Smart Cities and Resilience

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ABSTRACT

For most of history, cities have been coupled social-biophysical systems. Recently, information and communications technologies (ICT) provide a basis to create trebled social-biophysical-cyber systems. This emerging situation will enable better monitoring, modelling, and evaluation of services that support health, safety, and welfare—including the creation of forms of system organization and services that were previously not possible. New opportunities may, though, result in new vulnerabilities as sub-systems become more interconnected and interdependent. This paper discusses urban planning and design strategies to prevent, reduce, manage, and recover from stresses that can negatively effect populations. It offers that different kinds of uncertainty are addressed with different approaches to create order in complex urban systems and, thereby, establish capabilities and capacities. Specifically: (1) sustainability concerns moral or normative uncertainty and is approached through the internal management of resources; (2) resilience concerns epistemological uncertainty and is approached through mitigating harm from external disruption ; and, (3) antifragility concerns ontological uncertainty and is approached through risk exposure and experimentation. An adapted implementation of the Political-Military-Economic-Social-Infrastructure-Information (PMESII) framework is used to describe urban functions. Three ways of ordering urban systems are identified: (1) order from above through the combination of political, military, and infrastructure sub-systems, (2) order from below through the combination of social, economic, information sub-systems, and (3) order from within through the combination of political, infrastructure, and information systems or the combination of economic, infrastructure, and information systems. Special attention is given to the adoption of Information and Communications Technology and the smart cities, which offer new ways to augment sustainability, resilience, and antifragility.

1.0 INTRODUCTION: THE VULNERABILITY OF CITIES (AND OF STATES)

At the geopolitical level, cities mediate the relationships between states and their citizens and, increasingly, between globally interconnected cities and their stakeholders. At the local level, cities provide services that enable large numbers of strangers to live among one another in close proximity and pursue individual economic interests. Across these activities, cities are open to exogenous and endogenous uncertainty that can affect the lives and livelihoods of residents. These include the timing, duration, and intensity of natural and anthropogenic disasters, political instability, economic upheaval, technological disruption, and terrorist attack. In light of these situations, urban societies continually re-organize to establish and improve capabilities that allow the prevention, reduction, management, and recovery from disruption.

Such capabilities will become increasingly important. Now that more than half of the world's population lives in urban areas.[1] Over the coming decades, urban populations will continue to grow in raw numbers and as a percentage of total populations.[2] Further, beyond needs to care for large numbers of urban residents, cities play vital roles in the success of their host nation states. In this light, the wellbeing of cities and metropolitan regions are central to national interest to international stability. This premise was foreshadowed just after World War II when it became recognized that *national security* was more than *national defense*. Speaking before Congress, former US Secretary of the Navy James Forrestal said, 'Our national security can only be assured on a very broad and comprehensive front. … The question of national security is not merely a question the Army and Navy. We have to take into account our whole potential for war, our mines, industry, manpower, research, and all the activities that go into normal civilian life.'[3] Since then, those involved in security matters have progressively become aware of not just of rising external threats, but of internal vulnerabilities. Recently, NATO Secretary General Jens Stoltenberg started calling attention to the interconnections between civilian and defense sectors to provide security. Explicitly noting the need for significant use of civilian infrastructure to support the military mission,[4] he has called for member nations to improve the resilience of their societies.[5] Defense-related editorials and policy organizations have been quick to second the remarks.[6] Looking forward, it can and should be argued that security in the 21st century will require an understanding of and an engagement with cities, what might be humanity's most complex creations.[7]

2.0 CITY AS SYSTEM: FUNCTIONS AND FORMS

1.1 City Functions

A city can be understood as purposeful, emergent, complex, open, and self-organising system.[8] More concretely, a city can be understood as a coupled system that combines social systems and biophysical systems. Increasingly, cities are becoming trebled systems that combine social-, biophysical-, and cyber systems. The various system configurations provide capabilities that support the gamut of social and society goals. The laws of physics (that is, what must occur) and the negotiated settlement of norms (that is, what could and should be done) both contribute

[1] United Nations Fund for Population Activities, *State of World Population 2007: Unleashing the Potential of Urban Growth* (New York: UNFPA, 2007).

[2] United Nations, Department of Social and Economic Affairs, Population Division, *World Urban Prospects—2014 Revision* [ST/ESA/SER.A/366] (New York: United Nations., 2015).

[3] J. Forrestal, Testimony, *Hearings on S. 825 on Establishing a Research Board for National Security Before the Senate Commission on Naval Affairs,* 79th Congress, 1st Session (1945).

[4] J. Stoltenberg, Keynote Address, Global Security 2020 (GLOBSEC) Bratislava Forum (October 7, 2020), https://www.nato.int/cps/en/natohq/opinions_178605.htm.

[5] J. Stoltenberg, Twitter post (October 21. 2020) https://twitter.com/jensstoltenberg/status/1319300381290172420.

[6] E. Braw, 'A 21st-Century Reality Is Dawning on NATO', *Defense One* [online newspaper] (October 14, 2020), https://www.defenseone.com/ideas/2020/10/21st-century-reality-dawns-nato/169230/; S. Sprenger, 'NATO chief seeks technology gains in alliance reform push', *Defense News* online newspaper] (October 9, 2020), https://www.defensenews.com/global/europe/2020/10/09/nato-chief-seeks-technology-gains-in-alliance-reform-push/

[7] J. Portugali et al eds., *Complexity Theories of Cities Have Come of Age: An Overview with Implications to Urban Planning and Design* (Berlin: Springer, 2012).

[8] M. Batty, *The New Science of Cities* (Cambridge, MA: MIT Press, 2013); M. Barthelemy, *The Structure and Dynamics of Cities: Urban Data Analysis and Theoretical Modeling* (Cambridge, UK: Cambridge University Press, 2017).

to a city's capacity to meet these goals and to distribute benefits across space and over time. System processes are evident through the concentrations, interactions, and flows of people, water, food, goods, energy, and information.[9]

Notably, urban systems can exhibit nonlinear dynamics, reciprocal feedback loops, time lags, heterogeneity, and surprises.[10] These qualities combine to create uncertainty and volatility. This uncertainty allows for the emergence of both positive outcomes, such as economic growth through innovation,[11] and negative outcomes, such as the disruption and degradation of basic services that could contribute to the formation of so-called 'feral' cities.[12] Policy questions related to the distribution of city services and exposure to risk result in moral or normative uncertainty. Anticipating the locations, timings, durations, and intensities of identifiable external disruptions results in epistemological uncertainty. Possibilities of unidentified or unprecedented disruption result in ontological uncertainty.[13]

In a companion paper, the Political-Military-Economic-Social-Infrastructure-Information (PMESII) framework was adapted to more explicitly identify functional aspects of cities by rephrasing the prompts for each of the six primary variables to 'how…?' questions and by identifying 'how…?' questions to consider interactions.[14] Figure 1 provides an illustration of these interactions. Answers provide descriptions of the ways fundamental questions about the provision of services. The answers can also reveal how issues and uncertainties relating to the provision of services within a city are framed and stances within debates about provisioning could and should change in the future.

[9] P. Baccini and P.H. Brunner, *Metabolism of the Anthroposphere: Analysis, Evaluation, Design*, 2nd edition (Cambridge, MA: MIT Press, 2012).

[10] Jianguo, L. et al., 'Complexity of Coupled Human and Natural Systems', *Science* 317, no. 5844 (2007), pp. 1513–1516.

[11] K. Christiaanse, 'The Open City and its Enemies', in *Open City: Designing* Coexistence, edited by K. Christiaanse, J. Singler, and T. Rieniets, 25–35 (Amsterdam: SUN Architecture, 2009).

[12] R.J. Norton, R.J. 'Feral Cities,' *Naval War College Review* 55, No. 4 (2003), pp. 97–106.

[13] H. Ban and O. Ahlqvist, 'Visualizing the Uncertainty of Urban Ontology Terms, *Studies in Computational Intelligence* 61 2007), pp. 85 –94; R. Sela, 'Global Scale Predictions of Cities in Urban and in Cognitive Planning', in *Complexity, Cognition, Urban Planning and Design*, edited by J. Portugali, E. Stolk (Cham: Springer Proceedings in Complexity: 2016), 181–196 .

[14] A.W. Shearer, 'Functions of a Large and Complex City', NATO S&T Technical Course SAS-149: *Basics of Complex Modern Urban Functions and Characteristics* (2020).

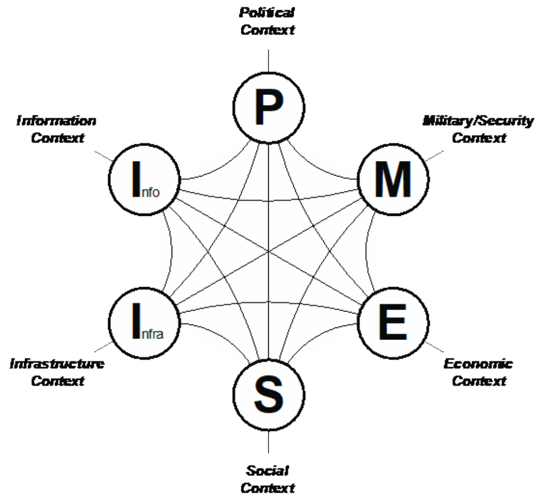

Figure 1: PMESII Interactions.
(Source: A.W. Shearer)

2.2 Establishing Order in Purposeful, Emergent, Complex, Open, and Self-Organising City Systems

Each of the six questions about the primary variables and the fifteen pairwise questions contribute to understanding how services are organized provided within cities. By doing so, order is created in the city system. It is offered here that three triplets of interaction have particular importance for establishing order within the complex system and enable the other functions to emerge. Figure 2 provides an illustration of these three ordering foundations.

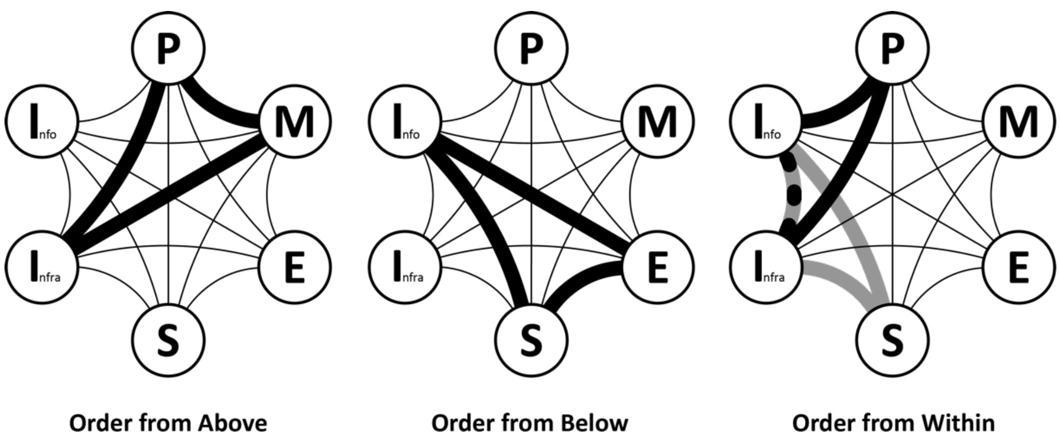

Figure 2: Triplets of Urban Order.
(Source: A.W. Shearer)

'Order from above' combines the Political, Military, and Infrastructure questions and their pairwise interactions. An example is Baron Haussmann's nineteenth century layout of Paris stared under the rule of Emperor Napoleon

III. The narrow mediaeval streets were replaced by wide boulevards prevent citizens from creating barricades. The street layout also provide a way to organize new water and sewer systems.[15]

'Order from below' combines Economic, Social, and Information questions and their pairwise interactions. It is predicated on notion that neighbors, who know each other well and see each other often, and voluntary social groups, in which members have some familiarity and interaction based on common interests, enable many small-scale negotiations. An outcome is a basis for mutual support and local-scale consensus on rights, responsibilities, and norms of behavior. An example is Greenwich Village in lower Manhattan as described (and for some time protected) by social critic Jane Jacobs.[16]

'Order from within' is an evolving model that is made possible by the use of new computational technologies in urban areas. The technologies and their implications for system change will be discussed in greater detail below. Two models are possible and both may operate simultaneously. One possibility of 'order from within' combines Political, Infrastructure, and Information questions and the their pairwise interactions. Given the role of governmental involvement and control, it might be viewed as a new form of 'order from above.' An example is the Chinese Social Credit System, which assess trustworthiness based on economic and social activities and reputations.[17] The other source of 'order from within' combines Social, Infrastructure, and Information questions and their pairwise interactions. It might be viewed as a new form of 'order from below.' An example is Facebook or other social media platforms.[18] The two modes or models of ordering under this heading reflect an ongoing tension in debates on the e-government. On the 'order from above' side is the prospect of networks of sensors and automated control executed by algorithm.[19] On the 'order from below' side is the proposition of using the technology to facilitate participatory governance.[20]

2.3 City Forms

The layout of a city—its physical form—supports urban functionality by structuring spatial and temporal relationships of the various concentrations and flows. Architect Cedric Price humorously but aptly described eras of urban form to eggs at breakfast[21]: Ancient cities were like hard boiled eggs with clearly defined centers and protective outer walls. Industrialized cities of the eighteenth and nineteenth cities were like fried eggs. There were still identifiable centers, but the walls was gone (rendered useless by artillery) and lower density development was spread over increasing distances along paved roads, canals, and railroads. Cities of the twentieth century were like scrambled eggs. There was no longer a center and relatively dense development covered over large areas.

[15] S. Kirkland, *Paris Reborn: Napoleon III, Baron Haussmann, and the Quest to Build a Modern City* (New York: Picador, 2014).

[16] M. Page and T. Mennil eds., *Reconsidering Jane Jacobs* (New York: Routledge, 1991); J. Jacobs, *The Death and Life of Great American Cities* (New York: Random House, 1961).

[17] D. Mac Sithigh, M. Siems, 'The Chinese Social Credit System: A Model for Other Countries?', *Modern Law Review* 82:6 (2019), pp. 1034–1071; F. Liang et al, 'Constructing a Data-Driven Society: China's Social Credit System as a State Surveillance Infrastructure', *Policy & Internet* 10:4 (2018), pp. 415–453.

[18] C. Barry et al, P*utting Social Media to Work* (Boston: Bain & Co., 2011)

[19] M. Dholer et al, 'Smart Cities', *IEEE Communications Magazine* 51:6 (2013), pp. 70–71.

[20] A. Caragliu, C. Del Bo, and P. Nijkamp, 'Smart Cities in Europe', *Journal of Urban Technology* 18:2 (2011), pp. 65–82.

[21] C. Price, 'The City as an Egg', *Papers of Cedric Price, Collection of the Canadian Centre for Architecture (1982)*, https://www.cca.qc.ca/en/search/details/collection/object/420807; see also R. Banham, 'City as Scrambled Egg', *Cambridge Opinion* 17 (1959), pp. 18–23.

Extending the metaphor, twenty-first century cities and mega-regions might be understood as frittatas with overall dense development and specialized districts.[22]

Beyond the surface of the breakfast metaphor, the different approaches to structuring flows and concentrations have been enabled by alternative dominant models of development based on degree of public (that is, governmental) or private action. Early city walls required highly centralized public control and the ability to marshal resources for a single project. (Walls were sometime taken down and rebuilt to allow city growth, but there was typically only one wall to protect the city in a given period.) Roads, canals, and railroads required public coordination of interconnections, rather than control, of multiple private providers/builders. The 'scrambled' mix of the twentieth century urban development further relaxed public control and empowered a great many private providers/builders to provide a kind of scaffolding—a temporary support—until surrounding projects were completed and continuous development was established. A result of this kind of private led development is what can appear to be 'formless' urban form. In the ancient city, the walls provided a mold and the city took on the shape of the hardened perimeter. In the early industrial city, major transportation routes provided an internal skeleton or framework on which subsequent development was hung. This type of urban form was not fully dependent on the shape of the skeleton, but it was closely related to it. In cases of scaffolding, signs of spatial and locational logic—and the related distributions of risks and opportunities associated with urban flows—can be hidden. Twenty-first century cities largely continue the practice of privately led development; however, large transportation network projects are still undertaken to connect existing or potential hubs of activity.

3.0 SMART CITIES

While the physical organization of a city typically evolves over decades, functional capabilities and capacities can change relatively quickly alongside the introduction of new technologies. Such rapid transformation is currently being experienced in urban areas around the world through the increased use of Information and Communication Technologies (ICTs) and the Internet of Things (IoT). The expression 'smart cities' is often used to describe these new configurations, but it must be understood that ideas about how a city might be 'smart' varies across interests that span efficient use of resources, progressive government, and economic development.[23]

Minimally, smart cities incorporate digital wired and wireless devices within a city to share information. Devices include those in peoples' pockets (such as mobile phones), placed throughout buildings (such as sensors for water, electricity, and heating use), and built into city streets (such as vehicular and pedestrian traffic counters). Estimates of the number of connected devices vary, but one study noted that there were and expected 30 billion devices connected to the Internet of Things (IoT) by 2020 (the time of this writing).[24] Beyond hardware, smart city applications may include advanced data acquisition and information management techniques (such as remote sensors, augmented reality (AR) visualization, etc.), 'big data' analytics that find patterns in human behavior, public

[22] R. Weller, 'The City is not an Egg', in F. Steiner, G.F. Thompson, and A. Carbonell, eds., *Nature and Cities: The Ecological Imperative in Urban Design and Planning* (Cambridge: Lincoln Institute of Land Policy, 2016), pp. 27–45.

[23] L. Mora, R. Bolici, and M. Deakin, 'The First Two Decades of Smart-City Research: A Bibliometric Analysis', *Journal of Urban Technology* 41:1 (2017), pp. 3–27; A.M. Townsed, *Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia* (New York: W.W. Norton, 2013); M. Battyet al, 'Smart Cities of the Future', *The European Physical Journal Special Topics* 214:1 (2010), pp. 481–518; R.G. Hollands, 'Will the Real Smart City Please Stand Up?: Intelligent, Progressive or Entrepreneurial?', City 12:3 (2008), pp. 303–320.

[24] S. Munirathinam, 'Industry 4.0: Industrial Internet of Things', *Advances in Computing* 117:1 (2020), pp. 129–164.

space management (such as interactive planning efforts), public safety (cameral surveillance, disaster management, etc.), social services support, and e-government.[25]

While public and private sector interest having being a smart cities is high, the difficulties of developing them cannot be underestimated and progress toward idealized images has been uneven. The challenges include: public acceptability, security and privacy issues, lack of interoperability, legal issues, lack of IoT governance and expertise, ethical and social concerns, cost of investment and maintenance, mobility of devices, data availability and quality, and the complexity of problems.[26]

In most instances, smart city technology is being adapted to (or grafted on) existing urban infrastructures.[27] Such adoption is not limited to rich cities located in industrialized nations and high impact projects have been undertaken in the Global South. For example, smart phones have allowed city information services to be distributed and also enabled interactive mapping of informal slum settlements.[28] As a result, new forms of civic participation and governance are starting to be seen in developed and developing nations.[29]

There have also been several efforts to create a smart city from scratch.[30] One example of new smart city proposal is high-tech enclave of Masdar City, which is currently being built-out 17 kilometers from Abu Dhabi.[31] It was one of several sustainable cities initiatives undertaken in the United Arab Emirates.[32] The city takes its name from the government owned company that is overseeing the project. It operates as a high-tech district or incubator and serves as a demonstration of urban conditions that are expected to emerge in future urban environments, Construction started in 2006 with the intent to base 1,500 businesses, educational institutions, and international organizations. When complete, the city will house 50,000 residents, and its daytime population will swell by

[25] E. Glaeser, K. Kourtit, and P. Nijkamp, 'Do Urban Empires Rule the World? An Introduction', in E. Glaeser, K. Kourtit, and P. Nijkamp, eds. *Urban Empires: Cities as Global Rulers in the New Urban World* (Routledge: New York: 2021), pp. 1–28.

[26] M. Janssen, et al, 'Challenges for Adopting and Implementing IoT in Smart Cities: An Integrated Approach', *Internet Research* 29:6 (2019), pp. 1589–1616.

[27] A. Datta, 'New Urban Utopias of Postcolonial India: Entrepreneurial Urbanization in Dholera Smart City', *Dialogues in Human Geography* 5:1 (2015), pp. 3–22; T. Bakici et al, 'A smart City Initiative: The case of Barcelona', *Journal of the Knowledge Economy* 4.2 (2013), pp. 135–148.

[28] B. Ndemo, 'Slum Digitisation, Its Opponents and Allies in Developing Smart Cities: The Case of Kibera, Nairobi', in S. Hawken, H. Han, and C, Pettit, eds., O*pen Cities* | *Open Data* (Singapore: Palgrave Macmillan, 2020), pp. 129–149; H. Hodson, 'The Streets with No Name', *New Scientist* 224:2992 (2014), pp. 21–21.

[29] D. Linders, 'From e-Government to We-government: Defining a Typology for Citizen Coproduction in the Age of Social Media', *Government Information Quarterly* 29:4 (2012), pp. :446–454; N. Wehmer, 'Towards Smart & Resilient Urban Settlements in Asia & the Pacific, a Pro-Poor Perspective', *Journal of Architecture* 11:1 (2012), pp. 97–118; D. Sadoway and S. Satyarupa, '(Re-) Prioritizing Citizens in Smart Cities Governance; Examples of Smart Citizenship from Urban India', *The Journal of Community Informatics* 10(3) (2014):article 1179, http://www.ci-journal.net/index/php/jiej/article/view/1179; S. Goldsmith and S. Crawford, *The Responsive City: Engaging Communities through Data-Smart Governance* (San Francisco: Josey-Bass, 2014).

[30] S.T. Shwayri, (2013) A Model Korean Ubiquitous Eco-City? The Politics of Making Songdo, *Journal of Urban Technology* 20(1):39–55; L. Carvalho, 'Smart Cities from Scratch? A Socio-Technical Perspective', *Regions, Economy, and Society* 8:1 (2015), pp. 43–60.

[31] T. Yigitcanlar et al, 'The Making of Smart Cities: Are Songdo, Masdar, Amsterdam, San Francisco and Brisbane the Best We Could Build?', Land Use Policy 88 (2019), article 104187; T. Mezher, 'Building Future Sustainable Cities: The Need for a New Mindset', *Construction Innovation* 11:2 (2011), pp.136–141; N.O. Madichie, 'IRENA—Masdar City (UAE)—Exemplars of Innovation into Emerging Markets', *Foresight* 13:6 (2011), pp. 34–47; P. Kingsley, 'Masdar: The Shifting Goalposts of Abu Dhabi's Ambitious Eco-City', *Wired* (2013), http://www.wired.co.uk/magazine/archive/2013/12/features/reality-hits-masdar.

[32] J. Willis, 'Fast Forwards: 10 Years of Sustainability Initiatives in the Gulf Region', *Architectural Design* 85:1 (2015), pp. 114–119.

another 40,000–60,000 commuters. The overall structure of the city is based on historical precedents of ancient Arab cities that accommodated the hot climate without mechanical systems.[33] Accordingly, a traditional wind tower captures prevailing breezes for distribution within the city. The streets are very narrow and shaded by buildings. The streets are also short in a staggered city that grid produces updrafts to help circulate the air. As a result, temperatures can be 15–20°C cooler than Abu Dhabi. Within this physical framework, design decisions were made to accommodate 21st century infrastructure. The main city is elevated on a platform supported by steel and concrete columns. Street level is carless. Wheeled transit operates below. Originally, there were to be self-driving pods, but these have been replaced by ordinary electric cars. Also, below grade are water management systems that allow up to 80 percent of the water used to be recycled. Electricity is generated by a 22 hectare solar array that is supplemented by rooftop panels. Consumption is managed in the buildings by automated sensors that activate and deactivate circuits as needed by people. Also of note is that Masdar City exists as a business venture and as part of its business plan, smart city technologies are developed, tested, and then licensed for use in other parts of the world. Moreover, projects are viewed not just to support the city, but are part of an effort to diversity the national economy of Abu Dhabi.[34] Again, noting the challenges of creating smart cities, the project has not been viewed by many as a flawed experiment that failed to meet expectations, since not all components, such as an energy-based currency and self-driving cars, have been realized.[35]

Across these implementations and activities, smart cities are predicated not only on the ability to count and measure, but the ability to apply the observed data for making policies, plans, and designs and for taking actions that change the performance of city functions. On the one hand, this observation is unremarkable in that such reflective practices have always been part of modern professional practices (and even used long before there were 'professions') to shape the built environment. On the other hand, the pervasiveness of the technologies, the volumes of data and meta-data (that is, data about the observed data) collected, the computational capacity to relate the various data from disparate sources, the uses of artificial intelligence (AI), shifts from automation to autonomous systems , and the and speed at which analyses can be made enables a higher level of system-wide understanding and influence to bring about change.

4.0 UNCERTAINTIES AND URBAN STRATEGIES TO MANAGE THEM

Urban systems operate under uncertainty. Each kind of uncertainty has led to its own approach for analysis directions for action. Figure 3 provides an illustration of urban planning and design paradigms, noting the dominant consideration of uncertainty. Relative attentions are indicated on lines connecting the three terms.

[33] A.M. Hassan et al, 'From Medieval Cairo to Modern Masdar City: Lessons Learned through a Comparative Study', *Architectural Science Review* 59(1 (2016), pp. 39–52.

[34] F. Cugurullo, 'Automation to Autonomy in the Smart City', *Frontiers in Sustainable Cities* (2020), doi: 10.2289/frcs.2020/00038.

[35] G. Gokce, S*paceship in the Desert: Energy, Climate Change and Urban Design in Abu Dhabi (*Durham, NC: Duke University Press, 2019).

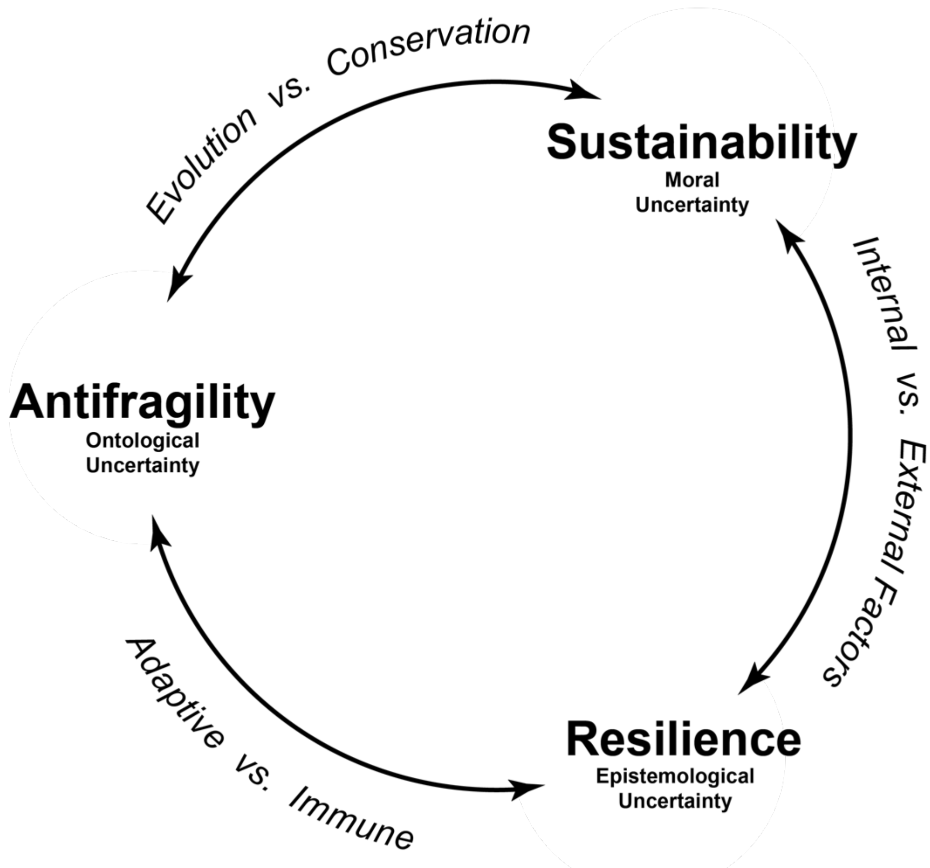

**Figure 3: Urban Planning and Design Goals and Kinds of Uncertainty.
(Source: A.W. Shearer)**

2.1 Sustainability

The concept of sustainability can be understood generally as a focus on the long-term management of resources that are internal to a system. The premise was common in texts on agriculture, forestry, and other natural resources fields since, at least, the 16th century,[36] but the term gained widespread attention in the late 1980s through *Our*

[36] J.A. Dixon and L.A Fallon, 'The Concept of Sustainability: Origins, Extensions, and Usefulness for Policy,' *Society & Natural Resources: An International Journal* 2:1 (1989), pp. 73–84; K.F. Wiersum, K.F. (1995) '200 Years of Sustainability in Forestry: Lessons from History', *Environmental Management* 19:3 (1995), pp. 321–329; P. Warde, The Invention of Sustainability', *Modern Intellectual History* 8:1 (2011), pp. 153–170.

Common Future (also known as the Brundtland Report).[37] The study was motivated by concerns about relationships between globalized economic growth and environmental degradation. Its authors argued that there is an explicit connection between natural resources conservation and human resources development goals of health, equity, and prosperity. It positioned the environment as 'where we live' and development as 'what we do to improve our circumstances.' The underlying argument is that continued development is predicated on the successful stewardship of limited resources. Further, development that overexploits resources reduces the options for development available to future generations. The theme that present generation should not meet its needs by compromising future generations has remained at the forefront of sustainability thinking. The report gave special attention to developing nations that were extensively using their resources to meet the needs of rapidly rising populations, but did not have the administrative or technical skills to implement conservation plans. The authors offered the opinion that such a condition could lead—and arguably has led—to chronic poverty in some parts of the world.[38] While the book raised awareness about the connections between place and society, it did not identify specific forms of governance or economic structures that would necessarily produce sustainable societies. While there is (still) not a unified sense of how sustainability should be operationalized, a general consensus can be seen around the 'triple bottom line' of environment, equity, and economics (or planet, people, and profits).[39] Determining what is 'right' or 'just' or 'best' in any one of these areas raises difficult questions . The asserted interdependent relationships of these variables presents the basis for moral or normative uncertainty. [40]

Smart cities might be seen as contributing to sustainability by the improved management of flows of services.[41] For example, advancements in the use of sensors can significantly affect how individual buildings perform with respect to energy and water use. Photovoltaic surfaces—including semi-transparent and transparent glass[42] [43]—battery storage,[44] and electricity grids would allow buildings to both consume and provide power.[45] Other examples include assessing the least congested roads at a given hour and available parking spaces near a specific venue and signaling when garbage bins are full.[46] Data acquired over time allows a basis for predictive analysis of city behavior and allow potential problems to be addressed before they reach a critical point.

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[37] World Commission on Environmental Development, *Our Common Future* (Oxford, UK: Oxford University Press, 1987).

[38] J. Von Braun and F.W. Gatzweiler eds., *Marginality: Addressing the Nexus of Poverty, Exclusion, and Ecology*, Dordrecht: Springer, 2014); S. Barrett et al., eds., *Environment and Development Economics* (Oxford, UK: Oxford University Press, 2014).

[39] J. Elkington, 'Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development', *California Management Review* 36:2 (1994), pp. 90–100; B. Bahal-Clayton and B. Sadler eds., *Sustainability Appraisal: A Sourcebook and Reference Guide to International Experience* (New York: Routledge/Earthscan, 2014).

[40] S. Veenman and P. Leroy, 'Environmental Outlooks: How They Frame Futures and Long Term Uncertainty', *Futures* (Vol. 82, 2016), pp. 63–75; D. Moellendorf, 'A Right to Sustainable Development', *The Monist* (Vol. 94, No. 3, 2011), pp. 433–452.

[41] N. Komninos, 'Intelligent Cities: Variable Geometries of Spatial Intelligence', in M. Deakin and A.W. Husam, eds., *From Intelligent to Smart Cities* (London: Routledge, 2012); S. Mutula, 'E-government Implementation Strategies and Best Practices: Implications for Sub-Saharan Africa', *Mousaion* 30:2 (2012), pp. 5–23.

[42] K. Kostantinos, and A.K. Athienitis, 'A Study of the Potential Benefits of Semi-Transparent Photovoltaics in Commercial Buildings', *Solar Energy* 115 (2015), pp. 120–132.

[43] N.W. Stauffer, 'Generating Power from Everyday Surfaces, *Energy Futures* [MIT Energy Initiative] (2013), pp. 22–26.

[44] S. Gupta, 'From Gadgets to the Smart Grid', *Nature* 526 (2015), pp. S90–S91.

[45] D. Cardwell, 'Tesla Ventures into Solar Power Storage for Home and Business', *New York Times*—New York edition:B3 (May 1, 2015).

[46] R.J. Firmino et al, 'Fear, Security, and the Spread of CCTV in Brazilian Cities: Legislation', Debate, and the Market, *Journal of Urban Technology* 20(3) (2013), pp. 65–84.

But would such changes in efficiency alone help cities achieve the goals of sustainability? Some research suggests they would not. A literature review of smart cities and sustainability found that most subject matter experts believed sustainability was a precondition for introducing smart technology. Doing so would ensure the larger goals were first met and then improved upon. Using technology as a way to achieve early stage sustainability was too technocentric, complex, and ad hoc.[47] Another review provided a critique that similarly found issues of equity to be undervalued in smart city practices.[48]

2.2 Resilience

The concept of resilience concerns abilities to withstand, recover, and adapt from external shocks.[49] The consideration of resiliency becomes increasingly important as a system's connections to its environment—especially its needs for exchanges with its environment—become uncertain or volatile.[50] With resilience, the moral questions emphasized under the paradigm of sustainability about which societal goals should be prioritized are replaced by epistemological questions related to the difficult task of the production of knowledge about complex systems for purposes of governance.[51] Bringing about the qualities of resilience in cities and urbanized regions requires not only efforts to identify possible sources of disturbance and potential direct impacts, but also ways to think through second-, third-, and subsequent order effects of the initial disruption. Understanding linkages across possible chains of impacts involves considering the ways independent or semi-independent agents (influential stakeholders and groups) act, react, and counter-react to the events as they unfold.[52]

Notions of resilience can be found across numerous disciplines and policy arenas.[53] The widespread prevalence of the term and what might be considered a shared general—but fuzzy—understanding of its meaning allows the concept to be shared by stakeholders who hold different perspectives. Two models or types of resiliency can be distinguished.[54] In what has been called 'engineering resilience,' a system is resilient if it has the ability to return to a preexisting state after experiencing a shock. An example is a suspension bridge that is stressed by strong winds in a storm. Engineering resilience assumes the system functions only at a single equilibrium (with

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[47] T. Yigitcanlar et al, 'Can Cities Become Smart without Being Sustainable? A Systematic Review of the Literature', *Sustainable Cities and Society* 40 (2019), pp. 348–365.

[48] J. Coldding and S. Barthel, 'An Urvban Ecology Critique of the "Smart City" Model', *Journal of Cleaner Production* 164:15 (2017), pp. 95–101.

[49] C.S. Holling, 'Resilience and Stability of Ecological Systems', *Annual Review of Ecology and Systematics* 4, no. 4 (1973), pp. 1–23.

[50] Rees, W.E. (2000) Eco-Footprint Analysis: Merits and Brickbats, *Ecological Economics*, 32:371–374

[51] D. Chandler, *Resilience: The Governance of Complexity* (New York: Routledge, 2014); C. Aradau, 'The Promise of Security: Resilience, Surprise and Epistemic Politics', *Resilience: International Policies, Practices and Discourses* 2:4, (2014), pp. 73–87; M. Welsh, 'Resilience and Responsibility: Governing Uncertainty in a Complex World', *The Geographical Journal* 180:1 (2014), pp. 15–26.

[52] S.T.A. Pickett et al. 'Resilient Cities: Meaning, Models, and Metaphor for Integrating the Ecological, Socio-Economic, and Planning Realms', *Landscape and Urban Planning* 69, no. 4 (2004), pp. 369–384.

[53] A. Rose, *Defining and Measuring Economic Resilience from a Societal, Environmental and Security Perspective* (Singapore: Springer, 2017); M.D. Cavelty, M. Kaufmann, and K.S. Kristensen, 'Resilience and (In)Security: Practices, Subject, Temporalities" *Security Dialogue* 46:1 (2015), pp. 3–14; R. Reid, L.C. Botterill, 'The Multiple Meanings of "Resilience": An Overview of the Literature', *Australians Journal of Public Administration* 72:1 (2013), pp. 31–40; F.S. Brand and K. Jax, 'Focusing the Meaning(s) of Resilience: Resilience as a Descriptive Concept and a Boundary Object', *Ecology and Society* 12:1 (2007), article 23.

[54] G. Peterson, G. et al., 'Ecological Resilience, Biodiversity, and Scale', *Ecosystems* 1 (1998), pp. 6–18; C. Folke, 'Resilience: The Emergence of a Perspective for Social-Ecological Systems Analysis', *Global Environmental Change* 16:3 (2006), pp. 253–267; S.T.A. Pickett et al, 'Ecological Resilience and Resilient Cities', *Building Research & Information*, 42:2 (2014), pp.143–157.

allowances for variable boundary ranges). In contrast, with 'ecological resilience,' a system is resilient if it can maintain critical functions when transitioning to and in different equilibria states. An example is an estuary that is sufficiently stressed by a storm and its geomorphology (such as a new coastal drainage pattern, wider river mouth, etc.) is changed and allows the introduction of new species that disrupt or displace the prior food chain. These differences in focus can create difficulties for interdisciplinary operationalisation.[55] The idea of resilience with regard to urban systems is based on several lines of thought including those from engineering, disaster planning, socio-ecological systems, and governance, but has leaned toward the idea of resilience in the environmental sciences.[56]

As a consequence of this mixed intellectual lineage, even within a relatively narrow discourse, a common definition remains illusive.[57] One proposed synthetic definition is:

> 'Urban resilience refers to the ability of an urban system – and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales – to maintain or rapidly return to desired functions in the face of disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.'[58]

The primary advantage of this definition is that it leaves open multiple and—central to open social systems—negotiable pathways for adaptation.

Figure 4 illustrates the principle of disturbance and recovery. In this diagram, the process of recovery may result in a return to prior functional capacity. The system may have been degraded or improved by way of an adaptation.

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[55] B. Pizzo, 'Problemetizing Resilience: Implications for Planning Theory and Practice', *Cities* 43 (2015), pp. 133–140.

[56] H. Ernston et al., 'Urban Transitions: On Urban Resilience and Human-Dominated Ecosystems', *Ambio* (Vol. 39, 2010), pp. 531–545; A. Smith and A. Stirling, 'The Politics of Social-Ecological Resilience and Sustainable Socio-Technical Transitions,' *Ecology and Society* (Vol. 15, No. 1, 2010), article 11; J. Ahern, 'From *Fail-Safe* to *Safe-to-Fail*: Sustainability and Resilience in the New Urban World', *Landscape and Urban Planning* (Vol. 100, 2011), pp. 3441–343; J. Walker and M. Cooper, 'Genealogies of Resilience: From Systems Ecology to the Political Economy of Crisis Adaptation', *Security Dialogue* Vol. 42, No. 3, 2011), pp. 143–160; A. Bahadur and T. Tanner, 'Transformational Resilience Thinking: Putting People, Power and Politics at the Heart of Urban Climate Resilience', *Environment & Urbanization* (Vol. 26, No. 1, 2014), pp. 200–214.

[57] H. Ernston et al., 'Urban Transitions: On Urban Resilience and Human-Dominated Ecosystems', *Ambio* 39 (2010), pp. 531–545; A. Smith and A. Stirling, 'The Politics of Social-Ecological Resilience and Sustainable Socio-Technical Transitions', *Ecology and Society* 15, No. 1 (2010): article 11; J. Ahern, 'From *Fail-Safe* to *Safe-to-Fail*: Sustainability and Resilience in the New Urban World,' *Landscape and Urban Planning* 100 (2011), pp. 3441–343; J. Walker and M. Cooper, 'Genealogies of Resilience: From Systems Ecology to the Political Economy of Crisis Adaptation', *Security Dialogue* 42, No. 3 (2011), pp. 143–160; A. Bahadur and T. Tanner, 'Transformational Resilience Thinking: Putting People, Power and Politics at the Heart of Urban Climate Resilience', *Environment & Urbanization* 26, No. 1 (2014), pp. 200–214.

[58] S. Meerow, J.P. Newell, and M. Stults, 'Defining Urban Resilience: A Review', *Landscape and Urban Planning* 147 (2016), p. 39.

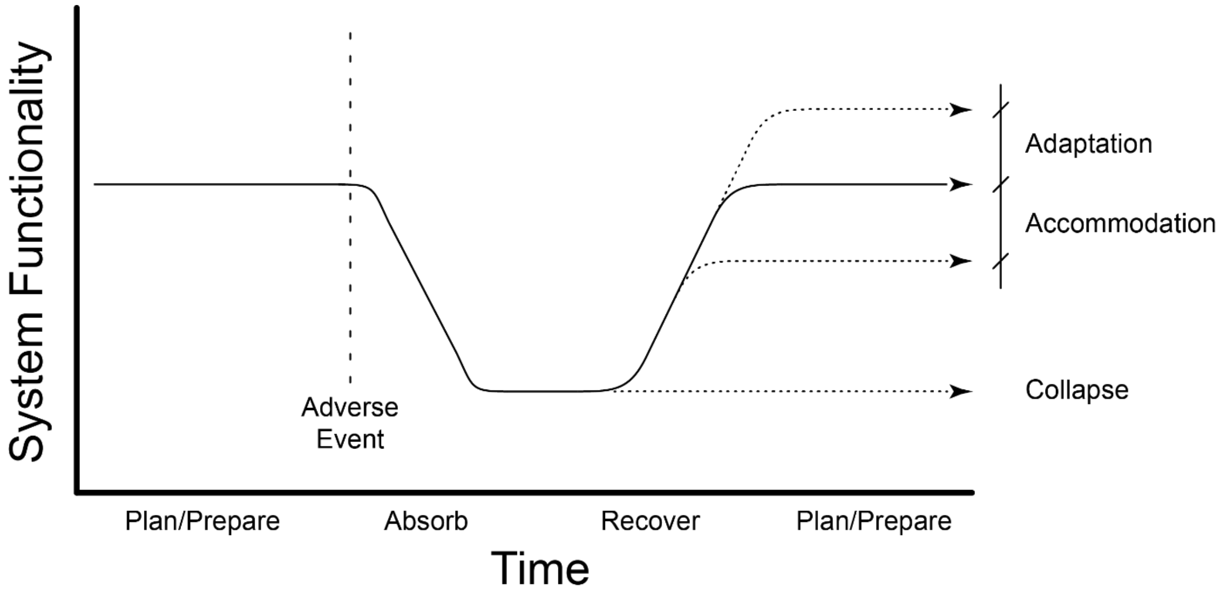

Figure 4: Triplets of Urban Order.
(Source: Adapted from E.B. Connelly et al, 'Features of Resilience', *Environment Systems and Decisions* 37 (2017), pp. 46–50.)

Figure 5 presents an illustration of the cost challenge that comes when increasing resilience. In early stages, there is the benefits in investing in methods to prevent, withstand, and recover from known risks outweigh the expense. But as more and more safeguards are acquired and used, the return on investment becomes increasingly difficult to justify when faced with limited resources.

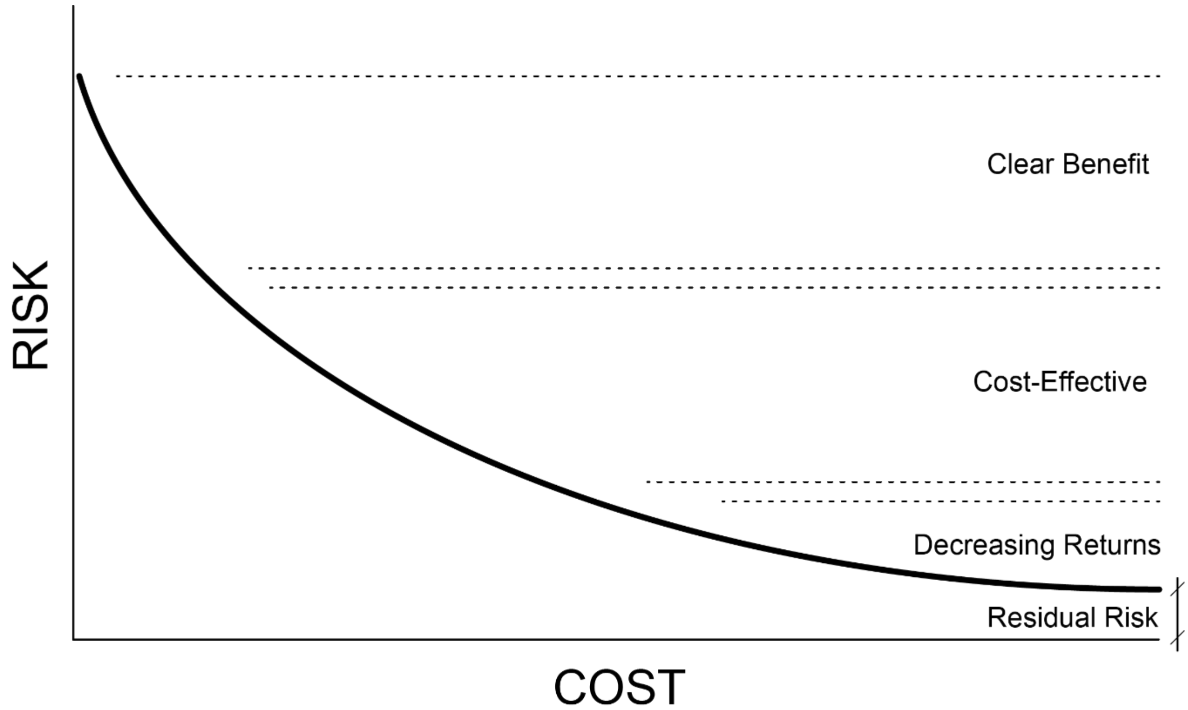

Figure 5: Resilience and Return on Investment.
(Source: Adapted from T.P. Bostic et al, 'Resilience Science, Policy and Investment for Infrastructure', Reliability Engineering and System Safety 175 (2018), pp. 19–23.)

The topic of city resilience receives considerable attention. In could be said that in large part this interest reflects the number of people who live in cities, the unprecedented size of some cities, and the recognition that disasters are becoming more hazardous. Resilience engages uncertainty about what might be done given—or in spite of—the limits of human knowledge. The application of smart city technologies should enable better understandings of present conditions and, therefore, wiser plans with regard to precautions to be taken.

There is evidence that smart city technology has improved responses to disruption. For example, Rio de Janeiro's Intelligent Operations Center was built to help respond to disasters. It brings together representatives of 20 city agencies to monitor 60 layers of real time data [59] and produced a 30 percent drop in emergency response times a few years after it went online.[60] Some research, however, has shown that smart cities are less resilient than 'not-so-smart cities.'[61] Such results may reflect the relative newness of the technology and a lack of integration with decision-making processes and with trusted legacy systems. One can ask if the myriad projects undertaken to be smart have outpaced policymaking and stakeholder acceptance that would have made them intelligent.

[59] N. Singer, 'Mission Control, Built for Cities', *New York Times* (March 4, 2012), p. BU1, http://www.nytimes.com/2012/03/04/business/ibm-takes-smarter-cities-concept-to-rio-de-janeiro.html?_r=2&ref=business.

[60] J. Berst, Why Rio's Citywide Control Center has Become World Famous, *Smart Cities Council* (2013) http://smartcitiescouncil.com/article/why-rios-citywide-control-center-has-become-world-famous.

[61] S.Zhu, D. Li, and H. Feng, 'Is Smart City Resilient? Evidence from China', *Sustainable Cities and Society* 50 (2019), article 101636.

2.3 Antifragility

Antifragility allows the possibility that a system cannot only recover from disturbance, it can benefit from exposure to uncertainty and volatility. The word was coined by Nicholas Taleb after observing the behavior of financial markets, but he argues for its general applicability.[62] In addition to the qualities of city systems already mentioned, antifragile systems tend to be risk allowing or risk seeking, evolve through small-scale experiments, have even distribution of resources, have redundant functional abilities to deliver services, have loosely coupled sub-systems. Cities often display at least some these qualities, but individual cities may not display all—especially with regard to the distribution of resources. Since its introduction, the concept of antifragility has been extended to domains of knowledge ranging from genetics[63] to athletic performance[64] to business operations[65] to computer science[66] to homeland security[67] among other fields.

Taleb distinguishes antifragile systems from fragile and robust systems. Fragile systems suffer harm by volatility, randomness, disorder, disturbance, or other forms of stress. A point of emphasis, with fragile systems there is little to no gain from exposure to volatility but great exposure to loss and potentially to catastrophic failure. An example of a fragile object is a teacup. Robust systems are unaffected by volatility within knowable bounds and resist failure. With robust systems, risk of failure due to volatility is reduced, but chances for large gains are also limited. Taleb's notion of robustness can be related to the concept of resilience as used in this paper.

The ability to manage stresses that had previously not been experienced or that were even unimagined is the quality that distinguishes antifragility from resilience. It is also a point of confusion because it can appear to be a difference of degree rather than a distinction of kind. It must be acknowledged that some understandings of resilience include the possibility of adaptation that enables the system to better withstand future shocks. The improvement, though, is an improvement to address epistemological uncertainty related to the ability to anticipate and guard against the same disruption. For example, after receiving a vaccination (that is, a treatment in which a harmful, but weakened or neutralized pathogen is inserted into a body), the person develops antigens that enable stronger doses to be resisted later. In such cases, the potential cause of harm (the virus) is the same, but differs by the strength and the time it is introduced to the system. A flu shot in the autumn helps prevent contracting flu in the winter, but the same shot does not protect against a different virus, such as measles. With antifragility, attention shifts from resilience's epistemological uncertainty (about understanding the nature of this year's flu strain and how to develop and distribute vaccines) to questions of ontological uncertainty related to the environment and its interaction with the composition, organization, and behaviour of the system. For example, a person who exercises regularly develops antifragile characteristics. During workouts, the body undergoes a temporary metabolic shift as it moves faster or lifts weight and as a result becomes able to run farther and lift heavier objects. An outcome of the temporary stress, the body becomes more generally fit and able to do some things not necessarily anticipated, such

[62] N.N. Taleb, *Antifragile: Things that Gain from Disorder* (New York: Random House, 2012).

[63] A. Danchin et al., 'Antifragility and Tinkering in Biology (and in Business) Flexibility Provides and Efficient Epigenetic Way to Manage Risk', *Genes* 2 (2011), pp. 998–1016.

[64] Y. Hill et al, 'Antifragility in Climbing: Determining Optimal Stress Loads for Athletic Performance Training', *Frontiers in Psychology* 11 (2020), article 272.

[65] A. Jaaron and C.J. Backhouse, 'Building Antifragility in Service Organizations: Going beyond Resilience', *International Journal of Services and Operations Management* 19:4 (2014), pp. 491–513.

[66] K.J. Hole, *Anti-fragile ICT Systems* (Cham: Springer, 2016).

[67] J.T. Egan, *Homeland Security as a Stock Market: Antifragility as a Strategy for Homeland Security*, Master of Arts in Security Studies Thesis (Monterey: Naval Post Graduate School, 2013).

as having improved stamina to assist in an unforeseen emergency. Succinctly, antifragile success is not simply managing the crisis or learning how to handle the same sort of crisis better, but how to handle crises in general.

The fact that urban systems have antifragile characteristics is evidenced by the longevity of many settlements around the world. This quality allows for the residual risk (Figure 5) associated with resilience and epistemological uncertainty to be narrowed. However, there is a question with regard to how the concept of antifragilty could be put into practice due to an inability to assign probabilities and risks of unknown unknowns. A potential answer comes through the use of smart city sensors, a models of the spatial and distributions of services, and urban analytics. With these technologies, it is becoming possible to monitor the distributions and flows of city services and small and medium disruptions across a city in real-time and with locational accuracy.

Figure 6 provides an illustration of the flow of such analysis. At the top, societal capacities are quantified. Moving clockwise, kinds of disruption are noted. These include slowly evolving changes in the context of the city (such as affluence of the regional population or climate change) and fast moving acute disturbances (such as earthquakes, tsunamis, and pandemics), moderately scaled disturbances (such as the flooding of a river or factory explosion), and minor disruptions (such as traffic jams, power outages, political protests). The range of responses include doing nothing, restoring to status quo, reallocations of resources to improve future responses (which might reduce resources to combat other disturbances), or major, capital intensive upgrades (introducing a new major road network, building hospitals, enabling universal education through post-secondary levels of schooling).

The adapted (city function focused) PMESII framework could be utilized to assist in this process by applying quantified indicators of system capacity related to the set of 'how…?' questions. Figure 7 provides a diagram of this framework. Multiple space and time units of analysis need to be tracked. It can be assumed that small disruptions (such as traffic accidents) take place relatively frequently and result in more localized disruption and that larger disruptions (such as broken water mains) take place less frequently and result in larger disruptions. Spatial units would include the mteropolicant region, city-as-a-whole, district, neighbourhood. Temporal units would be once-in-a-generation (say, 25–30 years), a many times in a generation (say, 2–5 years), and perhaps down to individual days. The indicators would be ratios that indicate type or types of response, speed and magnitude of response, and time to the return if normal operations. A system that is increasing in antifragility should display a faster return to normal and, perhaps more important for antifragilty, flexibility in nature of the response. Demonstrations of this redundant capability can not only suggest flexibility in approach, but also, if there is evidence of experimentation of responses, an ability for the system to learn.

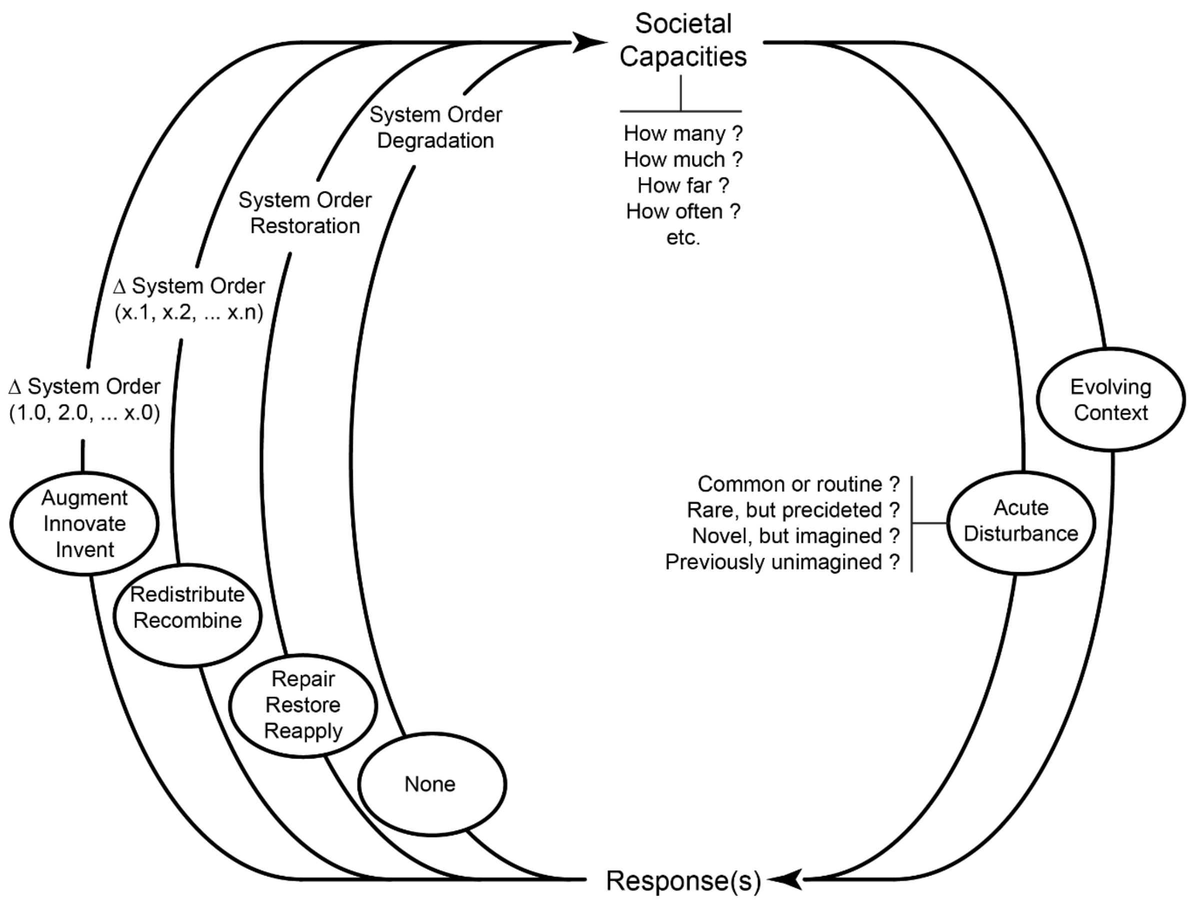

Figure 6: City Systems, Stress, and Response.
(Source: A.W. Shearer and D.J. Kilcullen)

The possibility of identifying and tracking patterns of functional capacities and responses to disruption would allow additional insight on the flows with the larger metabolism of the city. It would serve as a way to assess the impact of small adaptations (changes that are relatively fast and cheap, such as redeploying the distribution of first responders, grocery stores, and the timing of traffic signals) and large adaptations (changes that are slower and more expensive, such as infrastructure investments) to the ways services are provided. Given that each city is unique based on environmental and cultural contexts, it is unlikely that comparative case studies would reveal universal solutions to common problems, but such undertakings might reveal the benefits of some combinations over others. Formal antifagility investigation would also provide a different metric than routinely mentioned goals of optimization and efficiency. From the opposite perspective, decline in the indicator values might also suggest that a city is becoming a more fragile system. While such a determination would not suggest that failure or becoming 'feral' is immanent, it may point to increasing vulnerability.

	P	M	E	S	Infra	Info
P	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month
M	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month
E	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month
S	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month
Infra	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month
Info	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month	Indicators 30-Year 3-Year 1-Year 4-Month

Figure 7: Framework to track antifragilty indictors using the PMESII framework. (Source: A.W. Shearer and D.J. Kilcullen)

5.0 CONCLUSION

Although perhaps an apocryphal story, it has been said that John von Neumann convinced the Institute for Advanced Studies in Princeton, New Jersey to purchase its first computer based on the argument that the ability to count very, very fast would not only change the way some problems were solved, but expand the kinds of problems that could be solved. Now, increasingly widespread use of sensors and volunteered data through social media is giving us more things to count, growing computational capacity is allowing us to count them, and algorithmic sophistication through artificial intelligence is allowing us to make better sense of relationships across tabulations. Combined, these technologies are changing the ways cities are understood. In turn, there new approaches for making policies, plans, and designs for urban areas. As described in this paper, smart cities will allow new approaches to manage uncertainties—including moral or normative, epistemological , and ontological uncertainty—relating to the provision of health, safety, and welfare.

The changes in the administration of services will also have broader implications on the relationships among residents and stakeholders as they are mediated by the city. For most of history, cities have been spatial configurations. Future urban environments will also be spatially enabled and some have even said they will possess a kind of sentience.[68] Future cities will not only actively acquire data about the given moment, they will proactively anticipate and 'nudge' individual and collective behaviours. This point pivots on the concept of providing 'order from within' the city system, and it is arguably through the negotiation of the two models (one based on the Political-Infrastructure-Information triplet, the other based on the Social-Infrastructure-Information triplet) that the forms of kind of influence will become evident.

However the two models of 'order from within' are balanced, there are likely to be new uncertainty, risks, and hazards as coupled human-biophysical systems become trebled human-biophysical-cyber systems. Minimally, there are and will be continuing concerns about identity theft, destruction or degradation of systems, and digital resources held for ransom.[69] And there will be layers of distributed computing, each of which will have its own vulnerabilities. At a high level, capturing, storing, and processing the disparate data will require cities to have operating systems. These may risk becoming outdated faster than the fabric of the city and open to attack.[70] Given the heterogeneity of hardware and software that will be used and the uneven distribution of resources, the potential attack surface of a smart city is large and it is exceedingly unlikely that any one entity could take responsibility (or have the authority) to protect its entirety. More than these vulnerabilities, however, the increasing complexity of the trebled system will contribute to the emergence of new socially contingent relationships. These will inevitably construct new risks.[71]

A final question concerns the role of cities as intermediaries between the nation state and citizens. Over time, sovereign control has shifted from managing territories to managing populations and people.[72] Ubiquitous, geographically and temporally synced Information and Communication Technologies will allow more extensive and perhaps more intensive control. In such situations,

6.0 ACKNOWLEDGEMENTS

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[72] R.S. Rose-Redwood, 'Governmentality, Geography, and the Geo-Coded World', *Progress in Human Geography* 30:4 (2006), pp. 469–486;