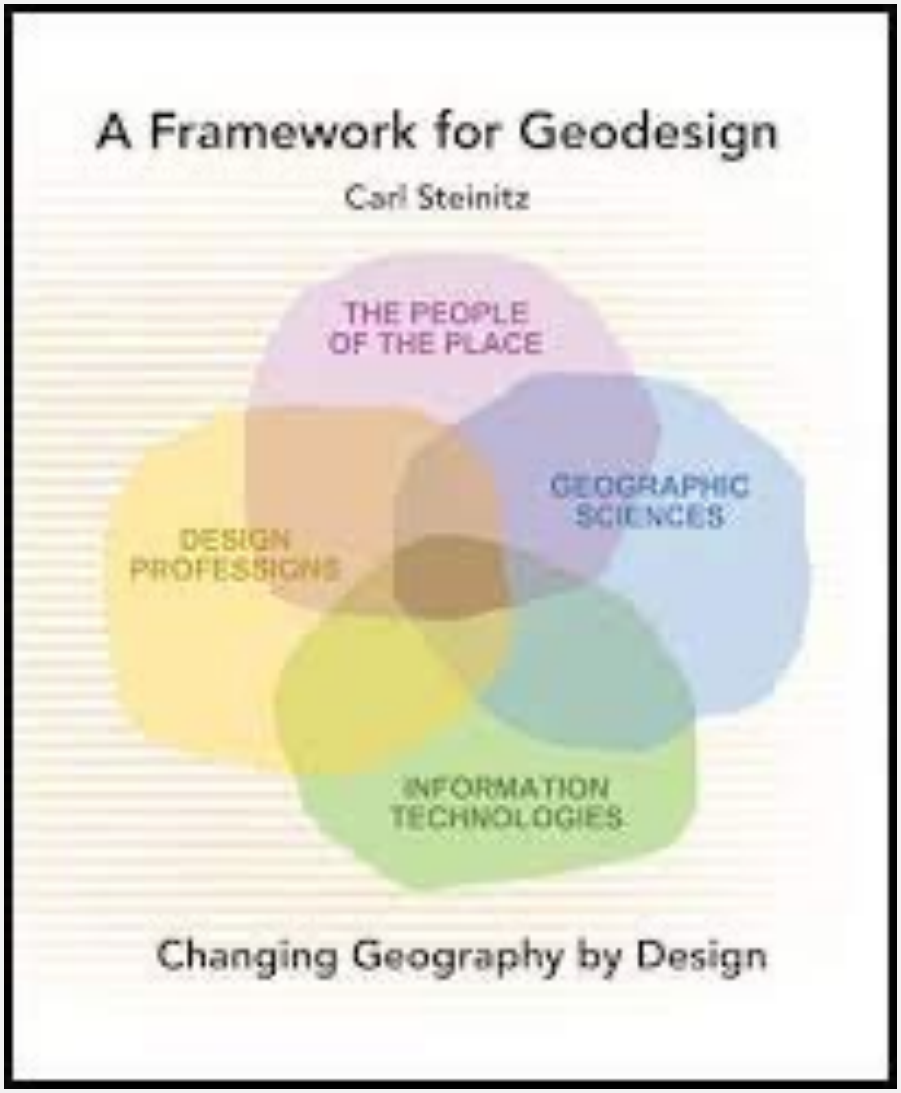
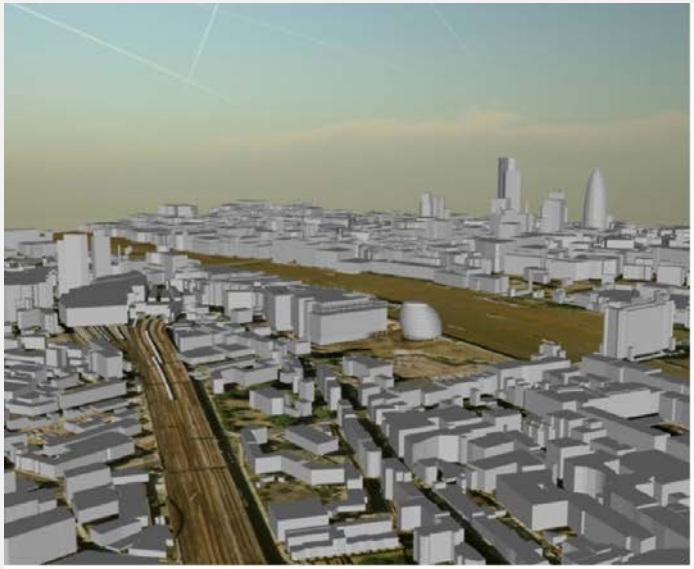
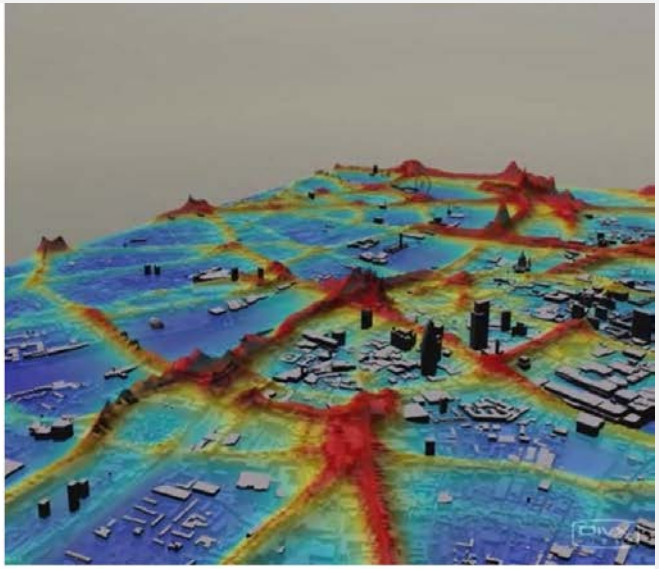

Every town and city should have an "URBAN ROOM"
AN EXHIBITION SPACE
A LEARNING SPACE
A COMMUNITY SPACE
1850
2014
1950
2050
EXPLORING OUR PAST ...
... AND PLANNING THE FUTURE!!

Urban Rooms

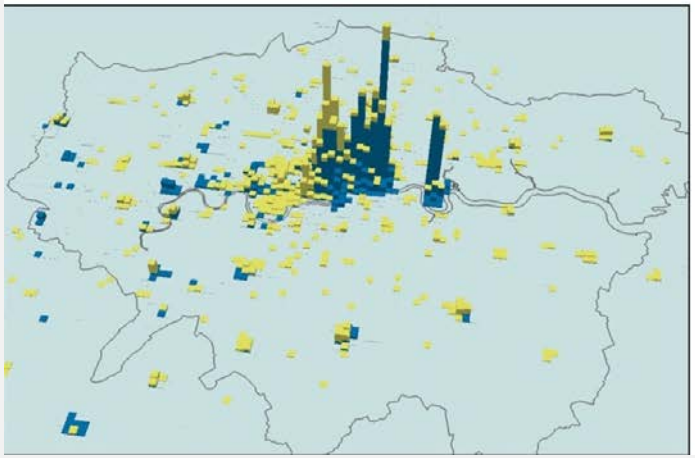
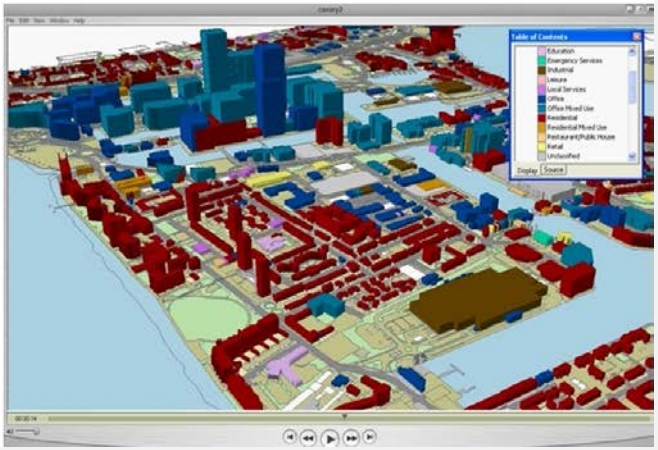
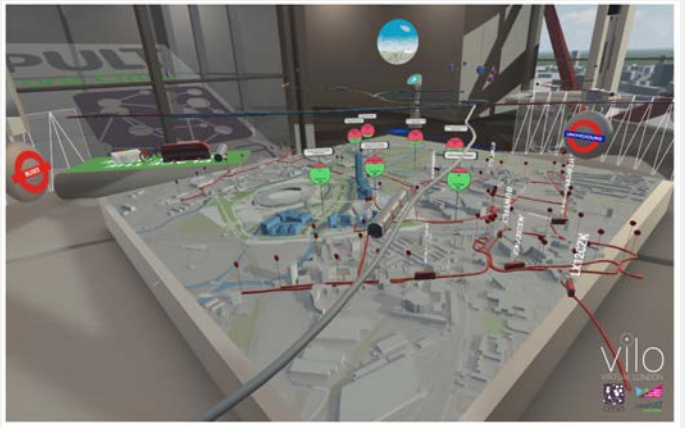
Geodesign PP and GIS







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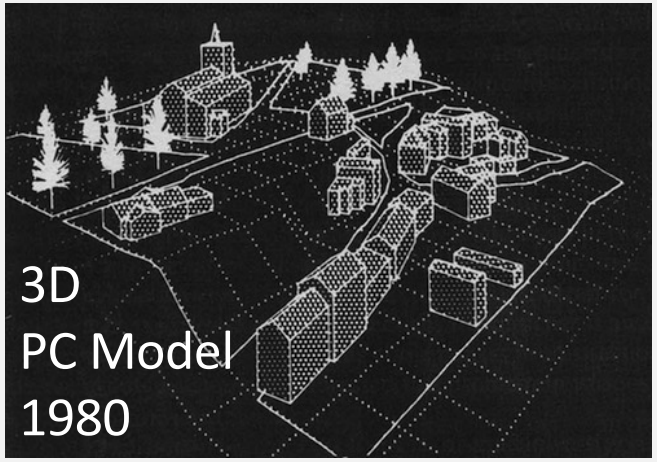
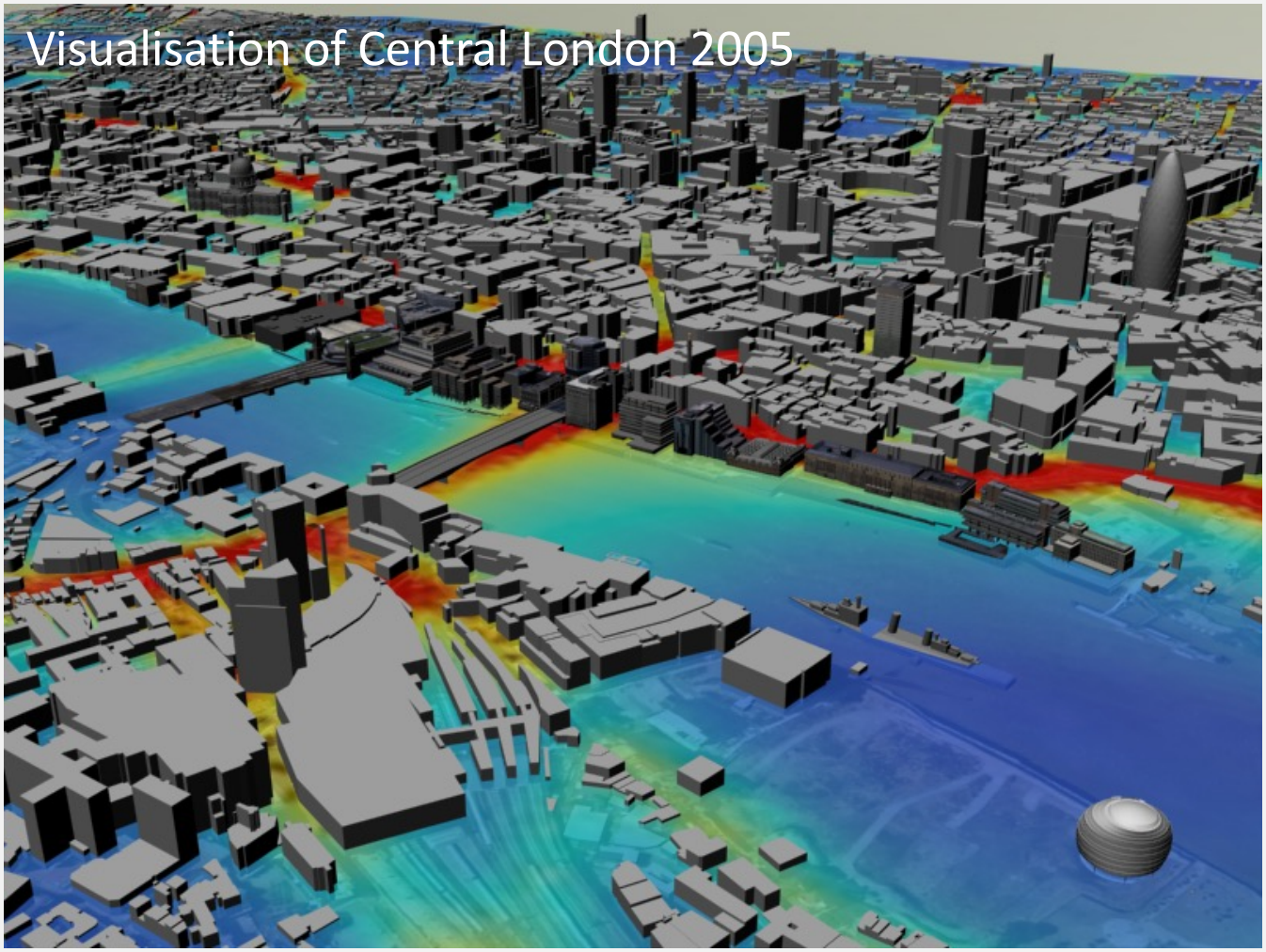




Batty, M. (2024) Digital twins in city planning, **Nature Computational Science,** 4, 192–199
https://doi.org/10.1038/s43588-024-00606-7

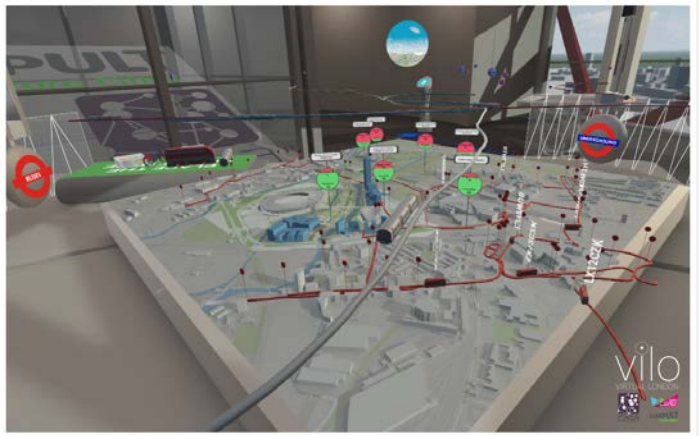
- **Different Scales of Similar Models in the Same Location**

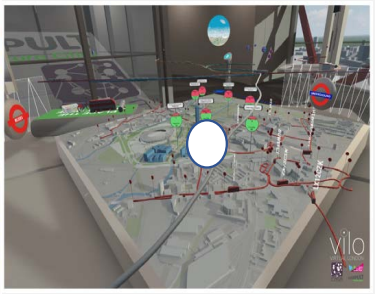
  VR and A + 3D City Models: Smart Buildings + BIMS: ABM Transport Models in Real Time: Long Term Urban Change + QUANT

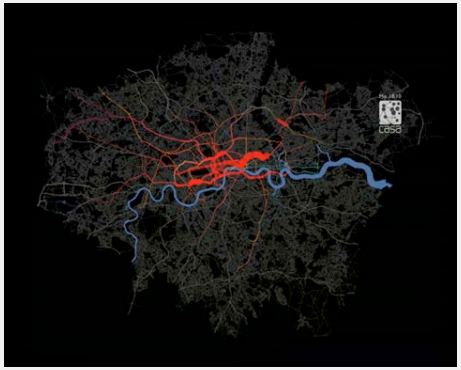
- There the idea that might be more than one twin of a system with many parts can be controversial. But what do we have if we have more than one model but of the same system all in the same place but only a difference in location. The models may be different but cover the same locations. We have a digital twin we have built for Britain.

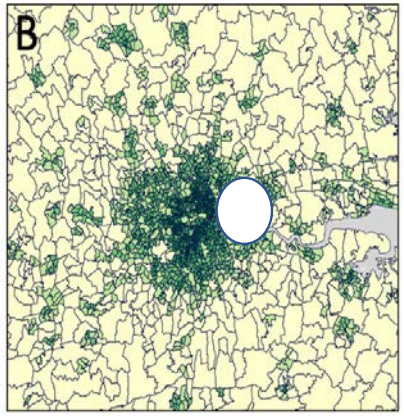
- However the models or system may be at different scales or there may be more than one model, each at a different scale. The models may be good or best in their own right but each might be at a different scale. Scale then is a key differentiator but this doesn't explain everything

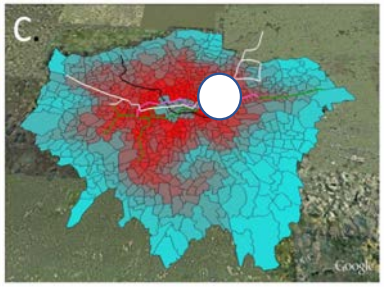
Four Computer Models – Digital Twins – All Focussed on Activities at the Here East Building –











Using AI and Digital Twins in Public Participation

From Architectural Design, Volume 75 (6), 42-47, 2005

As the digital revolution deepens and pervades every aspect of daily life, virtual realities begin to penetrate one another in a multiplicity of ways. The amount of sensing data being compiled on the city grows, enabling the construction of virtual realities that can, in turn, be transformed for diverse purposes. Here, Michael Batty and Andrew Hudson-Smith from the

1. Virtual Cities

Jean Baudrillard (1994) defines a simulacrum as a 'simulation of a simulation', a model of a model if you like.[1] In terms of cities in the digital realm, it is easy to translate such a conception into multiple layers of abstraction that we build up from the raw data we sense, perceive and explain in simulating urban form and structure. A generation or more ago, when computers were first used to represent cities, typical simulations were immediate and direct. Either the geometry of the city was used to construct digital 'iconic' models through which one could navigate, and sometimes use for CAD (computer-aided design), or geographic and economic functions were represented using 'symbolic' mathematical models that could be analysed and manipulated for the same ends: better design, better planning. As the digital revolution has matured, these conceptions have blurred, and now there are mathematical models that sit within iconic models, and vice versa, whose symbology exists on many levels. More importantly, perhaps, as computers have come to be used in everything from extracting data remotely, to mining it to find new patterns, visualising it in diverse ways, modelling it for the same diversity, and embedding users virtually into the process of use, models have come to be represented within models, worlds within worlds, as the power of recursive digital construction has gathered pace. This is simulacra: virtual cities within virtual cities where such embedding twists the process in curious but illuminating ways.

We will begin by describing the construction of a digital iconic model of central London that we somewhat euphemistically refer to as 'Virtual London'. Virtual London is in fact a 3-D geographic information system (3-D-GIS), which is in essence a large spatial database that can be analysed and queried. We can view it in 3-D because we can hold and file the data via digital representation of streets and building blocks. However, this is just one way of viewing the data – one perspective on the virtual city – and there are many others that need not stress the spatial dimension nor its built form. We construct this model as a series of data layers that we can overlay in 3-D. We can then embellish the model, adding a variety of digital media that we can deliver and display in everything from web browsers to holographic-like displays.

Such models can also be imported into other digital media. We illustrate the conception of a simulacrum by embedding it within a virtual world – a virtual design studio or exhibition space – which users can enter as avatars and then view and manipulate the model in the presence of other users, who are also avatars. This embedding can be recursive in that we can enter such worlds, view the model and then fly through it, adding new digital media at points where we need to render the environment with different images. Like many of our simulacra, Virtual London is designed so that users can learn about and redesign their environment in a

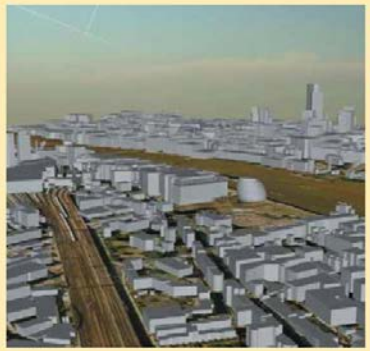
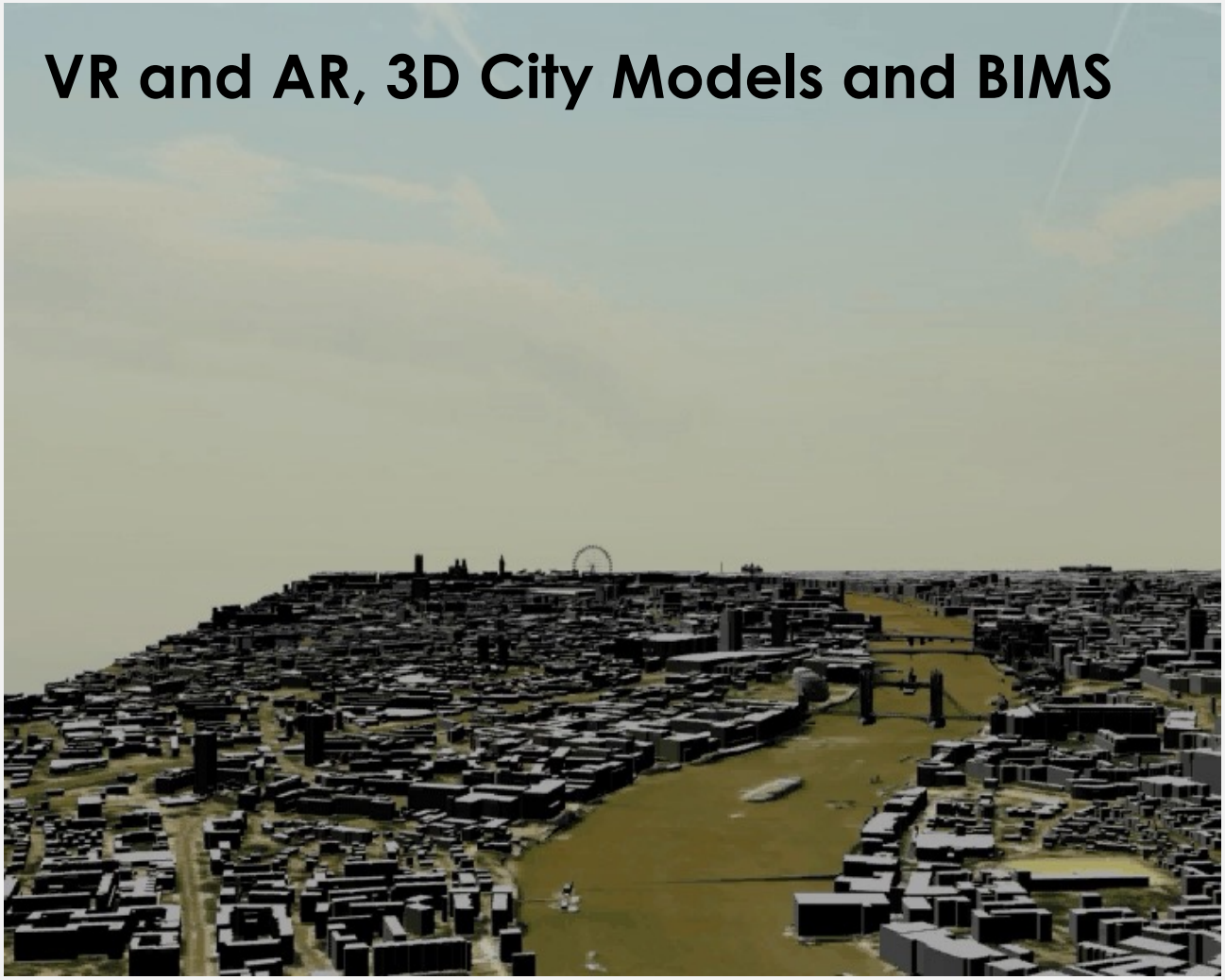
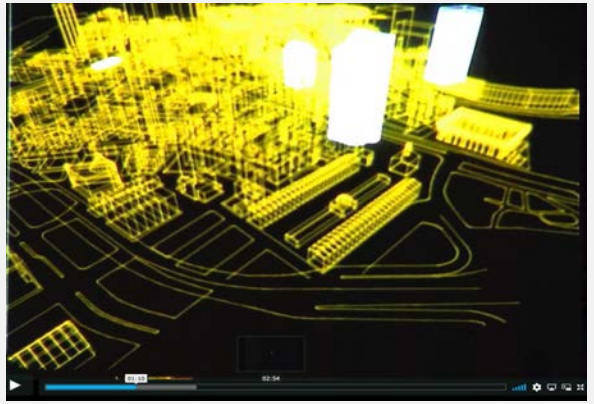


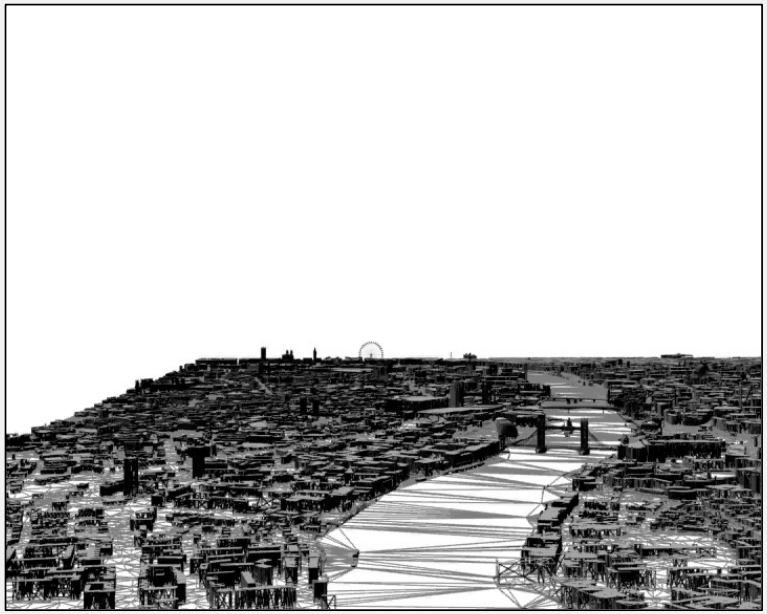
Figure 1: View west from Tower Bridge across Virtual London, showing the raw geometry of the virtual city before it is populated with data.

Figure 2: Building the virtual city in layers from the ground up. (a) Extruding parcel data to average height and inserting a LOAM image of St Paul's Cathedral into the scene. (b) Adding a digital panorama of the area around the Swiss Re headquarters building.

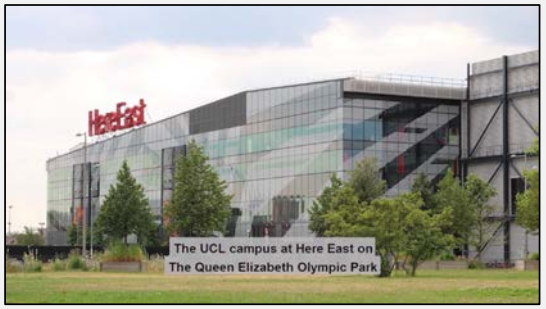
VR and AR, 3D City Models and BIMS





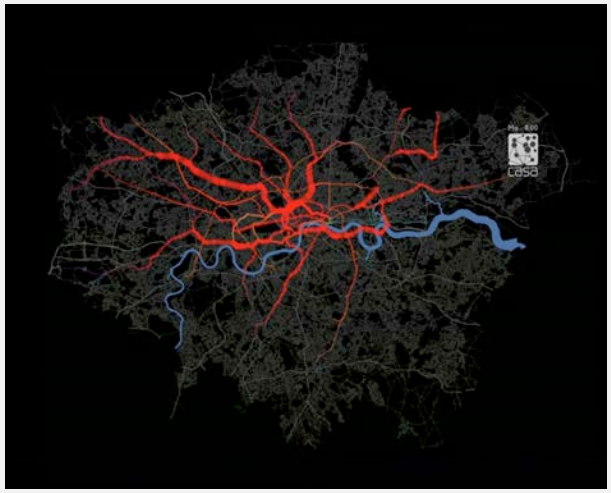


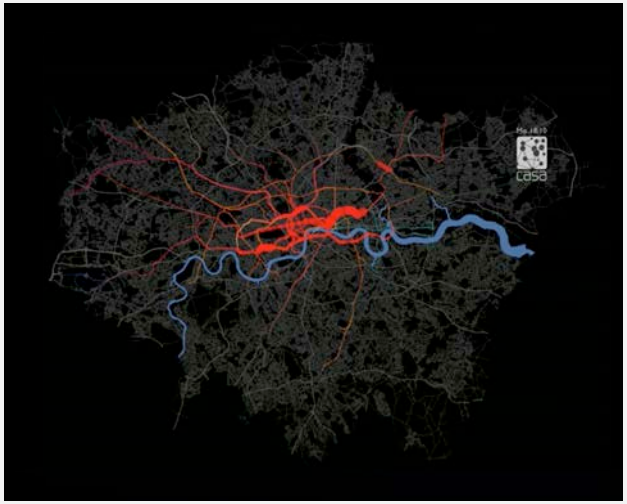
Smart Buildings – UCL Here East



Passenger Demand for Travel: Flows From Tap-In to Tap-Out Data and then Supply of Trains from the Tracker Net

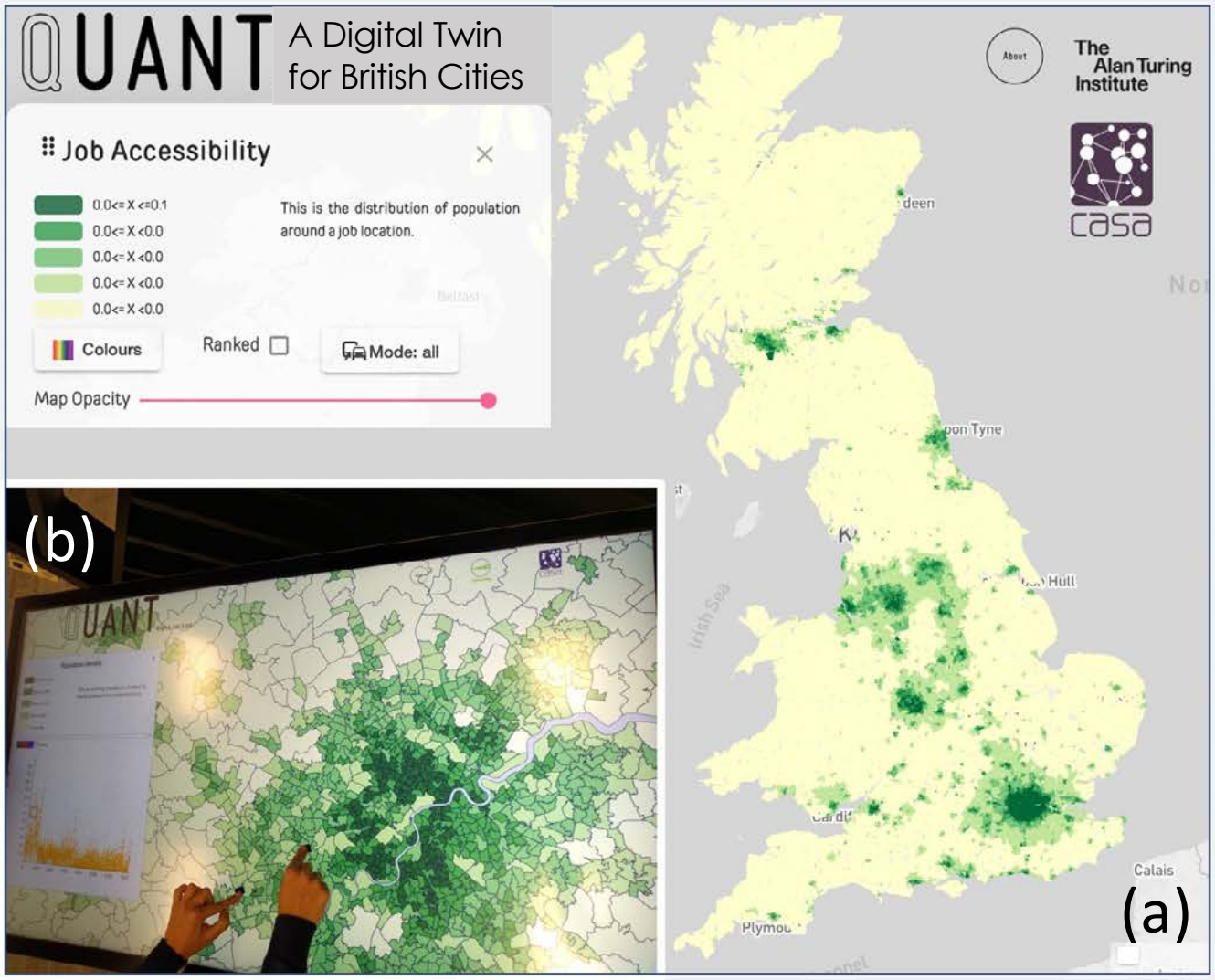

OYSTER GIVES UP PEARLS





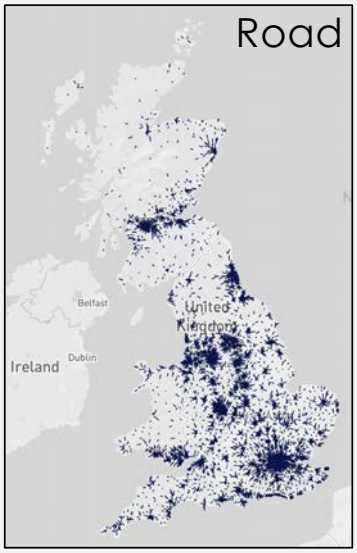
- **A Digital Twin for Britain: The Importance of Scale**

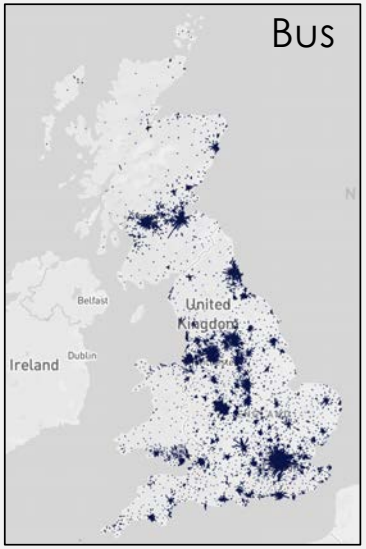
- Ok Let Me Finish by Showing You How We are Building a Digital Twin for ALL British Cities – All 8500 Urban Areas
- **QUANT** means **Q**uantitative **U**rban **AN**alytics forecas**T**ing
- A Land Use Transportation Interaction model (LUTI) for the entire UK (well E, S, W)
- Based on road, rail and bus modal split
- It is Web-Based to test many plans, not Open Source but Free Access – we want planners in the UK to use it
- Runs Very Fast to Keep a User's Attention ~8500 zones, ~70 Millions Interactions X 3 or more, Runs in ~30 Seconds:
- With 41,000 zones runs in 8 mins but with more than 1.7 billions potential interactions -

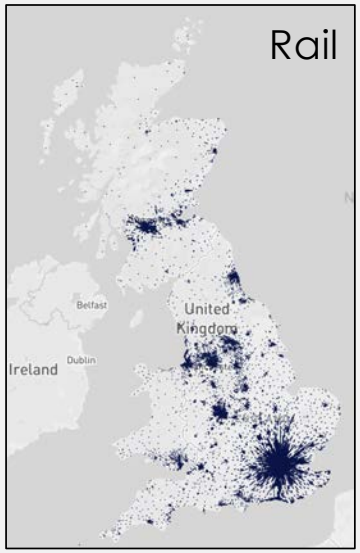


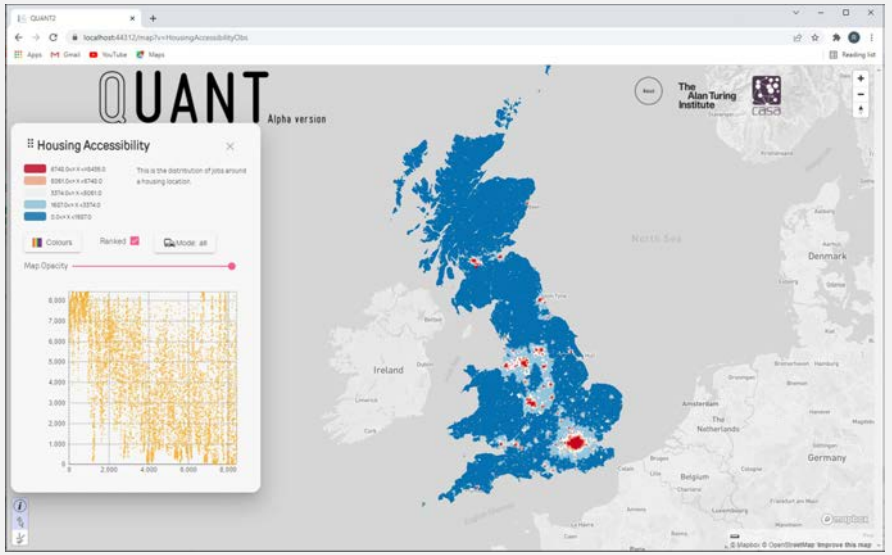
Using AI and Digital Twins in Public Participation

What QUANT looks like



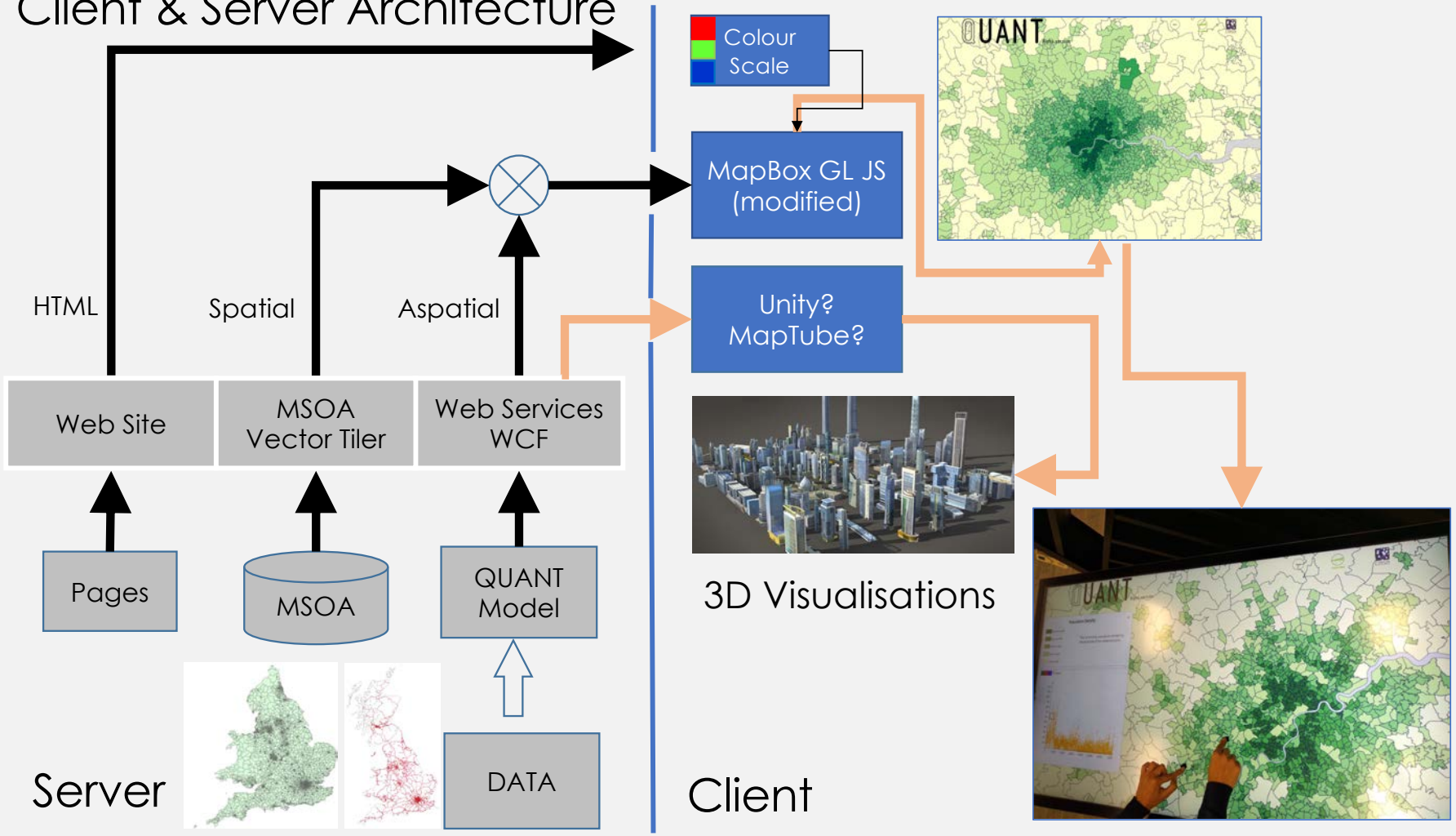


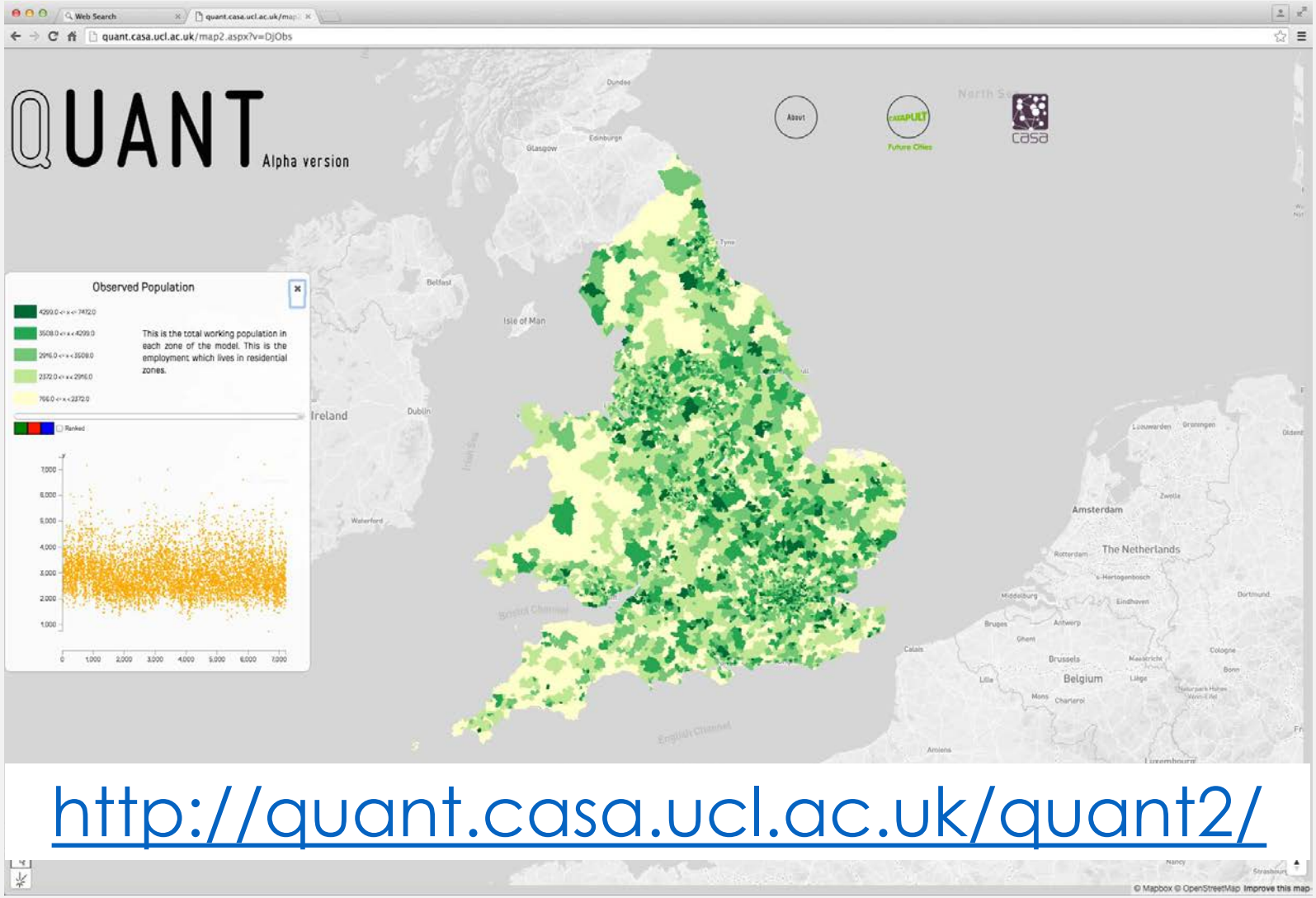




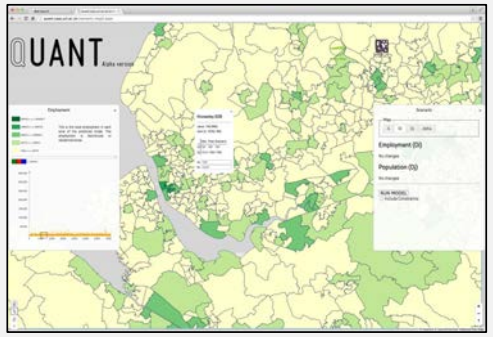
Travel to Work: Road, Bus, Rail
Flow lines show mean magnitude and direction of people commuting

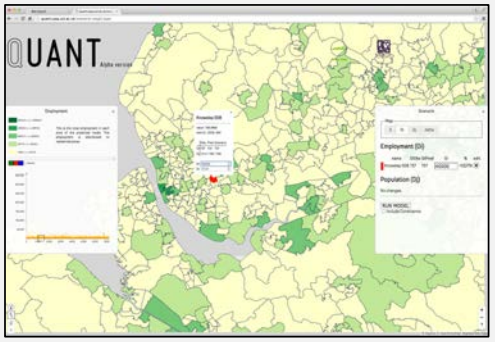
Client & Server Architecture

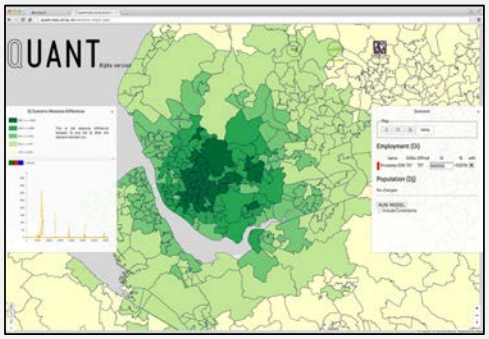


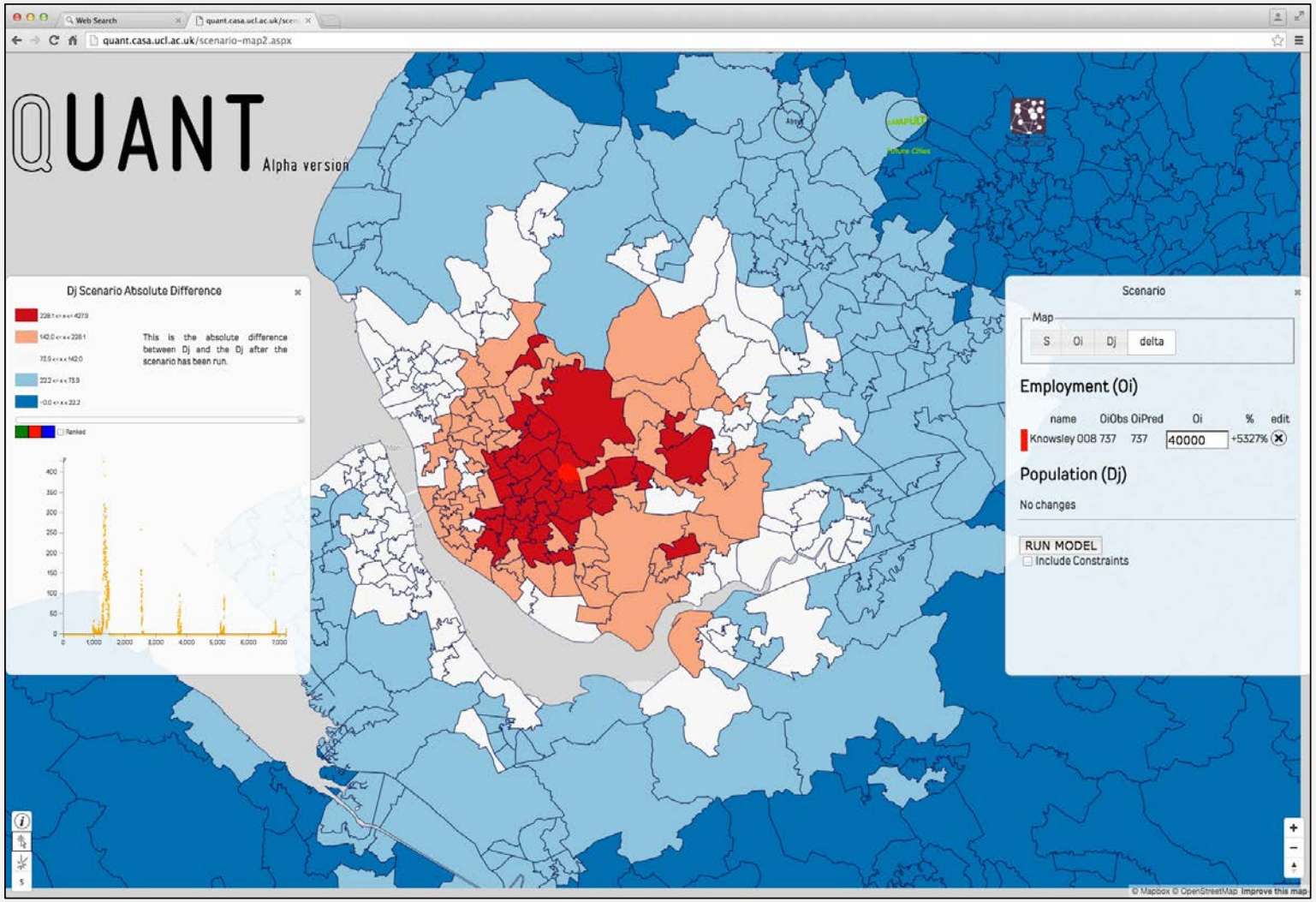


http://quant.casa.ucl.ac.uk/quant2/





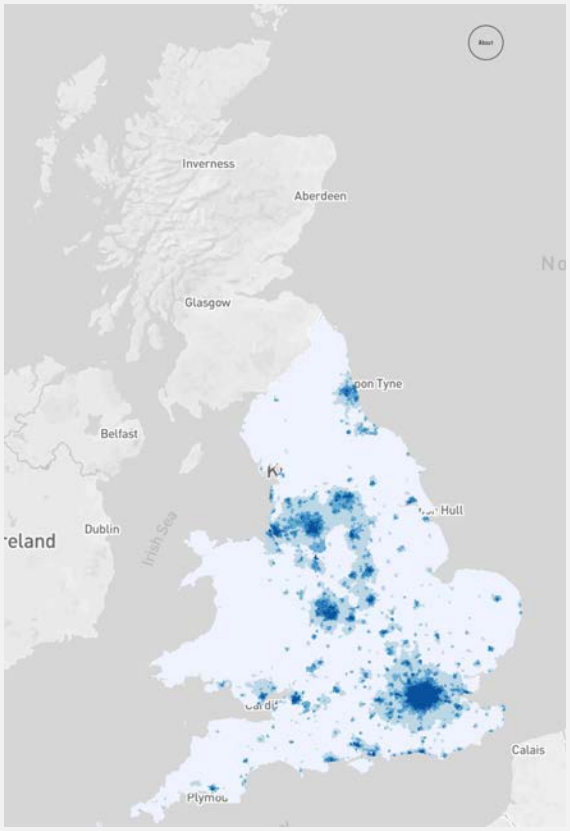


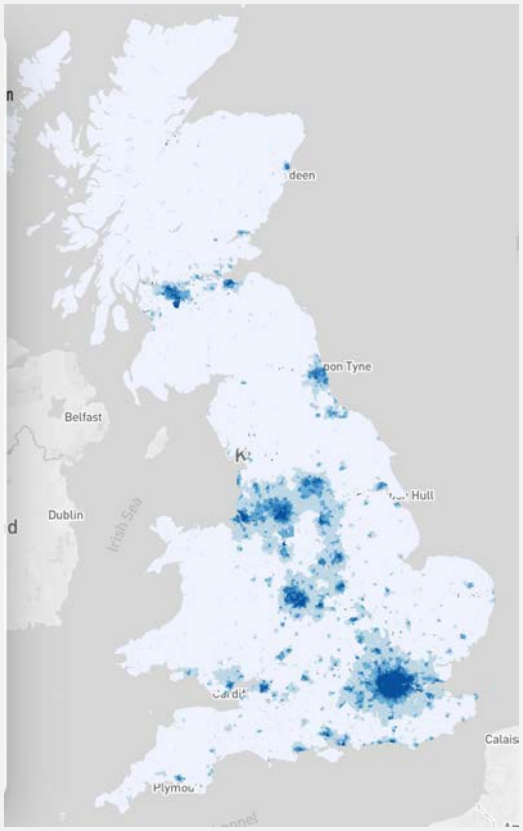


Using AI and Digital Twins in Public Participation

Changes in Scale Generating Twins from a Basic Model Type

Adding Scotland





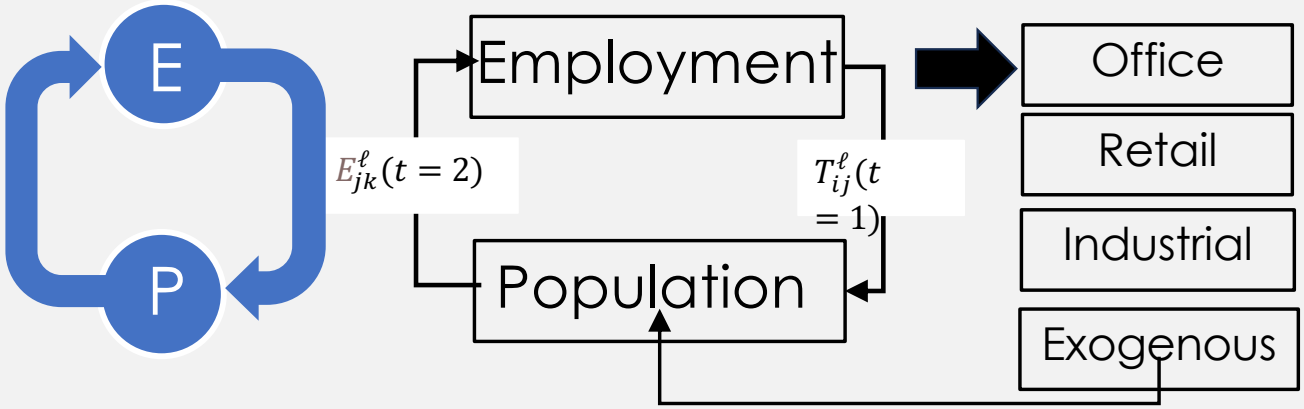
The Performance of EW vis ESW seems good

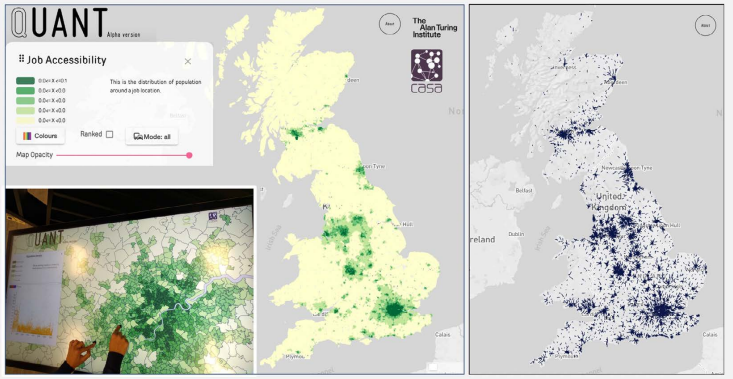
Parameter on mean trip lengths

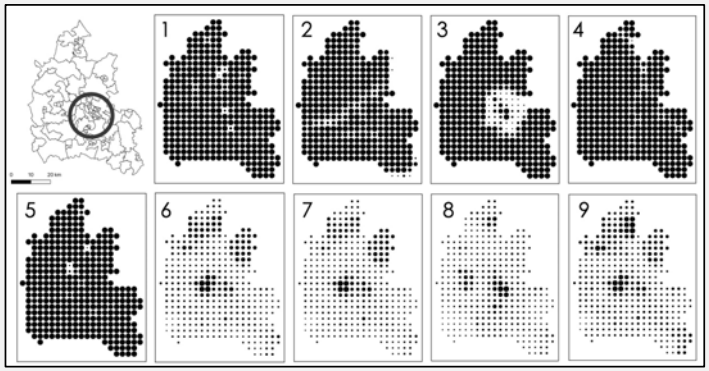
Road	0.137
Rail	0.074
Bus	0.049

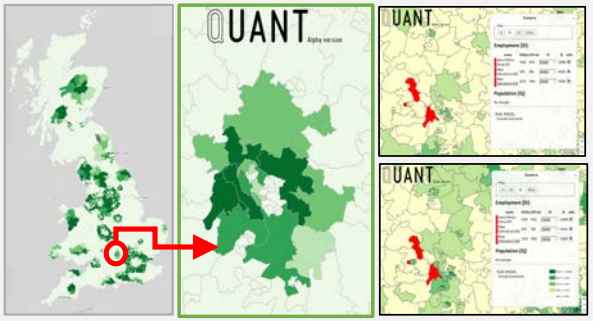
Can We Devise a Template for AI Applications in Cities?

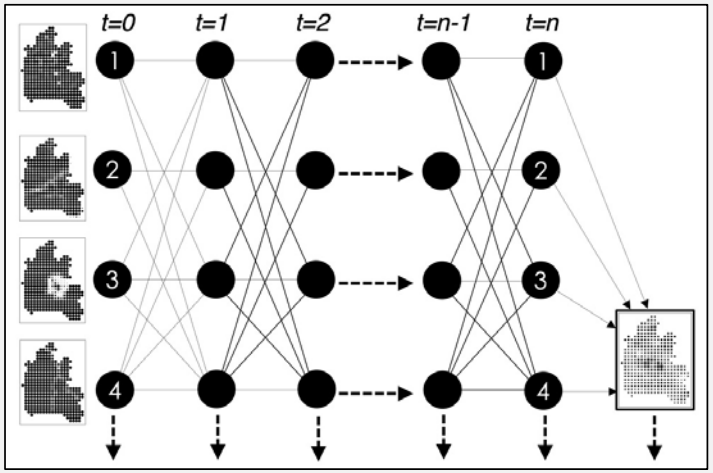
- We need to take our theories and our data and examine how AI methods might improve them and extend them
- Issues pertaining to social structure and segregation can be informed by AI?
- Mobility is an area rapidly changing as much due to AI itself such as automation in transport
- AI is core to Automation in the Creation of the Built Environment
- Growth and development, regeneration, how we generate prosperity in all its guises needs to be informed by AI
- Let me finish with one slide which deals with our digital twin based LUTI model extending it with new AI techniques

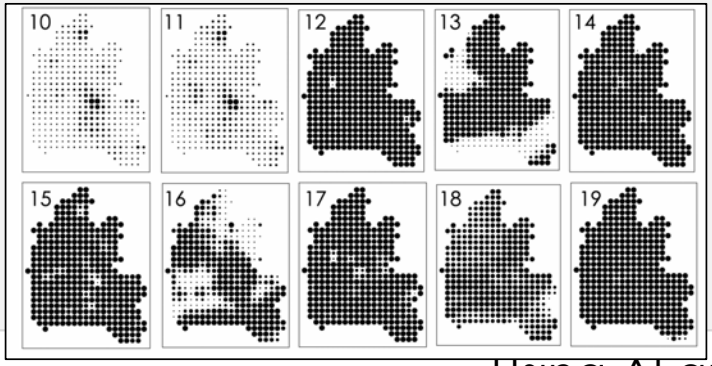


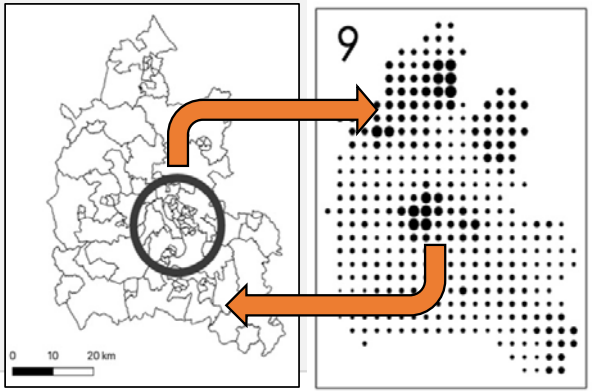












Linking the LUTI Model to a Land Cover Model which is trained through ML and various kinds of iterative trial and error.

Thanks for Listening

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Perspective

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Digital twins in city planning

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Check for updates

Michael Batty

Here, I provide a perspective on digital twins of cities that cover a wide array of different types, ranging from aggregate economic and behavioral processes to more disaggregate agent-based, cellular and micro-simulations. A key element in these applications is the way that we as scientists, policymakers and planners interact with real cities with respect to their understanding, prediction and design. I note a range of spatial models, from analytical simulations of local neighborhoods to large-scale systems of cities and city systems, and briefly describe computational challenges that geospatial applications in cities pose.