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Singapore and the science of cities

How does one design a sustainable city fit for the future and its many challenges? Here's a glimpse into the emerging science of cities, its tools and how Singapore is applying it in urban planning.

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Above: In preparing for climate change, Singapore is piloting the use of polders in order to protect a large island, Pulau Tekong, against rising sea levels while proving that land reclamation costs can be reduced at the same time, says the writer.
PHOTO: HDB

Left: Whole areas, like the Punggol Digital District, will be living labs for researchers and companies to pilot new ideas and solutions, and for people to explore new lifestyles.
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In her influential book, The Death And Life Of Great American Cities, the world-famous urbanist Jane Jacobs wrote: "City processes in real life are too complex to be routine, too particularised for application as abstractions. They are always made up of interactions among unique combinations of particulars, and there is no substitute for knowing the particulars."

Cities are complex in large part because they are made up of millions of people. In the parlance of complexity science, these people are agents. In each city, every person – every agent – interacts with countless others and with the environment. But these interactions are usually hidden from view and very often unpredictable in nature. The aggregate result of these countless interactions can defy conventional analysis and produce outcomes that will confound and astonish.

Ms Jacobs' insight defines the challenge. To understand how a city works, we must understand not only the behaviour of each person living in it, but also how the people interact with one another, and then how they behave as a whole. Given the state of science in the past, this would have seemed an enormous – even insurmountable – challenge. But the situation is changing.

THE NEED FOR A SCIENCE OF CITIES

Physicist Geoffrey West, a former president of the Santa Fe Institute, who is at the centre of efforts to develop a science of cities, explains in his marvellous book, Scale, that "almost all theories of the city are largely qualitative, developed from focused studies on specific cities or groups of cities, supplemented by narratives, anecdotes, and intuition. They are rarely systematic and typically do not integrate issues of infrastructure with those of socioeconomic dynamics".

Yet, this is precisely what Professor West and others are now trying to do: To understand the deep structure of the city and its defining patterns. He argues that we cannot make our cities work better until we know how they work.

But this might seem a quixotic ambition, given how complex cities are. They are often disorganised, even chaotic. How is it possible to uncover commonalities, regularities and behavioural patterns in cities as diverse as Singapore, Mumbai, New York and Shanghai?

For hundreds of years, the basic approach to understanding complex systems was reductionism. It reduces complex systems – like cities – into smaller and simpler parts that are easier to study, analyse and evaluate. Instead of studying cities as a whole, their complex problems are sliced and diced into digestible pieces, such as into functional areas like transport, environment, energy, public health, social dynamics, economics and so on.

But there is a flaw in this approach. The big assumption is that when these smaller parts are reassembled, the whole will behave like the sum of its parts – that in aggregate, the results will approximate the real world. But unfortunately, outside the realm of the hard sciences, reductionism has not been very useful in predicting the holistic behaviour of complex systems like cities, whether they will flourish or fail.

It is not too difficult to understand why. The ancient Chinese philosopher, Lao Tzu, instinctively grasped the complex nature of the world when he wrote that "everything is connected, and everything relates to each other". Agents – people – are not independent. Instead, they are interdependent. They interact and influence one another in ways that defy a deterministic or linear analysis. Their interactions lead to outcomes that are inherently unpredictable ex ante, and that are revealed only when they occur. In other words, we know what is going to happen only when it happens. This is the property of emergence, which characterises complex systems.

THE LAW OF UNINTENDED CONSEQUENCES

As a result of emergence, complex systems are prone to the law of unintended consequences. An intervention in a complex system can create unanticipated – and often undesirable – outcomes.

An obvious example can be found in transport. Traffic congestion, deaths and injuries from car accidents, air pollution and global warming are all unintended consequences of the invention and large-scale adoption of the car.

Unintended consequences can result from failing to appreciate that non-native animals, like the infamous cane toad, introduced into complex – and delicately balanced – environments to control pests, can become pests themselves.

Then there is the failure to consider human behaviour itself. When the British government in India offered rewards for people who killed cobras, the unexpected outcome was a new cottage industry: people began breeding the snakes. Then when the reward was scrapped, the population of cobras in India surged as people released the ones they had bred. This phenomenon, of the outcome being the opposite of the intended one, is known as the cobra effect.

INTERDISCIPLINARY STUDY

So, it is important to look at complex systems not just in their component parts, but also together as a whole. In Singapore today, government-funded urban research requires research proposals to incorporate a social or behavioural component.

But for a very long time, investigating the features of complex systems like cities at a holistic level was eschewed in favour of investigating the properties of the components. It was easier, and the scientific tools for analysis at that micro-level were already available.

Part of the reason for this is that scientists have been conditioned over centuries of reductionism to dissect the complex world into smaller and less complex parts, and to favour explanations framed at the lowest level of scale.

However, more recently, pioneers like Prof West and his colleague, Professor Luis Bettencourt, have been looking at problems of complexity holistically, acknowledging that the properties of higher-level entities like cities are often quite distinct and unrelated to those of the components that constitute them. This is a radical departure from studying problems within disciplinary silos.

Interdisciplinary study achieves a holistic understanding not by rejecting reductionism but by building on it.

In Singapore, like in countless cities around the world, the urban planning process considers the complexity of packing in housing, green space, industrial land, commercial and retail space, land for transport needs as well as other public infrastructure like hospitals, roads and power stations. This process involves integrating the perspectives of economic, social and development agencies, as well as consultations with various stakeholders in the private sector and the public.

This whole-of-government approach is in essence an interdisciplinary approach to planning that enables all stakeholders to better understand the interdependencies and implications of land use and strategic decisions.

The irony is that this interdisciplinary approach has occurred without a parallel foundation in an integrative science of cities, at least until now.

NEW TOOLS FOR THE SCIENCE OF CITIES

The challenge of taking an interdisciplinary approach was compounded by the lack of the tools for looking at complex systems holistically. But the situation is changing.

Complexity science tools, when applied to cities, are beginning to provide fresh and usable insights that deterministic models have failed to produce. These tools include agent-based modelling, which examines how agents in a complex system interact with one another and influence system behaviour.

To explore how such tools can be used in Singapore's context, government agencies are already conducting research and acquiring confidence in using them. This is a major step towards establishing a science of cities as a foundation for urban planning.

EMERGENCE OF BIG DATA

Furthermore, the availability of data to assist in the quantitative – as opposed to the qualitative – study of cities has grown significantly in recent years. Indeed, there is so much data being generated that the amount of data created over the next three years will be more than the data created over the past 30 years.

The agents within a city – the people, public and private institutions, markets and networks – all generate a lot of data. The Internet of Things produces enormous amounts of data from an ever-increasing network of interconnected sensors that also interface with and impact the real world. All this constitutes what we now refer to as big data. The revolution is that we now have the technology both to capture big data, as well as to process it.

Singapore's Smart Nation initiative is in essence an exercise to systematically capture this big data. When combined with high-performance computing, increasingly powerful data analytics, and artificial intelligence, such big data can be converted into useful content to discover new patterns and trends. This is a truly powerful capability that is vital to the development of the science of cities.

The tools of complexity science combined with the insights from big data can help us to "see" the city differently, through new lenses. What then are the fresh possibilities to imagine and shape a different and better city for the future? And if we can imagine a different city of the future, we can take active steps towards realising it. This is what a good science of cities should be able to achieve.

THE RESEARCH BEING DONE

In Singapore, there is no shortage of research into urban matters. The Lee Kuan Yew Centre for Innovative Cities, the Singapore-ETH Centre's Future Cities Laboratory, the Lee Kuan Yew School of Public Policy as well as a host of other university-based centres, laboratories and institutions study aspects of the urban setting. The next step is to integrate such research – combining the reductionist with the holistic. In time, this will evolve into the science of cities that Prof West and others are championing.

Already in Singapore, the Centre for Liveable Cities is taking the lead to integrate the efforts of these various research institutes, using new tools of complexity science.

Others have begun to embrace this holistic approach. One is the Government Office for Science in the United Kingdom. In 2013, it launched the Foresight Future of Cities project. Its concluding report, Future Of Cities: Science Of Cities And Future Research Priorities, examined how cities work by adopting a systems level view of cities – both city systems and systems of cities, cutting across multiple scales – local to national – and sectors – people, organisations, resources, land, infrastructure – with an emphasis on understanding the interdependencies between city systems. This neatly frames the study of cities in holistic terms, and is a contribution to the growing body of work to develop a science of cities.

TESTING AND SCALING UP

In complex systems like cities, exploration and experimentation are often more valuable than relying on predictions of analytical models. There needs to be a willingness to try things out, to experiment with new approaches and solutions. The approach is to probe, sense patterns and to act, even in the absence of complete information. Pilot programmes, demonstrators, prototypes and "beta versions" should be embraced as a foundational approach to deal with complex systems. If they work, they are evidence that the hypothesis can be scaled up. If they fail, then the damage is limited.

In Singapore, this approach is adopted for some complex urban challenges. In preparing for climate change, we are piloting the use of polders in order to protect a large island, Pulau Tekong, against rising sea levels while proving that the costs for land reclamation can be reduced at the same time. We are prepared to experiment at scale.

Whole districts, such as the Punggol Digital District for the smart digital economy, and the Tengah Forest Town for sustainability, will be living laboratories for researchers and companies to pilot new ideas and solutions, and for people to explore and embrace new lifestyles.

In 2016, a floating solar photovoltaic system was test-bedded at Tengeh Reservoir. With its success, the pilot was scaled up 60 times to create one of the world's largest floating solar farms. This will power our local water treatment plants, making Singapore's waterworks one of the very few in the world to go 100 per cent green.

BETTER PLANS AND POLICIES

As Prof West observes, the future of humanity and the long-term sustainability of the planet are inextricably linked to the fate of our cities. This is compelling reason to develop a science of cities that can provide a framework for understanding how they work, and what drives their growth and functioning.

Many of the building blocks for a science of cities are already in place. We have long experience in studying cities at the component level. The next step is to study them holistically. For the first time, this appears possible. The tools of complexity science are steadily improving. Big data is now available and the technology to collect and analyse it is there.

Together, these should be a spur to assemble and integrate the different building blocks, with a new science of cities superimposed on it. It should not just be an interdisciplinary approach, but also a practical approach of partnerships between companies, government agencies and communities in pilots, demonstrators and experiments.

Strategically directed funding can shift research in this direction. In Singapore, the Urban Solutions and Sustainability research domain is a major funding platform that is already being deployed to support efforts to build a new science of cities. The hope – and the ambition – is that it will produce new knowledge through research and experimentation that can lead to the development of better plans and policies to ensure Singapore's future liveability and sustainability.

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