Philosophy of the City

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City in Code: The Politics of Urban Modeling in the Age of Big Data

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Abstract: A model is "any representation or concept that helps us to understand the world whenever common sense or direct observations are inadequate." Common sense and direct observation often prove inadequate to the complexities of the twenty-first-century cities. Thus, models abound in urban life and governance. However, a model is not only a tool for control but a way of defining a situation. Framing the city so as to render it susceptible to interpretation and intervention is an exercise not merely with scientific or technological value but with rhetorical power. The tradition of comprehensive urban models, beginning with the advent of computers and culminating in the self-analyzing "smart city," I argue, sidelines this rhetorical power in favor of a tone of scientific authority that, while justifiable in technical domains, does not legitimately scale to the level of a political community. Making good on the civic potential of Big Data thus requires recontextualizing properly scientific enterprises within an adequate political philosophy of the city, allowing for the construction of cultural urban models that set human freedom at the core of its inner workings.

Keywords: smart city, urban space, philosophy of technology, politics, culture

1 Introduction

A model is "any representation or concept that helps us to understand the world whenever common sense or direct observations are inadequate." Common sense and direct observation often prove inadequate to the complexities of twenty-first-century cities, in everyday life as in professional study or administration. Thus, from navigational maps to travel demand models, market studies, and population forecasts, models abound in urban life and governance.

However, a model is not only a tool for control but a way of defining a situation. When what is being defined is not merely a technical problem, but a collective human situation, defining its meaning is an act with a political dimension. Framing the city so as to render it susceptible to interpretation and intervention is an exercise not merely with scientific or technological value but with rhetorical power.

The tradition of comprehensive urban modeling, beginning with the advent of computers and culminating in the self-analyzing "smart city," I argue, sidelines this rhetorical power in favor of a tone of scientific authority that, while justifiable in technical domains, does not legitimately scale to the level of a political community. Making good on the civic potential of Big Data requires recontextualizing properly scientific enterprises within an adequate political philosophy of the city to allow for the construction of cultural urban models that set human freedom at the core of its inner workings.

¹ Council for Science and Technology, "Computational Modelling," 14.

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I will introduce the components of my argument in terms of an imaginary example. Say a municipal government's planning department commissions a study to identify neighborhoods that are likely to gentrify. Employing various measures as indicators of gentrification – say, rapidly rising property values and increased outside investment in real-estate development – the model compares attributes of the neighborhoods in question with areas that have already gentrified in order to generate its predictions. In this, the model merely acts as a tool for analysis, performing statistical grunt work on a curated data set under the watchful eye of a consultant. However, the city's actions on the basis of the model require judgments about what the observed or projected phenomena *mean* for the life of the city as a whole. These judgments do not proceed autonomously from the model's data; they are human interpretations of its meaning.

This example not only illustrates the latent rhetorical power of such a "gentrification model" as lending scientific legitimacy to this or that action but reveals that public-sector urban decision makers, as official guardians of the public interest, bear a many-faceted responsibility for their actions. Their interventions must not only interact intelligently with individual systems within the city – transportation, real estate, housing – to produce desired effects (a task difficult enough in itself, and which the model aims to aid). These acts must also be justified in terms of their impact on the life of the city as a whole to which the city s administrators are politically accountable.

The need to evaluate the impacts of public-sector interventions holistically is the rationale for comprehensive urban and regional planning, a profession that attempts to inform city-scale and regional-scale public-sector interventions with our best guesses for what the effects of those interventions will be. A tradition of comprehensive urban modeling has arisen to perform the equivalent of our imaginary gentrification model's specialized task at the scale of the whole city and for all the varied interests city administrators are called upon to balance. However, comprehensive urban modeling, as an attempt to predict the behavior of the city as a whole under given conditions, has historically proven to be a massive failure, as I will detail later. Cities, modelers found early on, are complex systems that exhibit emergent properties and thus defy attempts to model them simply as composites of their constituent functional systems. Specialized knowledge of the workings of any component part is inadequate to build up a scientific understanding of the functioning of the city as a whole.

The rise of the data-powered "smart city" promises a new solution to urban governance's dilemmas of complexity. By integrating data captured from the city's various constituent systems into a single knowledge repository, "smart" infrastructure promises to usher in a new era of comprehensive city management, in which the impacts of interventions in one area can be empirically evaluated across all systems. Although "smart" urban management may seem to overcome the technical limitations of comprehensive modeling, it, too, I will argue, is unable to eliminate the political dimension of comprehensive urban management. By downplaying the role of human judgment in urban administration in favor of technical expertise, both traditional comprehensive modeling and the "smart city" paradigm risk collapsing political questions into technical problems.

Behind and beyond the technical diagrams of urban functions produced by urban models and the data trails of "smart" infrastructure, a political community relies on cultural models, images, and narratives to justify collective actions and lend individual actions meaning in the city's life.² In the example introduced above, the narrative that public-sector decision makers employ to make practical use of this gentrification model – a narrative of what is just or good for the city as a whole – is not limited in its implications to justifying public-sector actions. It also implies an interpretation of the meaning of the actions of individuals and private actors within the systems in question. The legitimacy of such a narrative, then, depends at least in part on its validity as a heuristic for these private actions.

² Although running parallel to the particular concerns of this paper, Hamilton et al.'s research agenda for "The image of the algorithmic city," which applies Kevin Lynch's analysis of the "image of the city" to the city as navigated by the screen, performs helpful conceptual work to translate the categories of the "smart city" into a language of everyday experience.

Thus, if the city administration acts on a judgment that rapidly rising property values in rental-heavy inner-city neighborhoods are unjust or are bad for the city as a whole, then the city judges that those investors and higher income individuals who privately profit from such transformations are themselves acting unjustly or against the public interest. The city implicitly stakes its legitimacy as a neutral public actor on the adequacy of this narrative to characterize the meanings of the actions of all the actors involved. However, this implies that, in principle, those actors could come to identify with the cultural model this narrative projects. If such public-sector actions are purported to be justified only on the basis of a neutral scientific study, then the full political and moral meaning of the intervention, and the cultural model that justifies it, is cloaked.

The "city in speech" of Plato's Republic is a paradigmatic example of such a cultural urban model. Socrates and his interlocutors construct their "city in speech" over the course of an afternoon conversation in Athens. This verbal model, ranging from the abstract to the technical to the mythical, not only permits the group to work out shared conceptions of justice and equality but also furnishes grounds for a shared experience of their own city, Athens. By occasioning communal contemplation of the salient features of their society, the collaborative creation of this model fulfills a vital civic function, in a real sense enabling these fellow citizens to occupy a shared world.

Such "cities in speech" are implicitly operative in urban governance in our day, but the scientific objectivity projected by "data-driven" governance techniques underplays the importance of these cultural narratives in justifying their practical application. Cultural narratives are at play, but without an explicit recognition of their power, they are free to be formed willy-nilly by the prejudices of individual actors, ironically ending up unaccountable to the very facts that obscure their importance.³

Sophisticated systems of technical management and powerful scientific models have arisen around cities for a reason: the challenges facing contemporary urban life are great. However, the need for human judgment to keep pace with this technical sophistication is equally acute, and human judgment is equally in need of the cognitive aids provided by cultural urban models.

The failure to distinguish these modes of engagement with urban realities - and to give each due weight - risks contaminating real science with politics and replacing real politics with wars between incompatible versions of reality. Political and moral meanings require political and moral modes of expression, not scientific ones. Proper political debates are not arguments about which data are real, but rather arguments about what real data mean for common life.4

In a moment in which the ends to which the new data-capture capacities of "smart" infrastructure are to be put are still being decided, I advocate the recovery of an explicitly cultural role for urban imagemaking alongside Big Data's power to illuminate well-defined technical problems. Holding up Plato's "city in speech" next to contemporary urban models, I ask, can these models not only enable greater prediction and control of urban systems but also allow us to construct shared cultural models of the places we hold in common?

Properly understood as exercises in rhetoric, I argue, data-powered depictions of the city can work alongside technical models to furnish factually grounded, culturally resonant, politically powerful images of the city as an arena for creative proposals for common life, and so animate twenty-first-century civic discourse.

³ Friedmann makes this point in his critique of comprehensive urban planning: "In projecting an image of the future from uncertain knowledge, [planners'] own intuitions, professional judgments, and values must be used to fill the gaping holes of ignorance. But planner's [sic] intuitions can be and, indeed, often are challenged successfully by groups with an effective veto power over the pertinent decisions. These groups will insist, quite possibly with reason, that their own intuitions have as much, if not greater, validity than those of the professional planners." "Comprehensive Urban Planning," 318.

⁴ For a thought-provoking exploration of these dynamics in the context of recent history, see Rocco's April 14th, 2020, post on the London School of Economics' blog, arguing for the truth of its title: "The fragmentation of federal expertise has enabled the politicisation of Covid-19 numbers in the USA."

2 The failure of comprehensive urban modeling

It is tempting to think that a city could be modeled simply as an aggregate of its constituent systems. However, the relationship between urban whole and part is more complex. In this section, I will trace the historical record of attempts to model the city as a total system, or a system of systems, and note the kinds of criticism they have consistently invited. This record demonstrates that attempts at comprehensive urban modeling have consistently failed precisely because they have attempted merely to extend modeling techniques developed for constituent systems to the city as a whole. The fact that this is a failing strategy tells us something important about cities.

There have been many moves and countermoves in the history of attempts to study, plan, and manage the city. This history is one not merely of evolving techniques but of successive articulations of fundamentally different, even opposite, approaches to the problem. Thus, no critique I present here is without a precedent – but nor are the tendencies I criticize without numerous contemporary proponents. Tracing this history will allow us to situate the "smart city" as an heir to this tradition's aspirations and permit an assessment of how well it responds to the critiques outlined here.

The dream of a comprehensive urban model was born in the 1950s of the coincidence of rational planning with the development of computers – and, incidentally, of automobiles. Dominated by the priorities of traffic engineers increasingly equipped with computers, planners set off on the quest to build the perfect predictive model, conceiving the city as a system to be optimized. The work carried out in the 1950s to theorize the city as such a system, borrowing techniques from the natural sciences and adopting them from the burgeoning social sciences, gave way to ambitious attempts in the 1960s to create mathematical and statistical models to guide urban decision-making. Models developed over the next several decades incorporated more and more variables of urban social life, but experiments consistently revealed unruly degrees of complexity, and empirical results were slim.⁵

As early as 1961, the legendary urbanist Jane Jacobs argued that this rationalistic approach to the city was based on a category error. Cities are best understood as systems of organized complexity, she argued, and are therefore more amenable to analogies from the life sciences and the art of medicine than from the deterministic laws of classical physics. In the final chapter of her classic *The Death and Life of Great American Cities*, titled "The kind of problem a city is," Jacobs pronounced grimly:

As long as city planners, and the businessmen, lenders, and legislators who have learned from planners, cling to the unexamined assumption that they are dealing with a problem in the physical sciences, city planning cannot possibly progress. Of course it stagnates. It lacks the first requisite for a body of practical and progressing thought: recognition of the kind of problem at issue.⁶

By 1971, voices like John Friedmann's were raising a pluralist cry against the very project of comprehensive central planning, which justified these attempts at scientific problem-solving. Friedmann's critique was based both on the political principle – that comprehensive planning assumes a singular common good, when in fact contemporary American cities are complex assemblages of competing interests and conceptions of the common good – and on the empirical performance of these attempts. He writes:

During the last decade, a substantial number of empirical studies of central planning have been carried out. These studies are nearly unanimous in their findings that the manifest purpose of this style of planning – to shape the development of cities and nations in accord with a pre-conceived design and to do so on the basis of functionally rational criteria – was not being accomplished. Where it was tried, and judged by its own claims, comprehensive planning turned out to be a colossal failure.⁷

⁵ Batty, "Since 1960."

⁶ Jacobs, Death and Life, 439.

⁷ Friedmann, "Comprehensive Urban Models," 317.

While Jacobs and Friedmann take planning practice as their target, both critics diagnose a certain way of conceptualizing the city as central to the discipline's woes. Jacobs contrasts the deductive logic of rational planners with the lived knowledge of "ordinary people, untrained in expertise, who are attached to a neighborhood, accustomed to using it, and so are not accustomed to thinking of it in generalized or abstract fashion."8 For his part, Friedmann writes:

The "whole" of the metropolis cannot be visualized except through highly abstract models of symbolic representation. But the very power of these models to explain behavior at one level of reality means that all other possible realities drop out of view; each of these can be grasped in turn, but they cannot be put together into a total, all-encompassing view.9

For critics like Jacobs and Friedmann, the planning profession strayed when it conceived of its task as being to implement solutions that proceeded logically and necessarily from a comprehensive, scientific viewpoint - because for the city, a political creation of its inhabitants, such a viewpoint simply does not exist.

While the confidence that the urban code was imminently to be cracked seems to have abated in successive decades, the myth that such a thing is conceivable has never really died out. A group of Australian researchers writing in the 1980s acknowledged both its remoteness and its desirability when they stated, in a report titled "Optimizing urban futures," that "although the ultimate perfect projection technique is still as elusive as ever, the stimulus to improve the overall process remains strong as there are substantial social and economic penalties associated with poor forecasting." 10 Although employing different methods, physicist-turned-urban-modeler A. G. Wilson expressed the same aspiration to comprehensiveness in 2017, noting in a presentation to his colleagues at the Alan Turing Society that given the "interdependence" of urban processes, "the comprehensive or general, urban model [...] should remain our ambition."11

Nonetheless, successive generations of urban modelers have conceded Jacobs' point: since the early failure of rationalist attempts to model cities as straightforward functions of a few variables, there has been general scholarly consensus that cities are "complex." As modeler Michael Batty summarized in 1976, "If there is only one definite point which the last 15 years has demonstrated, it is that the cities are enormously complex, and that such complexity must be faced directly."12 A new generation of urban models arose from this recognition; computational models (computer simulations) employing cellular automata, a technique that could model cities not as the outcome of deterministic laws but as an irreducible order emerging from the independent interaction of many contributing factors.

In an agent-based travel demand model, for example, rather than predicting the behavior of the system as a whole at the aggregate level of an entire population, the researcher creates numerous individual profiles, with each individual combining a diverse set of variable values. Thus, rather than calibrating the model with a population that is 13% pedestrian, 49% male, and 40% aged 35-55, the researcher would program a 37-year-old male pedestrian, a 65-year-old female driver, etc. The researcher then runs the simulation – lets the "automata" loose – and observes the resulting emergent order arising unpredictably from countless individual interactions.

Although this genre of model is much more successful than static, deterministic models at generating the kinds of surprise that characterize real-life complex systems, its very verisimilitude makes its relationship to those systems problematic to interpret. Computational models of this sort mirror – rather than explain – the unpredictability of the real world. Rather than laboratories for testing hypothetical laws of cause and effect, these simulations become tools for exploring the range of possibilities that a single set

⁸ Jacobs, 441.

⁹ Friedmann, 318.

¹⁰ Sharpe et al., "Optimizing," 209.

¹¹ Wilson, "Future," 6.

¹² Batty, "Since 1960," 96.

of parameters may produce on successive runs, or for exploring or the conditions under which unexpected results may emerge.

Many reflective practitioners and philosophers of science have argued for situating models used in the natural and social sciences within broader contexts - intellectual, political, and cultural - that would enforce the epistemological boundaries of such models and restore usurped territory to the domain of other kinds of reflection and cultural production. Such a critique is especially compelling in light of the political power of models of urban systems.

Writing in 2005 with colleague Paul Torrens, Batty takes it as a given that the behavior of complex systems cannot be predicted: "A complex system is an entity, coherent in some recognisable way but whose elements, interactions, and dynamics generate structures and admit surprise and novelty that cannot be defined a priori."13 The validity, and therefore the usefulness, of models of such systems cannot then be reduced to an empirical validation of precise predictions. They cite another researcher as arguing that "complex systems modelling is generative by definition, more a strategy for generating possible model structures and showing their consequences than a technique for developing fully fledged definitive models with strong predictive capability." ¹⁴ Batty and Torrens themselves suggest that "A particularly useful way of defusing the role of modelling is to consider the process of use as one of 'story telling'," that is, as "provid[ing] just another way of examining a situation." Models of this sort may often play "an educational role," since "learning about any problem involves different and contrasting viewpoints, some of which may be dismissed, others which will gain ground."15

If Batty and Torrens' language seems to relegate these sophisticated models to a shockingly modest place in the project of scientific discovery, consider a more general treatment of the use of models in science made by philosopher of science Nancy Cartwright in a 1991 paper titled "Fables and Models." To summarize rapidly, Cartwright argues that scientific models function similar to fables, in that a model, like a fable, constructs a controlled space in which relationships between elements can meaningfully be described. Like fables, however, models leave to the user the responsibility of applying the "moral" to real life. Models, like fables, cannot thus be said to be straightforwardly "true" as descriptions of reality but are rather to be judged by their helpfulness in supplying a heuristic for interacting with that reality.

As a claim about the epistemological status of scientific theorems, Cartwright's claim is not uncontroversial in the philosophy of science, as the response of metaphysician Robin Le Poidevin, published in the same paper, makes immediately clear. Cartwright's analogy is particularly apt, however, to describe the function of computational models of complex systems, models that are notable for the degree of fictionalization required in their construction. The simulations produced by computational models exist in an artificial system that is not just hived off from physical reality by linguistic abstractions or the stringent controls of a laboratory experiment but which is constructed from the ground up by the researcher.

Philosopher of science John Symons makes this very point, writing of Cartwright's claim that generalizations derived from scientific models "provide local truths concerning very restricted domains," "Without agreeing to her more general claim concerning the generality of physics, it seems quite clear that CA [cellular automata] models fit her characterization precisely." The results of a computational model of a complex system leave the user in much the same position as the hearer of a fable: with a responsibility for exercising human judgment in the applications of its lessons.

Symons makes this point as follows. If the strength of a model of a complex system lies in its ability to imitate its irreducible wholeness, how is an observer to isolate particular lessons about real-world factors?

¹³ Batty and Torrens, "Modelling and prediction," 745 (abstract).

¹⁴ Ibid., 759.

¹⁵ Ibid., 760.

¹⁶ Cartwright and Le Poidevin, "Fables."

¹⁷ Symons, "Computational models," 484. Cellular automation is a technique for modeling complexity in which individual cells following local rules interact to produce a macro-level emergent order. The agent-based modeling, introduced earlier, is a version of the basic concept of cellular automation.

In a traditional model, assumptions about the behavior of individual elements of the system can be distilled and tested. For instance, if we widen a freeway, we postulate that motorists will respond in a predictable way, leading, e.g., to an overall decrease in congestion in the transport network. Such neat (and, as it happens, false¹⁸) lessons cannot be distilled from a model that uses cellular automata: the interventions will contribute obscurely to a new Gestalt, their individual impact inextricable from the flux of a million branching reactions and interactions from individual users.

Computational models are useful for illuminating the range of possibilities inherent in complex systems, for visualizing their behavior, and, when combined with statistical analysis, for forecasting or risk assessment. However, employing computational models to such ends requires stepping outside the epistemic bounds of positive science:

The task of validating the computational model is absolutely dependent on human judgment insofar as we must judge that the analogy holds between the patterns in the model and the patterns in the object [...] if we have not built the right system for the job, then we simply do not have a model.19

Making use of computational models of urban systems requires that the user has a sense of what "the job" for the model is, a kind of knowledge that cannot, itself, be learned from the model.

Further, Symons maintains, questions may be raised by computational models that the model in principle cannot answer - notably, what is the ontological status of an emergent property? Is it derivative from the components that produced it, or does it represent a kind of genuine novelty? Symons maintains that computational models are "ontologically agnostic" when it comes to emergent properties.²⁰ A thorough exposition of the significance of this point would broach metaphysical debates that are beyond the scope of the present article, but the practical application of his argument to my purposes can be distilled from the following citation:

Computational models are likely to satisfy our ordinary demands for explanation insofar as they provide a simulation or an analogy which permits the possibility of some measure of control over the system in question. This limited kind of explanation would leave deeper metaphysical questions about the individuation, reality and even the physical reducibility of emergent properties untouched.21

In other words, a model may be built to explore the behavior and properties of a complex system, without facing head on the full complement of questions raised by that system and, in particular, by its complexity. While this may seem to be a trivial point ("Of course no single investigative method answers all possible kinds of questions at once," one might rightly protest), it bears stating here, since what is at stake in the present inquiry is the legitimacy of comprehensive models' promises to provide answers with scientific status to the kinds of questions planners and administrators pose about urban futures. It is apparent, then, that that legitimacy depends on what kinds of questions they, in fact, pose. This point will be explored further below, but for the moment it is suffice to say that certain questions about the reality being modeled, and precisely those questions that concern it as a whole, lie essentially beyond the purview of computational models.

3 The "smart city": a revival of the myth

The myth of the perfect predictive model of the city, operationalized through traditional modeling techniques as well as in computational models, appears to have been decisively debunked. The classical

¹⁸ Duranton and Turner, "Fundamental law."

¹⁹ Symons, "Computational Models," 483.

²⁰ Ibid., 485.

²¹ Ibid., 487.

mathematical models are incapable of capturing the inherently unpredictable behavior of complex systems such as cities, and computational models prove their usefulness mainly as exercises in highly informed imagination, illuminating a range of possible outcomes that may result from given conditions, while leaving their users to adapt prudently to an ineliminable element of uncertainty. In some quarters, however, the myth appears to be rising again in new guise: that of the "smart city."

The "smart city" can be many things, most of them neither utopian nor apocalyptic. Generally speaking, the apparatus of the "smart city" exploits the data-gathering capacity of ubiquitous information and communications technology (ICT) to improve the functioning of urban systems across all sectors. Everyday examples include "smart" infrastructure such as adaptive traffic control systems and responsive public lighting adopted by local government units looking for efficiency gains.²² At minimum, the "smart city" is simply the city in all its familiar functions as it evolves in an era of exponentially expanding computing capacity and network connectivity.

It is also interesting, however, to consider what the "smart city" means at maximum. A recent scholarly survey on the subject includes in its taxonomy of definitions of the "smart city" a whole category that take "the integration of all the elements that compose a city" as the distinguishing feature. Under this genre of definition, "even though the city may have ICTs included in every sector, if the system is not integrated as a whole, the city cannot be considered smart." While not the central feature of all definitions, some version of "interconnection between different services and technologies inside the city" figures in most.²³ For their part, U.S. government programs, such as the U.S. Department of Transportation's 2015 "Smart City Challenge" and the National Science Foundation's ongoing "Smart and Connected Communities" grant program, use "integrated" almost as a synonym for "smart" in their definitions and criteria for the initiatives.24

Much of the allure of the "smart city" seems, indeed, to derive from its panoptic affordances. Regardless of the use to which it is put, data capture is a sine qua non of "smart" urban initiatives. In this way, the "smart city" paradigm presents itself as an instrument of urban governance that resembles comprehensive modeling in several important aspects, while differing from it in others.

First, comprehensive modeling and the "smart city" share similar aims. The aim of a comprehensive computational model of the city as a complex system is to provide researchers and decision makers with a perspective from which to observe the interactions of the agents and subsystems whose activity collectively produces the city – even if the particular entities depicted are computer-programmed fictions. The "smart city" paradigm in its maximal incarnation promises to afford a similar perspective, with the difference being that the data supplied are not laboratory dummies but captured from real life.

The aims of comprehensive modeling and the "smart city" converge in another way: the data-capture capacities of "smart city" infrastructure meet a real need in the domain of modeling. One of the main challenges faced by models of complex systems is the difficulty, or impossibility, of including all relevant factors that contribute in some way to the macro-level behavior of the system. Batty and Torrens refer to this as "the problem of closure," ²⁵ meaning the difficulty of legitimizing a given boundary drawn around the system to be modeled. As discussed above, Symons addresses it from the other direction, noting that the fact that computational models "are generally conceived such that interactions with the world beyond their boundaries are excluded or tightly controlled" makes their application to the real world, with its myriad "interfering conditions," particularly "problematic." 26

This challenge may explain the centrality of "integration" in the rhetoric of the "smart city:" if data shed at every possible turn in the complex of systems that make up the city can enter one "integrated" pool, then the complex problems facing urban administrators can find appropriately integrated, rather

²² E.g., Hawi et al., "Smart Traffic Control;" Ożadowicz and Grela, "Street Lighting Control."

²³ Sánchez-Corcuera et al., "Smart Cities Survey," 2-4.

²⁴ U.S. DoT, "Smart City Challenge;" NSF, "Smart and Connected Communities."

²⁵ Batty and Torrens, "Modeling and Prediction," 754.

²⁶ Symons, "Computational Models of Emergent Properties," 480-1.

than siloed, solutions. Trained on such wide-ranging data sets, models and simulations can improve their fidelity to the interconnectedness of the real world.

Second, the "smart city" bears a deep structural similarity to the tradition of computational urban modeling for the apparently banal reason that both run on computers. Although materially different – i.e., the "smart city" may be a set of institutional practices and networked technologies embedded in a real city, while a computational model may be a self-enclosed simulation – both paradigms interact with their subject matter only through the categories of information technology. We might even say that both paradigms interact with the city through the mediation of a digital twin. As in the artificial environment of a model, in which data may be borrowed from real data sets or be entirely generated within the system, the data gathered by smart infrastructure from the real-life city are themselves only a copy of the real thing, with all the processing and packaging implied by its digital syntax.

To counter the unreflective notion that data are natural by-products of reality. Martin Dodge and Rob Kitchin examine the roots of the word "data," which comes from the Latin for "given," as contrasted with "capta," which comes from the Latin for "taken." The common use of "data," they argue, is rather misleading. What we are usually dealing with, they explain, are "capta:"

[Data] are the total sum of facts that an entity can potentially "give" to government or business or whomever is constructing a database. Capta [...] are those facts that those constructing the database decide to 'take' given that they cannot record or store everything. They are elements of the continuous material-social reality of everyday life that are most easily intelligible and distinguishable. Capta thus have a specific form, specific modes of representation, purposes, are meaningful to the agency that selected them, and have contexts. Capta are inherently partial and selective, and the distinguishing criteria used thus have consequence.27

Far from providing an unmediated view of the city, urban Big Data frame the city according to the categories that the apparatus that produced them is capable of collecting. Although the data at play in models normed by the scientific method are artifacts of theories, hypotheses, and measurement techniques, the Big Data under discussion - often, information picked up by sensors embedded in infrastructure, the digital residue of online activity, or the traces of a smartphone-embedded GPS – are artifacts of functional systems. The lenses through which they mediate the city are not theory and hypotheses, but the technical apparatus of these systems - the global supply chain, the Internet, electoral politics, the highway system, online shopping, delivery apps, short-term rental platforms, the real-estate market, and their accompanying technologies and metrics. The data they produce, although massive, are indeed "partial and selective," shaped by the logic of these systems and what they make visible.28

Thus, the relationship between the computational model and the real city is not entirely different from that between the "smart city" – the sum of those aspects of the city that leave a data trail – and the real city in its lived totality. Both require a degree of digitally mediated abstraction, and both leave to their human handlers the responsibility of interpreting their implications.

But that mediation risks falling out of view in the "smart city," in that in its ultimate realization all the mediation occurs "upstream" of observation: the city is not just observed but actually functions within digital categories.²⁹ This tight integration of measurement with function gives Big Data a powerful allure of comprehensiveness and objectivity as a window on the city. The cognitive limits imposed by scientific rationalism, on the one hand, and by the challenge of the real-world applicability of simulations, on the other, seem to give way before what then-Editor-in-Chief of Wired magazine Chris Anderson called in 2008

²⁷ Dodge and Kitchin, "Codes," 854.

²⁸ For a richly philosophical, book-length study of data as a paradigm for perception and governance, see Halpern, Beautiful Data. For more critiques of and commentaries on data in society, see Boyd and Crawford, "Critical Questions;" Christin, "What Data Can Do;" Aiello, "Social Semiotics;" and Miller and Goodchild, "Data-driven Geography."

²⁹ Batty frames the historical development of the "smart city" out of the modeling tradition in his 2018 book Inventing Future Cities: "Ever since computers were developed, digital simulations of the city have been attempted [...] What is different [about the "smart city"] is that within the past 10, and certainly 20, years, digital devices - computers and sensors - have been introduced into the real city [...]" (110).

"the data deluge" – as in "The Data Deluge Makes the Scientific Method Obsolete" – and what longtime urban modeler Harvey J. Miller has referred to as "The Data Avalanche." ³¹

While agreeing on natural-disaster metaphors for the phenomenon, Anderson and Miller make opposite arguments about what the advent of Big Data means for the future of knowledge. Anderson proclaims "The End of Theory," with theory replaced by mere effective technical manipulation, while Miller invites a renewed scientific engagement with new data sources: "Shouldn't We Be Digging?" I, like most, would take scientist Miller's judgments about the future of science to heart sooner than Anderson's, but the latter's articulation of the myth is worth considering here for two reasons.

First, the implementation of the "smart city" paradigm within democratic regimes is quite naturally as much or more at the whim of tech companies and popular opinion than it is accountable to the opinions of scientific researchers. Further, Anderson represents only an unsubtle incarnation of a long-standing tension between rationalism and empiricism that it is also quite natural to see coming to a head as the information age embraces everyday life.

Data, the Big kind, the kind generated not by hypothesis and experiment but as artifacts of functional systems laced with sensors or radiofrequency identification or location trackers, sit right at the crux of this tension. In a book chapter, "Fact, Explanation and Expertise," the philosopher Alasdair MacIntyre argues that the *fact* – the conceptual ancestor of the data point – was an invention, more or less, of Francis Bacon. The idea that scientific knowledge could be collected like specimens, in discrete units, independent of theory, was, MacIntyre argues, simply the outgrowth of one rather unreflective theory of the scientific process itself. Perception is itself conditioned by theory, he argues: where a modern observer "sees stars and planets," an ancient observer of the night sky "saw chinks in a sphere through which the light beyond could be observed."³²

One purported solution to the problem of the apparent subjectivity and, therefore, incommensurability of these diverse theoretical frameworks, MacIntyre writes, is empiricism: to reduce this perceptual experience to its preinterpretive form, that of "many small light patches against a dark surface."³³ However,

if all our experience were to be characterized exclusively in terms of this bare sensory type of description [...] we would be confronted with not only an uninterpreted, but an uninterpretable world, with not merely a world not yet comprehended by theory, but with a world that never could be comprehended by theory.³⁴

"The End of Theory," of course, is just what Anderson maintains Big Data brings about. Hypotheses, representative sampling, and abstract modeling, he argues, were tools developed to extend our ability to manipulate the material world beyond the limits of our direct observation. The data-capture capacities of modern infrastructure have pushed those limits beyond view. The "bare, sensory" descriptions of systems and phenomena furnished to us by "the data deluge" give us a panoptic view of the world, but of a world that never can be comprehended by theory. However, Anderson says the effective manipulation of phenomena – he cites Google's uncannily accurate targeting of online advertisements as an example – can be achieved based on observed correlations alone, in the absence of interpretation and articulations of causality.

Miller argues convincingly that Anderson's manifesto fails as a new paradigm for science: "Rather than being atheoretical or antitheoretic," he writes, "the knowledge discovery process [analysis of Big Data] harmonizes well with traditional avenues to knowledge construction in science." In much the same way that Symons upheld the role of "human judgment" in applying the findings of computational models to real-life systems, Miller maintains the importance of human intelligence in distinguishing relevant from

³⁰ Anderson, "Data Deluge."

³¹ Miller, "Data Avalanche."

³² MacIntyre, After Virtue, 79.

³³ Ibid.

³⁴ Ibid., 80.

irrelevant patterns detected by artificial intelligences in large data sets: "the knowledge discovery process benefits from domain expertise and theory to focus searching through vast information spaces and distinguish between real and spurious patterns discovered in these spaces."35

As a paradigm for governance, unexamined automation such as Anderson champions it in an entrepreneurial context would risk aptly fulfilling Jacques Ellul's definition of modern propaganda: "The aim of modern propaganda is no longer to modify ideas, but to provoke action. It is no longer to change adherence to a doctrine, but to make the individual cling irrationally to a process of action."36 Sidestepping ideas and arguments entirely to make way for automatic solutions in the social sphere would be little more than technological totalitarianism – the apotheosis of the comprehensive planning already long suspected as perhaps "more appropriate to totalitarian than to pluralistic-democratic polities," as Friedmann notes.³⁷ As in the gentrification scenario sketched in Section 1, technical systems embedded in political contexts raise more than technical questions and, therefore, demand a more than technical mode of engagement.

4 The city as cultural creation

How might we flesh out the meaning of these "more than technical questions" and this "more than technical mode of engagement"? The idea of the city as a kind of whole - complex, and more organic than mechanical – has emerged as central to the problem of predicting or controlling any of the systems within it. Alongside a philosophy-of-science account for the unpredictability of cities, I have alluded to politically founded objections to the idea of prediction or control of the city as a whole - that it would amount to a form of totalitarianism. In the present section, I pick up this second line of critique and argue that the two problems are profoundly intertwined.

The resources of a phenomenological tradition in the philosophy of technology³⁸ enable us to place scientific models and the systems they model on a continuum with the everyday construction of urban space. The former formalizes what the latter enacts, namely, a certain way of dealing with the world. Once again, as Jane Jacobs famously insisted, theories and techniques related to the city are in constant need of being referred back to the lived human context from which they arise, one which is fundamentally shaped by the ordinary plans and activities of individual city dwellers.³⁹ The following phenomenological description of urban space is meant to be just such an exercise: a grounding of formal study of the city in the city as experienced in everyday life, as a political community, and as a cultural creation. I build upon this perspective in my conclusion to show how data-informed models can enrich cultural models of the city – a class of model that, I argued above, is crucial to an authentic urban politics.

From this perspective, then, space is a setting for action, the substratum of an agent's contact with her environment. This lived space is articulated in a recursive feedback loop between the agent and the environment; in a shared space, the loop also passes by the other users of the space. An agent's intentions project the possibilities around her, and the environment's affordances invite, reject, or are revealed by these intentions. Actions, the external expression of an agent's intentions, leave their trace on the environment as artifacts to be found by others. An artifact might be a passive trace, like a track left in the grass, or an active construction or tool, like a cement path.

Artifacts and tools modify the possibilities inherent in a space: pointing them out, bringing new possibilities into existence, and foreclosing others. A series of tools can be linked into a system, a

³⁵ Miller, "Data Avalanche," 182.

³⁶ Ellul, Propaganda, 25.

³⁷ Friedmann, "Comprehensive Planning," 1971.

³⁸ Although Heidegger is the most prominent figure in this tradition, Merleau-Ponty's study of space in Phenomenology, esp. 253-311, is the one to which my description of lived space in terms of agency is most greatly indebted.

³⁹ See Jacobs, Death and Life, especially "Introduction" (3-25) and "The kind of problem a city is" (428-48).

scaffolding for intention that connects actions to outcomes in a repeatable, predictable way. In place of one path, or a million individual tracks across the grass, we might establish a path system throughout the environment. When our path system reaches a certain point of complexity, we will likely produce a map or a model to reduce the cognitive burden of navigating it.

A model is a simplified representation that guides action by making the possibilities latent in a space or a system explicit. The more the possibilities of a space are articulated in shared models, the more the agents who share those models can appropriate the space together as a common terrain for mutually intelligible and potentially coordinated action. Once we have a map, we can arrange a meeting point or plan a mission.40

Thus, space evolves under the weight of past actions; agents adapt their intentions to the character of space as it is revealed and shaped in experience; and shared space emerges as a medium of communication and coordination. Intentions, actions, artifacts, tools, systems, and models are all articulations and appropriations of space by agents who carry some communicative power. None is simply a brute fact: all bear the marks of intelligent agency, shaped by the logic of the intentions that produce them. In this communication ecosystem, models play a privileged role: as explicit, deliberate and shareable representations of the possibilities given in a space, they carry great power to define possibilities and coordinate action.41

But just as a city functions as a complex system whose behavior is irreducible to the systems that compose it, so a city affords something more than the possibilities already given in the specialized spaces it contains - dwellings and employment centers, museums, stadiums, and concert venues, restaurants and retailers, parks, and circulation spaces. The possibilities implied in urban space are the meta-possibilities of stumbling upon any one of these particular goods or of discovering or inventing entirely new ones. As an invented space and a space of creation, urban space is specially characterized by the continuous introduction of new possibilities, not given beforehand. Such a description accords rather well, I think, with the intuitive experience of what we might call "urbanity" - the aura of indefinable opportunity generated by, yet not reducible to, the sum of all the concrete opportunities a city already offers.

This quality of urbanity helps shed some light on the coherence of urban planning practice, as well. The scientific study of the city has come in for a fair amount of criticism in the article, but my concern with it is ultimately only as it becomes an instrument of governance. In theory, planners sit at this interface, responsible to the findings of urban science but operationalizing that knowledge through practical engagement with a particular city's affairs.

It is interesting to note, then, that urban planners often express their professional obligation to the public interest in part through a commitment to what lies between all the specialized spaces listed above: advocating for public spaces, for the aesthetic coherence of ensembles of private buildings (conceivable as an ensemble only from a vantage point outside any one of them considered individually), and for projectagnostic "incubators" that take community initiatives as something inherently worth fostering, regardless of their particular content. The concrete expressions of urbanism are so diverse that the unifying matter is elusive. But I think the concept of urbanity we have been exploring comes close to naming it. In fact, I would propose "urbanity" to name what this emergent order of cities that we have been discussing from the outside feels like from the inside, in the experience of a city dweller.42

So a link has been established between the experience of urban modelers, the practice of urban planning, and an attempt at a description of one lived experience of what makes cities distinct. Besides the

⁴⁰ For an empirical study of this phenomenon, see Stout et al., "Shared Mental Models." For a study from a political economy perspective, see Denzau and North, "Shared Mental Models."

⁴¹ For a classic exploration of space as a social artifact, see Lefebvre, Production.

⁴² For a critique of the city as an analytical unit that grapples with its conceptual stickiness, see Wachsmuth, "Ideology": "In recent decades, qualitatively new patterns of urbanization have transformed inherited sociospatial landscapes and thereby called into question the coherence of the city as the basic unit of urban analysis. But these patterns have not necessarily had the same impact on everyday consciousness of urbanization - the 'cognitive maps' of these new urban spaces may still resemble the traditional city," 87.

admittedly interdisciplinary fields of urban studies and urban planning, there is, of course, another discipline that purports to take a civic community as its object per se: politics. Granted, in our nation-state era, the term "politics" has lost its etymological identification with the city (Greek: polis) to become scale independent, and its Latin-derived equivalent, "civic," while perhaps more likely to attach to a local political imaginary, has largely been emptied of its content and is comparatively rarely used. But, to follow this etymological hint, I think Aristotle's description of the specifically political, in his Politics, bears an illuminating resemblance to our description of the specifically urban and, before that, to whole-and-parts problem at the root of this discussion of urban modeling. Following this hint will allow us to make a link between the challenges faced by urban modelers and the nature of the city as a political community.

What distinguishes the political community from any other kind of community, Aristotle argues in the opening of his treatise, is the ultimacy of the good at which it aims:

Every state $[\pi \delta \lambda \eta]$ is a community of some kind, and every community is established with a view to some good; for mankind always act in order to obtain that which they think good. But, if all communities aim at some good, the state or political community, which is the highest of all, and which embraces all the rest, aims at good in a greater degree than any other, and at the highest good.43 (I.1)

Aristotle describes this ultimate finality not as if it were a distinct goal that city dwellers happen to share alongside their particular interests – for instance, an aesthetic predilection for flag-waving parade attendance, as we might imagine the "civic" today - but rather as a more ultimate goal capable of justifying those particular interests:

When several villages are united in a single complete community, large enough to be nearly or quite self-sufficing, the state [πόλη] comes into existence, originating in the bare needs of life and continuing in existence for the sake of a good life. (I.2)

On this account, cities are created with a view to survival, coming into being as individuals seek to meet their basic needs through cooperation, specialization, and exchange. But this very coming together somehow produces or suggests the possibility of a goal beyond survival: that of the good life. This new goal then sustains a mode of life - the political - that is no longer reducible back into the realm of mere survival but rather has to do with what makes survival desirable in the first place.

I cite this classical formulation not to make an argument from authority, but rather for its potential to illuminate the relationship between the parts of a city and the whole. Aristotle's distinction between the particular goods aimed at by particular communities and the "highest good" aimed at by the community that "embraces all the rest" bears at least an analogy to the relationship we have been exploring between specialized spaces within a city and urban space per se, and by extension, to the relationship between constituent systems and the functioning of the city as a whole.

If we are to draw any insights from this analogy, perhaps it is in how Aristotle characterizes the relationship between these particular goods and "the highest good." Thus, urban space is generated by the coming together of particular functional spaces that hold definite possibilities. But once it exists, it opens up a more ultimate range of possibilities that have to do with the motivations that prompt and ground the creation of those specialized spaces in the first place.

Locating the pursuit of "the good life" at the scale of a political community seems to invite all the criticisms that are drawn from pluralist quarters by a classical liberal attempt to posit a singular "common good" as the aim of political deliberation.44 The interpretation of this point offered by so thoroughgoing an Aristotelian moral and political theorist as Alasdair MacIntyre argues against taking a concept of "the good life" too univocally. Drawing on the medieval concept of a quest to characterize the indeterminate character of this seeking ("a quest is not at all [...] a search for something already adequately characterized"), MacIntyre proposes that "the good life for man is the life spent in seeking for the good life

⁴³ Aristotle. Politics.

⁴⁴ E.g., Young, "Difference."

for man."⁴⁵ Framing the good life as a quest forecloses the possibility of a particular articulation of that goodness being theoretically given in terms of an equation, as in an optimization problem. An answer cannot be deduced, but only discovered – or invented.

Using this Aristotelian language of goods, we might describe the second-order possibility inherent in urban space as the freedom to pose and propose answers to the question "What is the good life?" The urbanizing activities that produce the city's total form, then – not just legislation and electoral politics, but planning, design, construction, entrepreneurship, activism, art, hospitality, and, perhaps most of all, the practices of everyday life – have both political and creative characters to them that make it impossible to reduce them to predictable, mechanical processes. They are creative, because they are new articulations of the possibilities of social life and intentional appropriations of the space by human agents; they are political, because these proposals and appropriations leave their mark on the space, affecting possibilities encountered there by others who share it.

What ultimately makes cities unpredictable, this account suggests, is not just their complexity as analytical problems but their political and creative characters as products of human freedom. If urban systems are in fact crystallizations of collective human intentions and actions in pursuit of perceived goods, my analogy between complexity theory and moral philosophy may be granted to be more than merely poetic. Cities exhibit behavior that, Harvey Miller points out, "is inherently surprising." MacIntyre, as cited above, describes the way in which unpredictability is an inherent characteristic of social life, given that my power to choose entails that my future actions are always unpredictable even to myself.⁴⁶ Given that cities are concentrations of human agents, these facts seem likely to be related.

If Aristotle seems like a remote source for insight into specifically the twenty-first-century urban issues, consider the witness of geographer Michael Batty, whose more than fifty-year career modeling cities and writing about it has issued in a bibliography that reads like a complete history of the endeavor. The argument emerges immediately in the difference between two titles: "Optimizing Urban Futures," cited above as an archetypal expression of the myth of the perfect predictive model, and *Inventing Future Cities*, Batty's most recent book. What the first lacks that the second includes is the recognition of an irreducible element of creativity that makes literally predicting the future of cities not just difficult but conceptually incoherent.

Everything turns on the difference between optimization and invention: optimization is an analytical-deductive problem to which the solution is included, however, cryptically, within the initial terms. Invention, by contrast, implies the introduction of genuine novelty. Such a distinction does not do away with urban models, as Batty's life's work testifies, but it radically reorients their purpose from a tool of control to an aid to imagination and cultural invention.

5 The city in code: Big Data and cultural models of the city

Thus, we arrive at the same point from two directions, the scientific and the humanistic: our most sophisticated tools for analyzing and depicting the city as a material system – computational models and the "smart city" – appear ultimately as aids to human judgment.

I have been exploring the ways in which the paradigm shifts that are being brought about by Big Data pose a challenge to the kind of communal contemplation that might enable the disparate elements of a single political community to deliberate within a shared image of reality. But there may also be ways in which the rise of Big Data opens new possibilities for collaborative urban image making. The researcher dealing with Big Data is often facing an interpretative and communicative problem. What, among all these data, is important? What does it mean? What does it mean for this or that goal? The data do not provide

⁴⁵ MacIntyre, After Virtue, 219.

⁴⁶ Ibid., 96.

the answers; they occasion the questions that the researcher – and/or a political community – must then pursue. The profusion of relatively messy data could be one reminder that cities, like the models we make of them, are cultural, and not merely technical, artifacts.

The alternative that the critic John Friedmann proposed in 1971 to the comprehensive planning whose efficacy and democratic appropriateness he doubted was "urban policy analysis," a term that attempted to convey the idea that decisions made to order common life are inherently political and deserve exploration from multiple angles. Friedmann envisioned the process as one of "mutual learning" between the analyst and the client (whether a government body or a community group):

The policy analyst [...] is not a man having a superior knowledge in some field, but a superior ability to learn. To be a rapid learner, he will need new tools for exploring complex problem situations, a facility at concept formulation, and a background of relevant theory that will help him integrate new observational data into ad hoc models useful for strategic intervention. But capability for rapid learning is not enough. Unless potential client groups can be taken along on this learning trip, the expert's models will [...] simply remain models. Expert and client must share in the learning experience so that a joint reconceptualization of problems can occur and the possibilities for concerted action be discovered. The policy analyst must thus be able also to structure the learning experience of others, to be a teacher and learner at the same time.47

The role Friedmann imagines for the policy analyst describes very well what the foregoing account suggests as the use of urban models and simulations and the use to be made of the capabilities of the "smart city." Similar to Plato's "city in speech," shared models of the sort Friedmann describes enable "a joint reconceptualization of problems," enabling the discovery of "possibilities for concerted action." Moved by the social and political complexities of the 1970s' urban sphere, Friedmann recognized the operative role of differing images of the city held by its various inhabitants.

This account implies a certain moral responsibility of model makers or anyone who undertakes the translation of data into humanly comprehensible forms. Like the choices that give rise to the city, the choices we make about how we envision our city are debatable. Data interpretation and visualization is not merely science or technique: it is work with a political and even moral dimension to it. It is a distinctly twenty-first-century form of rhetoric, a way of proposing a meeting ground for fellow citizens. We, users and consumers of models and their policy implications, should engage with them in this way: conversationally.

Rather than obscuring human agency behind apparently autonomous processes, good urban models reveal human agents to themselves and give them common terms in which to articulate, evaluate, and revise their intentions. In Michael Batty's words, they function as acts of storytelling, or in Mary Cartwright's words, they provoke us like fables.

An example of such a model, particularly germane to the account I have offered here, is one developed by Juval Portugali, a researcher in the Environmental Simulation Lab at Tel Aviv University. He proposes a modified agent-based model in what he calls "A structural-cognitive approach to urban simulation models."48 Portugali's design for such a simulation draws on current cognitive science to posit that "agents' behavior in the city is strongly influenced by their 'image of the city' and by the global-structural properties of the city."49 In the image that emerges from Portugali's simulation, it is the interplay between the objective structure of the city and the subjective perceptions of that structure formed by agents within it that – in an ongoing, circular feedback loop – produces the city. Thus, no serious examination of urban systems can fail to ignore the role of the images of the city we form formally or informally and collectively or individually, as factors in the city's construction.

Besides being an eloquent expression of the phenomenological sense of the city I have drawn upon here, Portugali's model calls to mind the close ties between modeling as a scientific exercise and modeling

⁴⁷ Friedmann, "Comprehensive Planning," 320.

⁴⁸ Portugali, "Structural-Cognitive Approach."

⁴⁹ Ibid., 358. Note that "global" here is used not in opposition to "local" or "urban" but in the sense of "total" or "related-tothe-whole."

as a form of play. Like the world-building simulations to whose developers the scientific and logistical world owe many of their most sophisticated tools,⁵⁰ his model invites imaginative engagement. It offers its results not as authoritative empirical predictions of the future urban form but as provocations to a consideration of the city's unseen dynamics. The model's maker and its audience, rather than being cast as independent observers of a closed system, are invited to reflect on the internal principles by which they navigate and construct the city and to imagine those of others. By inviting imaginative, even playful, engagement, the model thus serves as a move in a dialogue and as a means for education.

Portugali's model also illustrates the point that although adequate cultural models cannot be constructed by positive science alone, they should be informed by it. Portugali's model transposes the findings of neuroscientific studies into a broader civilizational context. Similarly, alongside more technical management tasks that the "smart city" facilitates, everyday cultural models of the city can be enriched through well-crafted visualizations of Big urban Data.

Visualizing Cities is one such project. Curated by Marian Dörk and colleagues at the University of Applied Sciences in Potsdam, the platform promotes the translation of research findings and commercially produced data about cities into accessible and interactive visualizations. "The complexity of the processes at work [in urbanization] calls for methods and tools to improve understanding of the urban realm and underlying relationships and connections, for all stakeholders from urban planners, decision makers and companies to citizens" explains the project's website, which currently hosts upward of a hundred interactive visualizations of data on urban issues created by contributors from around the world.⁵¹

The cultural and political, and not only scientific, values of such projects should by now be clear. Models map systems, illuminating the possibilities they contain. Data play a similar role, generating representations not with the clear strokes of hypotheses and assumptions but with the pointillism of retrospect. Through both media, images emerge of systems of our invention, which fix and formalize proposals for ways of being in the world, technologically enabled sets of actions and outcomes. What the models and data cannot themselves discover, predict, or replace is the very inventiveness that gave form to the systems they now help to manage and the human judgments of worthwhileness that justify their continued existence.

Maintaining a sense of this original and ongoing agency is a human responsibility. It is eroded or sustained in the way in which we produce and receive the models, data visualizations, and automated systems that help us navigate our world, in the kind of status we give them, and in our persistence in evaluating the reasonableness of the proposals they contain about the good life, about what is worth doing.

Framing the role of modeling and data visualization in urban governance in this modest – but also demanding – way may dampen delusions that data will autonomously solve urban challenges like congestion, environmental degradation, or inequality in the investment of public resources. Data have a role to play in empowering responses to these issues, but their applications remain bounded by our intentions and imagination. As transpositions of scientific findings into a political context, urban models and data visualizations bear the weight of rhetoric. As acts of storytelling, they can challenge and enrich cultural models of the city, frame political deliberation, and orient cultural intentions within the technically bewildering yet enduringly human possibilities of the twenty-first-century urban space.

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⁵⁰ E.g., Forbes, "Improbable."

⁵¹ Visualising Cities, "About;" Poon, "Data Visualizations."

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