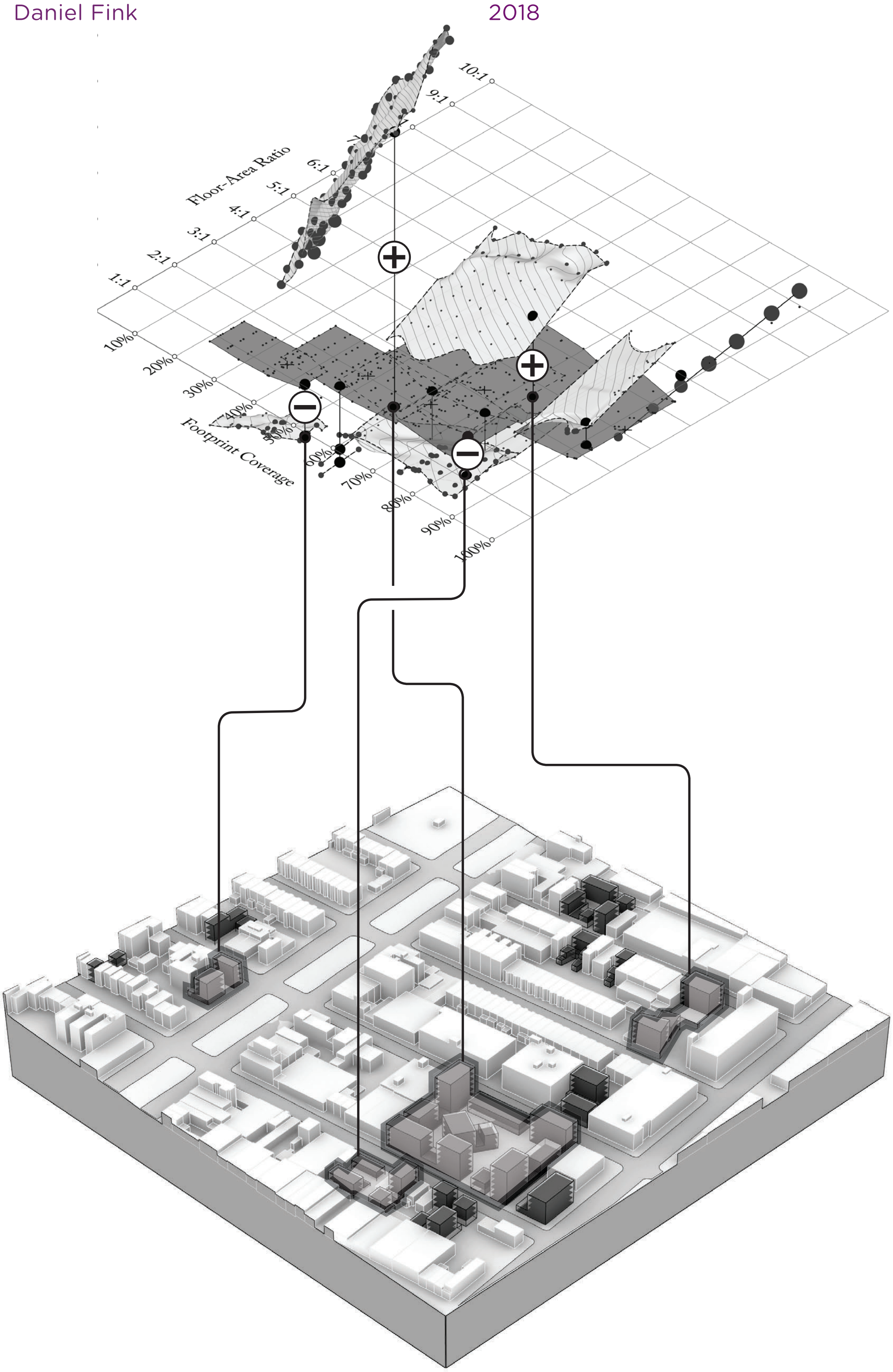
Complex Urbanities

Complex Urbanities:
Digital Techniques in Urban Design

Daniel Fink

Byera Hadley
Travelling Scholarships
Journal Series
2018



NSW
Architects
Registration
Board

The Byera Hadley Travelling Scholarships Journal Series is a select library of research compiled by more than 160 architects, students and graduates since 1951, and made possible by the generous gift of Sydney Architect and educator, Byera Hadley.

Byera Hadley, born in 1872, was a distinguished architect responsible for the design and execution of a number of fine buildings in New South Wales.

He was dedicated to architectural education, both as a part-time teacher in architectural drawing at the Sydney Technical College, and culminating in his appointment in 1914 as Lecturer-in-Charge at the College's Department of Architecture. Under his guidance, the College became acknowledged as one of the finest schools of architecture in the British Empire.

Byera Hadley made provision in his will for a bequest to enable graduates of architecture from a university in NSW to travel in order to broaden their experience in architecture, with a view to advancing architecture upon their return to Australia.

Today, the Byera Hadley Travelling Scholarship fund is managed by The Trust Company, part of Perpetual as Trustee, in conjunction with the NSW Architects Registration Board.

For more information on Byera Hadley, and the Byera Hadley Travelling Scholarships go to www.architects.nsw.gov.au or get in contact with the NSW Architects Registration Board at:

Level 2,
156 Gloucester St,
Sydney NSW 2000.

You can also follow us on Twitter at:
www.twitter.com/ArchInsights

The Board acknowledges that all text, images and diagrams contained in this publication are those of the author unless otherwise noted.

Complex Urbanities:

Digital Techniques in Urban Design

New technologies and processes have a profound impact on the shaping of cities. The incorporation of digital techniques into urban design practice presents practitioners with a radically productive set of tools to engage and orchestrate contemporary urban development.

1

Introduction

As an emergence from a multitude of conceptual, environmental, political, financial and social forces, the city is a complex phenomenon, and its understanding a key skill that architects have at their disposal.

As cities become more extensive and their dynamics more impactful, we are also offered more powerful tools and methods that can analyse, speculate, and produce designs for the city's fabric. In a similar fashion to the power of digital techniques for the design and fabrication of complex pieces of architecture, I am interested in the effect of computational approaches to the design and production of complex urban development.

In order to explore this I have structured three lines of investigation: a review of the field of computational urban design; a series of interviews with thought-leaders, researchers, scientists, and practitioners in the field; and a speculative design project that utilizes digital techniques.

Opening with urbanist & technologist Dan Hill's interview, his calls for a reimagining of urban design & development arise from a sincere appreciation for the impact of technologies on the city. This prompts a contemplation on how computational modelling embeds assumptions and frameworks that may presuppose particular findings or outcomes, and is followed by a survey of current schools of thought & methodologies in the field.

Three interviews follow. The first is a discussion with José Duarte & José Beirão; academics in architecture who have been developing conceptual frameworks that underpin digital methods for urban design & planning. They highlight the position of current research with respect to broader questions in architecture & citymaking. The second is a deep-dive into the art & science of computational techniques for urban design with the computer scientist Peter Wonka. He frames the challenges that cutting-edge research is engaged with, and proposes tighter cross-disciplinarity between designers and computer scientists to advance the field. Finally the conversation with architect & urban designer Christian Derix charts the development of these techniques from academic research to how they are deployed in practice, and outlines the complexities and opportunities for their further use in real-world projects.

Finally, I present a design project that speculates on how the trend towards democratization of these digital techniques in urban design may facilitate new processes and organizations of real estate development. The project envisions that technological diffusion of urban design and development knowledge could enable clusters of self-organizing households to design, fund, and construct their own networks of mutually co-dependent & mixed-use infill projects. These collectively-financed & mass-customized developments would dramatically expand the capability of citizens to influence the design and use of their neighborhood fabric.

2

Technology and the City:

An overview with Dan Hill

Dan Hill is an Associate Director at Arup, and Head of Arup Digital Studio, a multidisciplinary design team that helps develop transformative digital technology for cities, spaces, infrastructure, buildings and organisations.

A digital designer and urbanist, Dan's previous leadership positions have produced innovative, influential projects and organisations, ranging across built environment (Arup, Future Cities Catapult), education and research (Fabrica), government (SITRA), and media (BBC, Monocle), each one transformed positively via digital technology and a holistic approach to design.

Dan is a visiting professor at Bartlett School of Architecture, UCL London, as well as an adjunct professor at RMIT and UTS. Books includes "Dark Matter & Trojan Horses: A Strategic Design Vocabulary" (Strelka Press, 2012), as well as numerous pieces for books, journals, magazines and websites. He has produced the groundbreaking and highly influential weblog City of Sound since 2001.

DF:

As a designer, how would you characterise the effect of technology on the city?

DH:

I'd argue that technologies have always shaped cities, probably more than anything else — whether it's blast furnaces leading to cities of the industrial revolution and then load-bearing floor plates and steel columns that enabled factories, or the elevated safety mechanism enabling skyscrapers along with the flushing toilet. Air conditioning and the automobile enabled Brisbane and Miami and cities like that — those are the things I think that have shaped cities, as much as anything done by architects and planners. That in a way is the motive force of cities, because cities have been built around people coming together to create commerce or culture, not people coming together to inhabit an urban plan.

So I think the impact of technology on cities is really profound, just as it is on us generally. And therefore, we need to appreciate that as designers of the built environment, it's something we really need to understand — why our focus on design technology is for the production of an inert building, as opposed to say, what Uber or Airbnb are doing? They're profoundly changing the way cities work, but without building anything. This could be tied to the business model of architects; being unfortunately hitched to *x* percent of a construction project. Without those constraints, if the architect's thinking, "How do I change the way the people inhabit space in cities?", you'd come up with Airbnb; a much more effective way of doing it, right? Imagine trying to change the city with a building, it's like the most awkward tool you could imagine, right!? It's just slow, intransigent, and difficult, takes bloody ages! Now Airbnb don't own any buildings, and they have more rooms available than the Hilton hotel chain. It did take a long time to make all those buildings, and that kept architects in business through that time, but now Airbnb have come along installing applications in a city that's already built, largely. — Uber, likewise.

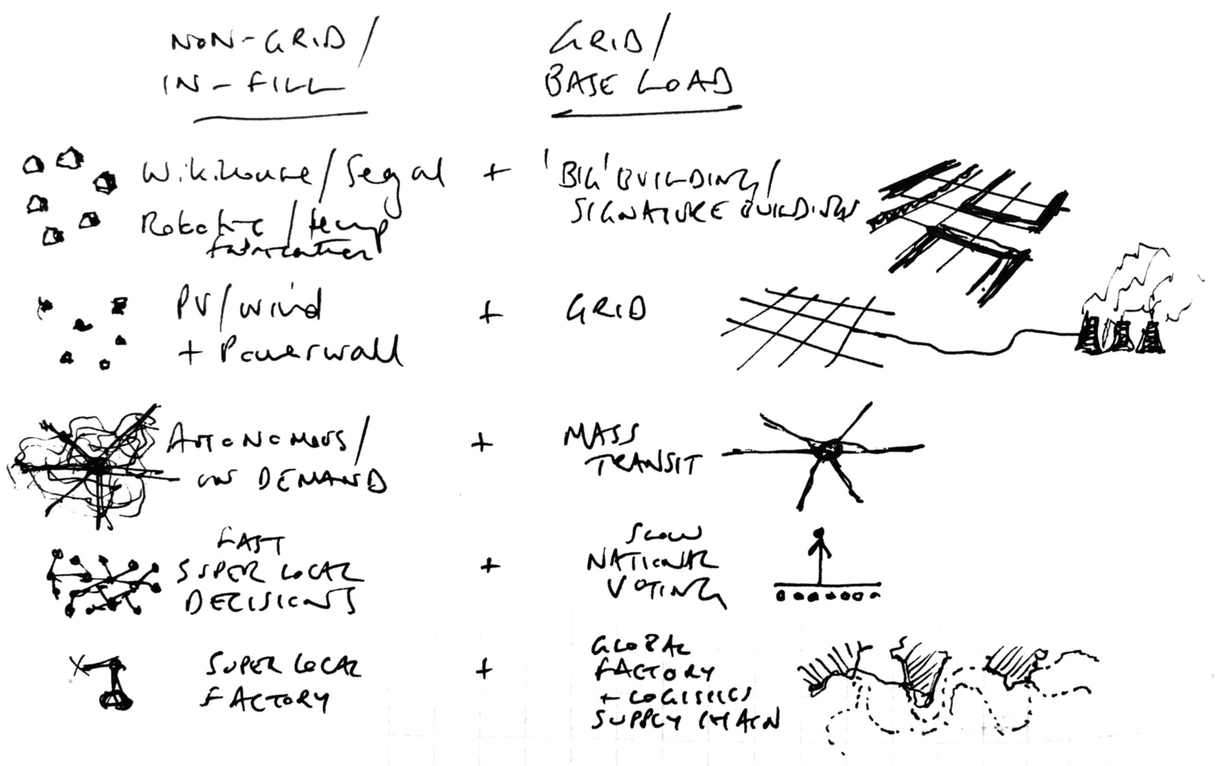
So I think there's a very interesting question about what's the role of design in the city — if it's to shape a city that has public good at its heart, or a convivial place, or is a place of equal opportunity, as well as a place that generates commerce and culture in equal measure. As a designer, what tools do you use in your toolkit? To start with buildings is a bit difficult. Equally though, the value of architecture is the slowness of it. Precisely because it's difficult to make a building, they tend to stick around in a way that a corporations don't, for instance. The average lifespan of a corporation even on the S&P500 is I think less than 20 years now. So the chances of Uber being in business in five, ten, 15 years are pretty slim — whereas if you designed a library tomorrow, it's gonna be there for another 50 to a 100 years, perhaps. So, it bakes in a certain kind of activity into the

"[T]here's a very interesting question about what's the role of design in the city... As a designer, what tools do you use in your toolkit? To start with buildings is a bit difficult. Equally though, the value of architecture is the slowness of it. Precisely because it's difficult to make a building, they tend to stick around in a way that a corporations don't, for instance."

- Dan Hill

"'Grid'-based systems like subways and local energy grids are still needed at a certain scale and density; we just also have non-grid systems, like on-demand mobility or nano-grids, that can work in the gaps. They are additional, rather than replacements, and this new interplay between the non-grid and the grid—when to build a subway; when to build a power grid—could be a crucial design, planning and operational question for cities in the 21st century"

From Hill, Dan. "Grid, Non-Grid." But What Was the Question? Technology & the City. August 2, 2016. https://medium.com/butwhatwasthequestion/grid-non-grid-da2267e86abf.



way the city works, and this has value as a kind of slow release of cultural meaning.

We need to understand that's the value of technology in building versus the value of technology in urban systems. I know that one is slow and the others are fast. The fast stuff is interesting 'cause it can profoundly change the city on a dime without even building. The slow stuff is interesting because it doesn't change that much. It changes a bit. It adapts over time. We don't really talk about that much. I think that's the thing — we don't really have an understanding of pace of change.

DF:

What then are your thoughts on the intent of the designer, and how it is different because of their toolsets? Uber or Airbnb have all of these technologies at their disposal, and they deploy them not necessarily knowing their full spatial or urban impact. How could we design for certain effects?

DH:

It depends on the way you design the system — I mean, you could build in constraints, and actually the inhibiting of their rate of growth and their business models is a way of creating an interplay, or feedback loop that tests these effects. That's

"We're talking about a profound shift in the way we conceptualise design, and because architecture has been increasingly backed into a corner, you have to make that shift [to] work at the more systemic level, or platform level, a la Uber and Airbnb"

- Dan Hill

exactly why designers need to both design and engage with those systems.

DF:

With that in mind, currently the urban designer's or architect's toolkit has quantitative and spatial visualisation as a primary focus — CAD & GIS systems, 3D models, Photoshop — and those techniques are fundamental to how they engage the city. Are these inhibiting their ability to comprehend and design these systems? Are we missing things?

DH:

I think there's numerous things we're missing. If as you just said, the architect's toolkit is spatial & CAD-based, then clearly, we're missing a lot — first of all, we're missing the qualities of materials — what Juhani Palaasma talks about, which aren't included in CAD at all. We're missing the social dimension that Michael Sorkin talks about. We're missing the infrastructural angle that Keller Easterling talks about, and we're missing a strategic angle that Cedric Price would talk about. We're missing the manufacturing angle that Kieren Timberlake would call 'the productive elements of the building and the way it's actually produced', we're missing the ownership model possibilities that Eric Lyons and his firm Span would talk about.

So, I think these are all clues within architectural history and culture. It's just that we've seen them all as outliers, or interesting variations on the core business. The problem is that the core business is disappearing rapidly. And this is why I'm more interested in the educators — I see in them a kind of dynamic that is more akin to contemporary systems like Uber and Airbnb. They're thinking strategically and they're thinking in terms of production. They're thinking in terms of infrastructure. They're also thinking in terms of apps, in an equivalent fashion to Juhani Palaasma's focus on materials and interface (though you might not use those exact words). The reason Uber works really well is 'cause the app is really bloody good — the same with Airbnb — and it's cheap (though that comes from skirting regulations). There's a quality of execution in running it as a service. No architect ever engages with that stuff, really — they should do, but they don't.

And that's where we're seeing the shift in general from assets to services, experience and strategies. It used to be enough to own the asset, and therefore architects would get paid five percent to design an asset. And frankly, they didn't care who moved in, unless they proposed a post-occupancy evaluation (which sounds like odd language, if you come from outside of the business — to not care what happens after the building is

"This is a new urban infrastructure: light, cheap, networked, optimising existing fabric rather than building anew. Yet also individualised, fragmented, market-based, potentially throwaway, with the internet underpinning it, and the extractive industries that power it, as increasingly centralised entities. Which is which? The object — in this case the Powerwall — embodies these fundamental systems and cultures, even if it does not obviously reveal them. It's up to us to unpick that and realise the potential rather than the pitfalls."

From Hill, Dan. "Elon Musk's Powerwall Could Change the Carbon Footprint of Entire Societies", Dezeen. May 14, 2015. https://www.dezeen.com/2015/05/14/dan-hill-opinion-elon-musk-powerwall-energy-storing-battery-could-change-carbon-footprint-entire-societies/

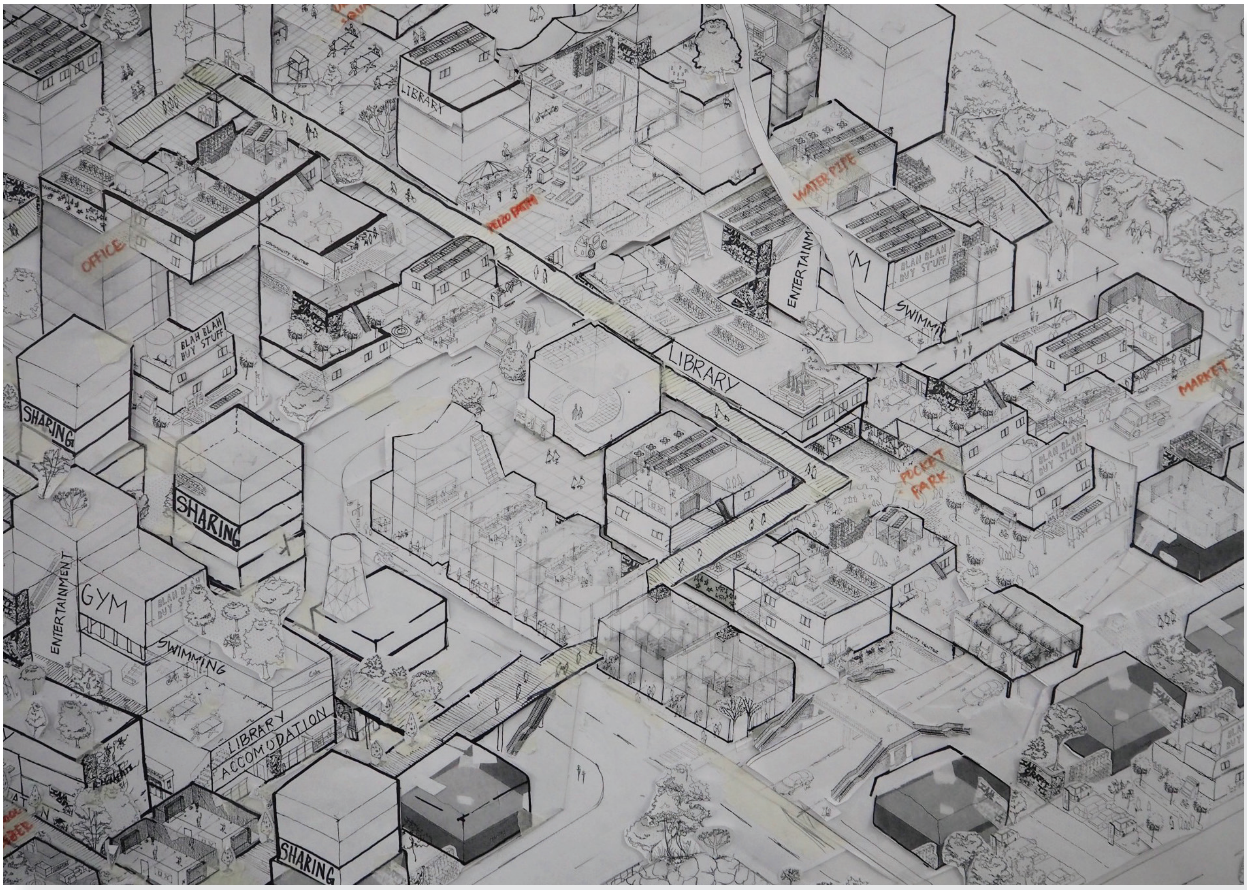
occupied). We're talking about a profound shift in the way we conceptualise design, and because architecture has been increasingly backed into a corner, you have to make that shift. So whether it's architects that are also developers, and therefore they own the value generated by their work, or it's architects that engage with production and manufacture and processes (super interesting ways of doing that), or urban designers that work at the more systemic level, or platform level, a la Uber and Airbnb. Whatever the hell that might be, I don't know, but it's really interesting to ask that question.

Technology transforms all of those things, but in a way, technology doesn't transform a traditional process of architecture. Any architect — good or bad — can access analytics like landmark visibility or solar radiation. But the difference becomes what happens when one needs to do that 50 times. Or 5000 times. That's hard. That's the question of the business model, not the practice of architecture. It's perhaps not somewhere where you'd like to be as an architect — making software to work to the rules of someone else. Just thinking of Jony Ives now — the highest profile designer in the world at the moment, working in the world's most valuable company, with a seat on the board at Apple and responsible for making these things work really well. You're in control of the whole thing as a designer. Your agency is quite powerful; challenging levels of technology and trade-offs in design problems. That is your design values enabled by technology.

DF:

This sounds like you are describing the vertical- or supply-chain focus of product design, or platform design, crossing over into architectural and urban design.

In cities there is this interplay between the designer, the authorities or regulators, and all the consumers or stakeholders who buy into a plan — and this brings with it all the complexities of our socio-political and economic constitutions. To really engage with the design of these sounds more weighted than consumer platform design. Where do you see design fitting into these power relationships, and moreso, where does design technology fit? If we frame this further, are we embarking on too difficult a problem? In comparison to Tesla's Powerwall, Airbnb, Apple or Uber in terms of designing urban infrastructures, is it out of reach for community-led design or urban design to engage with these forces? As designers do we need additional specialisation to access this type of agency?"



The Incomplete City: A Bartlett School of Arhcitecture studio exploring what an active, intentional design process, or design strategy, might look like which achieves distributed infrastructures, agile and iterative development models like Baugruppen, collaborative decision-making processeses like Brickstarter or PRES, and nascent district developments like Buiksloterham in Amsterdam.

From Hill, Dan. "The Incomplete City." But What Was the Question? Technology & the City. May 14, 2015. https://medium.com/butwhatwasthequestion/incompleteness-7adad1d58a3d.

DH:

So I think the most interesting kind of urbanism on the books at the minute is all of that stuff which is within reach of the community — and that's the promise of it. It's a distributive kind of urbanism, which is accreting on to existing structures and working up from that. It's post grid — let's take Tesla Powerwall for instance, with PV cells on the roof — enables you to go off the grid. It changes a lot. So, how do we think about community in terms of building its own modular kind of off the grid cellular infrastructure? It could be augmented with mobility on demand, it could have the Tesla equivalent of water and waste technology; something radically different. That is small pieces loosely joined, working up and building into something bigger. Funnily we've built a lot of this stuff already. We've kind of built everything we need to some extent. The street we're sitting in hasn't changed the way it looks probably for 200 years. It's not a challenge for the architects. What do you do when you've built most of it already? Well there's filling in the gaps and building this kind of infrastructure at the level of mobile phone upwards, and that takes a very different kind of understanding of urbanism and architecture.

I don't know where that goes yet. I don't know what that looks like, but if we bring up Thomas Heatherwick and Bjarke Ingel's vision for Google's new campus (although it's a kind of Utopian ideal and probably won't happen exactly like that), what I found interesting in all those images is that the architecture is somewhat invisible. Except for this big canopy which is following the landscape, and a bunch of 'cra-bots', or crane-carrying robots that are assembling stuff on the fly as needs dictate, which is interestingly a very, very different kind of architecture and urbanism again. Otherwise it's highly kind of Arcadian — kind of super-green because autonomous vehicles mean you don't need roads in the way that you used to have them, with hard edges and pavements and curbs. You can just dissolve all of that stuff — it can be highly green, it can be safer since it's built around humans as opposed to vehicles, it's energy demands could be calibrated on the fly and be generated totally autonomously. You don't have to plug into anything. So, it really begins to shift the way we think about "top down and bottom up". I don't like that language sometimes, but it speaks to building up out of the ground, as opposed to the idea of planning and design. And

"They've generated a super interesting vision about what kind of urbanism that might imply. It could be positive or negative, but it's very, very different to what we've had for the last hundred years"

- Dan Hill

WikiHouse is an open source construction system providing CNC machine-cut wood panels to build homes and other structures. People can print out a kit of parts in structural plywood and assemble them in a similar way to an IKEA product.

From SPACE10. "Chapter 1-Putting the "Fab" in Fabrication: Manufacturing in the Digital Age." Imagine. June 15, 2017.

the systems that produce that are modular cellular systems, like Telsa's power pack. You just keep adding those things on as needs dictate.

They've generated a super interesting vision about what kind of urbanism that might imply. It could be positive or negative, but it's very, very different to what we've had for the last hundred years, I think, and we haven't really worked these through yet. But all of these technologies to me share this pattern of decentralised, distributed, malleable—

DF:

But at the same time, that was top-down designed — Heatherwick and BIG were commissioned by Google to design a corporate campus by virtue of both their vision and their specialisation in the profession. It is a beskpoke—

DH:

Well it's a unique contract now. But let's try and reverse engineer the urbanism out of that vision. If you were to say we need to build a community around the corner, here. It could be social housing, let's say. What of that vision could you reuse there?

The design is in the systems. Let's say, for the fictional community I just made up around the corner, we suggest WikiHouse. They need a CNC router; they have access to a pattern book that has a kit of parts that makes some things possible and other things not (within a wide enough range) and you just let them crack on with it. It's safe. It'll stand up. It's got systems and services built into it. It's malleable and adaptable more or less. It might not look very nice. I mean it may or may not. It depends on how good they are. But nevertheless it seems like this type of urbanism is really interesting. This is going into my thinking and work plans — what does that look like? Is it good? Is it bad? Is it viable? Is it feasible?

DF:

Design technology then needs to both organise communities and to effect their realisation. So you have to be able to communicate with, or find that community that has the capital and leadership to actually do this, and then also be

able to design it. The platform has to be accessible enough so that someone who hasn't gone to seven years of architecture school or works at a company like Heatherwick can be able to actually implement it.

DH:
Totally. That's the interesting question, isn't it? Just to think out loud for a bit here, there's a set of constraints built in to any design, or there's a set of possibilities that are more likely than others for a given problem. I mean, people say that they can pick out say a building designed in Rhino, you know, because the software enables and limits the designer. And so they tend in a certain direction. The design of WikiHouse is just the same, and there'd be numerous variations on that which are open systems effectively, but they have constraints built into it. You can't make a 12-storey out of WikiHouse — you could make two storeys, 70 square metres, and that's the current limit of what it can do, and it wouldn't let you create the specific identity we need for this condition, and fine, but then what if it could? What would the next stage be? Because it's extensible, or hackable — what if you said pre fab timber (CLT), up to 15 storeys, then how's that gonna work? And in a way, the crane-bots from Google are doable. That's why I'm kind of interested in them, because they've got constraints on what they can do. So basically they'll be shipping around, in some variation, rectilinear forms, with services built in. They'll be plug and play, so when they connect together DC power will come on, just like that. So — and that's what's more important to them than whether it's a curved façade or something aesthetic — "Can I get that? Can I have that this afternoon, the power unit and water? Brilliant!" How extraordinary would that be? So there's a shift in emphasis here around systems and systems coming together and their sets of possibilities. I'm really thinking out loud here, but I'm interested in how could you design those systems in order to build in positive urban outcomes?

"[These technological drivers] are profoundly generative and valuable. To take architecture as a profession and just try to bolt existing technologies onto exactly the same model is incredibly limiting"

- Dan Hill

DF:

Somehow this parallels almost exactly the same question as those who are designing robotic systems themselves. How can you design in 'good performance', maybe even calling it 'humanity'? How do you design in these kinds of constraints or limits, or optimal outcomes into these systems that produce urban fabric that we'd call 'good'?

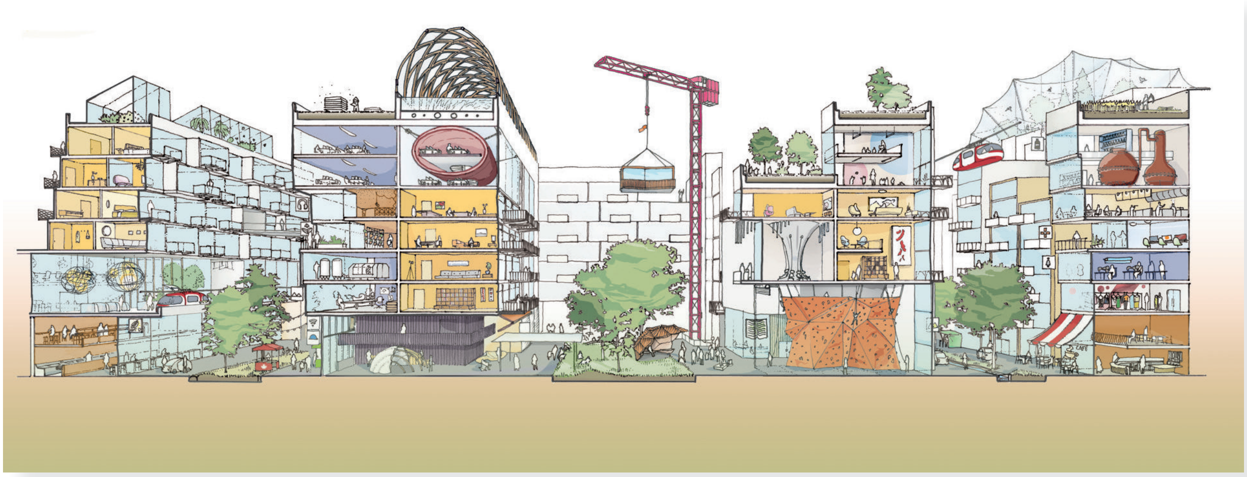
DH:

Well I think I'd be hard pressed to tell the difference between a car and a robot in about ten years' time. With that in mind — think of the adage "A house is a machine for living in".

The more it shifts in that direction, then the more we need to understand these technological drivers. And they are profoundly generative and valuable. To take architecture as a profession and just try to bolt on existing technologies on exactly the same model is incredibly limiting. Whereas, if you're able to look at the possibility of technolo-

Future Practice by Rory Hyde: introduced by Dan Hill, the book, and the emerging practices it describes provide clues as to how to back out of the cul-de-sac that architecture has partly built. Most of them rely in some sense on an even deeper form of systemic integration and cross-fertilisation, supported by alternative business models.

"Essay: Foreword to Rory Hyde's "Future Practice: Conversations from the Edge of Architecture"." Cityofsound. September 2012. http://www.cityofsound.com/blog/2012/09/future-practice-conversations-edge-architecture.html#more.



Sidewalk Toronto: a joint effort by Waterfront Toronto and Alphabet's Sidewalk Labs "to create a new kind of mixed-use, complete community on Toronto's Eastern Waterfront, beginning with the creation of Quayside. Sidewalk Toronto will combine forward-thinking urban design and new digital technology to create people-centred neighbourhoods that achieve precedent-setting levels of sustainability, affordability, mobility, and economic opportunity."

From "Sidewalk Toronto." Sidewalk Toronto https://sidewalktoronto.ca/

gy, in a much freer way, and then say – "Okay. As designers, we're responsible for achieving a set of outcomes for our plans, whether it's for a single house or a community — thinking, what are the limits of the range of technologies at my disposal?" It's amazing! How can you not make value out of that? You could not be doing it with less fundamentally valuable things — it's where people live, where they work, where they hangout. I mean if you can't make money out of that, then something's seriously wrong.

DF:

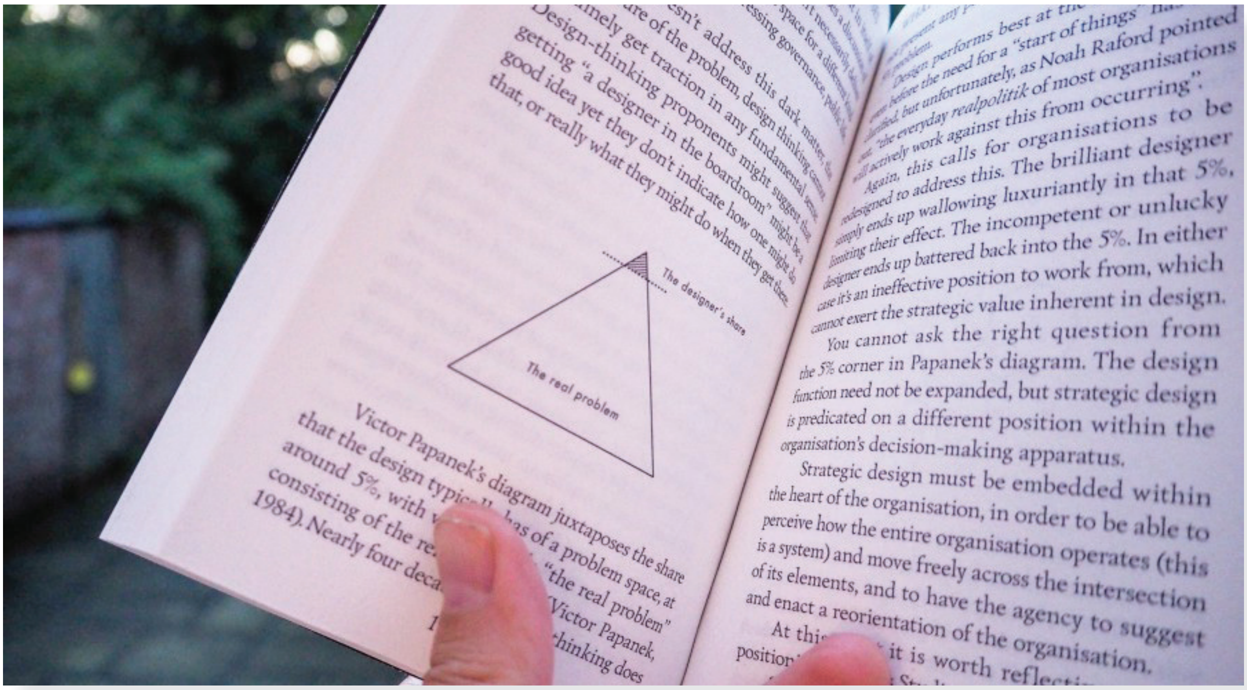
Then that brings up my next question. Because if we are getting into the realm of finance, then isn't there a difference between an app from a start that costs, what — one or two dollars a download, and the costs of real estate? Yes, you can distribute that to tens or hundreds of millions of people around the world, but isn't there a kind of threshold limit to effecting change that is out of the range of small-scale community financing?

DH:

I remember the Kickstarter for the pebble watch and it raised about ten, maybe eleven million dollars, which is a reasonable amount, but then it doesn't even cover the cost of a medium sized building. We do have to ask why that is — why is a single building costing 20 million dollars? Is it kind of obscene? If you come from outside the industry, you're just kind of, "What? What is — How does that happen!?" A car doesn't cost that much. A car is way more complex. A phone doesn't cost that much. It costs a fraction of it, and a phone is really complex. So it's not the complexity of the building that makes it cost that much."

DF:

Is the construction industry itself too fragmented? We can't immediately achieve the efficiencies or innovations like tech or finance — Google recently launched its first Google X labs offshoot, an analytics engine to test and visualise planning laws for potential developments, with the larger goal being to disrupt the entire built environment industry — which is an incredibly lofty goal. But they've found it really difficult;



16 *Dark Matter and Trojan Horses, by Dan Hill: "Increasingly, effective design means engaging with the messy politics—the "dark matter"—taking place above the designer's head."*

From Hill, Dan. "Dark Matter and Trojan Horses: A Strategic Design Vocabulary." Medium. August 08, 2012. https://medium.com/dark-matter-and-trojan-horses/dark-matter-and-trojan-horses-a-strategic-design-vocabulary-strelka-press-18551fff3133.

the industry and regulations and the players are so un-integrated, it's hard to find the so-called 'hinge-point' that will leverage disruption.

Big IT players like IBM and Cisco who have been hyping up the Smart Cities movement have pulled back a little and now target more narrowly that they'll just provide data services for cities. And they could command the kinds of almost-governmental capital that exists in the real estate industry. Perhaps we need to move out of a legacy where patronage creates the built environment – you know, you have a patron who commissions the design and construction of their own asset.

Is there cause for envisioning different models for financing housing, or types of buildings? A hedge-fund model? A VC model? Something that sees this new territory of data and technologies as much more core to a city alongside planning and design?

DH:

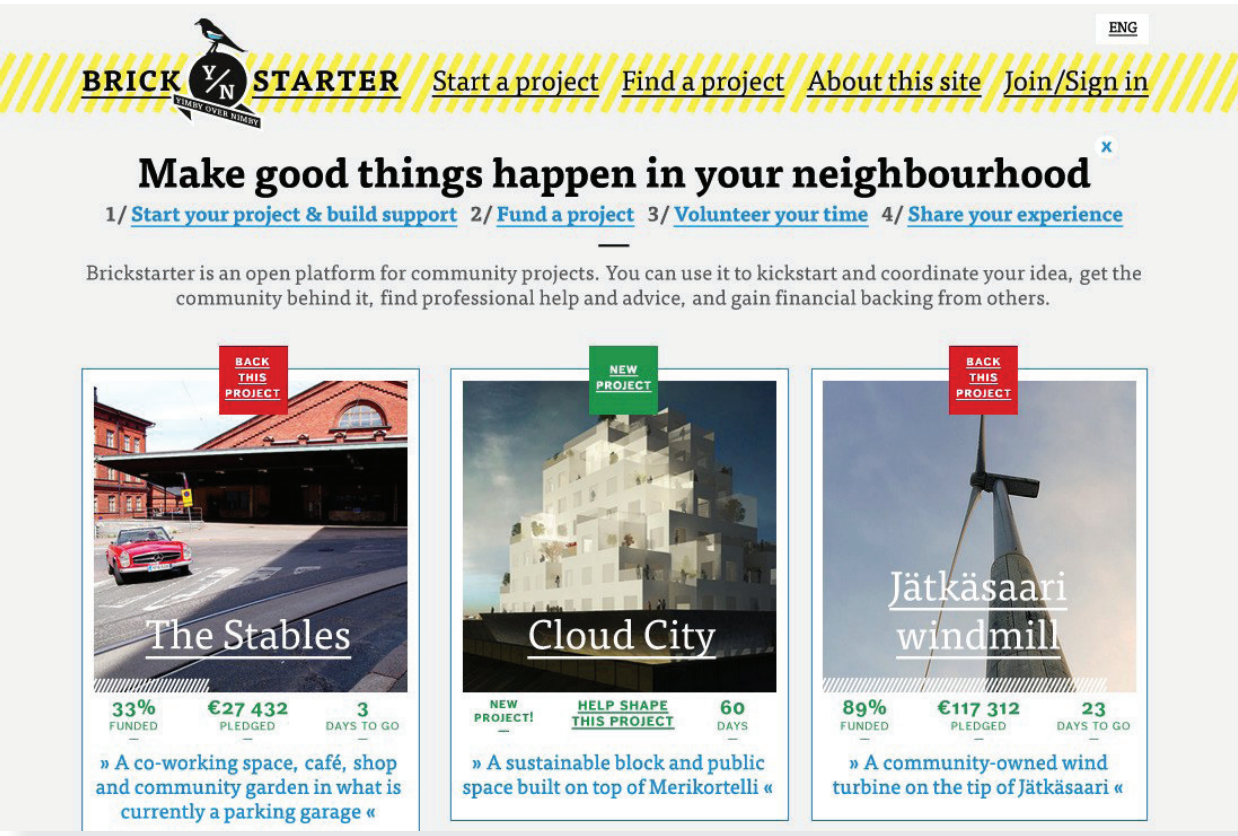
Housing is incredibly polarised at the moment. In the countryside, you could buy an entire street for about a pound, and yet London is putting on five percent a month. Highly polarised. It's partly because the public sector stopped building, which was a political-ideological decision from 1979. And that's what shifted the market in that way, and it's meant the architecture has been seen increasingly as speculation product — in a way that few other things are, in terms of products that one buys. And I'm very much thinking from a citizen point of view, not from the developer end of it — if you think about what one does purchase over the course of your life, which products are speculative assets? Probably not that much — you might have stocks or shares, but most people don't. The rest of your purchases, you'll use — they might have cultural or aesthetic as well as functional uses, but most I know I'm going to get rid of it at some point and move on to something else. So I'm just wondering again with our earlier conversation about a sort-of malleable-adaptive approach, because of building technology like robotics, and open software, and open systems and so on. Maybe we see a more consumer electronics-like mode aligning with buildings. That will surely change the business of buildings and then shift away from buying the land and then building something on the land, if you think about the assets in that way, towards something which feels much more like a service — space as a service. It's happening with mobility-on-demand already — people not owning cars as much 'cause the have Zipcar and the like, and then autonomous vehicles will soon come along making it mobility-as-a-service.

What we are seeing is multiple forms of value increasingly being factored into stuff, and I think that has to come in at some point more realistically than it is at the moment. So the interesting thing about the Low2No project was thinking of things like carbon as a value — as a form of capi-

[Shifting the] emphasis to more than just owning the asset into thinking, "Well, how did we build the asset? And then how is the asset operated?" ... means stretching out the kind of the business model of the developer and therefore the value creation over time, much more interestingly than it is currently.

- Dan Hill

tal basically — in the building. So if we have a low carbon building, then it should ultimately provide a return at some point. It's not just 'x' amount of square meters multiplied by 'y' amount of value for those square meters. At some point, the carbon aspects of this building is gonna be valuable in some way. Could be from tax, could be carbon trading, who knows? At some point, the building should work also in terms of social and cultural capital and so on. I'd like to think that smarter planners are beginning to find ways to get into that and value that, and you're beginning to see companies like — well, Airbnb exploit that to some extent, but actually the co-working companies like WeWork and Second Home really understand how to value that, how to run a service in an existing space and extract a lot of value from the way that that space because of its social or cultural or intellectual capital. So this is the idea of multiple forms of vale, kind of a Michael Porter of Harvard Business School kind of idea. That begins to free up the thinking around how you build a model of value around building broader than just financial capital. A lot of those values have impact on financial capital, luckily, but the real test of a large development would be to say: "Could we develop something for its social and cultural, or its carbon potential?" Which wouldn't necessarily have a direct impact on the financial bottom line, but its indirect impact is of course valuable.



Like its namesake, Kickstarter, Brickstarter is a platform for making it easier for DIY projects to get underway. People can propose projects, with all the usual trappings of video pitches, text updates, funding goals, and deadlines. The big difference is that it is focused on projects run at a neighborhood level, to be conducted in public, and to be connected with civil services and bureaucracy.

From Maly, Tim. "Yes, in My Backyard! Meet Brickstarter, the Kickstarter of Neighborhood Projects." Wired. June 03, 2017. https://www.wired.com/2012/08/brickstarter-for-neighborhood-projects/.

"Currently, we don't have fine-grained decision-making systems at multiple scales. We have a modernised planning system that somehow has to stretch across these decisions, irrespective of the scale and the technologies at work. So I do think there are needs for new forms of organisation... that can deal with how these technologies are changing — and could change — our neighborhoods"

- Dan Hill

All of those things to me, again, shift this emphasis to more than just owning the asset into thinking, "Well, how did we build the asset? And then how is the asset operated?" For say, carbon, or social, intellectual, or other forms of capital, you need to know how would the building affect those things directly. And then there's the way it's operated. Of course, that also indirectly or directly affects its carbon or cultural and other forms of capital. So thats means stretching out the kind of the business model of the developer and therefore the value creation over time, much more interestingly than it is currently. This is a really waffley answer, but I'm trying to reach for, again, this idea of, "What does the shift from assets to services mean? The shift from assets to experiences?" And that's what seems to be going on in other areas in the world of business — Uber doesn't own any cars; biggest taxi company in the world. Airbnb doesn't own any hotel rooms; biggest hotelier in the world. Alibaba, the biggest shop in the world; doesn't own any stock, and so on and so on. They're all interesting and profoundly lucrative business models. Granted, all have issues with them, all of those companies are problematic, but then they provide new opportunities and interesting propositions to invigorate the built environment.

DF:

Once again, It seems to come down to the design of the system, or at least the understanding of how the territory is working, whatever territory you're engaging in. I'm reminded of Keller Easterling's writing. She has a few terms — spatial products, or active forms — these kinds of resultant infrastructures from the interactions of say, global finance, and space, transport systems, politics, finance, etc — and their disposition, or the tendencies that these interplays have.

So for example if you couple together cheap gas, and an individualist approach to politics, and huge amounts of land, and the remnants of 'Manifest Destiny', you get sprawl — there is a 'disposition' towards sprawl in that set of infrastructures. So while a simplistic critique would just be that sprawl has poor spatial and social outcomes and we should design a new fabric,

how would we engage with something more intricate like the design of the politico-economic systems that would have better urban tendencies or dispositions?

DH:

That's a good reminder for me to go and read more of Keller Easterling. The active form of this distributed, de-centralised, malleable, individualised, architecture would be really interesting infrastructure, so they're really interesting, but what does that produce? Would it produce highly individualistic conditions which would be profoundly anti–urban? For example, if I take my house off the grid, it's like a real act of removal from the city – I'd guess I'm less likely to pay taxes, or I'd be less involved in city processes. Whereas if I were to gather together my neighbours, and we latch together some infrastructure for ourselves, then it could be profoundly interesting. The active form of that technology is a really interesting proposition because it's different to the active form of, say, cheap gas and a highway system which enables sprawl, or a centrally-distributed energy and transport system which fundamentally dictates the form of a city.

I'm really interested in decision making at that neighbourhood scale. When we did Brickstarter the thought behind it was: "What decisions can a neighborhood take, by itself?" And I'm really interested in how we locally negotiate the outcomes, because every decision has a kind of scalar impact — so let's say I want to put PV (photovoltaic) cells on my roof. My nextdoor neighbour might oppose it, or they are blocking my sun. We could coordinate with our block to place a PV farm on someone's unutilized land, and then the energy generated can be shared with the whole street. The next block over could actually get involved too—

DF:

But then how would you deal with negative effects? Like a water treatment plant?

DH:

Then you have a complex decision making system – it's almost like the story of cities, but in reverse! But we are now seeing the sort of technologies that should enable us to question: "What decision making at what scale?" Open question. I don't know the answer. Something like light rail only makes sense if you are connecting numerous neighborhoods. Bike sharing – perhaps something similar, or a little smaller. Energy storage? If it's small enough like this Tesla Powerwall, then it could even be a handful of buildings.

Currently, we don't have fine-grained decision-making systems at multiple scales. We have a modernised planning system that somehow has to stretch across these decisions, irrespective of the scale and the technologies at work. So I do think there are needs for new forms of organisation, probably all the way up to the city, that can deal with how these technologies are changing – and could change — our neighborhoods.

Imagine how robotic construction works with the current planning system? It could take 36 hours to build the actual house, but then wait 12 weeks for the planning system to get back to me regarding my application? It works now because the timeframes for construction and regulation are geared and sort-of make sense, but it won't with new technologies.

So that's my starting point — looking at ZipCar, plus autonomous vehicles, looking at Tesla Powerwall plus PV cells (or geothermal or waste-to-energy). The impact of technology in the city is so interesting and open and uncharted for me. The more technical aspects of design computing and engineering are required to demonstrate those relationships between outcomes and possibilities — they might provide the clue to unlocking decision systems for neighbourhood infrastructure — you know, "If we have a ZipCar station, it could be powered by our solar energy, or it could fund our daycare center, or..."

On Exactitude in Science

“ …In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it.

The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast map was Useless, and not without some Pitilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography.”

purportedly from Suárez Miranda, Travels of Prudent Men,
Book Four, Ch. XLV, Lérida, 1658

- Jorge Luis Borges, Los Anales de Buenos Aires 1.3 (March 1946), p. 53.

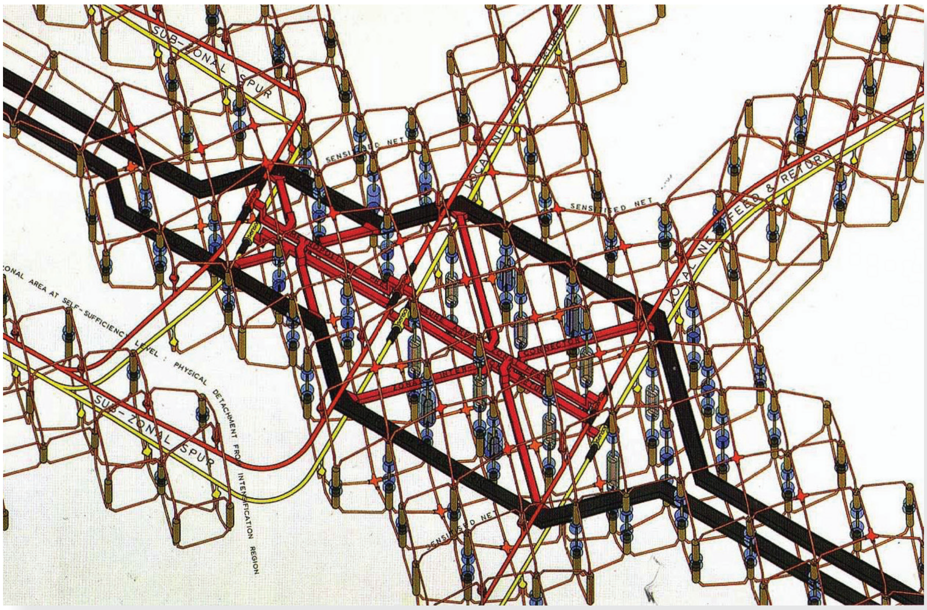
3

On Modelling:

A consideration

In 1996 the economist Paul Krugman ventured into interdisciplinary territory by admitting his admiration of evolutionary biologists in a talk he gave to the European Association for Evolutionary Political Economy; identifying that evolutionists have better grasp of the 'useful fictions' used to cut through complexities, and economists must re-learn "that models are metaphors, and we should use them, not the other way around." The field of Urban Design, especially when framed through computational models and intertwined with associated disciplines like economics, planning, architecture, politics and engineering, must be doubly aware of this warning.

The purpose of this discussion is to understand our continued limitations, but also our progress in developing empirically-based models of urban form. Importantly, these models form the fundamental cultural and disciplinary biases that can limit and expand the frontier of urban and spatial models or protocols, and these ultimately influence the design and economic production of our cities.



Archigram's Computer City diagram, drawn by Dennis Crompton, abstracting the sorts of monitoring systems (borrowed from radio0controlled taxis, ambulance services and airports) that permitted their project Plug-In City to operate smoothly.

Sadler, Simon. Archigram: Architecture without Architecture. Cambridge, MA: MIT Press, 2005.

A core issue for the understanding of cities is that urban models and data limit us. The models we use to frame how they work is often limited by the perspective or discipline of the modeller. Our sets of interests, the data at hand, and the availability of techniques to identify meaning in our analyses can limit the progress of our understanding. Even more so, we are often limited by our imagination's ability to perceive what is data and what is not. Progress towards what is computable, but what is left to art and the political realm is often changing between science and the humanities. And importantly, a model takes on a life of its own; it is reported upon and used in academia and beyond.

This use of the model may create perversions in feeding how the urban form works to begin with, in turn creating a self-fulfilling prophecy of how the complexities of architecture, design, engineering and economics come together. In this way, what was once thought to be iterative process of scientific progress becomes an autoregressive tautology, where assumptions can develop into laws without a more malleable and inter-disciplinary environment of rigorous questioning.

Although urban modelling remains in its infancy, its intellectual legacy has significant roots in one particular discipline: geography. Starting with the formulation of cybernetics by mathematician and philosopher Norbert Weiner in 1948 (a study of human and machine systems explained through feedback, control and communication mechanisms), it quickly generated newfound excitement in architects and planners for systematic approaches to analysing (and therefore shaping) cities (Weiner, 1961). By 1964, Dennis Crompton of Archigram had already fantasised about network and infrastructural effects on urban living in Computer City, and ES Savas, professor of public policy at Baruch College, applied Weiner's principles to urban government in his 1970 Science article, Cybernetics in City Hall (Savas, 1970).

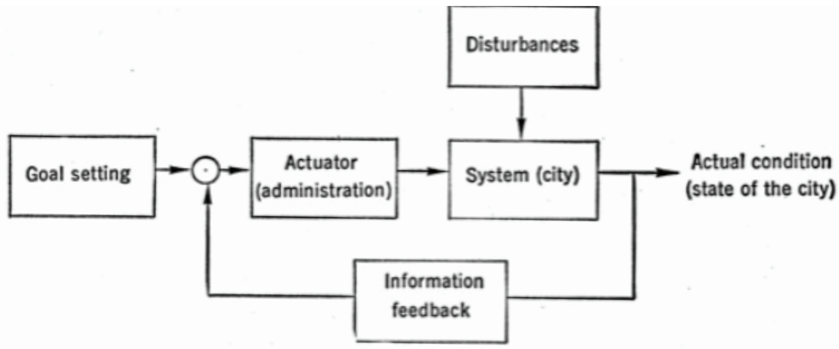


Fig. 1. A basic feedback-control diagram.

"The simple feedback-control diagram of Fig.1 is the basic tool of the cyberneticist, and it suffices to illustrate the elements of such a system. The desired condition of the system is selected by some goalsetting process, entered into a comparator, and then tested against the actual condition, which is observed and reported by some process of information feedback. Any discrepancy between the desired and the observed conditions causes the actuator to act upon the system to reduce the discrepancy. The continuing, dynamic nature of this entire process results from the disturbances that is, causative factors outside the system which upset the system and make it necessary to apply control action to counteract their effects."

- from Savas, E. S. "Cybernetics In City Hall". Science 168.3935 (1970): 1066-1071.

At the same time, the landscape architect Ian McHarg's Design with Nature (1969) testified the efficacy of layered hybrid maps for identifying ecological sensitivity in the geographic domain, which has been heralded as the 'conceptual founding' of modern-day GIS (in fact, Roger Tomlinson's Canadian Geographic System had already set the stage for computational approaches to urban modelling by the late 1960s) (Foresman, 1998). Yet despite 50 years or so of 'urban computation', the writer and architect Anthony Burke points out in The Urban Complex:

> *"Why has the urban condition remained so resistant to attempts to parametricise its inherent complexity? Put another way, why have the assumptions of urban systems models proven to be incompatible with the reality of the contemporary urban condition, and incapable of accommodating or recognising contemporary events and behaviours?"*
> *(Burke, 2010)*

Contemporary perceptions of urban complexity have increased demands on the discipline to move beyond theory and into the domain of empirical testing. While the question perhaps places unfair demands on the outcomes of computerised modelling (a model that so finely predicts the complex interactions of urban form with culture, finance, politics, geography, etc, may be approaching the 'map-territory' relation limit) (Becker, Korzybski, 1942), the question of whether an urban model's assumptions and its intended (or unintended) productivity is important for the frontier of designing better cities.

Modern GIS data-structures are predicated on two fundamental constructions of geography: two-dimensional layers comprised of either vector- or raster-based information. This allows rapid compositions of heterogeneous data into coordinated hybrid maps (as envisioned by McHarg), thus enabling spatial analysis that interrelates multiple domains of knowledge.

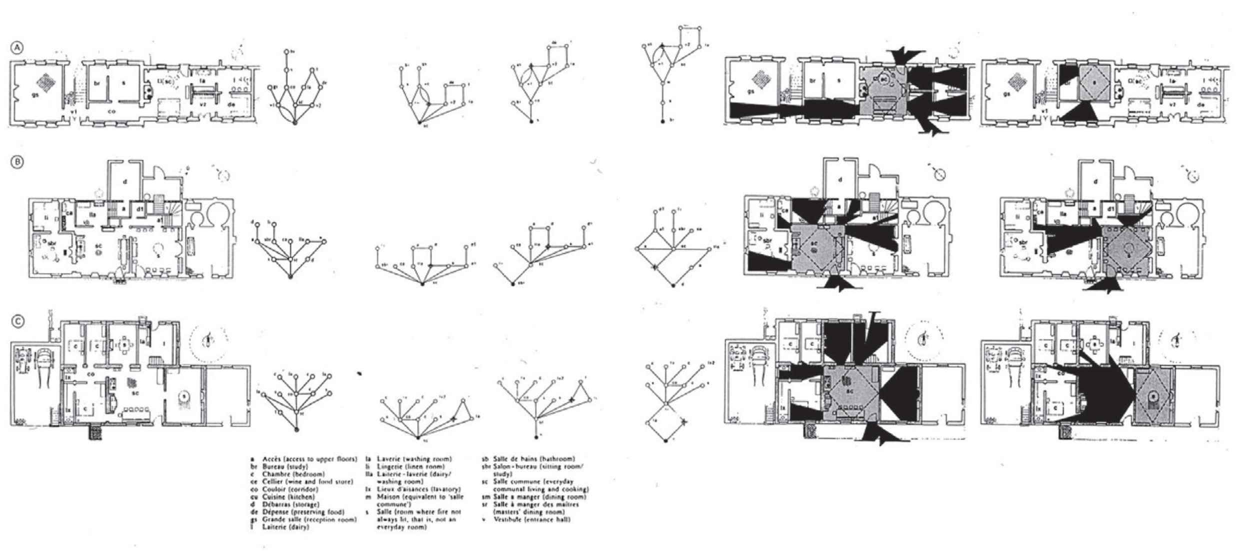
Combined with global reach (both geographic and population coverage) the productivity of the technology can be powerful — the U.S. Holocaust Memorial Museum's Crisis in Darfur project utilised both crowdsourced and institutional datasets to map and analyse genocide in unforeseen detail.

Yet it is important to recover what the writer and urbanist Keller Easterling (2014) characterizes as the 'disposition' of this infrastructure: not the actual activities performed upon the infrastructure inasmuch as the kinds of activities both invited and inhibited by the compositions of the infrastructure's elements.

What I wish to bring to the fore is the implicit assumption of objectivity given by the 'impartiality' and 'omniscience' of the map: while writers like landscape architect James Corner (1999) have already explored the inherent power structures employed in mapping by way of its ability to select and codify data, only recently have architects and urbanists explored techniques to map more subjective qualities of space.

In 1984, the urbanist and academic Bill Hillier published The Social Logic of Space (Hillier and Hanson, 1989) outlining new methods to graph and calculate networks of spaces that defined them by their experiential properties:

> *"Culturally and socially, space is never simply the inert background of our material existence. It is a key aspect of how societies and cultures are constituted in the real world, and, through this constitution, structured for us as 'objective' realities. Space is more than a neutral framework for social and cultural forms. It is built into those very forms. Human behaviour does not simply happen in space. It has its own spatial forms. Encountering, congregating, avoiding, interacting, dwelling, teaching, eating, conferring are not just activities that happen in space. In themselves they constitute spatial patterns."*

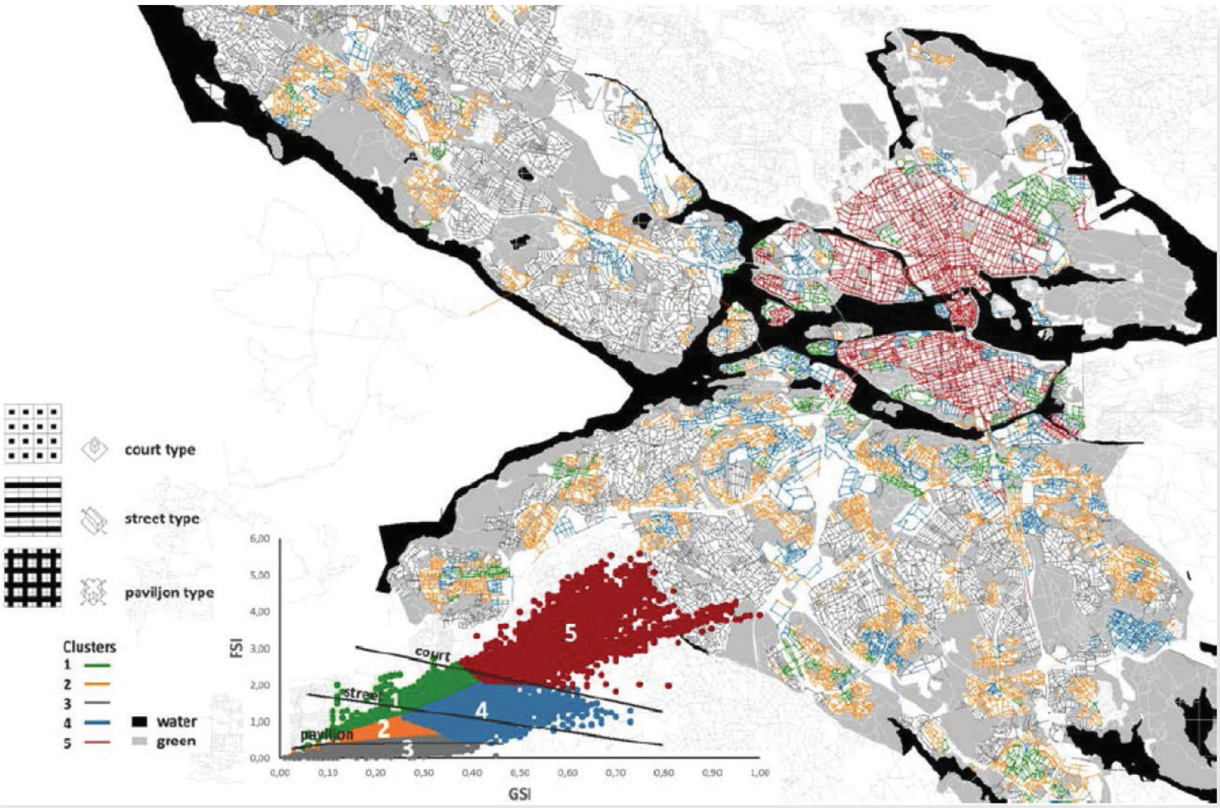


Above are space syntax analyses of residential floor plans, with their architectural, configurational and isovist graphs.It can be seen that despite the geometrical differences of each house, the strong similarity is that the central space lies on all non-trivial rings (a trivial ring is one which links the same part of spaces twice) and links directly to an exterior space — and acts as a link between the living spaces and various spaces associated with domestic work carried out by women. In this way Hillier claims space syntax is able to uncover the presence of cultural and social ideas in the spatial forms of buildings.

From Hillier, Bill, and Julienne Hanson. The social logic of space. Cambridge University Press, 1989.

From this premise, 'Space Syntax' analytic techniques such as the isovist (or viewshed polygon), axial space, integration, convex space, and more were developed to enable observer-oriented descriptions of inhabitable places (rooms, buildings, streets, plazas, cities...), that could parallel the similar ways network analysis enabled calculations of flow, robustness & dependency, influence and so on of real and abstract graphs. By combining these metrics with multi-variate descriptions of urban density, typology and use-mix, we are now able to formulate computable relations that can yield insight into urban properties like the character of a neighbourhood, or its atmosphere — qualities that have been previously left out of urban spatial analytics.

Critically, some measurements in space syntax like the isovist, and Berhauser-Pont & Haupt's Spacematrix (2010) metrics for density require three-dimensional geometry structures. The importance of this extends beyond the desire for GIS-esque mappings of urban space to acquire higher fidelity or accuracy. Instead, three-dimensional dataspaces allow the entry of spatial designers — architects, urbanists, artists, landscape architects, and others — to both represent and reproject spatial analytics into potential new forms and infrastructures.



The ability to build semantic properties of space from collections of syntactic descriptions (ie, the ability to quantitatively describe qualities of built typologies or floorplan layouts or urban fabric from their geometric properties) means that procedural computation to produce designs with desired properties is also possible. In this case, designers can author a set of operations that can be performed on geometry, and allow an algorithm to selectively choose and optimise those operations towards achieving a predefined geometric goal — whether it is the satisfaction of a density requirement, particular efficiencies in arrangement, or even more corporeal effects. Further, the accessibility of massive computational power now allows exploration of tens of thousands of these solutions; traversing a so-called 'design space' (analogous to the search- or solution-space in operations research or decision theory) and therefore also inviting modern optimization and sensitivity analytics as feedback mechanisms to design processes for complex projects.

(Previous page): Density patterns based on the cluster analysis in SPSS using accessible FSI, accessible GSI and L as input variables and the same clusters projected in the Spacemate model. The clusters capture besides variations in the density variables also variations in building types such as the court, street and pavilion type.

From Berghauser Pont, M., and L. Marcus. "Connectivity, density and built form: integrating Spacemate with space syntax." In Proceedings of the 22nd ISUF conference: International Seminar on Urban Form. Sapienza University of Rome, Faculty of Architecture, pp. 22-26. 2015.

In 1785, Thomas Jefferson proposed a Land Ordnance that would create a nation of "yeoman farmers" – a protocol for the surveying and conjugation of all land annexed by the United States in order for its subdivision and sale to speculators. Such a mechanism territorialized new terrain within the bounds of its technological disposition; new cities arose with their blocks demarcated at mile-markers; cropfields followed Cartesian axes rather than topography; and infrastructures were constrained to orthogonal boundaries. The intended –and unintended– effects of this technology substrate can be traced to those initial assumptions and constructions of two-dimensional mapping and surveying protocols and their appeals to objectivity and omniscience.

With our newly formulated capabilities that can situate more complex constructions of territory alongside our traditional ones, what new possibilities will emerge — both intended and unintended — for the formation of new ways of living, producing, and constructing meaning?

Below: a collection of aerial photos showing the diversity of spatial arrangements and programs within the Jeffersonian Grid.

Collected from Instagram user "The Jefferson Grid", https://www.instagram.com/the.jefferson.grid/

4

Urban Design Computation:

A survey of approaches

Following on from the previous discussion, a completely integrated and holistic approach to urban modelling has seen little in the way of productive outcomes, despite the aspirations of previous generations of urban designers and planners. In fact, most have turned out to be fairly arbitrary in the face of overwhelming complexities and forces influencing contemporary cities. (Schmitt, 2012)

In asking the question of how may the complexities, dynamics and contingencies of urban design and development be understood and operated on by a wider audience, researchers and practitioners usually turn towards 'loosely-linked' component-based models that aim to contextualize urban processes within surrounding social, governmental, economic and environmental conditions.

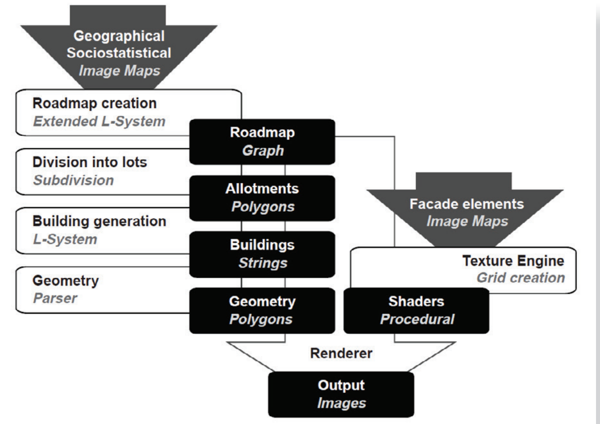
As an example, the UrbanSim software platform developed by Paul Waddell at University of California, Berkeley, utilizes a modular architecture to support disaggregate spatial microsimulation of land-use and transport interaction at a granularity approaching the parcel-level scale; simulating the preferences of households and businesses within a discrete-choice disequilibrium model. (Waddell, 2003) On the other hand, Christian Derix with Paul Coates at University of East London's Centre for Evolutionary Computing in Architecture contrast 'black box'-type generative computation that alienates a planner or designer with a set of modular, heuristic algorithms that can be assembled together for particular workflows, and intervened upon by the user. (Derix, 2012)

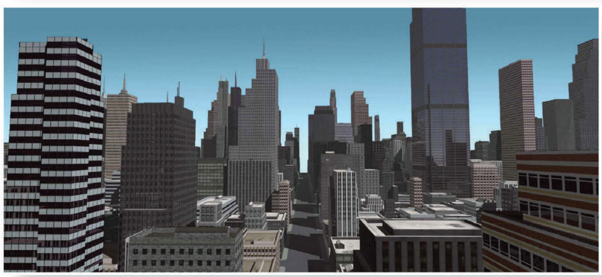
Both of these demonstrate a disparate disciplinary focus when in describing the nature of urban development, with overlapping but different scales and intentions behind the model In addition, both demonstrate that the choice of foundational or axiomatic descriptions of the model content must be carefully chosen to enable proper relation back to model subject.

Multiple approaches to synthesizing architectural form have been experimented with since the advent of computer-assisted design software in the 1960's, as detailed in Charles Eastman's compendium on Spatial Synthesis in Computer-Aided Building Design (1975), and Yehuda Kalay's Computability of Design (1987). The complexity of urban design, and its associated interrelations to planning, development, transport and infrastructure has meant its progress into computation has been slower, and more recent. Nevertheless, three key approaches have formed that attempt to handle these complexities.

Procedural approaches to design synthesis employ 'shape grammars' (Stiny, 1980) to derive subsequent designs from their ancestors. In this paradigm, initial design conditions are inscribed by the designer, who then chooses procedures from a library to operate on the initial shape. Complex forms can be created by applying iterative sequences of these operations to create more detail.

Research and implementation of this approach for urban design first came about with Pascal Müller and Yoav Parish's seminal paper on the Procedural Modelling of Cities (2001), which was then developed more thoroughly at ETH Zurich and finally spun-off to create the software CityEngine (ESRI). This uses a split-grammar-based procedural language (Computer Generated Architecture, or CGA) that enables designers to automatically generate urban form & texture visually similar to reality. The rules allow basic transformation, extrusion and subdivision of shapes, and texturing of surfaces. (Mueller and Wonka, 2007).





Procedural Modelling of Cities (2001):

Top: The pipeline of the city creation tool. The dark boxes list the results and data structures of the individual tools in the white rectangles.

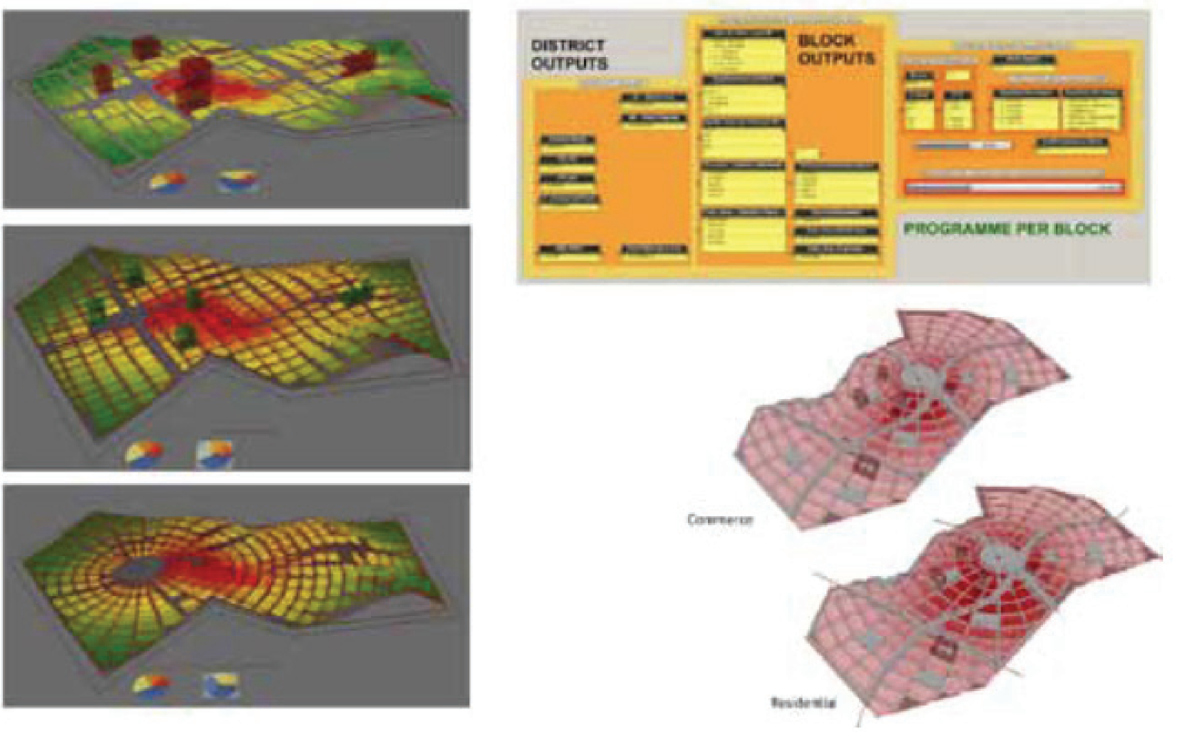
Middle: Street creation system applied to Manhattan.

Bottom: Rendering of virtual city

From Parish, Y. I. H., & Müller, P. (2001). Procedural modeling of cities. In Proceedings of the 28th annual conference on Computer graphics and interactive techniques (pp. 301–308).

Another, more design-led initiative has been on behalf of Jose Duarte at Universidade Técnica de Lisboa (UTL), where Jose Beirao's thesis on City Induction identified particular grammars and functions that are meaningful in urban design, in order to deploy these during early sketch stages for masterplanning (Beirao, 2012). However, implementation has not gone beyond academic programming to reach enterprise diffusion in design programs.

A plethora of 'parametricist' styles are effectively procedural methodologies at core. These have been showcased more recently, especially after Patrik Schumacher's manifesto (Schumacher, 2009) and have made their way into design schools globally (Verebes, 2013). However their rigor and consideration of urban design's dependencies on adjacent domains like planning and real estate are lacking.



Jose Beirao's City Induction: The three images on the left show the three available grids. The upper right corner shows the data output interface in which density indicators are shown at district scale, block scale and per block. The lower right corner shows the distribution of commercial and residential use in the plan.

From Beirão, José Nuno. 2012. "CItyMaker : Designing Grammars for Urban Design." Delft: Delft University of Technology, Faculty of Architecture, Department Architectural Engineering+ Technology, Department of Urbanism].

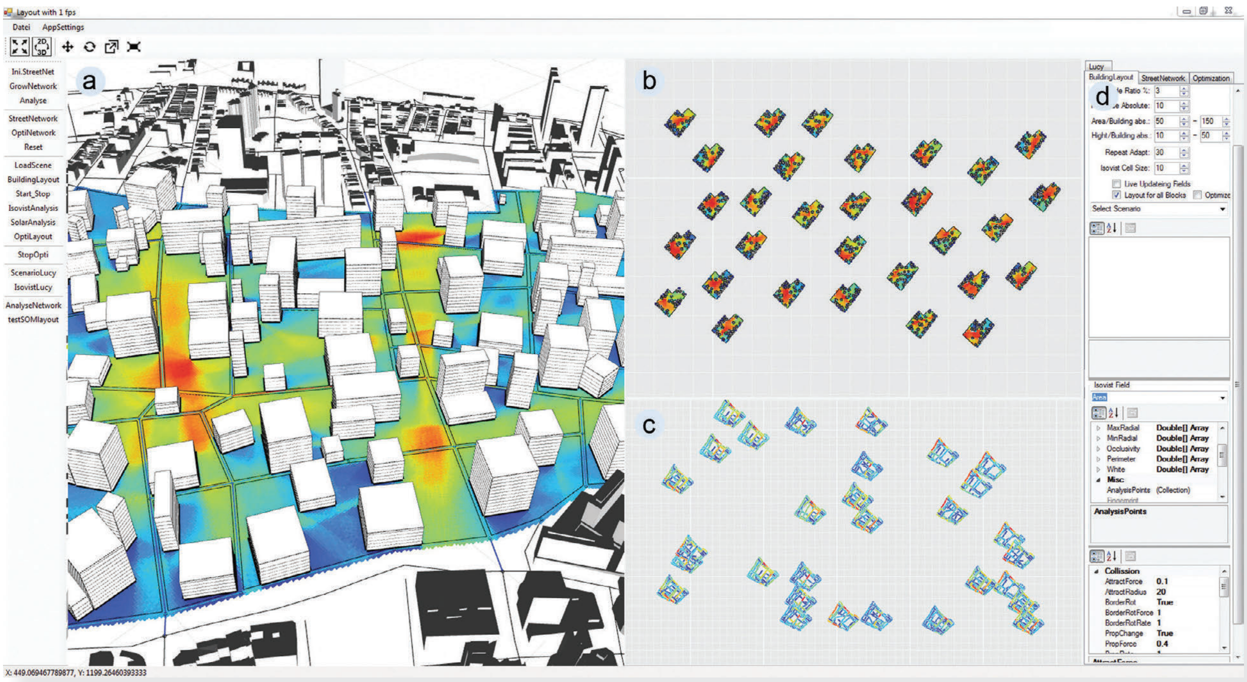
A fundamental difficulty with procedural modelling is its inability to incorporate global constraints, which means it is excellent as a means to visually explore design outcomes, but the exponentially increasing design space means the searching, optimizing and selecting of designs is computationally expensive. While local constraint implementation is possible through explicit specification of rules, these can be cumbersome due to the inflexibility of data structures used.

Despite this, Paul Waddell's group at University of California, Berkeley, has implemented a framework for the Inverse Design of Urban Procedural Models (2012) that overcomes some of these limitations by enabling global performance targets for the massing model to achieve. This technique estimates parameter changes required to the model using Monte Carlo Markov Chains (MCMC) and resilient back-propagation.

In contrast to procedural modelling, 'design space', 'parameter space', or 'performance space' explorations are borrowed from operations research and optimization. In this paradigm, a form is both generated and evaluated (either synchronously or asynchronously) — an algorithm generates a form from a vector of input parameters, and its evaluation is recorded as additional components to that vector. By graphing the coordinate points of this multi-dimensional vector, a hypersurface with measurable gradient can be interpolated and computed. Various techniques for searching through this space (gradient-descent, simulated annealing, or evolutionary algorithms) enable the identification of salient terrains (peaks, troughs, flat, or steep) that correspond to designs with particular input parameters and performances.

Using evolutionary and self-organising map algorithms to search urban design-spaces forms the framework for the research programme at ETH-Zurich's Future Cities Lab under Gerhard Schmitt (Koenig, Standfest, Schmitt, 2014).

However, for spaces with more than four or five dimensions, visualization becomes complex. As opposed to engineering-oriented optimization, design space exploration for designers is not absolutely concerned with achieving optimality in one or several criteria (Muller, 2014). Instead, the sensitivities of performances to formal changes is at times more interesting; designers want to be able to understand the potentialities and challenges of particular designs rather than just optimize. If design or performance criteria cannot be mapped or weighed against each other, evaluating multi-criteria outcomes against each other is difficult (Rutten, 2013). For example, it is difficult to provide an absolute baseline off which to measure multiple varieties of 'performance indicators': what is the relative value in doubling a floorplate's daylight autonomy against a tripling of construction cost?

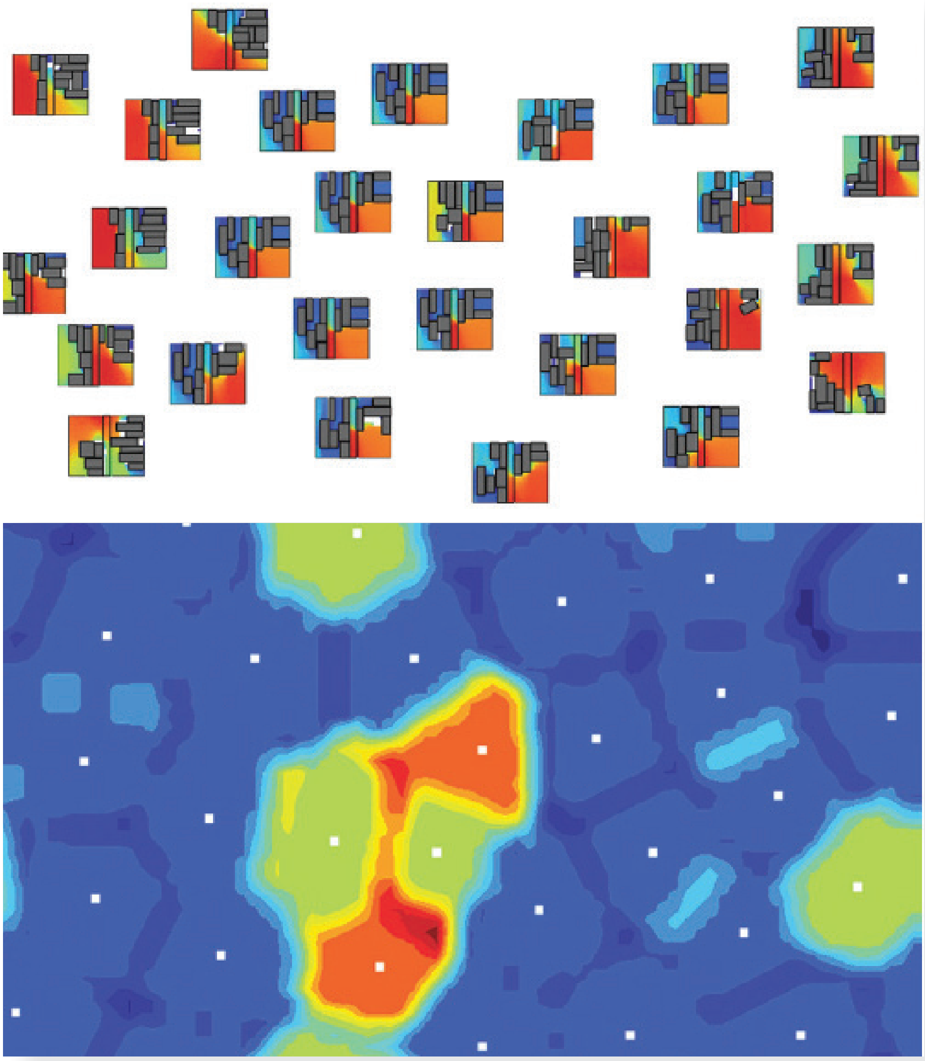


A Software prototype showing an example of a building layout with corresponding Isovist analysis. The coloured grid represents an Isovist field for "area" property and crosses the entire planning area. On the right is the Self-Organized Map that identifies similar designs.

From Koenig, Reinhard. 2015. "Urban Design Synthesis for Building Layouts Urban Design Synthesis for Building Layouts Based on Evolutionary Many-Criteria Optimization." International Journal of Architectural Computing 13 (3+4): 257–70.

Layouts with open space. Top: Arrangement of layout variants using the mapping of a SOM analysis. Colours show the Isovist "field area" property. Bottom: Visualisation of the PMatrix of the Databionic ESOM Software. Variants (represented as points) in clusters with warmer colours have more in common with respect to all dimensions than the variants in clusters with colder (blue) colours.

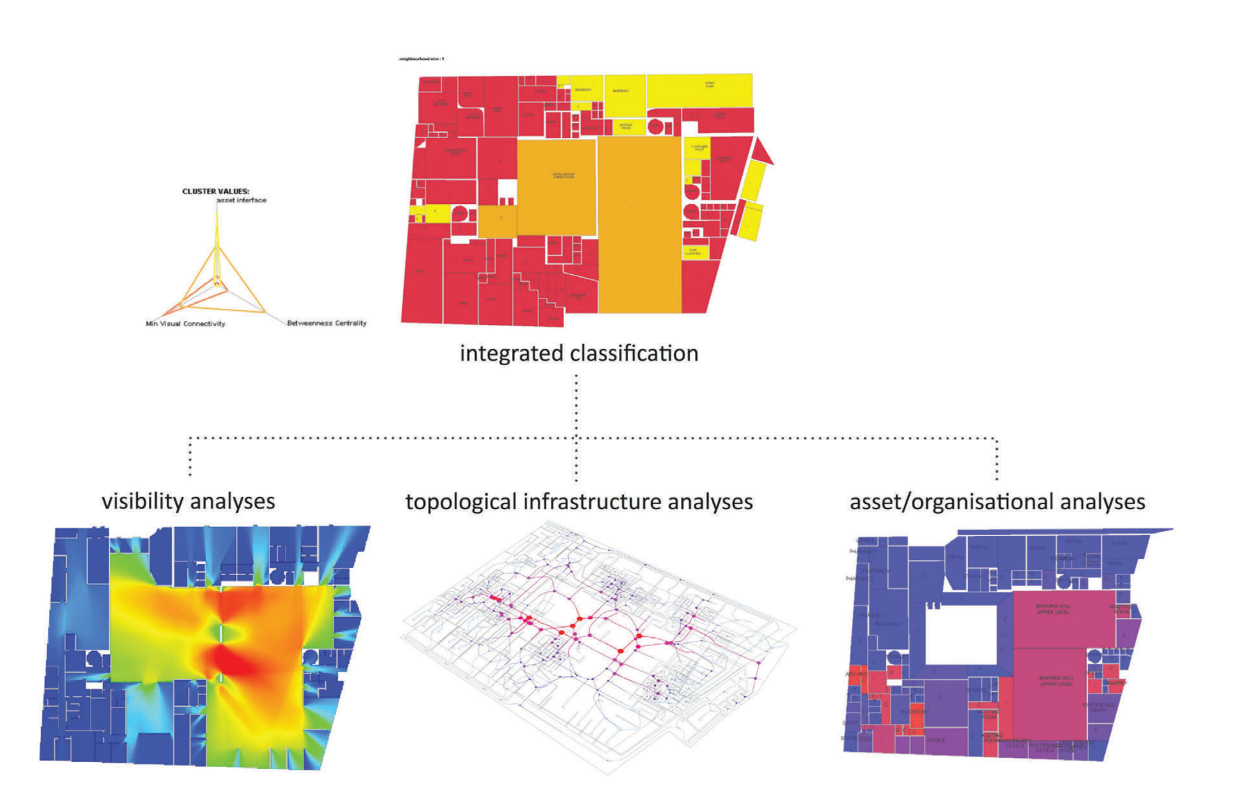
From Koenig, Reinhard, Matthias Standfest, and Gerhard Schmitt. "Evolutionary multi-criteria optimization for building layout planning." (2014).



Another approach to computation identifies designer-led 'heuristics' as a framework for various search, optimization, and generative methods that assist and amplify the role of the urban designer. This forms the framework of the research programme under Paul Coates and Christian Derix at the Centre for Evolutionary Computing in Architecture (CECA) at University of East London.

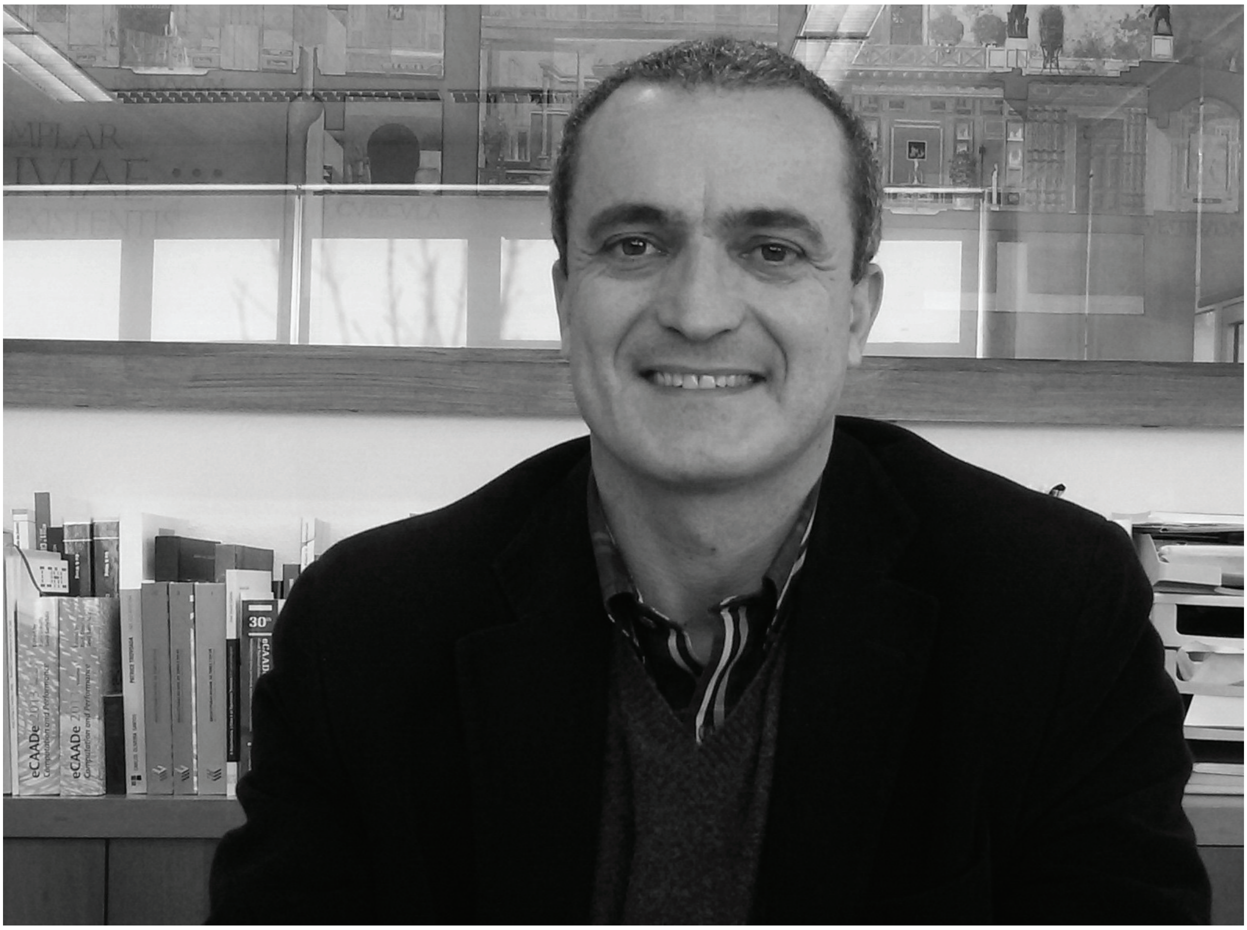
Implementation of this is more oriented towards practicable toolsets rather than academic pursuits. Initially at Aedas, the Smart Solutions for Spatial Planning (SSSP) initiative intended to create a digital chain of tools from GIS and census data surveys down to the scale of block massing and plot sizes (Derix, 2008). Now in its deployment at Woods & Bagot, Derix et al have defended the utility of this approach as being occupant-oriented, and thus utilize visibility analyses combined with space syntax legibility and path-finding analyses to yield computational performance indicators of designs from a human-centric viewpoint.

Form generation comes about by designer-led linkages of customized generative algorithms, manual input, and computational response, all oriented towards project-based implementation.



Above: Integration of three strands of development in the Resilient Infrastructure and Building Security (RIBS) project, utilizing Visual connectivity, space syntax, and organizational (asset interface value which is the highest value amongst its connected asset interfaces) analyses.

From Derix, Christian, and Prarthana Jagannath. "Digital intuition–Autonomous classifiers for spatial analysis and empirical design." The Journal of Space Syntax 5, no. 2 (2014): 190-215.



5

Generative Urban Design:

A discussion with José Duarte & José Nuno Beirão

Dr. José Pinto Duarte is the Stuckeman Chair in Design Innovation at Pennsylvania State University and director of the Stuckeman Center for Design Computing (SCDC). He was previously dean of the TU Lisbon School of Architecture, Portugal.

After obtaining his doctoral degree from MIT, Duarte returned to Portugal where he helped launch groundbreaking, technology-oriented architecture degrees and programs in two different universities, as well as a digital prototyping and fabrication lab.

José Nuno Beirão is an Assistant Professor at TU Lisbon's School of Architecture, where he develops research related to the applications of city information modelling (CIM) in urban planning and design. He received his doctorate from TU Delft, focusing on the development of shape-grammar based design patterns for urban design. Current studies focus on the integration of topology -based analysis in parametric urban design environments.

DF:

A lot of your work has focused on utilizing shape 'grammars' in urban design — you call them "urban induction patterns". What are the particular benefits of this?

JNB:

When came back to academia I was particularly interested in flexibility and exploring design variations — typologies and all that. At the time I didn't know anything about shape grammars but was introduced to it by Jose [Duarte]. However, after I started working with them more intensively I was a little disappointed in terms of what I expected, because there were so many difficulties in their implementation. Also, most of the work using shape grammars in an accurate way are basically analytical, whereas I was more focused on design — that's actually the reason why I became interested in the generation module of city induction. During the process of implementation I discovered that shape grammars allow us to have a very accurate approach to design problems — because it can be used both as an analytical methodology, as well as a generative media for developing designs.

With Urban Induction, the method was basically to infer the patterns of common design manoeuvres and systematize these into generative grammars in code. It became quite obvious that a parametric implementation was a lot more powerful than a shape grammar one. I was asked at the end of my defense by Dr. Rudy Stouffs: "In the end, why did you use the shape grammar approach?" And the main reason is that it really creates a kind of objectivity in the whole process – it structures the methodology. You have the structure of the patterns, the theory is presented, but the implementation must adapt to whatever medium is most applicable.

JD:

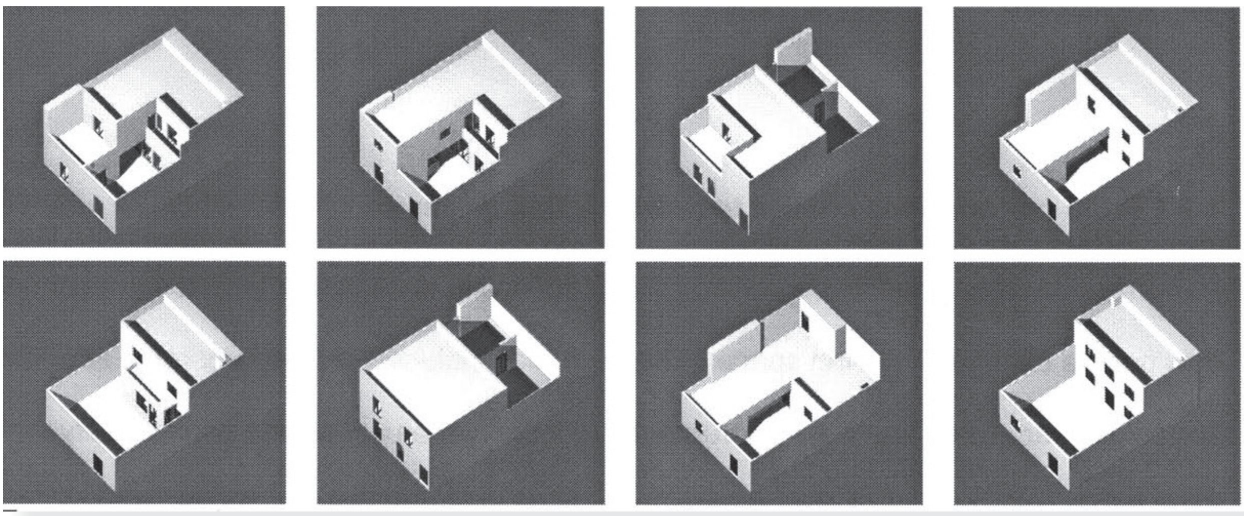
A grammar helps you to structure design knowledge in a way that lends itself to computation better than a parametric design model. But once you have the grammar, it's much easier to implement it as a parametric design model. So you need both actually.

DF:

Is there a particular benefit for a real-world context? Is a shape grammar approach more suitable for mass-customization beyond parametric design, or optimization, evolutionary algorithms, cellular automata, etc?

JD:

I see them as complimentary. I could say that I became interested in these systems because when I was getting my architectural degree, there was a housing shortage in Portugal and we had to build lots of houses. My interest was in a system that could allow me to plan or to design new environments with features that I values in more historical settlements. And I would characterise the



José Duarte's shape-grammar based design system for customizing mass housing is illustrated by imitating Alvaro Siza's Malagueira houses. A design by the author of the grammar after its rules was shown to Siza amidst several of his own designs. Siza did not distinguish the new design from his own.

From Duarte, Jose Pinto. "Customizing mass housing: a discursive grammar for Siza's Malagueira houses." (2001).

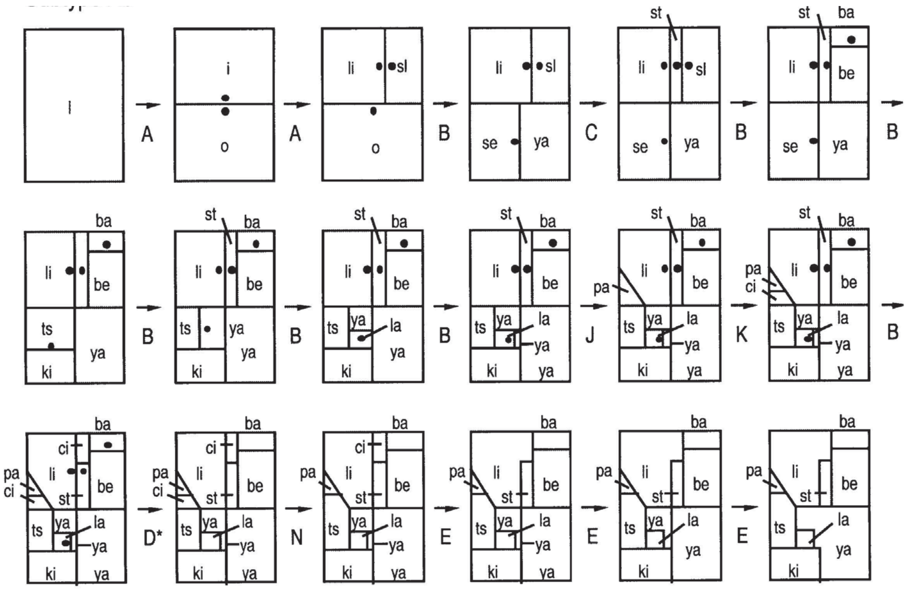


Diagram illustrating the sequence of grammar operations to derive floor layout. The compositional rules include perpendicular dissection, connection, and extension of rectangles, and assigning and permuting functions.

From Duarte, Jose Pinto. "Customizing mass housing: a discursive grammar for Siza's Malagueira houses." (2001).

requirements to be that a) I could customize the houses but at the same time give them a sense of shared identity — they should be perceived as in the same style, and b) to actually to be able to give each person a suitable house. So that was the idea — to satisfy individual needs and at the same time give them a sense of community.

So I liked the way of making plans that lend themselves to generational diversity or variation. And also, from my own experience of designing I had to make decisions and sometimes I had the feeling that I didn't have enough information to decide immediately — so I would like to have a way of generating design alternatives and assessing them.

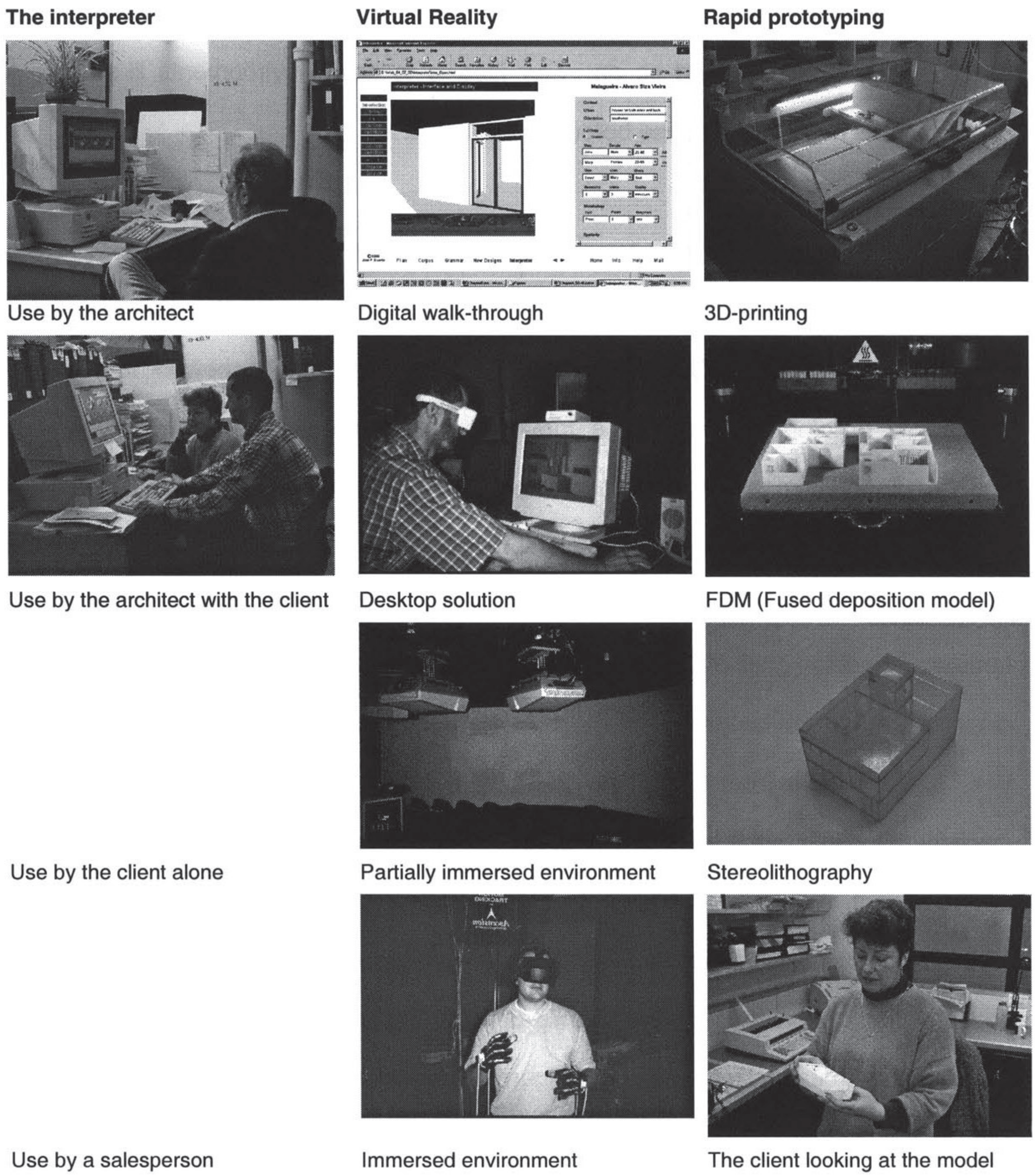
JNB:

I think depending on the design problem, it may or may not make sense to use grammars or parametric systems or any kind of adaptable systems. It does makes sense to address the problem with a system rather than a single solution, that's for sure. Housing is definitely one of these problems, and of course so is urban design — perhaps even a lot more because it must respond to a lot of people differently, and thus be very adaptable. One interesting illustration of that is regarding regulatory implementation of an urban plan. A parametric model may not be so easy to manage from the perspective of a planning instrument for a municipality — what are the methods by which they can edit and test a parametric model? It might be tricky — but the rules of the grammar may be easier to communicate and maintain, if you formulate the regulation in terms of testing and updating the individual grammars.

DF:

Are there any considerations here with respect to the scale at which design customization & generation (whether using grammars or any other generative system) is best used? It is one thing to have customization on the scale of an individual dwelling — for instance a homeowner bypassing a conventional design & construction contract to build their own custom home, and another when you are implementing whole-neighbourhood or city design. A city is a little bit different because you're designing for masses of people rather than individuals or families.

What is the attraction effectively behind computational approaches to overall city design and why are we pursuing them?



The envisioned framework for the design of mass housing: the interpreter is used either by the designer or the client to input requirements and generate solutions (left column), virtual reality environments with different degrees of immersion (middle column), and various rapid prototyping techniques (right column) are, then, used to visit and assess the solution before construction.

From Duarte, Jose Pinto. "Customizing mass housing: a discursive grammar for Siza's Malagueira houses." (2001).

JD:

I think it has to do with the impact of urban growth and the scale of the problem. When things where slower, we had the time to take it easy and design one house at a time. But some cities are growing so fast that you need new ways of approaching the design of cities, and we need systems like this because we can no longer afford to design one house at a time. We need to design thousands of houses at a time, so we need a system that allows us to generate varied designs suitable to different contexts, to different families, to different site context and so on

JNB:

I think one of the most important things is that the industrial era changed completely the way society works. It's also a political-economic issue — of course it allowed the production of massive quantities of goods. But it also effected the specialization of tasks and professions, and this caused a fundamental change in terms of the owners and users of capital. For example during the middle ages, buildings are constructed mostly by the end-user themselves, or by a skilled person that would help the owner to apply more specific knowledge, and this knowledge was passed from generation to generation quite locally. In the industrial age, specialization means someone becomes very skilled and knowledgeable about building houses and nobody else knows how to perform this task, and they are delegated all work related to house-building. In order to capitalize on this function, those specialists use repetition and mass-production for efficiency, and this is where mass-customisation really starts making sense — you need to have ways of addressing individuality if you believe that individuality is part of democratic society. So it becomes a need of the design process. Put the two together — specialization in efficiency, and individuality — and you see the need to use the computer for its capacity to respond to the scale of this need.

DF:

Do you think that these new computational paradigms have the ability to redistribute political and economic agency? So while we are currently within particular collections or consolidations of power structures, do these tools redistribute that widely or will they enable consolidating of power structures into another concentration, or silo?

JD:

It might work either way, it depends. It may be used by some to get more power or, if it works in a nicer way, it might redistribute power —

JNB:

Of course, my intent is to make it more democratic. I believe in the power of individuality very much. I also think that cities are a lot more interesting when you have individual concerns being represented. There's always a big question where one should have a more top-down decision process because some things need to be decided in a top-down fashion, but at the very least, I believe that cities should be a congregation of all these ways of representation.

DF:

It sounds like the types of next steps for computational urban design, rather than focusing on new ways of generating geometry or form, is actually tackling problems at the intersection of space with politics and economics and social issues. How could those concerns become embedded in a computational framework?

JD:

The potential is enormous but we haven't got to the stage of applying it in practise fully yet. Most of the applications of computational design has been in service of, let's say 'fancy' buildings, and it's deceitful because that's not the entirety of the point. I mean, obviously we all want more beautiful, more surprising, more striking buildings. There's nothing wrong with that, but it's not the main focus. The main focus should be building better cities for everybody, to make it more democratic for everybody, to give each person a nice house, a nice environment, a nice sense of community. And I think that's the most important

"[M]ass-customisation really starts making sense [when] you need to have ways of addressing individuality, if you believe that individuality is part of democratic society. So it becomes a need of the design process. Put the two together — specialization in efficiency, and individuality — and you see the need to use the computer for its capacity to respond to the scale of this need.

- José Nuno Beirão

use of this tool — that it empowers the achievement of that goal in a very complex and dynamic society, where things are moving very fast.

DF:

One concern is the broadcasting of the 're-demptive' qualities of a new technology or process, and this has been repeated multiple times through the history of urbanism — with highways and the automobile, or the elevator and skyscrapers for instance. However there always seemed to be the encapsulation of the aesthetic, as well as the limitations of the system, within the technology — or within the relationship of the technology to its context. Do you feel this is the same with computational urban design, or is it broader than previous technologies?

JNB:

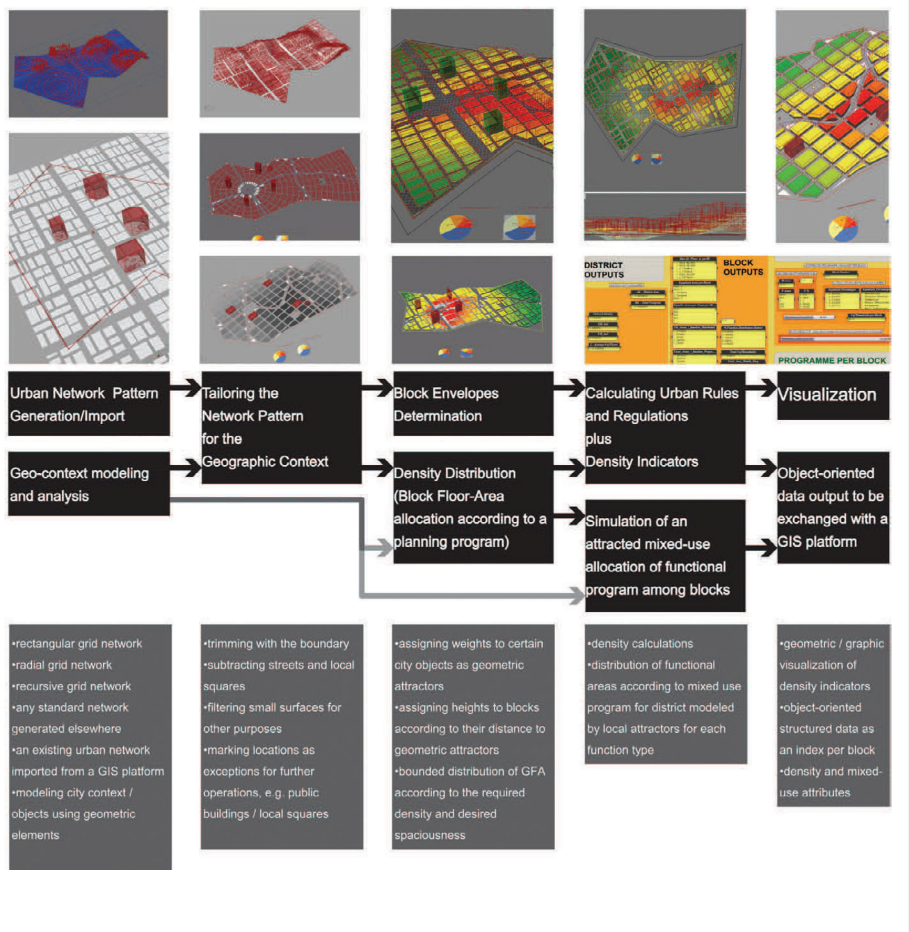
We had a very interesting discussion once where I pointed out that if we want to point out some 'universal' things about architecture, I would say that we have gravity and we have environments — so, any location on earth has a particular environment, cultural environment and ecological environment — and architecture reacts to both gravity and the environment. I think the one thing that is constantly changing regarding architectural tectonics is the way we build. It's not about form, but about how we build, and that's where fabrication is quite instrumental. This explains a lot about architecture, and it explains a lot of architectural history. So I don't believe that the possibilities of computational modelling will make much of a formal change. What we witness today is the current fashion, and that's okay. In the end, we will find new tectonic spaces regarding what digital fabrication will bring in. And we will still be responding to gravity and the environment to shape architecture.

JD:

Speaking very generally of generative geometry within the context of the computer as a universal computing machine, there is no necessary condition that it will lead to a particular type of architecture or a particular type of spatial configuration — it could be used to produce any kind of architecture. There is no particular precondition of form, unless you tie it to a particular performance or requirement, and that's when it might have an impact on architectural form. Computation can allow you to understand how buildings perform, and if you can model how they perform, we will be able to generate forms that have a better performance for particular metrics. In that sense, it is hard to foresee what the aesthetic will be, because we don't know yet what their performance will be measured by. On the other hand, I completely agree that probably the biggest impact will be on how we produce buildings. That is where revolution will be, I believe.

JNB:

I also think there is another topic that has been brought up by Bill Mitchell, which is the fact that our cultural habits will change, and are already changed, according to the possibilities of the computer, and especially of the internet. For instance, we can work remotely, far away from the location of our workplace, with little problem. However, the most important aspect of our economy is knowledge exchange, and this probably occurs more where you have more people. So people will probably tend to gather more densely in cities, and this probably explains why cities are growing so much nowadays. The most important thing of being together is to be able to trade, to meet people, to find out opportunities, and for that you need to meet, and meet in person many times.



Phase model showing the regular workflow for using José Nuno Beirão's interactive sketching system for neighborhood design.

From Beirão, J. N., Nourian, P., & Mashhoodi, B. (2011). Parametric urban design: An interactive sketching system for shaping neighborhoods. Respecting Fragile Places (29th eCAADe Conference Proceedings), 225–234.

DF:

In the context then of using computation to distribute information about the city to citizens — whereby it facilitates the communication of the impacts of urban design using computational tools as rapid simulators, for questions about city — changing infrastructure, or services, planning regulations, etc — have you had any thoughts about how that may impact or change the way in which the city works, and the way it looks and behaves?

JD:

I think, to a certain extent, the computer will help to go back to historic types. Why? You don't need to use public transportation as much anymore because one can work remotely. In that sense, it

CIM-St: A parametric design system for (semi-) automatic generation of street cross sections of street types selected by the designer. This aims to facilitate the work of the urban designer when it comes to specifying the composition of streets, allowing them to quickly test and evaluate different solutions. By relieving the repetitive workload of the designers, the design system allows them to focus on the qualities of their choices instead, supported by an interface with visual analytics and metrics.

From de Klerk, Rui, and Jose Nuno Beirao. "CIM-St: A Parametric Design System for Street Cross Sections." (2017). Image from https://stuckeman.psu.edu/events/scdc-lecture-jos%C3%A9-beir%C3%A3o will have an impact on the configuration of the city because not everybody needs to commute. On the other hand, we are social beings that don't do well being deprived of social contact, so we'll probably have two levels of interaction — one locally with the people that surround use, and the other one is remotely with the people we might be working with and so on.

The other thing is that since we can readily have information available to us regarding how the city is behaving, we might, in real time, do something to react to it. On one level you can change the patterns of use of the city, and on another, you can change the patterns of designing the city, because you can have more accurate information on how the city's behaving, performing, and so on. Once you can simulate this behaviour, and lay down the rules to generate a design solution, then you can simulate how the solution interacts with the current urban context.

JNB:

Once I had a discussion with a friend of mine. We were just discussing ideas about what could change in city form due to changing our means of transportation. Let's say that we stopped making big cars and we have smaller cars, like really much smaller, on the personal-scale. That could change a lot in the way we think about cities — the size of things, the distance between things. There is an interesting scale in the historical city, especially in the medieval city, that we lost with the rise of the car because of its needs for larger spaces — not just for driving but also for parking. The scale of the unit of transport can really change the shape and scale of the city in many aspects.

DF:

How do you see the role of design computation in this? Is design computation a simulator in which you can test a particular intervention or environment, or is there more to it?

JNB:

Yes. I see it a lot as a simulation device.

JD:

But not just simulation device, because simulation means that it allows you to understand the behaviour, the performance. But design computation also has an actuator — it is a facilitator and generator of design ideas. So it has two aspects — generating and simulating.

JNB:

On the urban level, probably before a plan is implemented it is actually a simulation somehow. What becomes the plan, especially if it is a flexible plan, is somehow a simulation which is open to adaptation for a long time, and kind of gets frozen progressively as it's being implemented.

Design computation can bridge the gap between planning decisions and people who have little knowledge of planning. Having models that show some simulation and allows some objective discussion about things makes a lot of difference. Two years ago we had a workshop in Brazil and we utilized parametric urban design. The students were designing relatively basic tower-in-park type apartment buildings because they tought that was the only way to achieve the density the developers wanted. And at a certain point, I asked the students, "Why don't you do a typical peripheral block? You have the same common space, but it is on the interior, with the same kinds of facilities, but your quality of street is much better?" We built up a parametric model to check which one had a higher density, and they immediately saw that when they reached a four-storey height, they'd reach the same density that they have with the tall building.

DF:

One thing I'd like to bring up is the tendency towards complexity or sophistication as a panacea. At UCL's Center for Advanced Spatial Analysis, Mike Batty has been been studying simulations of cities, and models of cities for almost 30 years, and he recently wrote a small op-ed expressing the state of the field. And he said that maybe half the time, the models that he was developing at the beginning of the field were more

powerful — not necessarily more accurate or sophisticated at all — but more instructive than the very complex 'agent-based' models that he's using now. The point being that, at the end of the day, it's always a model; it's always a simulation of the city we're reducing in some way, shape or form.

This begs the question really of "What model do you choose? What is the frame through which you see the city and does that bias it?" Within the context of computational design I think that is pertinent.

JD:
That point is very important because any simulation is a reduction of reality. And that's when things might get little bit tricky because there's an underlying interpretation. You choose a certain model and that will affect the way you perceive reality.

JNB:
When you have the wrong assumptions about a problem and you simulate, the results you get are as wrong as the assumptions.

DF:
I guess that's where my question about what kinds of power structures we are internalizing. If we are going down a road of computational design and we think that it is the new paradigm, what are these kind of implicit or hidden assumptions we are reproducing?

JNB:
Well, many of the arguments that some researchers bring forward are not really true in terms of our existing economy. One example is the common argument that digital fabrication allows the production of free form shapes with the same price as regular shapes, and that's not true. It's obviously more expensive because it's completely different to mass-produce something to cut straight lines than cutting curved lines. It takes more time, and the fact it takes more time makes it more expensive. There's no way of dealing with this in any other way. Of course digital fabrication expands the world of possibilities — it's very good in terms of added value objects. Customised jewellery is a great example of that — the added value is having your own aesthetic, a personalized object, and the added expense is compensated for. But for all the people saying, "We will use rapid prototyping tobuild houses for the poor," yeah, that's absurd. It will never happen that way.

JD:
However, remember architecture tends to be very conservative. It takes time to change. So I think in research, sometimes, we are very far ahead of what's the common practise, and that's why it's taking so long for the results to have a real impact on practise. It will happen at some point but it's slow and it's a little bit frustrating that it's that slow.

6

Programming Design:

A deep-dive with Peter Wonka

Peter Wonka is the Associate Director of the Visual Computing center (VCC) at King Abdullah University of Science and Technology (KAUST), and Professor in the Computer Science program.

He received his doctorate from the Technical University of Vienna in computer science, where he also received a Masters in Urban Planning and a Masters in Computer Science. After his PhD, Dr. Wonka worked as postdoctoral researcher at the Georgia Institute of Technology and as faculty at Arizona State University. His research interests include computer graphics, visualization, remote sensing, computer vision, image processing, machine learning, and data mining.

By combining computer science techniques with urban modelling and planning, Dr. Wonka has formulated core methods and technologies now utilized in various software programs and analyses in widespread use by industry professionals.

DF:
Why do you think there is interest in automating or assisting urban design with computation? Is it important to pursue this?

PW:
The reason why I think it's important is because I think that the city ultimately impacts the lives of so many people, so fundamentally. Given that half the world's population lives in cities, I really think that urban planning, if done well, has the potential for so much impact in so many people's lives. So, I think this is just huge.

DF:
Most of the literature in the field has to do with creating tools that achieve efficiencies in design or enable a designer to access much more information about their design. But in practice, most architects and designers don't use these tools — we are still stuck on what is effectively a digital drawing board. From your perspective, why is that?

PW:

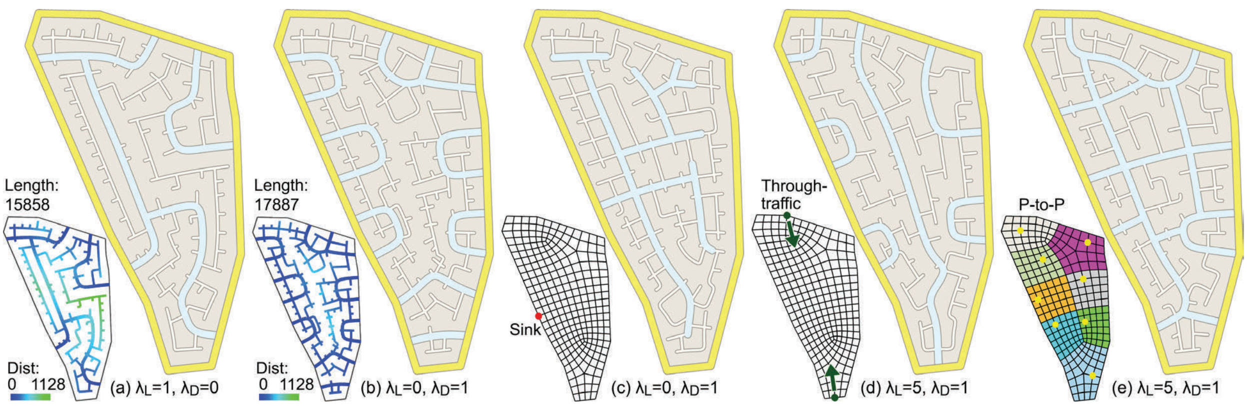
The flipside to what I was saying before is that I do not fully understand why more resources aren't spent on these urban problems and the tools to fix them. If it is such a big issue that has so much impact, it should rank highly in terms of what is important to us. One reason I suspect it isn't gaining the kind of attention it deserves is because the cause and effect in cities is not immediately noticeable, and not easily measurable. Say you go to the doctor because you have cancer, and the doctor cures you in 10 minutes, and then you leave. That's like, wow. This is an immediate impact and it's clearly measurable — come in with cancer, go out without cancer. But, let's say a city builds a new subway, huge construction, and some news reports how great it is that it reduced traffic, some say it's terrible, citizens are interviewed about how they have been inconvenienced, you know... Was it a great plan or not? How do you determine success? When is the horizon to measure its effects?

DF:

So following up on that, where the problem is very 'fuzzy' or it's a wicked problem — where might better tools assist this?

PW:

As a computer scientist, I think one way is this idea of measuring success and measuring if a plan is good or not. I think this is still very difficult. Even simple things like calculating the sunlight you get in a building — this can be strongly



Automated generation of street networks according to different functional specifications: the first two layouts are optimized for minimal network lengths and minimal travel distances to the boundary. The travel distances are shown in the bottom-left corners. The middle layout specifies a single exit on the left with a tree-like structure and allowance of dead-ends on secondary roads. The second from right layout encourages top-to bottom through-traffic. The rightmost layout derives from user-specified partitions and specifying interior-to-interior traffic.

Peng, Chi-Han, Yong-Liang Yang, Fan Bao, Daniel Fink, Dong-Ming Yan, Peter Wonka, and Niloy J. Mitra. "Computational network design from functional specifications." ACM Transactions on Graphics (TOG) 35, no. 4 (2016): 131.

"I think the interaction between the human and the computer is what makes something successful — we should try to build tools that can help a human be more successful, where a human can guide a computer or use its help to find solutions."

- Peter Wonka

simplified even though it's only medium complexity. You can simulate this and then build the actual building, and even then there's a good chance you still don't like it, there's something off... I think it is difficult to get these metrics right, and I think they're not fully explored. Can you really look at a plan and say, this is going to perform better, in terms of say, "quality of life" than another one?

DF:

Given that your background in computer science places you in the position of actually writing and choosing the computational approach to build these tools, what's your take on the landscape of different approaches to these types of problems?

PW:

My experience is that an approach is most successful when it gives an opportunity for a designer to specify high level goals, or to provide a good interface to evaluate many designs that have been generated. And so it combines human decisions with computation, for instance in how it generates lots of low-level solutions.

Lets give an example — it's too big a question to simply ask "What are the next 100 years of development going to look like" for a given city. This is too difficult a question. But if a designer can constrain the problem enough with a question like "Okay, out of these ten different urban expansion plans, which one has this-and-this set of properties", then there can be feedback to the designer where they can evaluate their priorities and question them. You know — "Oh, it seems like this particular performance metric isn't going to be possible, or maybe it's not important after all. I'll try a different configuration and then restart the computations." So I think the interaction between the human and the computer is what makes something successful — we should try to build tools that can help a human be more successful, where a human can guide a computer or use its help to find solutions.

DF:

Computationally, what are some of the difficulties you are encountering with these types of problems?

PW:

Well, I think one fundamental obstacle is simply that the problems are very difficult to tackle computationally. There isn't a simple and straightforward way to explore different geometric configurations. Other fields have made certain approaches like convex optimization popular, but this is because the formulation of the problem can be better specified. In urban or spatial computation, the problems are just very difficult.

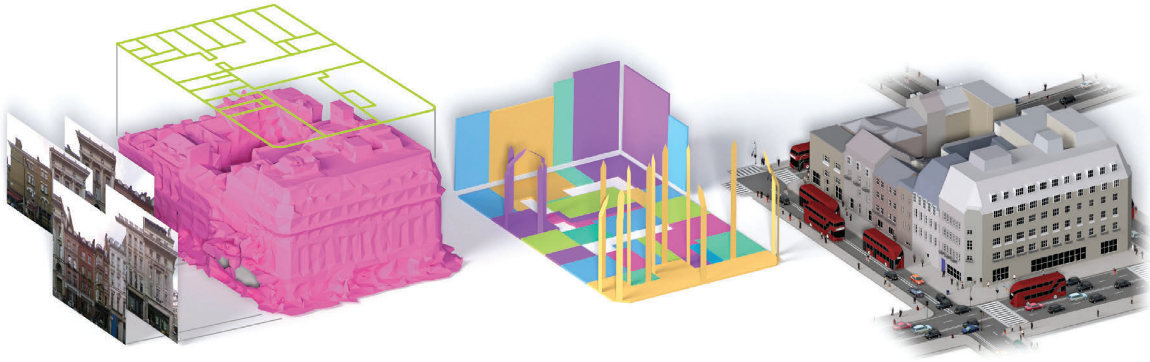
For example, let's say you take an approach using cellular automata. One obvious problem is you must start with a discreet layout; a grid. But in the real world some real layouts have features like a curved street, which cannot be implemented in the cellular automata layout. Even if you discretise the curvature you can end up with alignment problems and the cellular automata might struggle. It throws off the calculations because you build up lots of rounding errors.

So yeah, in general if you restrict all plans to complete axis-aligned boxes, you can generate a relatively simple equation that works nicely. You can even deal with collections of convex and concave shapes as long as they are strictly pre-defined, like "all concave parcels are strictly 'L' shapes". But the real world has such arbitrary things like a parcel that has a hundred sides and some section of it is curved. You know, it gets so complicated.

With something like shape grammars it is good at encoding ways in which I can modify a design. Say I have a building mass, the shape grammar tells me different ways to split it into floors. Or on a given floor, how do I split this into rooms. But the problem is what drives the grammar itself? There are countless solutions that a grammar can generate; most them are nonsense. It becomes a problem of how to optimise the modelling operations and their combinations, which is another tough optimization problem. I think it is hopeless to try to craft a grammar that will only end up in good solutions. My understanding is that actually a shape grammar is too general and it allows too many rules to be applied most of the time. It actually needs a designer to pick some of the more sensible rules out of the many rules. Perhaps what could work is if the shape grammar is augmented with some optimization approach so that out of

"[T]he tools would have to be producing solutions that are actually helpful — that are solving real problems. I think this can come from architects partnering with the computer scientists... which also gets the computer scientists to learn more about what is actually helpful"

- Peter Wonka



Structured Urban Reconstruction: Given street-level imagery, GIS footprints, and a coarse 3D mesh (left), the system formulates a global optimization to automatically fuse these noisy, incomplete, and conflicting data sources to create building footprints (middle: colored horizontal polygons) with profiles (vertical ribbons shown for several footprints) and attached building façades (vertical rectangles). The output encodes a structured urban model (right) including the walls, roof, and associated building elements (e.g., windows, balconies, roof, wall color, etc.)

From Kelly, Tom, John Femiani, Peter Wonka, and Niloy J. Mitra. "BigSUR: large-scale structured urban reconstruction." ACM Transactions on Graphics (TOG) 36, no. 6 (2017): 204.

the billions of billion designs, it's possible that the optimisation picks one that's maybe right.

DF:

In the literature, you see that – in most papers utilising shape grammars the derivation of the grammar is almost manual – they've tried to figure it out by hand. And the implementation of it has been computationally very difficult. Is that a problem where just not enough research has gone into solving their implementation or is there a fundamental issue with how shape grammars have been conceptualised that inhibit their engineering?

PW:

So, in a shape grammar operation, you look for a particular shape to replace with another pre-defined one. A shape is made up of component shapes — lines, segments, regions, and so on. The problem is that there is almost an infinite number of subshapes that could be defined in your operation, and so it is really difficult to specify computationally. The program must recognize and interpret each of those features almost combinatorically.

One strength is that when you craft a shape grammar you can sometimes get very surprising results — like "Wow, I didn't think this design could emerge! I didn't think of that when I wrote down the rules, but here it is!" But of course, most of the time it is nonsense. To specify the actual design rules to achieve some particular set of configurations, this is tough. Most grammars are too general and allow too many rules to be applied most of the time. You actually need a human to sensibly pick which rule to apply out of them all. I haven't seen one that really works. But you, know, maybe someone will come up with it! My impression is that because the programming is so tough, you really need a good software engineer and also someone who really explores all the different ways to specify design rules.

DF:

Are there methods being developed that try to learn from the steps designers take when they

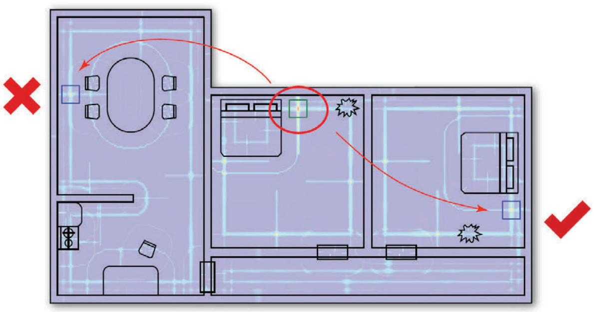
are designing? Coming from an Artificial Intelligence and Machine learning approach, can you encode the particular way you design?

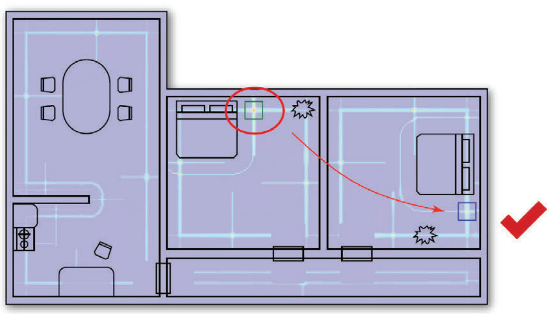
PW:
Yeah, we are attempting this but it is also difficult! The approach we take is that a designer illustrates an 'editing' operation on multiple shapes — parcels, let's say. So you have a concept for an operation — the operation is to split the parcel down the middle. It is trivial for simple shapes like rectangles or maybe 'L's. But what about something crazy like a star with hundreds of sides — going to be difficult right? If we show how a human designer did this for 20, 50 shapes to a computer, it can learn the pattern and apply it to another arbitrary shape. We are doing this now, but one problem we come to is that it is not robust. It will fail in several cases. So this could be a problem when we are talking about the requirements of urban or architectural design, or for a client who wants it to work all the time. If they have to fix the 20 percent that failed, it might take as much time as just doing everything from scratch!

There are more success stories with computer vision from something like character recognition, but they key thing to remember is that the input space is very constrained — you can tell the program that whatever it sees is definitely going to be some letter from the alphabet...

DF:
What is making it difficult to apply Machine Learning to geometry and design problems?

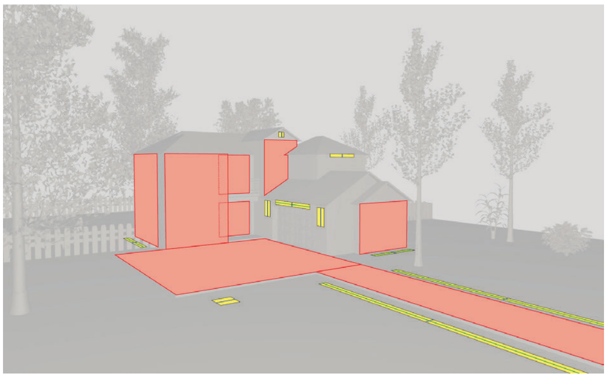
PW:
The thing you need for this to be really successful is the amount of training data, and this is a key difference between design fields and others. Let's say you are an architect and I tell you, "Hey! My neural-network is going to learn how you create a massing model on this parcel". You would say "Great!" "Unfortunately, I need you to give me 100,000 examples of your work" — you'd say "That's crazy, it will take too long, I can't even generate 1,000 designs!" The question is how can we access both all the information on existing designs, and also how can we rank them. You

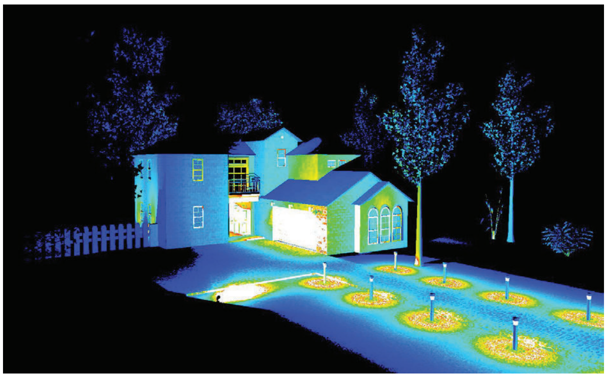




Propagating edit operations in floor plans, based on geometric relationship functions. These functions quantify the geometric relationships, such as the distance to the boundary or the direction to the closest corner vertex. Machine-learning techniques rely on labels to provide additional information about objects in a scene — relationships often depend on the semantics of objects in addition to their geometric relationship. For example, a night table is usually found next to a bed and not in the living room.

From Guerrero, Paul, Stefan Jeschke, Michael Wimmer, and Peter Wonka. 2014. "Edit Propagation Using Geometric Relationship Functions." ACM Transactions on Graphics (TOG) 33 (2). ACM: 15.





Automating lighting design: A building model is augmented by a procedural lighting design specification that expresses the desired lighting in terms of lighting goals, luminaire installation sites and constraints (top). The system generates an according lighting solution to suit (middle). The solution is rendered at bottom.

From Schwarz, Michael, and Peter Wonka. "Procedural design of exterior lighting for buildings with complex constraints." ACM Transactions on Graphics (TOG) 33, no. 5 (2014): 166.

know — which of them are good or bad? I don't think we can ever bypass this phase of training the model. We will have to somehow perform this evaluation, perhaps on computer-generated designs that are scored by humans, or by matching them to other sources of data.

DF:

Historically, the approaches to computer-assisted generation of urban design has been split between the ones that are catering for gaming or virtual environments — essentially fictional 'urban-like' environments, versus the ones that are attempting to model real-world cities and urban planning problems. Why do you think there has been this split, and are the approaches growing further apart or closer together?

PW:

I think that gaming & synthetic approach has been more successful because in some sense it's easier — you can do a lot more 'cheating and faking' you know? You can just focus on visual style without it needing to be realistic. And I think that makes it an easier problem and that makes it much more successful because the solutions that are here are adequate for the industry. There's a clear market for it and there's people paying money for it. Conferences like SIGGRAPH bring together computer scientists and video artists from major companies that create the modelling software, so there's a pretty good dialog there.

I don't really see these two branches merging in the future, and this was part of my decision to try to switch from entertainment-based problems to go more towards architecture and planning. Because I think there are more difficult problems and it's much more important. I mean, I do both types of projects so when I learn something in one type of project I can apply it in the other, but while there's a lot of possible synergies, there are also some big issues. I think one fundamental issue from the planning side is probably the financial model. What it needs essentially, is people paying for the software development. I don't really see much potential for programmers to work directly with architects but rather with a company that creates planning software that is bought by lots of architects.

I think the successful path forward is for architects and planners to specify the functionality of the tools they want, but a problem is that a lot of architects are too philosophical — they come with all these ideas but they aren't specified enough for us — we cannot translate them into our technical language. We would need to work hand-in-hand where they say, for instance, "floor-area ratio is really important, and I'd like a tool that maximises it while maintaining some other constraint, say the width of the building, or solar access" and so on. The architect can establish this link between the objectives of the system and some of the processes, but at the same time it needs to be achievable. There are some designers out there who have enough understanding of the technology, but not enough yet.

DF:

Where do you see the field's future? And what are influences that are driving it? For example, will it be driven by urban planning and real estate industries? Or perhaps more by tech companies with self-driving cars and sophisticated mapping? Or is there an intersection between these industries somehow?

PW:

Well this is a difficult question. Personally, I think something like self-driving cars are incredibly interesting. But, in the shorter term, I think success can come from people tackling doable problems, which are also lucrative enough to generate funding. Of course the tools would have to be producing solutions that are actually helpful — that are solving real problems. I think this can come from architects partnering with the computer scientists instead of trying to do it themselves, which also gets the computer scientists to learn more about what is actually helpful. It probably also needs a company or a start-up to implement this and distribute these tools on a large scale. And of course fundamentally what is really required is a larger user base. It can't be a one-time thing kind of problem, like the acoustics in a single concert hall — you create some complex simulation and analysis, you put in a lot of work, but then you move on. The large user base all have to have somewhat similar problems that need to be solved.

7

The Practice of Urban Computation:

A conversation with Christian Derix

Dr Christian Derix founded the first 'Computational Design' group in architectural industry and is a global leader in smart planning with 20 years experience of academic and professional research at the nexus of space planning with generative design, big data & machine learning.

He is the director of SUPERSPACE, Woods Bagot's design research group, which draws on the understanding of human experience using bespoke analytics to greatly enhance design outcomes. His focus is on embedding design computation into practice through pioneering artificial intelligence, artificial life and cognitive science in live design projects.

Prior to Woods Bagot, Christian founded the Computational Design Research group (CDR) of Aedas in 2004. He holds a PhD from TU Vienna and has taught at universities across Europe, is currently supervising architectural diploma theses at the University College London (UCL) and has been a visiting professor at TU Munich, and the University of Sheffield, UK.

DF:

Why were you first interested in using computation for urban design? Specifically for the creative aspects of design rather than just analysis?

CD:

Well, I'd start at the University of East Anglia with Paul Coates and the Centre for Evolutionary Architecture, where we were doing studies on spatial phenomena. Having lived in so many cities, I always liked drifting — Debord's derive — and I was very interested in the Situationists, who used drifting as a method. So my first project in '99 was a Self-Organizing Feature Map, or SOM, which was about having a machine drift through the city, and having it represent the city for me. It was again like a surrealist method of not using your own perception, but somebody seeing the city through somebody else's perception. So that was the first project I did, and it led to my MSc which was also on Self-Organizing Feature Maps and spatial and urban pattern recognition. But I wouldn't say that was design related. That was neither design nor analysis. It was just meant to create a new representation of the city, like surrealists tried to, with this new device. So that's how it started in the urban realm.

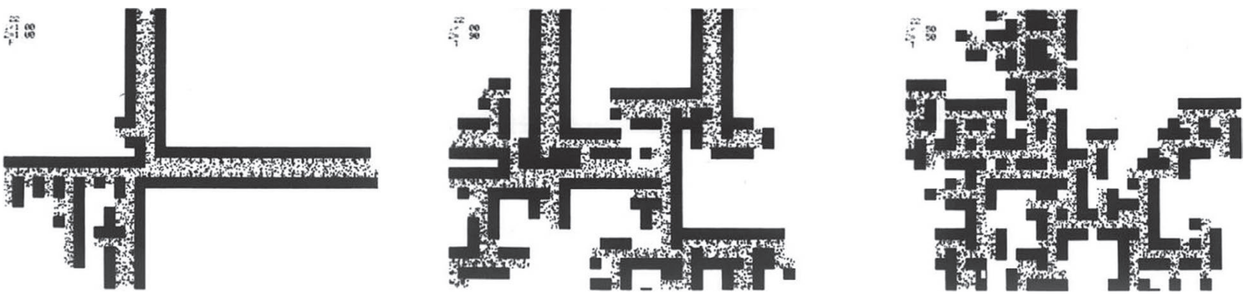
DF:

Was there anything specifically about computation that was required, or attractive?

CD:

When I was discussing my research objectives with tutors it was luckily presented as a thinking aid, rather than just a design aid, and that intrigued me. When I saw some of the work on agent-based design, initially I thought that could be very helpful. Like the Situationists' drift through the city, agents could possibly help us understand the city through different means, with other rules. And that's how it all started; to connect up agent-based modelling with urban conditions.

Then, in 2004 I went back to Politecnico di Milano to teach urban design strategy in the Master's degree. And there I did this design system for New Urbanism — looking at types of massing, types of pedestrian behaviours, densities, transport systems, and how they interact — which transport system due to which densities and so on. That was sort of the first "all-out" multi-dimensional urban design simulation that I did. From there I realised then that you can actually link it with regulation. And you can tie regulation with jobs & occupations through computing to create a system. I think that was one of the first times in urban design to mix together agent-based modelling with cellular automata and graph theory, where all three worked together in three different levels, and reinforced each other with feedback between them. I'd say that was getting to the design part more from a planner's perspective rather than an artist's or architect's perspective.



Global structures resembling permeable urban settlements emerge from Coates's first algorithmic simulation of Bill Hillier's syntax 3, with different clustering ratios. The aggregation takes information from existing field conditions to add cells locally.

From Derix, Christian. 2014. "The Space of People in Computation." Architectural Design 84 (5). John Wiley & Sons, Ltd: 14–23

"[Computation] was luckily presented as a thinking aid, rather than just a design aid, and that intrigued me. When I saw some of the work on agent-based design, initially I thought that could be very helpful. Like the Situationists' drift through the city, agents could possibly help us understand the city through different means, with other rules.

- Christian Derix

DF:

How would you characterize the difference in looking at the city from the statutory planning perspective than your original inspiration in the derive and the Situationists?

CD:

Well, I was still trying to understand the city, and I wanted to see how much those self-organising processes are constrained by regulation and vice versa. So I still set the model up in such a way that where lot of agents met, they would build something, and where a lot of them met again, they would reinforce the massing, etc. So, a very self-organised approach to the model, constrained by some regulatory framework. And the interesting thing was then to see how streets could emerge, so would Aldo Rossi's idea of genius loci be recognizable?

DF:

So you were trying to test the algorithms on how representative they were of real world structures and outcomes?

CD:

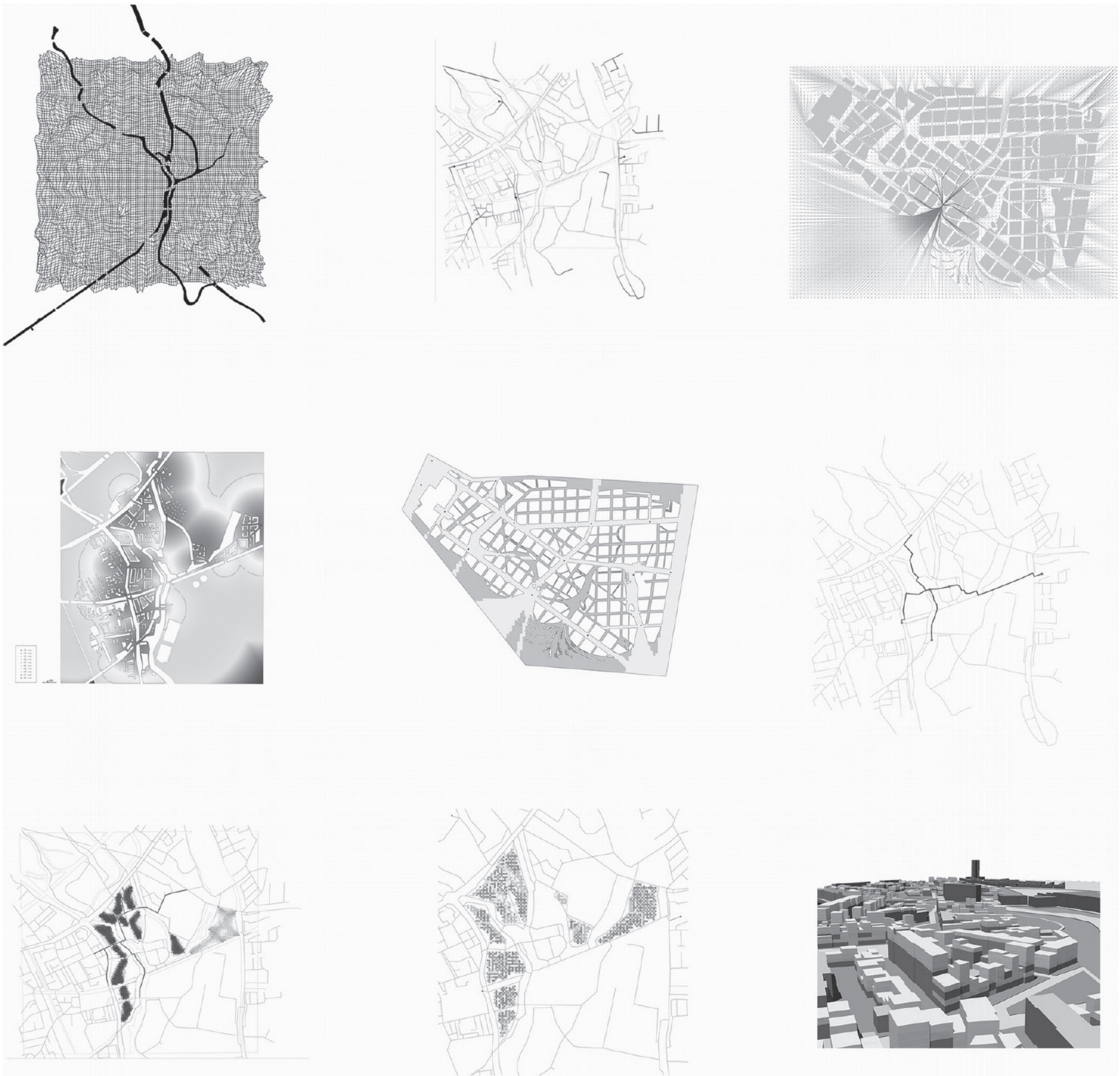
Yeah. Urban phenomena. And then how much we may be constraining the outcome through regulatory framework, or how much the regulatory framework actually produces the outcome itself?

DF:

What do you think the effect is of having of these new technologies? Are they changing the way you are looking at the city, or you're designing for the city?

CD:

I mean, I was very shocked in 2009 when we worked on the Masdar Zero-Carbon City Masterplan. I was surprised to see that Foster's had drawn this whole thing by hand. To me it looked like a quintessential cellular-automata model of the city — it looked exactly like that. I was very surprised that this was drawn by hand, because it wasn't refined and detailed at all — it was essentially just a block model with a human scale — and it was actually beautiful in that sense, but not at all as sophisticated in the way it was produced and marketed.



We realised designing cities through these kind of systems makes a lot sense, but the unfortunate effect at moment is 'feature-creep' — perhaps CityEngine is an example, where we design from the city network to the kerb in one second, one button-push. But of course this doesn't make any sense for planners or urban designers.

A matrix of applications produced for SSSP by the Computational Design Research team of Aedas|R&D. These include Accessibility simulation, Urban structure simulations, and Block assembly.

From Derix, Christian. 2012. "Digital Masterplanning: Computing Urban Design." Proceedings of the ICE - Urban Design and Planning 165 (4): 203–17.

But that did reinvigorate interest, and so we began the Smart Solution for Spatial Planning (SSSP) Project, where we started to build these multi-level simulations where you could move up and down the scales, so to speak. And we tried to break down the usually-perceived effect that 'everything can be automated now' to what we call semi-automated urban planning.

DF:

This is design-assistance rather than a black box?

CD:

Yeah. But at stages where it's partially assistive, and others where it's its own driver. There's times that the computation does it itself because it probably does it better than a designer — like say, land use distributions due to conditional constraints. You can have a very productive initial stab at this through a good model, and then you refine it. A computer is not as good as refining it, so it becomes a collaborative stage.

Nowadays, the solutions for the stages can be very-well made — the individual pieces, if you like. But there's again the thinking that everything should be integrated, that you just push a button and it all comes out correct. I think this is a red-herring, but in some parts of the world it is creating an effect, a misunderstanding of what urban design is, and we are forgetting how to design places or cities properly because there is a concept that as long as you have all the inputs — the ingredients, you can weigh them, and press a button. That could be a real problem. I haven't seen this exactly because we are not that far along yet, but it's a potential.

DF:

Do you have a vision of what you'd like the field to produce in terms of its effects on city design?

CD:

Yeah. My desire for it is that it becomes a 'civic defence' mechanism.

DF:

What do you mean by that?

CD:

So, my experience is that in places that are quote-unquote developing countries like Malaysia, and what have you, the 'Western style' of urban design and masterplanning that has been implemented there completely ruins the place. It's really unbelievable. Even at home, like in Adelaide, all the newer, bigger buildings ruin the old fabric of the city. What is definitely possible is to make much more succinct decisions on how a design fits into what we plan, how it fits into the city and enhances the city, rather than destroy it as we do currently.

"[A]s long as we're treating masterplans as an investment opportunity rather than a place, that won't change, no matter how sophisticated your methodologies are"

- Christian Derix

DF:

Would you say that architects and urban designers do not have enough agency and power to 're-value', or insert into our current value-systems, those design decisions that balance or overcome forces (like economic or financial constraints) that effect poor design outcomes?

CD:

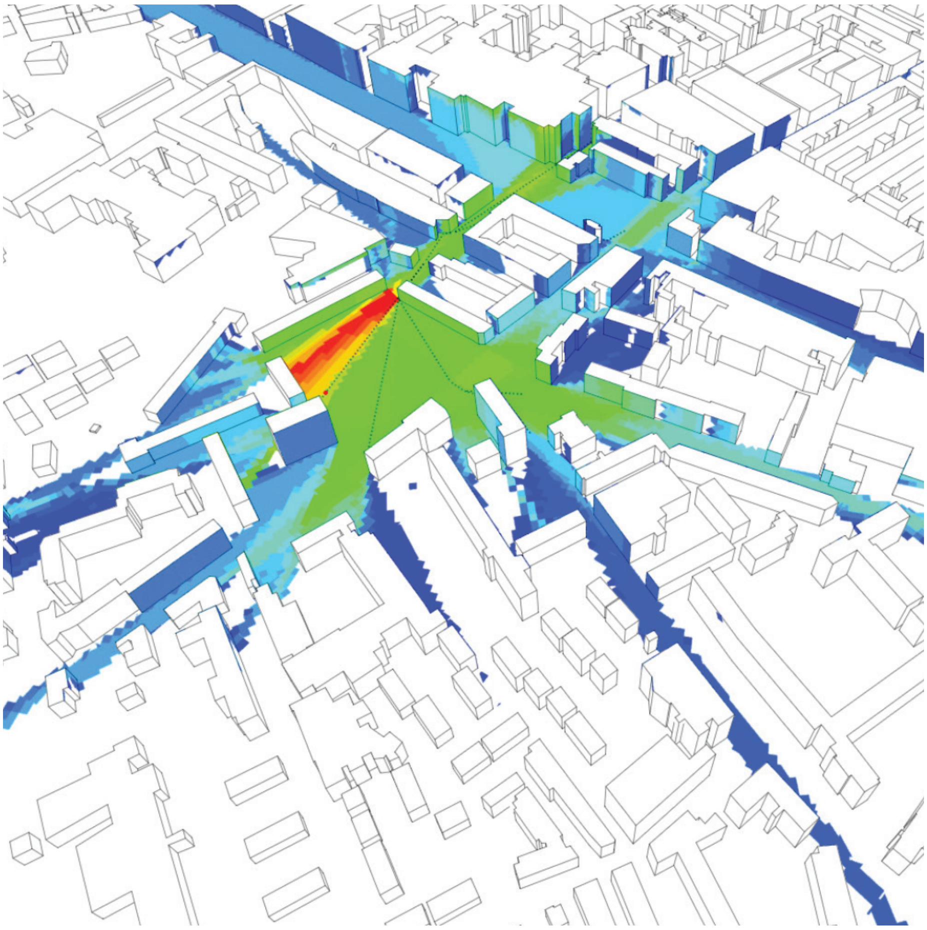
Yeah, and I believe it stems from culture — it's a political and cultural problem. It's not necessarily something we can change from the bottom up so much, because the design methodologies have always been available. To design sustainable and resilient, good public spaces, right? But at the moment, the emphasis is on the speed and return of investment for a masterplan, and that these values don't play a role in terms of resale value. So that's the issue; as long as we're treating masterplans as an investment opportunity rather than a place, that won't change, no matter how sophisticated your methodologies are.

DF:

So in that light, perhaps the latest work that you're doing as being in some way quantifying, or in some way being able to communicate computationally, the value of place? Is the strategy to utilise the work as a 'design argument' with clients and the public?

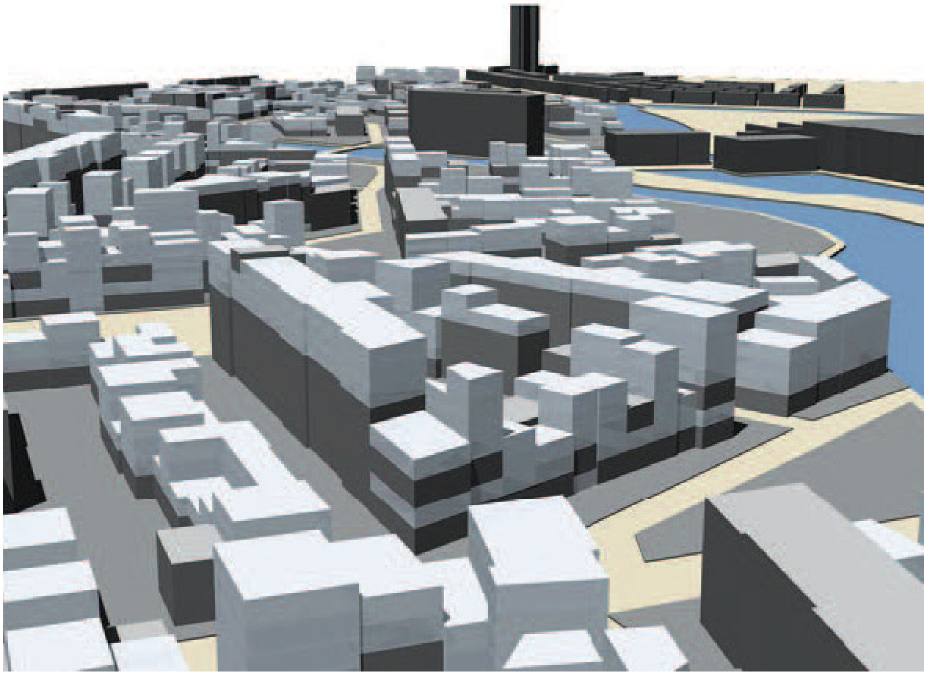
CD:

Definitely — we have a whole range of value-generating or value-revealing methodologies. But



Route visibility: 3D mapping of visibility along access routes for CrossRail Whitechapel station. The dynamic visibility mapping was used to validate the entrance scenarios in relationship to crossing locations, part of a simulation of 'desire lines' that inform land-use allocation, street widths and crossing locations.

From Derix, Christian. 2012. "Digital Masterplanning: Computing Urban Design." Proceedings of the ICE - Urban Design and Planning 165 (4): 203–17.



Below: A massing scenario on site from the Pareto Optimization as a result of the application of the complete SSSP matrix. A Pareto front contains solutions where parameters are not improving at each others expense and thus produce a well-balanced compromise between apparently contradicting performance criteria

From Derix, Christian. 2009. "In-Between Architecture Computation." International Journal of Architectural Computing 07 (04): 565–86.

the frustration is that even though we have them, they're not interesting to developers because they know that again in turn, those methodologies won't necessarily correspond to extra income, even if they adopt those values.

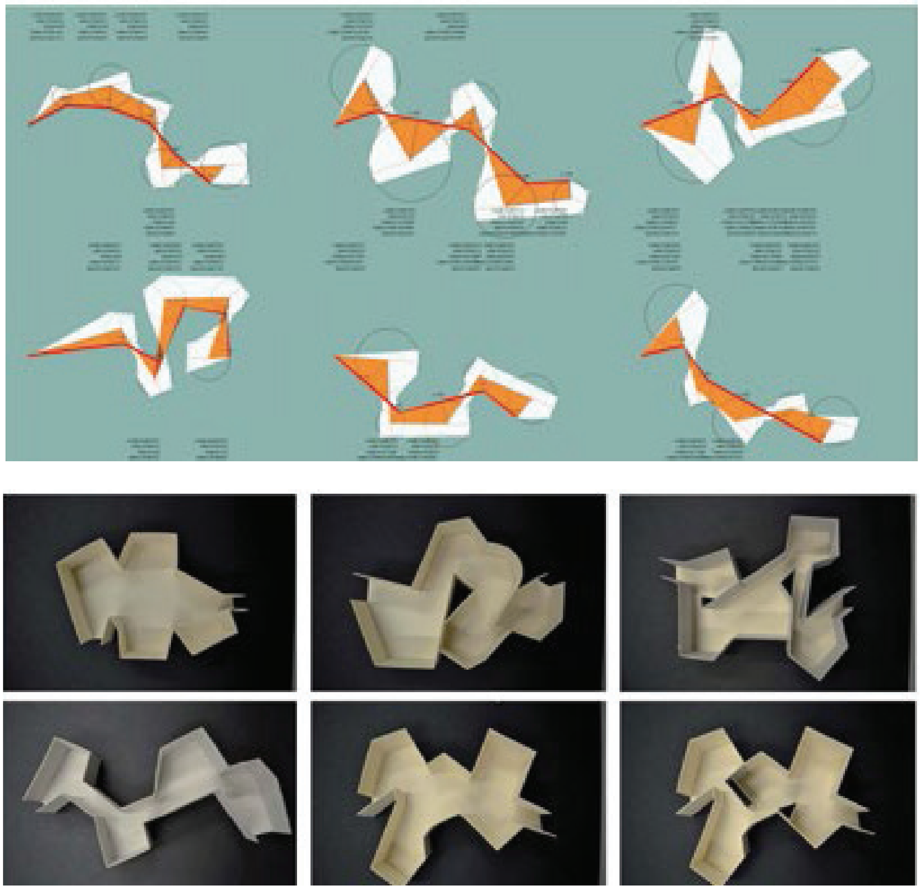
But my interest is that as long as you don't change your attitude towards these values of good city-making, it doesn't matter if they are explicit or not. So — we could just say we build them in by default — "We're going to produce the most efficient, profit-generating masterplan with these values built in". Of course, people will bark that you wasted time on building them in, in the first place. So you have to kind of do it by stealth, I suppose. I mean there was a time like this in UK. At the end of the mid-90s when CABE (Commission for Architecture and the Built Environment) was the instituted, it was emblematic of a drive towards improving planning, towards good public space. And now it's being dismantled again. It's because there has been a cultural shift. So I wouldn't say it is necessitated by whether you have or don't have the methods. It's more about this political-social atmosphere.

DF:

Given that you have been bridging between the worlds of academia and practice for 15 or so years, how would you characterise the field of computation in urban design at the moment? How is the relationship between research and the profession? What is showing the most prominence, and what needs more attention and development?

CD:

It's become really fast recently, I find. For a long time it was quite dormant — it took forever. It was only in 2010-2012 when we published the SSSP, and I called the topic 'computational master planning'. There were some approaches like CityEngine and a couple of others oriented towards more gaming and virtual-world-building, but not focused on actual design. It was only a theory, sort of like space syntax. Paul Waddell



Henry Zimmerman, Takahiro Ishihara, Miguel Izaguirre and Matthew Deutrom, Grammar of Transitions, Technical University of Munich, 2011–12: Three types of media informing each other: Top: mapping of movement-to-space behaviours in a generative computer model developed by students. Bottom: scale models exploring spatial properties from generated compositions.

Derix, Christian, and Åsmund Izaki. 2014. "New Curricula: Syntonic Systems." Architectural Design 84 (5). John Wiley & Sons, Ltd: 122–29.

and his group also had some experiments, but I'd say there was nothing much out there. And all of a sudden now with these visual programming interfaces (Grasshopper and Dynamo), everybody is doing a bit. And of course it's exploding in all directions, not just in urban design.

One thing I see is that it originates from this sort of, very 'hard-nosed' positivistic design paradigm — we "do what we see", or we "do what we need". (And even academia is falling prey to that, with Big Data and mapping whatever we can map). So it is all to help you to generate designs that are efficient and easy to produce. But there's very little in between — there is very little 'creative computing'. Computing seems to have been taken over by the professional outlook, whereas in the '90s there was a more creative and philosophical outlook. We're now thinking that it's so mainstream, it has to be used professionally and efficiently. And so, often it doesn't have as much of the 'poetry' around it that you would hope for, where you could search for new conditions and different phenomena that could be uncovered and designed for, and so ascribed value. I am hopeful that you could theoretically uncover a whole new set of complexities nowadays. You could. And it could produce a lot of benefits.

DF:

What is going through your mind when you say something like that?

CD:

If you start from mapping huge quantities of data, mapping their relations, and understanding the complex relations between quantities and drivers, that would be very, very useful. The question, as always, is how is it going to be used — is it going to be made into a mundane optimisation or efficiency tool, or is it actually to be used by the planning body?

When we worked on this SSSP in '07-08, city planners said "This is fantastic. We'd love to have this in order to do due diligence and assess developers' masterplans, because we always suspect there is more potential public benefit to be drawn out from the plans. So this would infinitely help us, but unfortunately we don't have the budget to train someone and buy a license". So, a very simple message: they'd love to have this because they know that using this can make their cities better, but they can't afford it. So the question again is how planners can get involved. For example, those on the non-profit generating side could use these methodologies to do something positive that's not just increasing profit margins, FSRs, or whatever. That'd be fantastic, and there would be a lot of scope.

DF:

One thing I feel is consistently brought up in the discussions I've been having, is that the tools being built are bespoke solutions to particular problems, and because of this their rationale and their application is actually very political. Their intended user-group and their development funding has a clear political component. Does this mean there needs to be more governmental or non-profit involvement in the field?

"[Design Computing] often doesn't have as much of the 'poetry' around it that you would hope for, where you could search for new conditions and different phenomena that could be uncovered and designed for, and so ascribed value. I am hopeful that you could theoretically uncover a whole new set of complexities nowadays, and they could produce a lot of benefits"

- Christian Derix

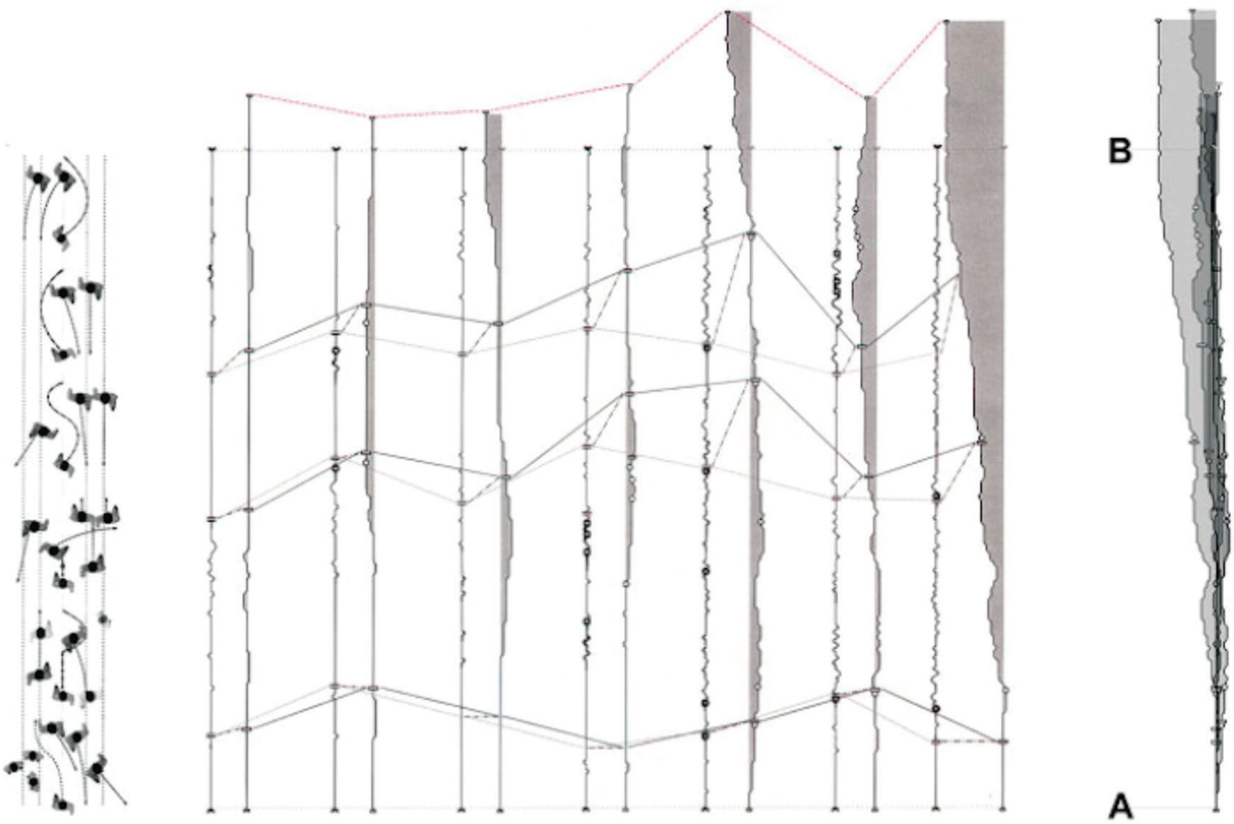
CD:

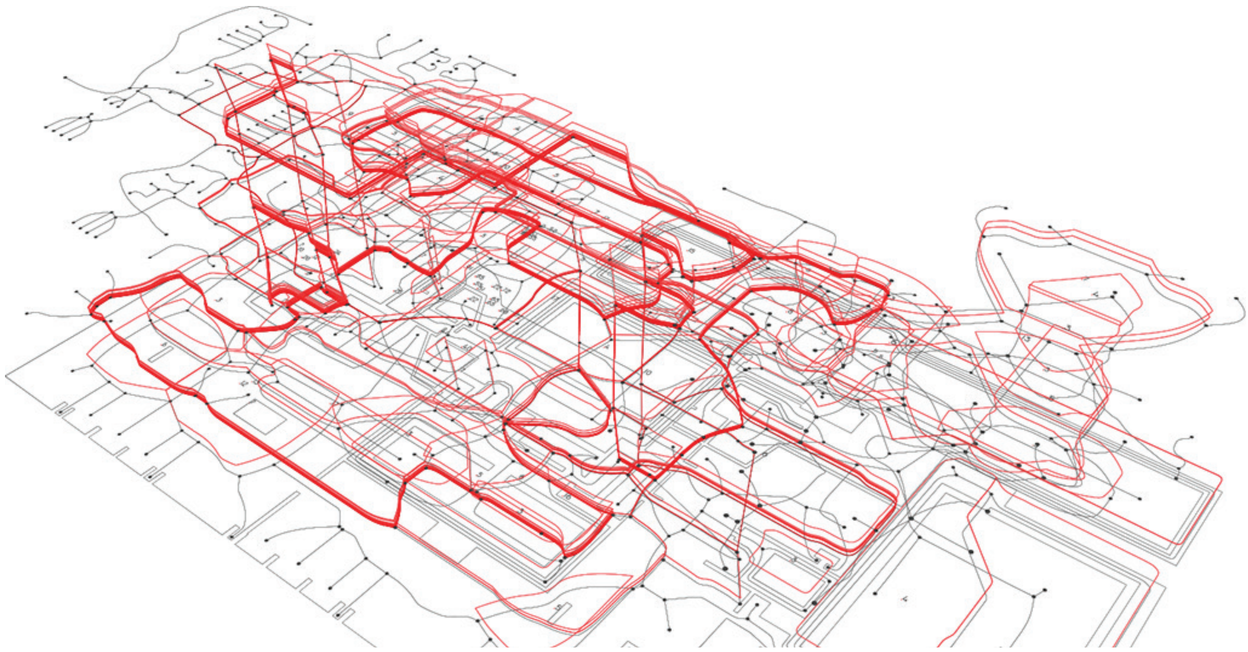
Take Singapore for example. By now, everybody's aware that Singapore wants to develop its own planning simulation system. Other cities have let's say a 'document-based' planning system, Singapore wants to have it all simulated, or 'computed', so to speak. They don't want to rely on consultants; they want to do it themselves. They want to build the first complete city planning simulation, where they can feed in whatever change they want, and then see how it affects the city. So Singapore is one city that actually tries to take control of development itself, and then try to suggest what would be good.

And this brings up that question of who fundamentally benefits — with Singapore the land owner and the city are the same hand, so they will be able to rigorously assess a masterplan from a developer, determine what is good, and then implement it for themselves. So this is a very interesting condition. I've wondered about this

Christian Derix, Walking Maps, Centre for Evolutionary Computing in Architecture (CECA), University of East London, 1999. Left: Key to movement of subject in centre. Centre: Seven walks through the same environment showing different durations and deviations from assumed fixed gates. Right: Superimposition of actual walking behaviours.

From Derix, Christian, and Prarthana Jagannath. 2014. "Near Futures: Associative Archetypes." Architectural Design 84 (5). John Wiley & Sons, Ltd: 130–35.





Aedas|R&D CDR: Movement structure and spatial affordance, 2013: Graph analysis of an old bank building revealing different properties of permeability. Using medial axis transformations allows the designer to access otherwise intuitive qualities of space, such as 'spaciousness', due to the connectivity of rooms or choice of movement.

From Derix, Christian. 2014. "The Space of People in Computation." Architectural Design 84 (5). John Wiley & Sons, Ltd: 14–23.

mismatch when it comes to more conventional arrangements with developers and major architects working on masterplans. You would think theoretically there is a mutual alignment but in reality the benefit for an architecture firm to do a masterplan is to be the project architect on the buildings that come from it; it's just the way the design fees are structured.

I also see this in the non-profit, academic side. The material I see from universities is mostly going down the same route of trying to develop very efficient masterplanning tools, rather than grappling with the political-economic dimension.

For example, with CityEngine that came out of ETH-Zurich, while it is being utilized more as a game-environment generator, it is also being marketed as a sort of 'quick masterplanning' tool. Perhaps similarly with Paul Waddell and Synthicity — to be able to quickly assess the viability of planning decisions and investments. It's quite remarkable that everything seems to be going towards this direction, and there isn't a strong alternative in the field. In university this happens too with computing — when you think about 'analogue' practice, there is plenty of alternative urban design thinking and approaches, but not with computing practice, because computing is always categorised as the 'big number cruncher', as I wrote in the AD special on design computation [Empathic Space: The Computation of Human-Centric Architecture]. And number-crunching is immediately mistaken for 'objective quantification towards optimization', and people don't think outside that box very much.

DF:

So if you were to riff on that a little bit, let's say you were given the opportunity to assemble a team that would work towards this alternate conception of urban computing. Who would compose that team?

CD:

Yeah. I mean when we did the SSSP project. We put together a team of government planners, computational designers, architects, urban planners, consultants, geographers. So we put together a very diverse team of people — mixed stakeholders, and we also had a development site. Which meant it was not a question of purely "What's most interesting here economically?", but rather a questioning of how can you mix economics with good urban design, with principles that are not necessarily perceived to be valuable economically.

To come back to your question about my experience now in academia and practice, in practice we're meant to produce economically viable research. But when I go back to academia, I'm always very happy and keen to do something that's economically not viable. Because if you don't try that, you're not going to find anything new and interesting. That's basically my criticism — what I see at the moment in academia is that it is trying to replicate what we do in practice, or trying to appeal to the same target market, which is bizarre.

So therefore, if I wrote a paper, and somebody from ETH or UCL wrote a paper, they will almost sound exactly the same, which is crazy because they should sound very different, or they should look very different, or the target content should be very different. Either it's us; we're doing too much academic research and practice, or I think (at this current moment) academia is trying to do too much professional research (or apparent professional research without often having the project context). So it's interesting, it's very difficult sometimes to collaborate on this work.

DF:

What was the result at the end of the SSSP Project? How would you characterise it and any findings after this period of intensive practical research?

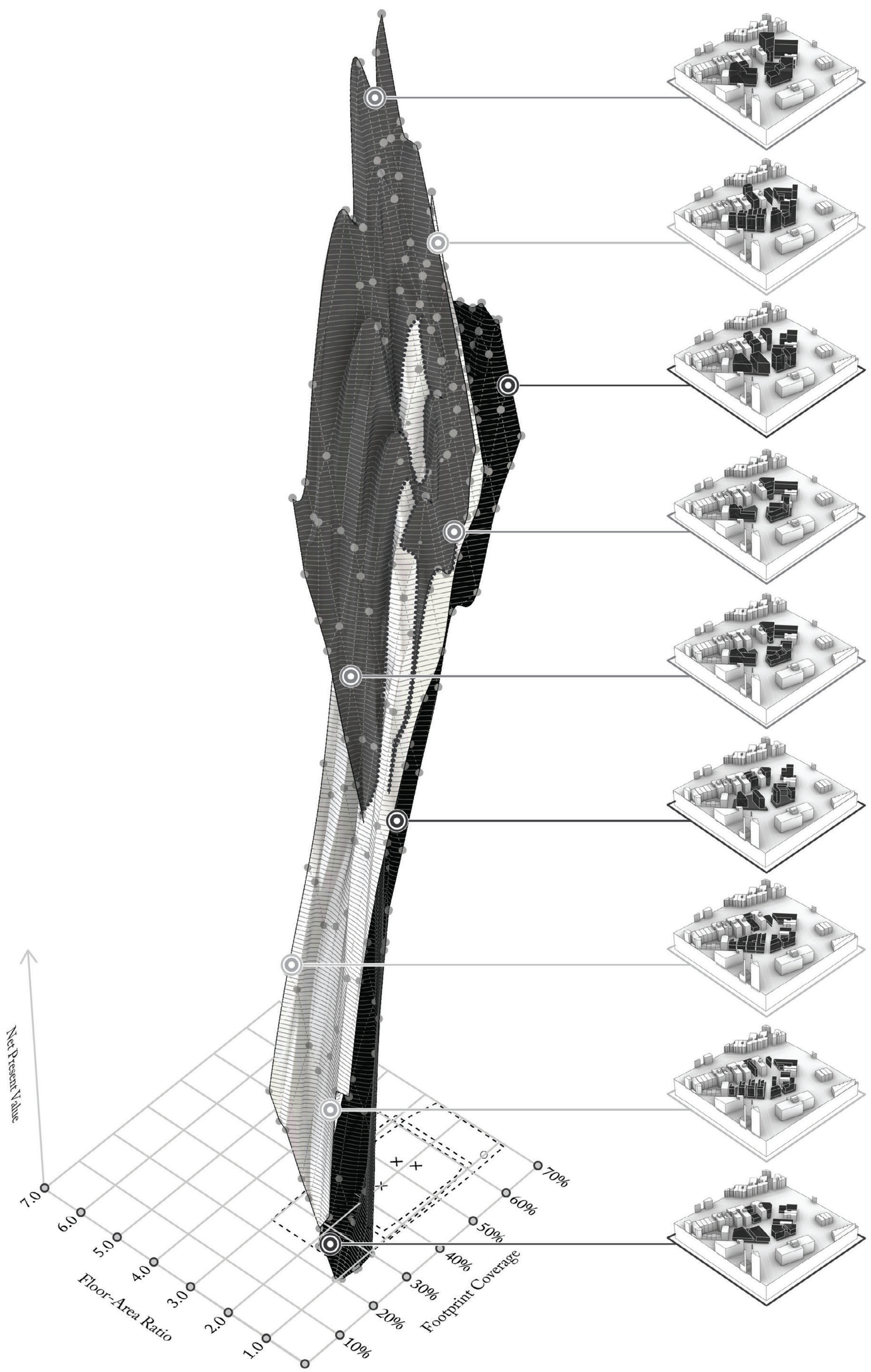
CD:

Well, after the SSSP, it led to two different types of results.

On one hand, we had internal, practical new developments, and new areas of work. For example, immediately after 2009 we were commissioned by TFL (Transport for London) to perform urban impact analysis on some CrossRail stations. They said they'd never done it before, but with this new material we could do it. It was literally urban impact, so that was good — they were saying, "We're not interested in doing our stations more efficiently but rather understanding how station design impacts on the neighbourhood."

And on the other hand, it triggered a whole series of academic research which found its way into publications like the ICE, and at ETH, Springer Books. These publications were used by the guys over in Portgual for some frameworks. A whole set of universities used them for research foundations.

So, it triggered all of that, and maybe the reason why it triggered both practical as well as academic research and new developments was because it was in the first place built around this mixed stakeholder group. We could all see a value in that, rather than saying it was just developers, or just academics. That was quite fruitful in that respect.


Net Present Value
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Floor-Area Ratio
70%
60%
50%
40%
30%
20%
10%
Footprint Coverage

8

Computation for Co-development:

A speculation

In order to speculate on potential outcomes from mass accessibility to the kinds of urban data, and design computation highlighted in the interviews and research above, I draw on my thesis, "Linking Design to Finance: Enabling a Co-Operative Developer Platform through Automated Design and Valuation" (2017), produced during my SMArchS degree at MIT. The thesis hypothesizes that with the widespread adoption of these kinds of technologies, clusters of households will use them to provide the opportunity to collectively originate, fund, and construct their own networks of mutually co-dependent developments.

This vision follows on from well-precedented projects of co-operative development. Utopias fomented into reality in the form of kibbutzim, co-operative housing, communities of New Urbanism, and even loosely into closed gated communities of suburbia. In more recent times, co-operative spaces have moved into other programs with the rise of co-working, co-retail and maker spaces. These nascent precedents being implemented around the world justify their programmatic exploration in this project.

Furthermore, there is some recent academic precedent: David Birge's thesis on the potential for automization technologies to underlay a new narrative for the middle-class culminated in co-operative and integrated communities predicated on co-production and co-habitation (Birge, 2015).

However, we can also draw inspiration from innovation theory in economics; specifically the concept of 'creative destruction' most readily identified with Joseph Schumpeter. Its lineage in Marx and Engels' arguments first asserted that destructive-constructive capabilities of capitalism recurred in market crises (Marx and Engels, 1848). Schumpeter's investigations of business cycles led him to specify that these crises were driven by technological innovation, where entrepreneurial activity that developed new markets, processes and products fueled waves of economic shifts that toppled previous supply chains and market

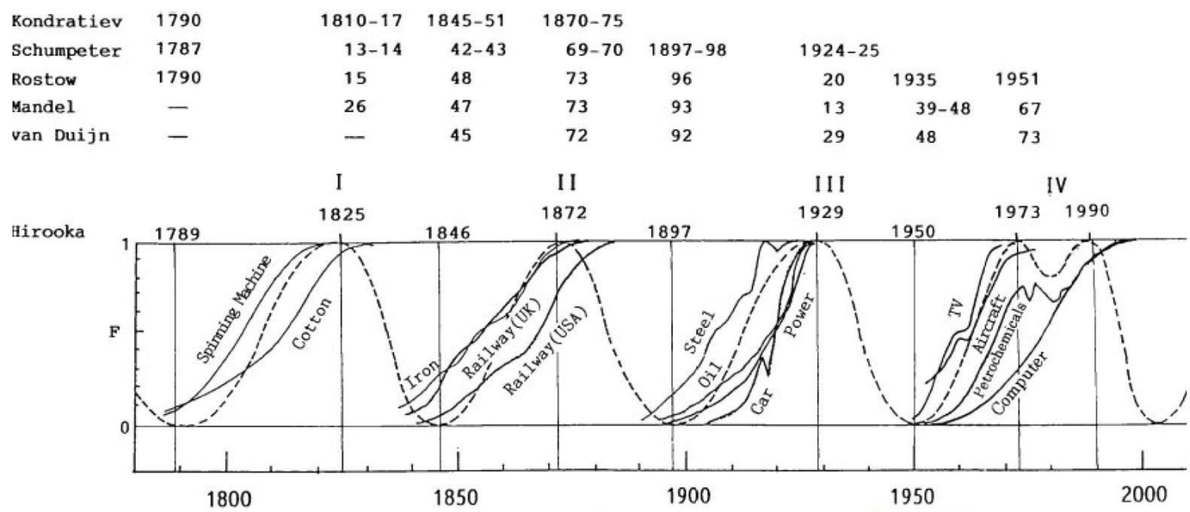


Fig. 6. Kondratiev's business cycles and diffusion of innovations; — Diffusion of innovation products, – – – Kondratiev's business cycles

Above: Documenting the timing of waves of innovation across thirteen different emerging technologies and five different cycle speeds. This curve demonstrates the rise and fall of all technologies as they become commonplace and mainstream in society.

From Hirooka, Masaaki. "Nonlinear dynamism of innovation and business cycles." In Entrepreneurships, the new economy and public policy, pp. 289-316. Springer Berlin Heidelberg, 2005.

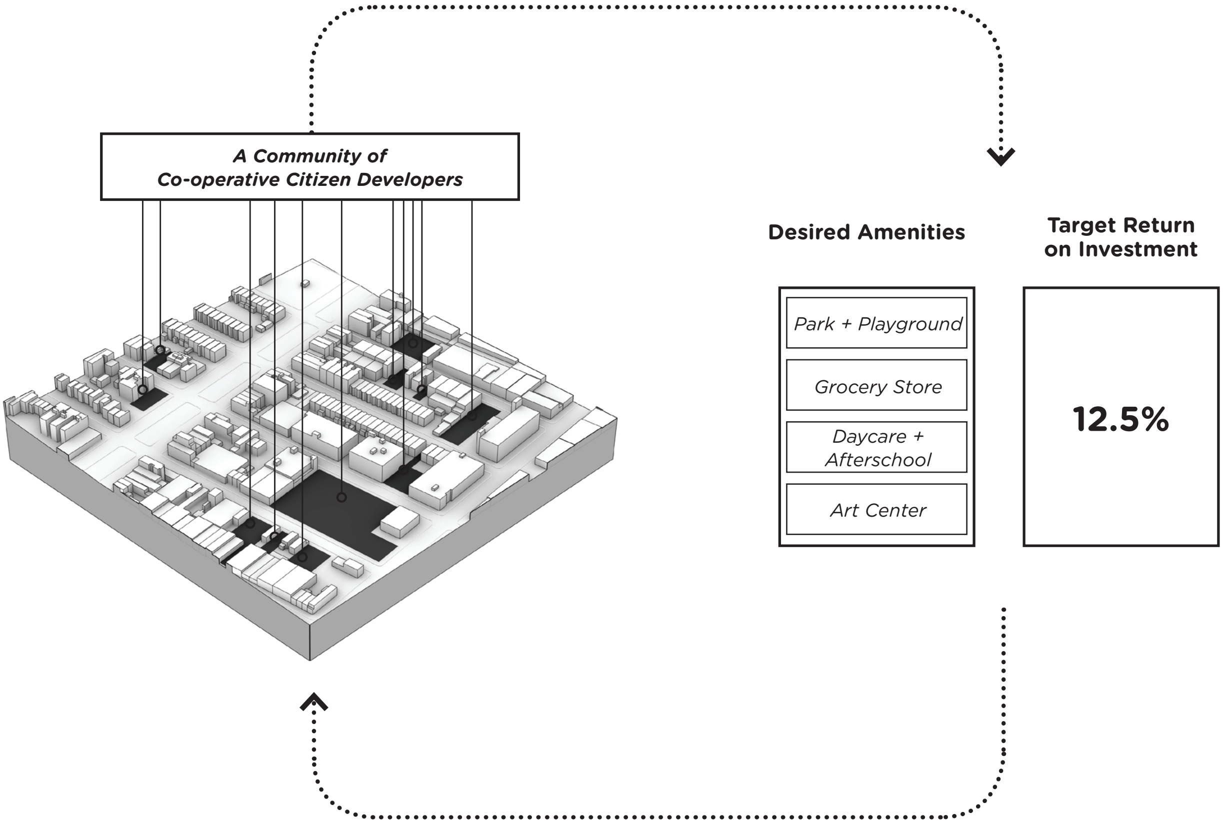
structures, and erected new organizations in their place (Schumpeter, 1942).

Critically, the communications theorist Everett Rogers proposed that a critical component of the creative-destruction cycle is the diffusion of innovations through society (Rogers, 1962), and identified the social and technical stages a technological innovation must progress through on its journey to community-wide adoption.

Seen from this perspective, the unique, specialized skills and knowledge required to perform urban development are a domain undergoing rapid change. No longer are 'gut feelings' for the feasibility of a development proposal, or the cultivated friendships that grease political machinations, a prerequisite to understand or realize real estate development. Instead, the torrents of urban data and analytics that clarify trends, constraints, and opportunities are overlaying and replacing human-learned experience with machine-learned findings. Automation of rote design practices are enabling specialists to spend more time on complex projects and questions, but also providing new accessibility for laypeople to access insights about urban design and development that previously required training and experience.

While typical examples of similar processes demonstrate dramatically reduced costs associated with innovations in products (a Gutenberg printing press is now effectively a cheap desktop printer, or CAD software for the aerospace simulation is now Sketchup), there is a significant difference with development projects: the cost of land, which follows almost inelastic supply curves, since it is impossible to create more of it (save for reclamation). The inability to treat land as a commodifiable and fungible good means that land prices reflect fundamental costs for the production of goods due to their location, and cannot be reduced unless there are shifts in entire demand and supply chains. Since these chains are embodied in complex networks of trade and production between cities across the globe, land prices are inherently stable, and for locations with large demand — expensive.

Since land prices will not foreseeable be reduced to the point where individuals will be able to purchase locations and real estate products in high-demand areas, new technologies that enable easier and more secure pooling of funds may provide the ability for collections of interested parties — individuals, households, and organizations, to collectively draw resources that enable them to satisfy urban development needs that could not necessarily be attained independently. These mechanisms — currently in early-stage deployment — are termed 'crowd-funding' or 'crowd-sourcing' and serve to co-organize capital and information into a synthesized source. In this way a community of shared creators have incentives to contribute knowledge, activities, commerce and capital to create a collective community.



Above: A design project implementing an optimization method to match suites of sites, project-massings, and financing arrangements, which demonstrates the ability for the inhabitants' spatial needs to be met within financial constraints. The project makes use of two computational methods: the first is a method to automatically re-mass urban typologies using procedural scripting and a geometry constraint engine, that achieves set targets for openspace and density amounts. The second is the automated valuation of a real estate development using projected cash flows per financial modeling and construction cost estimations — a so called "net present value" of the development.

To demonstrate the application of urban design computation with autmated financial simulation methods, I have formulated a project where common agency is employed to enable a co-developer strategy.

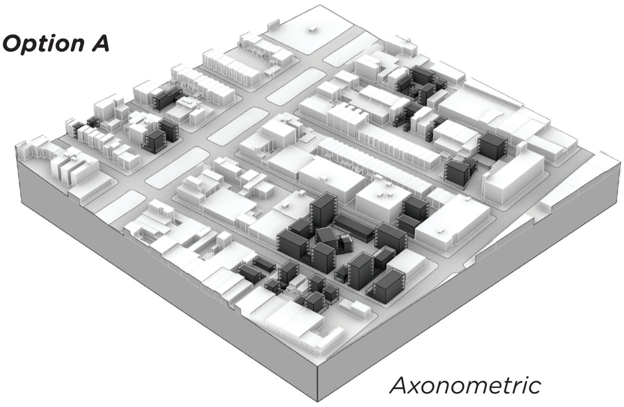
In this way, the principals and agents involved in a real estate development are mutually aligned through co-ownership, co-programming, co-designing, and co-financing the project. The thesis project is located in the 'Sunset Park' neighborhood of New York City — chosen because it is representative of communities that are undergoing significant transitions in land use and built form patterns. Specific parcels were chosen in these neighborhood areas through a geospatial analysis that identified vacant lots, or lots that were significantly underutilized in comparison to their maximum built floorspace regulated by New York City Department of City Planning zoning designations.

The method involves inputting manually-designed massing and use-mix arrangements ('blocking-and-stacking' sketches) into two computational design calculations. The first involves automating the re-massing of input designs to achieve new density and open-space targets, while maintaining particular design features and overall design intent. The second calculates the financial performance of each output re-massed design scenario by automating a financial pro-forma. The outcomes are graphed in a 3D space that matches input parameters (density: FAR, and

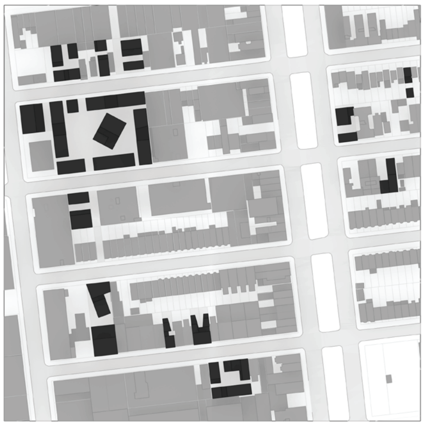
Sunset Park's twelve sites are situated near the 45th Street subway stop and border the Gowanus Expressway. They are a mixture of residential, manufacturing and commercially-zoned parcels, and have a diversity of sizes and block-configurations (corner-lot, cut-through, and oddly-shaped from previous amalgamations. Primary uses for these are light-manufacturing, worker housing, auxiliary functions like children's daycare, and the potential for cultural program like an arts center.

Initial Manually-Authored Massing Options:

Option A

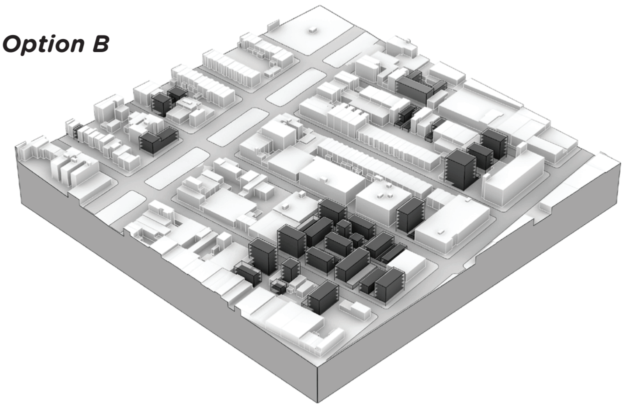


Axonometric

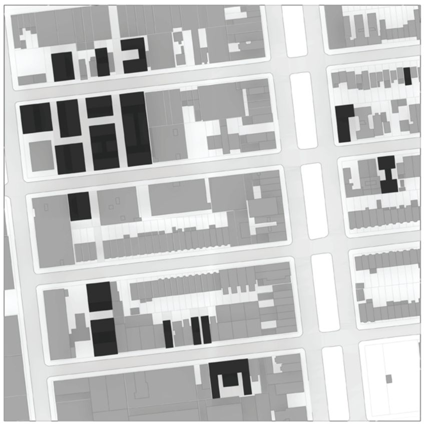


Plan

Option B

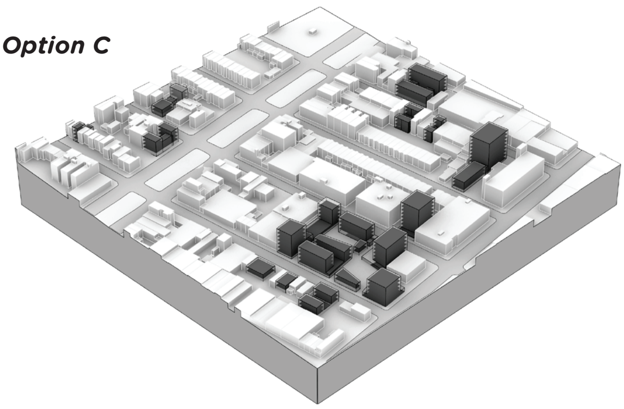


Axonometric

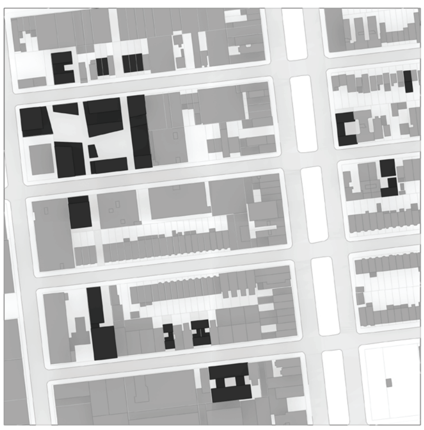


Plan

Option C



Axonometric



Plan

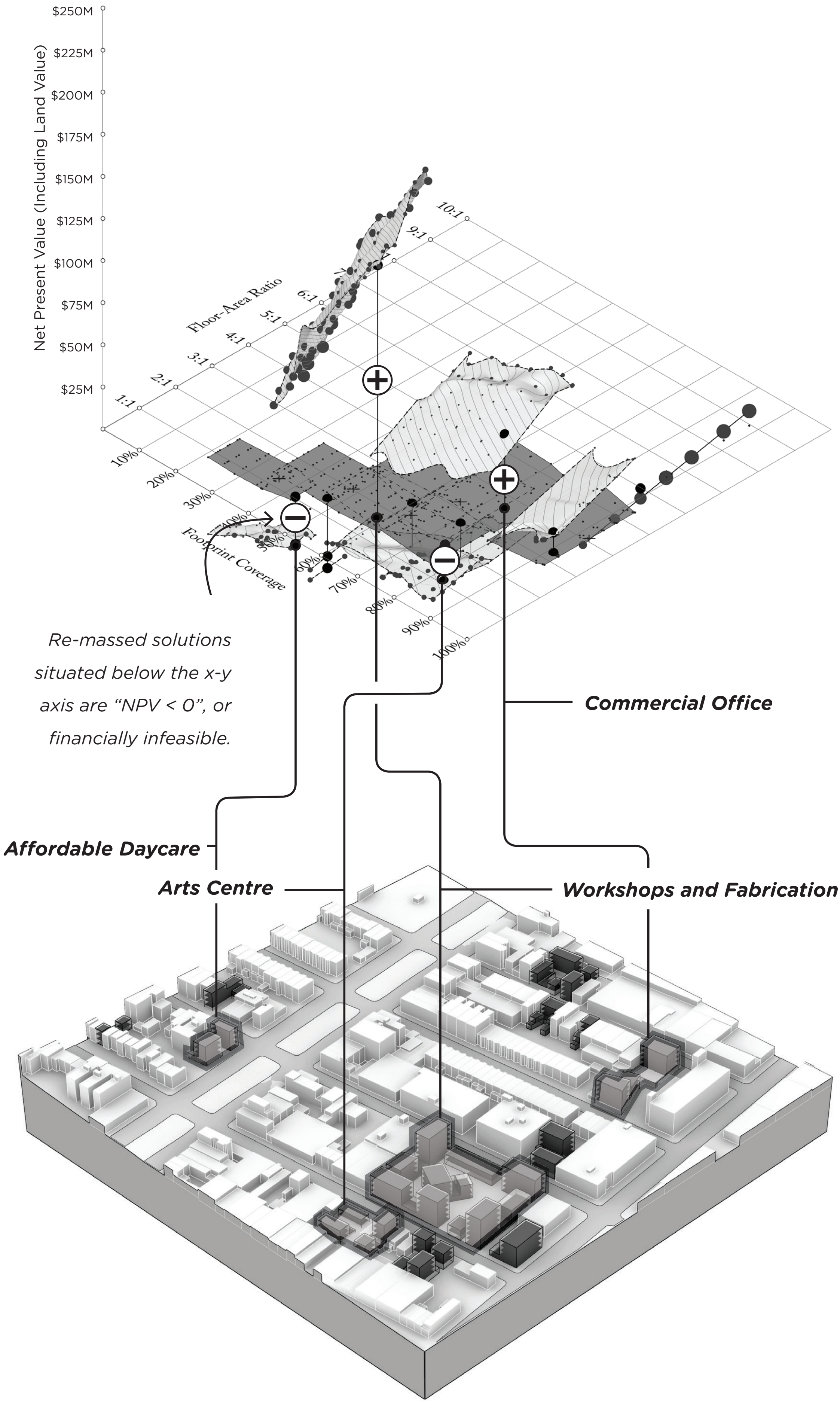
openspace: footprint coverage) with the scenario's respective financial performance, so that the relationships and sensitivities between input designs and output performances can be visualized.

A key observation for the strategy is the incorporation of uneconomical design scenarios. Conventionally, and when each development project is seen on its own, each project must justify its feasibility on its own merit — in the case of a financial feasibility, on the requirement that its net present value (NPV) is greater than zero. However, an exception to this is indicated by Geltner et al. (2013) by identifying the difference between the market value of a property and its investment value. A property may be more or less valuable than its theoretical expected price in an efficient market (its market value), due to particular investor-specific concerns like holding period, portfolio composition, or development strategy. In the case of a suite of potentially developable sites, each with idiosyncratic location, use, or spatial advantages and disadvantages, financial performance must be calculated on the basis of the performance of the developments as a collection rather than each individually. This effectively creates an integrated, but scattered site mixed-use portfolio of developments, and moves the analysis into the domain of portfolio theory, which is a framework that enables the assembly of a range of investments that collectively maximise return while minimizing risk. (Markowitz, 1952).

At the core of this strategy is enabling more mutually-beneficial development for the community, and the remainder of this section focuses on developing a portfolio strategy for the mixed-use co-developed sites.

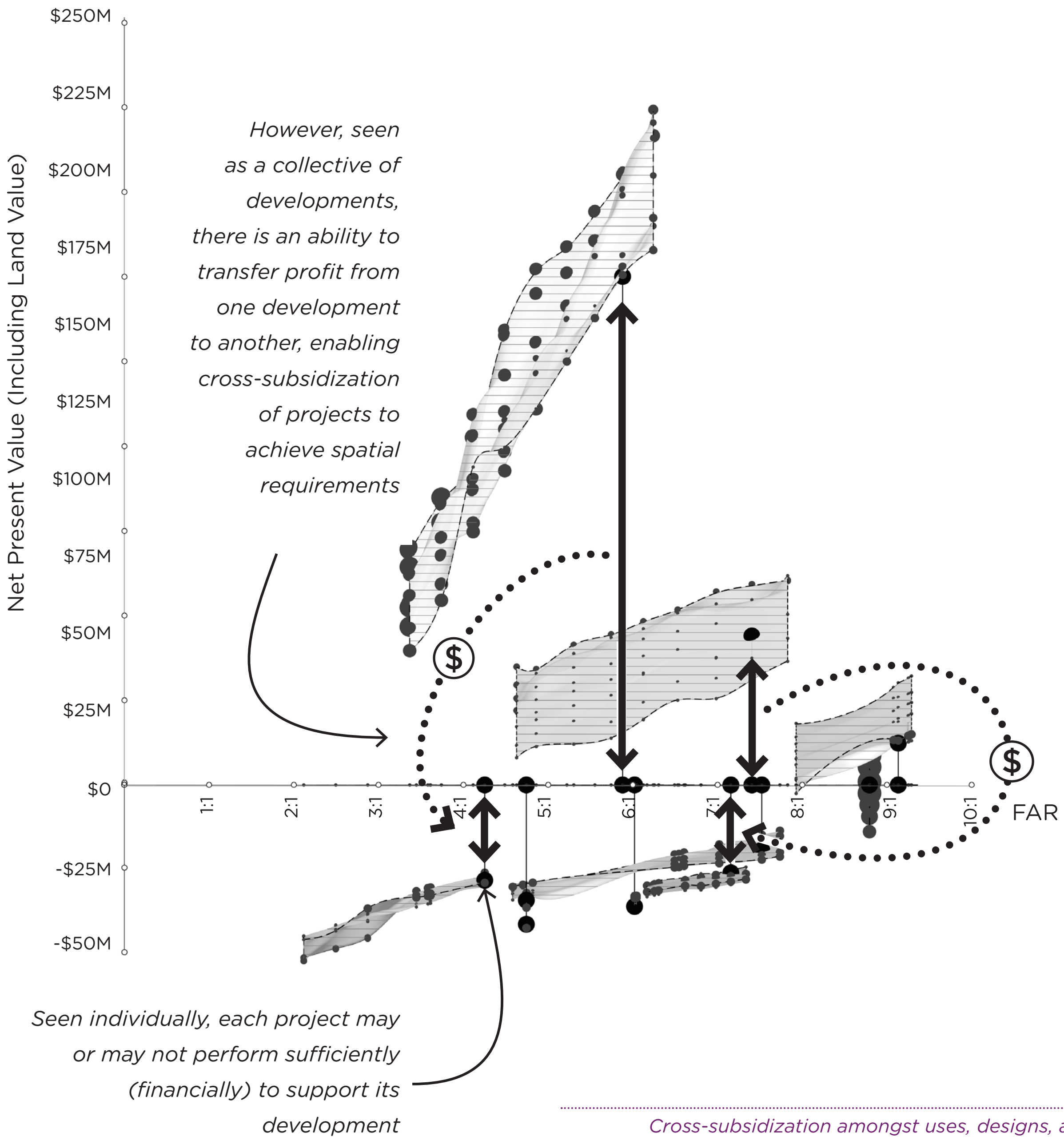
The financial performance of massing option 'B' (visualized in the axonometric below). Each site's computed re-massing solution is also located as its parameter-coordinates in the design space above, and interpolated to genrate a 'performance' surface. If a surface point sits above the plane the re-massing solution is 'net present value positive' and thus a financially feasible design (since it raises more value than it costs). If it sits below, it is infeasible to develop since it costs more than it raises. The length of the line between the plane and the point identifies the total value earned or lost.

A scattered-site development project that associates different land-uses to different locations. This arrangement is made in order to avoid difficulties with land-use zoning, but maintain locational adjacency so that residents and members can easily access all functions.


$250M
$225M
$200M
$175M
$150M
$125M
$100M
$75M
$50M
$25M
Net Present Value (Including Land Value)
Floor-Area Ratio
1:1
2:1
3:1
4:1
5:1
6:1
9:1
10:1
10%
20%
30%
60%
70%
80%
90%
100%
Footprint Coverage
Re-massed solutions situated below the x-y axis are "NPV < 0", or financially infeasible.
Commercial Office
Affordable Daycare
Arts Centre
Workshops and Fabrication

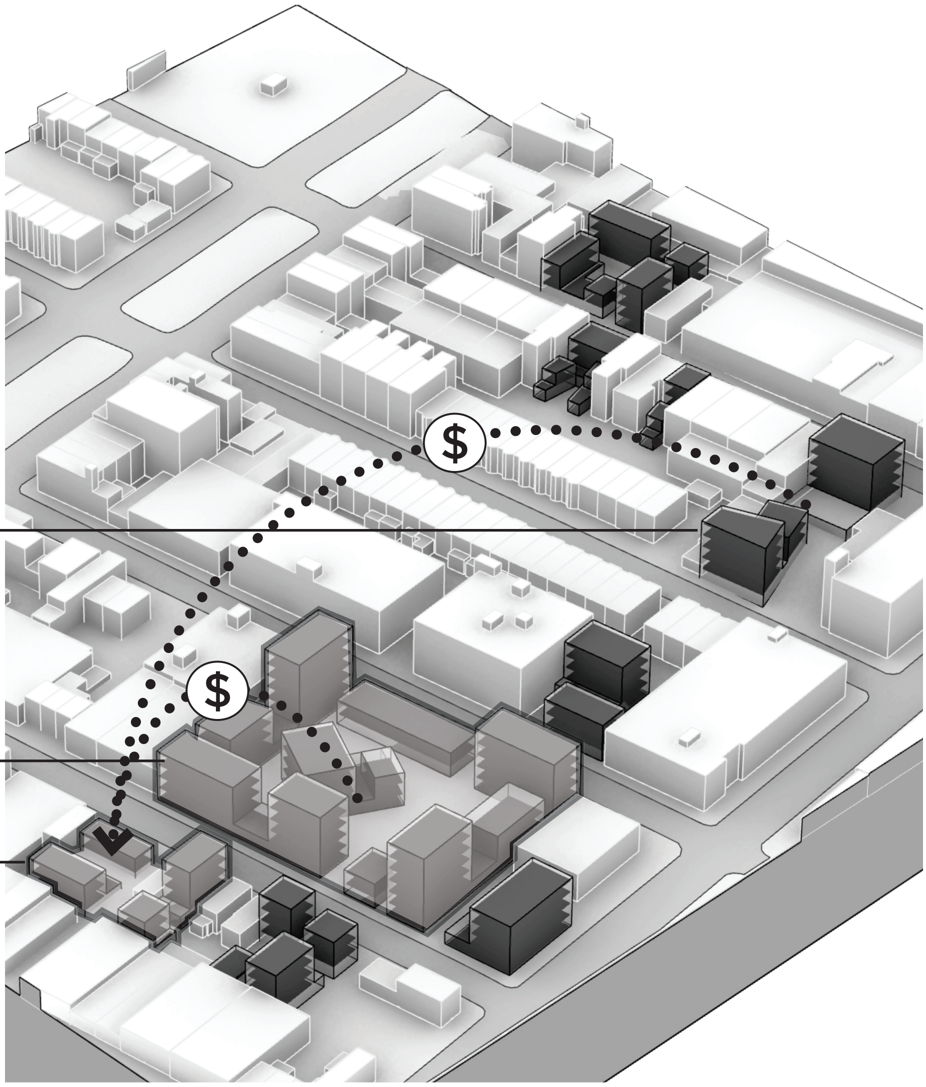
To do this analysis and enable the feasibility of this portfolio-based strategy, we must identify the linkages across multiple sites, uses, size and financial constraints to create an optimal co-development project. Financial analysis of an investment usually reduces value to a single measurement — money — and identifies two components to the flows of that value over time: the return rate of initial investment; and the riskiness of receiving those returns.

However this project adds another measure of value in the form of space utility: this is the inherent value created by the provision of the required amount of space for designated uses within the scattered site development project.This composition of the portfolio establishes two performance criteria with their own constraint sets: a portfolio return that is above an exogenously-defined rate, and the provision of a sufficient amount of floorspace areas throughout the portfolio's assets.



Cross-subsidization amongst uses, designs, and locations to achieve a holistically optimal development scenario, constructed as a generative urban design and mathematical optimization problem.

Visualization of the transfer of funds from profitable developments like commercial office and workshops to individually uneconomic development projects like an arts center, thus enabling a portfolio of spatial programming within financial constraints.



Since zoning, layout, and design are constraints on land and floorspace uses in particular locations (ie, uses are not necessarily exchangeable across portfolio sites), a technique of cross-subsidization is used to transfer funds from a profitable development to an unprofitable one. In this way, the 'negative externalities' caused by incorporating poorly performing developments (from a financial standpoint) can be internalized into the system-as-a-whole, and their positive effects properly weighted and valued. The objective of the cross-subsidization strategy then is to identify the best performing selection of sites with associated massing arrangements and program enumerations.

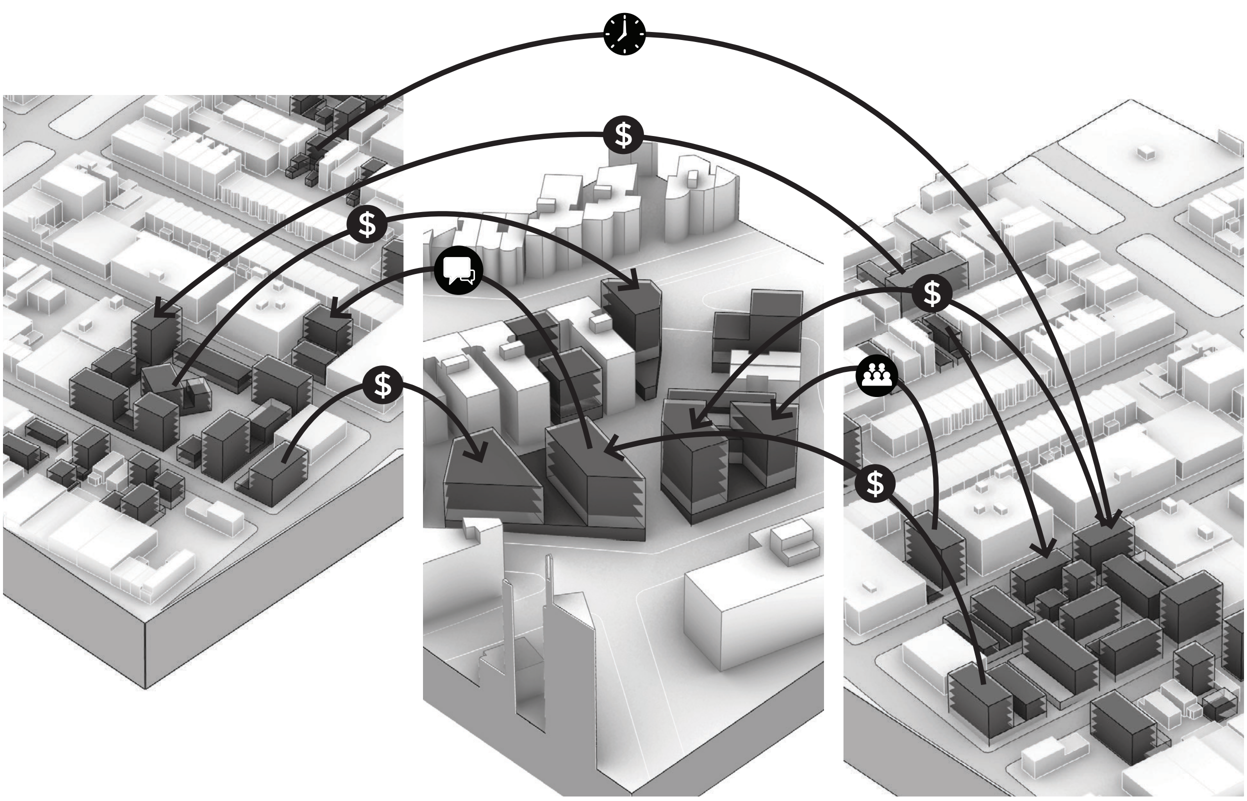
However, selecting and tuning the sites, programs, designs, and optimal financial returns over tens of thousands of combinations requires computation.

While the constraint equations for mathematical optimization in this case are relatively linear, the complexity of geometric-constraint solving means the relationships between input parameters and output performances are not: the 'performance surfaces' in the outcome diagrams are folded and lumpy. Due to this they are not readily describable by analytical methods, and so require non-linear optimization to compute the best performing set of massing options and sites within design and financial constraints.

The effective result of this newfound capability to assemble urban development projects is a more publically accessible capital stack. Currently the composition of investors that contribute capital towards real estate projects is limited to sophisticated or well-capitalized institutions, and their return prioritization (in order of investment) often has influence over strategic directions in its design and realization. Currently absent from most of these financial structures is an owner-operator-type syndicate who also fronts entrepreneurial seed equity — in effect acting beside or potentially even replacing the developer. Since these actors are intimately tied to the performance — both financial and more comprehensive — of the development project, their interest, via both capital and decision-making, is a worthwhile addition to the capital stack.

The end result is an extended valuation that goes beyond purely financial quantities and begins to appraise qualities of architecture and urbanism that benefit their users and the wider community: a centrally-located and affordable daycare for member's children saves not only time and money, but brings social and communal connections; an arts center acts as nexus between the co-operative and their wider community.

Such a platform will enable a co-operative to self-design and self-decide the makeup of their engagement with the city; echoing and realizing the Lefebvrian conception of the 'right to the city', and fomenting a means for collective power.



9

Acknowledgments:

In some way, this scholarship has been a meditation of mine for a number of years, and I owe an enormous degree of gratitude to those who have encouraged, supported, and nurtured me through this time.

I would first like to thank the N.S.W. Architects Registration Board for their generous support. Without the initial belief that my interests were worthwhile of further investment, I would never have uncovered this community of like-minded researchers and practitioners. I am especially grateful for the patience and backing of Tim Horton.

I also wish thank the American Australian Association for their support, and belief in the potential for young researchers to change the world.

I was fortuitous enough to find a home at MIT with a group of kindred researchers and educators, and I am indebted to their generosity of intellect — my thesis team of Mark Goulthorpe, Dr. David Geltner, and Rafi Segal, and my fellow 'centaurs' at the Real Estate Innovation Lab, bridging the ravine between design and finance — Dennis Frenchman and Dr. Andrea Chegut.

Finally, I wish to extend my sincere gratitude to my interviewees and hosts during my travels — Dan Hill, Dr. José Duarte & Dr. José Beirão, Dr. Niloy Mitra, Dr. Chi-han Peng, Dr. Peter Wonka, and Dr. Christian Derix. You shared your ideas, experiences, and hometowns with me, and our discussions and conversations have no doubt led me to where I am today. Thank you.

10

About the author:

Daniel Fink

Daniel Fink is a researcher and computational urban designer with a decade of experience in academia and practice. He is currently a Research Lead at MIT's Real Estate Innovation Lab, where he develops advanced computational methods that bridge the domains of urban design, real estate finance, and geospatial science.

He has co-founded a startup, Placeful Technologies, that implements these methods into projects for city governments and real estate developers.

Prior to graduating from MIT's School of Architecture + Planning with a SMArchS degree, Daniel was a founding member & Project Architect at Grimshaw Architects' Sydney studio. His hands-on project experience ranges from multi-unit residential to civic and large-scale urban design, concentrating on complex masterplanning and strategy.

Daniel has been an invited lecturer and tutor at major Australian universities, and exhibited & published with University of Technology Sydney, authored a SIGGRAPH paper, and is a recipient of the American Australian Association Fellowship and the Byera Hadley Traveling Scholarship.

11

References:

Arisona, S. M., Aschwanden, G., Halatsch, J., & Wonka, P. (2012). *Digital Urban Modeling and Simulation*. (S. M. Arisona, G. Aschwanden, J. Halatsch, & P. Wonka, Eds.) (Vol. 242). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-29758-8

Beirão, J., Arrobas, P., & Duarte, J. (2012). Parametric Urban Design: Joining morphology and urban indicators in a single interactive model. *eCAADe 30, 1*(City Modelling), 167–176. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Parametric+Urban+Design+-+Joining+morphology+and+urban+indicators+in+a+single+interactive+model#0

Beirão, J. N., Nourian, P., & Mashhoodi, B. (2011). Parametric urban design: An interactive sketching system for shaping neighborhoods. *Respecting Fragile Places (29th eCAADe Conference Proceedings)*, 225–234. Retrieved from http://cumincad.scix.net/cgi-bin/works/Show?_id=ecaade2011_050

Berghauser Pont, M., & Marcus, L. (2015). Connectivity, density and built form: integrating Spacemate with space syntax. In *Proceedings of the 22nd ISUF conference: International Seminar on Urban Form. Sapienza University of Rome, Faculty of Architecture* (pp. 22–26).

Berghauser-Pont, M. Y., & Haupt, P. (2010). *Spacematrix: space, density and urban form*. NAi Publishers Rotterdam.

Birge, D. (2015). *Embedded Autonomies: Projecting an American Middle-Class Polis.*

Braach, M., Architects, K. C., & Zurich, E. T. H. (2014). Solutions You Cannot Draw. *Architectural Design*, *84*(5), 46–53. https://doi.org/10.1002/ad.1807

Burke, A. (2010). The urban complex: scalar probabilities and urban computation. *Architectural Design*, *80*(5), 86–91.

CityEngine, E. (2013). *3D Modeling Software for Urban Environments*.

Coates, P., & Derix, C. (2014). The Deep Structure of the Picturesque. *Architectural Design*, *84*(5), 32–37. https://doi.org/10.1002/ad.1805

Coates, P., & Derix, C. (2008). Smart Solutions for Spatial Planning: A Design Support System for Urban Generative Design. *Architecture "in Computro": 26th eCAADe*, 231–238.

Derix, C. (2009). In-Between Architecture Computation. *International Journal of Architectural Computing*, *7*(4), 565–586. https://doi.org/10.1260/1478-0771.7.4.565

Derix, C. (2012). Digital masterplanning: computing urban design. *Proceedings of the ICE - Urban Design and Planning*, *165*(4), 203–217. https://doi.org/10.1680/udap.9.00041

Derix, C., Gamlesæter, Å., Miranda, P., Helme, L., & Kropf, K. (2012). Simulation heuristics for urban design. *Digital Urban Modeling and Simulation*, 159–180.

Derix, C., & Jagannath, P. (2014). Digital intuition—Autonomous classifiers for spatial analysis and empirical design. *The Journal of Space Syntax*, *5*(2), 190–215.

Derix, C., & Jagannath, P. (2014). Digital intuition—Autonomous classifiers for spatial analysis and empirical design. *The Journal of Space Syntax*, *5*(2), 190–215.

Duarte, J. P., Beirão, J. N., Montenegro, N., & Gil, J. (2012). City Induction: a model for formulating, generating, and evaluating urban designs. In *Digital Urban Modeling and Simulation* (pp. 73–98). Springer.

Easterling, K. (2012). We Will Be Making Active Form. *Architectural Design*, *82*(5), 58–63. https://doi.org/10.1002/ad.1461

Easterling, K. (2014). *Extrastatecraft: the power of infrastructure space*. Verso Books.

Easterling, K. (1999). *Organization space: landscapes, highways, and houses in America*. MIT Press.

Eastman, C. N. (1975). *Spatial synthesis in computer-aided building design*. Elsevier Science Inc.

Esch, G., Wonka, P., Muller, P., Zhang, E., & others. (2007). *Interactive procedural street modeling*.

Fink, Daniel. (2017) L*inking Design to Finance : Enabling a Co-operative Developer Platform through Automated Design and Valuation*. Master's thesis, Massachusetts Institute of Technology.

Foresman, T. W. (1998). *The history of geographic information systems: perspectives from the pioneers*. Prentice Hall.

Geltner, D., Miller, N. G., Clayton, J., & Eichholtz, P. (2001). *Commercial real estate analysis and investments* (Vol. 1). South-western Cincinnati, OH.

Helme, L., & Derix, C. (2014). Spatial configuration: Semi-automatic methods for layout generation in practice. *The Journal of Space Syntax*, *5*(1), 35–49.

Hillier, B., & Hanson, J. (1989). *The social logic of space*. Cambridge university press.

Kalay, Y. (1987). Computability of design.

Koenig, R., Standfest, M., & Schmitt, G. (2014). Evolutionary multi-criteria optimization for building layout planning.

Kolarevic, B. (2015). From Mass Customisation to Design "Democratisation." *Architectural Design*, *85*(6), 48–53. https://doi.org/10.1002/ad.1976

Krugman, P. (1996). What economists can learn from evolutionary theorists. *A Talk given to the European Association for Evolutionary Political Economy.*

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance*, *7*(1), 77–91.

Martin, L., & March, L. (1972). Urban Space And Structures, Cambridge Urban and Architectural Studies. Cambridge University Press.

Marx, K., & Engels, F. (2002). *The communist manifesto.* Penguin.

McHarg, I. L., & Mumford, L. (1969). *Design with nature*. American Museum of Natural History New York.

Müller, P., Wonka, P., Haegler, S., Ulmer, A., & Van Gool, L. (2006). Procedural modeling of buildings. In *Acm Transactions On Graphics (Tog)* (Vol. 25, pp. 614–623).

Müller, P., Zeng, G., Wonka, P., & Van Gool, L. (2007). Image-based procedural modeling of facades. *ACM Transactions on Graphics (TOG)*, *26*(3), 85.

Musialski, P., & Wimmer, M. (2013). Inverse-Procedural Methods for Urban Models. *Proc. of 1st Eurographics Workshop on Urban Data Modelling and Visualisation*, 31–32. https://doi.org/10.2312/UDMV/UDMV13/031-032

Nes, A. van, Pont, M. B., & Mashhoodi, B. (2012). Combination Of Space Syntax With Spacematrix And The Mixed Use Index . The Rotterdam South Test Case. *Eighth International Space Syntax Symposium*. https://doi.org/urn:NBN:nl:ui:24-uuid:d865e5b6-519e-4959-8c3d-800054d1b351

Parish, Y. I. H., & Müller, P. (2001). Procedural modeling of cities. In *Proceedings of the 28th annual conference on Computer graphics and interactive techniques* (pp. 301–308).

Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.

Sadler, S. (2005). *Archigram: architecture without architecture*. Mit Press.

Schmitt, G. (2012). A planning environment for the design of future cities. *Digital Urban Modeling and Simulation*, 3–16.

Schumacher, P. (2009). Parametricism: A new global style for architecture and urban design. *Architectural Design*, *79*(4), 14–23.

Schumpeter, J. (1942). Creative destruction. *Capitalism, Socialism and Democracy*, *825*.

Steadman, P. (2014). Density and built form: Integrating “Spacemate” with the work of Martin and March. *Environment and Planning B: Planning and Design*, *41*(2), 341–358. https://doi.org/10.1068/b39141

Steadman, P. (2014). Generative design methods and the exploration of worlds of formal possibility. *Architectural Design*, *84*(5), 24–31.

Stiny, G. (2006). *Shape : talking about seeing and doing* (Vol. 1). Cambridge, Mass: MIT Press.

Stiny, G. (1980). Introduction to shape and shape grammars. *Environment and Planning B: Planning and Design*, *7*(3), 343–351.

Vanegas, C. a., Kelly, T., Weber, B., Halatsch, J., Aliaga, D. G., & Müller, P. (2012). Procedural Generation of Parcels in Urban Modeling. *Computer Graphics Forum*, *31*(2pt3), 681–690. https://doi.org/10.1111/j.1467-8659.2012.03047.x

Vanegas, C. A., Garcia-Dorado, I., Aliaga, D. G., Benes, B., & Waddell, P. (2012). Inverse design of urban procedural models. *ACM Transactions on Graphics (TOG)*, *31*(6), 168.

Verebes, T. (2013). *Masterplanning the adaptive city: Computational urbanism in the twenty-first century*. Routledge.

Waddell, P. (2002). UrbanSim: Modeling urban development for land use, transportation, and environmental planning. *Journal of the American Planning Association*, *68*(3), 297–314.

Wiener, N. (1961). *Cybernetics or Control and Communication in the Animal and the Machine* (Vol. 25). MIT press.

NSW Architects Registration Board

A publication of the NSW Architects Registration Board 2015
architects.nsw.gov.au