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"GOVERNANCE IN COMPLEXITY: A SINGAPORE PERSPECTIVE"

Introduction

This morning, I will talk about the impact of complexity on governance, in particular urban governance, with reference to the Singapore experience.

It is as a city that Singapore confronts a central challenge of its existence. That is, it is a complex human system. As a city, Singapore is home to thousands, if not millions, of people – or agents, if you prefer. And the population is diverse, as Singapore is a multi-racial, multi-religious, and multi-cultural society. The people interact with each other in ways that are very often out of sight and mostly unpredictable. Machines add another layer of complexity. Not only do they enable people to communicate with other people. Increasingly, machines talk to other machines. Mobile phones communicate with GPS satellites to pinpoint our location so that ride-hailing drivers can find us, without our being aware that this communication is taking place.

Emergence

Such interactions give rise to collective behaviours that are emergent. This property of emergence is a defining characteristic of all complex systems. Even if we could work out how every single agent in the system interacts with

one another, predicting the behaviour of the entire system is usually not possible, because the whole is greater than the sum of its parts. Outcomes are unpredictable *ex ante,* and are only revealed when they happen. So, we are surprised. That is why predicting the results of an election is often a fraught exercise, despite the deployment of countless surveys, polls, electronic markets, and regression models. That is why certain narratives can go viral, almost spontaneously, creating social change, like Greta Thunberg's speeches on the climate crisis that have helped spark a movement for action against global warming.

Circular Causality

Furthermore, a city is not just complex. It is also a complex adaptive system. That means it has the ability to adapt and evolve in response to changing conditions. The implication for governments is that it is not sufficient to use deterministic, linear analysis to work out the effects of a policy input. The Newtonian characteristic of clear cause and effect is absent. Instead, circular causality is often present in complex systems. For example, does a city become rich because it has good infrastructure? Or does a city have good infrastructure when it becomes rich? This is like the proverbial *chicken and egg* problem. It can pose big headaches for governments which often assume that causality is linear.

Scale

As complex systems, cities are also subject to scale. What happens when a city grows? Does the demand for infrastructure, or energy, or food, or water, grow at a corresponding rate? But if the correlation is not linear, then planners ought to know what the scaling factor is. This is in order to ensure that there are adequate provisions in the plans to meet the needs of a growing city. I recall many years ago being told that for a city like Singapore, the rule of thumb was that its demand for energy – and water – grew at twice the rate of its population. I do not know whether there was a theoretical or empirical basis for this. But it hints at a feature of cities as complex systems in which economic activity is systematically enhanced with increasing size of population. The term used to describe this aspect of complexity is *increasing returns to scale*, or *super-linear scaling*. This non-linear characteristic means that plans and policies which work in a small city-state like Singapore might not work in a mega-city like Tokyo.

The Growth of Complexity

Cities are the result of thousands of years of evolution. Today they stand at the apex, the most complex units of human society. But they are the mother lode of many of the gravest problems that mankind faces today – poverty, crime, inequality, disease, pollution, wasteful consumption of energy and resources. At the same time, they are the main generators of wealth. They

create economic growth, produce ideas, and catalyse innovations that change the world. It is this duality, arising from complexity, that makes it important to understand how cities work. Cities are indeed a fascinating and important object of study.

The Emergence of Cities and the Rise of Complexity

It was not always so. Life was simpler and significantly less complex when people lived in small groups as hunter-gatherers during prehistoric times. It was the emergence of agriculture that led to the Neolithic Revolution some 12,000 years ago. The nomadic life of the hunter-gatherers began to be replaced by more sedentary societies based in human settlements like villages and towns. Villages and towns grew into cities over time. And this urbanisation trend has continued unabated to the present day. The tipping point arrived in 2012 when more than half of humanity were living in cities. By 2030, 60% of the projected world population of eight billion will be urban dwellers.

It is the urban milieu that has been the catalyst for the development of a multitude of new human capabilities. Over time, people were no longer just hunters or farmers. They became builders, craftsmen, businessmen, entertainers, teachers, scholars, and so on. As inhabitants of towns and cities took on increasingly specialised roles, interdependency and diversity multiplied, and complexity grew in tandem.

The Imperative to Create Order

The complexity that emerged created an imperative for a new type of organisation – government – to manage it. An early and rudimentary form of government was the Council of Elders, which governed through consensus rather than imposed rules. Before written records became widespread, knowledge was passed down by word of mouth. Naturally, the elders had the most knowledge and wisdom because they were around the longest. The people trusted their judgement, and gave them the power to decide for the group based on their past experience.

But as complexity increased, a more sophisticated form of government emerged to replace the much simpler Council of Elders. The Code of Hammurabi, dating back to around 1754 B.C., provides clues as to how early civilisation began to learn how to manage complexity. The Code comprised 282 laws covering a variety of subjects. It prescribed punishments for those who flouted it. Through the Code, King Hammurabi maintained political order and managed the complexity arising from the different practices, precedents and norms in the Babylonian empire. The Code is significant because it was the first set of laws in the ancient world that dealt with everyone – the agents – in society. There were laws for the lower classes, and laws for the upper classes. In so doing, the Code implicitly acknowledged the complexity of human society, and the resultant need to regulate the behaviour of all the agents in the

system. While Hammurabi's Code may no longer be in use today, its conceptual underpinnings remain with us to this day.

Arguably, the crux of governance has been to apply – if not impose – orderly solutions to the myriad of complex problems that afflict our societies, our politics and our everyday lives, in an effort to make what is complex merely complicated or even simple. Indeed, the bureaucratic propensity is to create consistency in behaviour, in order to reduce complexity and increase predictability. For example, we see this in legal systems that are based on uniform punishments even for complex and varied crimes.

So, it is not surprising that governance in independent Singapore was exercised through strong regulation, seeking compliance with policy rules. This approach enabled the government to embark on a number of major initiatives that helped to lay the foundations for Singapore's prosperity and stability. These included a massive public housing programme; heavy investments in infrastructure – in public transport, our port and airport; and an activist, government-led approach to attract foreign investments and build up the capabilities to support higher value-added activities.

But while governments try to reduce the complexity out there by coming up with all kinds of laws and regulations, there is a limit to how much order they can – or should – produce in a complex environment.

Economic Complexity

Per capita GDP, levels of industrialisation, trade volume, and so on, are conventional indicators of economic health. However, some economists like Ricardo Hausmann, César Hidalgo, and Luciano Pietronero, have suggested that the most important predictor of growth is economic complexity, or the diversity of products that an economy possesses.

Countries with the most natural resources tend to have simple economies, as they do not produce unique goods. Thus, economies that are dependent on a particular kind of product – for example, oil or timber, or automobiles in the case of Detroit – may do well when demand for these products are high, but when demand falls, they cannot compete in other sectors because they are not diversified.

The ability to produce unique goods and services depends on the amount of "productive knowledge" in an economy. Innovation occurs when these bits of productive knowledge are connected. The serendipity that is the basis for innovation is more likely to occur in economically complex systems, either by harnessing existing capabilities in new combinations, or by accruing new capabilities.

So, governance of a city-state like Singapore cannot be all about reducing complexity – far from it. Instead, in certain contexts where the aim is to

generate economic growth, it should catalyse complexity, by breaking down barriers and creating more networks to connect multiple economic domains. Silicon Valley is a prime example of economic complexity. Talent from all over the world, people bringing with them different skills, experiences, ideas, and dreams, come together, connect with venture capital, and generate start-ups whose innovations transform the world.

But I would like to sound a cautionary note here. The anthropologist Joseph Tainter is famous for his study of complex societies. His proposition, developed in his seminal book "The Collapse of Complex Societies", is that as complexity increases in a system, eventually the marginal value of complexity diminishes. At this point, the flow of information is throttled. There is less sharing and redistribution of resources.

My interpretation of Tainter's work is that there is a point of optimality – or tipping point – where complexity enhances rather than reduces value. Towns and villages are too small – so they often end up as laid-back sleepy communities, undiversified in their offerings to the world.

On the other hand, many countries are too large – they are clearly closer to the points of marginal disutility and collapse in Tainter's characterisation. He cites the Western Roman Empire as a prime example. While it had great military power and resources, it had also grown too big and barbarian invasions and plague began to weaken the empire. The empire finally disintegrated when

an increasing number of communities were lost to invaders.

Cities, being somewhere in-between, are more resilient because they have sufficient complexity to sustain themselves. But it begs the question of what will happen to the mega-cities like Beijing, or New Delhi, or Jakarta, where populations threaten to burgeon into unthinkably large urban sprawls?

The Conundrum of Boundaries

To this end, boundaries are very often used to reduce complexity. This is achieved by drawing boundaries around smaller parts of a larger system in order to make things easier to manage. So, nations are divided into provinces, provinces into cities, cities into municipalities, and so on.

So, we are conditioned into thinking of a boundary as something that separates one thing from another. In reality, a boundary does not just separate, but also connects the system to its environment. Singapore may be a small city-state of 721 square kilometres, but it trades across its borders with the rest of the world, to the extent that its trade dependency ratio of 3.5 is among the highest in the world. To understand this point, it is worth recalling what the Renaissance polymath, Leonardo da Vinci, once wrote: “Everything connects to everything else.”

This is important for cities. The trading of goods, the distribution of capital, and the movement of talent, people and ideas keep cities in the

economic game. This activity leads to productivity gains and innovation that are the basic source of economic growth, and which raise living standards. Without such movement across borders, without distribution and re-distribution, productivity will be stifled and cities will stagnate. This is entropy, a concept borrowed from thermodynamics which says that a system will ultimately degenerate into disorder. That is why free trade is vital to the modern global economy.

In this regard, the economist Richard Baldwin says that the flows of know-how have grown more important in the past two or three decades, as infocomm technology has improved, enabling coordination from a distance. He writes that, "The contours of industrial competitiveness are now increasingly defined by the outlines of international production networks rather than the boundaries of nations." Globalisation increases the porosity of boundaries, while increasing connections. The internet plays a similar role in cyberspace.

Towards a Science of Cities

While Singapore has made remarkable progress since independence, the approach to develop the city-state has been much more art than science. Arguably, the policies, plans and innovations that created the Singapore of today did not follow any particular theory or science. The government took an emergent, problem-solving approach. It solved problems in a pragmatic way,

sometimes tackling them through experimentation, test-bedding and pilot projects, and sometimes just acts of faith.

But this emergent, problem-solving approach that served Singapore well in the past will not be enough as the urban environment becomes ever more complex. Instead, if we can discover – or uncover – scientific principles and laws that underpin the complexity of cities, then we can make better plans and policies to cope with a world that is growing increasingly VUCA – or **V**olatile, **U**ncertain, **C**omplex and **A**mbiguous.

In his brilliant book, "Scale", the theoretical physicist and complexity scientist, Geoffrey West, asks this intriguing question:

> "Can we develop a *science of cities* … meaning a conceptual framework for understanding their dynamics, growth and evolution in a quantitatively predictable framework?"

Today, most theories of cities are qualitative. Typically, they do not integrate the physical aspects of the city like infrastructure with those of society and human behaviour. Complexity, which actually demands a holistic and multidisciplinary approach, is abjured in favour of the much simpler *reductionist* approach. This relies on an assumption – that what is complex can be reduced to simpler subsets that are easier to analyse, and that when re-aggregated, will produce results that approximate the real world. In

government, reductionism is expressed in a tendency to divide big problems into smaller pieces, which are then dealt with separately by specialised agencies.

But despite the practical utility of this approach, it gives the false impression that investigating the features of things at a holistic level is less useful than investigating the properties of the components. In fact, it carries the risk of missing the wood for the trees. By not viewing a problem in its totality, the trade-offs necessary for resolving complex problems cannot be made.

In contrast, complexity science looks at the behaviour of the whole system. It employs tools such as agent-based modelling, which examine how autonomous agents interact with one another and influence system behaviour. These tools, when applied to economics and to other areas like urban planning, provide fresh and useable insights that deterministic and reductionist models have failed to produce. In Singapore, government agencies are beginning to use such tools to address complex problems in areas such as land transportation, health, and housing.

A science of cities, as proposed by Geoffrey West, would likely use the tools and holistic approach of complexity science to search for commonalities, regularities, patterns, principles, and universalities of the whole complex system.

Let's take a look at the massive public housing system, which is a foundational policy of independent Singapore. Today, more than 80% of the population now live in twenty-three public housing towns. The question is whether we can derive some scientific theories from the experience of building and managing these towns that would improve the quality of future towns, and the revitalisation of the older ones? What are the rules that make a town compact and self-sufficient? What plans and designs would optimise infrastructure and the provision of amenities? What are the hidden connections in the social and economic features of a town that attract residents to stay or to move out?

Are such questions just *pie in the sky* musings, or are the conditions ripe to develop a science of cities that is Geoffrey West's vision? There are good reasons to feel that such an ambition is within reach today.

Big Data

First, there is big data. Embedded in big data is information and insights about the agents that generate it. There is a lot of big data, and cities generate most of it. Last year, all the data in the world was estimated to amount to 33 zettabytes. A zettabyte is a mind-boggling 10^{21} bytes. By 2025, it is estimated that this will grow to 175 zettabytes, or a compound annual growth rate of 61%. The last two years alone generated 90% of all data in the world since the beginning of time. This pace is accelerating with the growth of the Internet of

Things. The challenge is to extract useful information and insights from this big data. If we can process and analyse all that data, then we can see patterns, and identify correlations that were previously hidden from view.

Smart Nation is a strategic initiative in Singapore to harness infocomm technologies and networks to create tech-enabled solutions that will enhance the way people live, work, and play. At the core of Smart Nation is big data, collecting it, and analysing it. Today, up to 80% of data is unstructured, including images, videos, and voice recordings. Luckily, huge strides have been made in the technology to collect and process big data. High performance computing, new technologies, and recent advances in data analytics are now available to enable us to turn such unstructured data into useful content.

Then there is artificial intelligence, or AI. AI, combined with computing power and data analytics, will allow us to analyse a greater variety of datasets in fresh combinations, cross-referenced for new insights, to discover patterns, trends, and associations, especially relating to human behaviour, that could not be readily analysed before.

This can help agencies and decision-makers to track and monitor the development and staging plans of key infrastructure in tandem with population and economic growth. This can help to improve public service delivery and improve resilience through better predictive management. It can be harnessed to support strategic long-range scenario planning in land-use, transport and

infrastructure. In the development of new public housing towns, big data can be mined to understand the demographic profiles, needs and social aspirations, so as to provide better amenities for the residents.

A Singapore Experience

The Centre for Liveable Cities – or CLC – is a Singapore government think-tank that takes an integrated and inter-disciplinary approach to the research of cities. Today, it is collaborating with the Santa Fe Institute to apply the tools of complexity science to study Singapore's urban systems – housing, mobility, health and wellness, the economy, and the environment. Urban issues are being studied at three levels: the city as a system and the coarse-grain science for such as system; the networks and flows within the system; and people as the agents in the system, their behaviours and choices. The aim is to derive scientific principles to complement our empirical methods of urban planning and policy-making. The research is scoped to exploit the data, tools and applications that government agencies have acquired and developed in recent years, such as geospatial analytics, datasets, agent-based modelling, and so on.

A collaborative eco-system made up of government agencies, research institutions, and industry, is supporting this research. Hopefully this effort will lead to a science of cities developing in Singapore, with potential application to other cities in other parts of the urbanising world.

Conclusion

Complexity is a powerful lens that can illuminate for us the challenges of urban governance, and what we can do in response. For this reason, complexity is now becoming part of the vocabulary of government in Singapore. Acknowledging its importance and relevance to good governance, the Singapore Civil Service College has just launched a primer on complexity entitled "Navigating a Complex World: A Simple Guide for Public Officers".

Governments will have to learn to better govern in complexity, and to manage complexity. New tools of complexity science, and for analysing big data, are now making this possible. Hopefully, this will inspire and support research into urban systems, leading to the development of a new science of cities, an effort that Singapore hopes to contribute.

Thank you.

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