City for the Future: Resilient, Equitable, and Regenerative

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Executive Summary

The goal of this report is to imagine and propose a new urban settlement in the United States that is sustainable, resilient, equitable, and regenerative and can be used as a model for redeveloping existing cities.

According to the United States Census Bureau, the average population density for cities is 1,594 people per square mile. By 2050, it is projected that two thirds of us will live in cities. Cities that account for the use of over 75% of global natural resources currently produce over 50% of global waste and emit 80% of greenhouse gasses. This is a result of our linear take-and-make materials economic model, which is unsustainable and highly vulnerable to climate change. This model also produces significant inequalities among community members. The negative consequences of applying a fundamentally linear construct have resulted in an urgent need for us to rethink the urban pattern and metabolism. To create a city that is economically, socially and environmentally resilient, and sustainable, we need to consider a new regenerative circular model that encompasses a systems approach. The pattern needs to incorporate the tenets of all natural systems and be designed with humans in mind. While many urban settlement strategies have been applied to cities, there is no current example that represents a holistic systems approach that adequately characterizes a resilient, sustainable, circular, and equitable city.

A city's metabolism is the flow of all materials and associated energy in the urban system, but it is with a circular economy a city changes its focus from the managing flow to managing the stock. This paper will highlight current best practices in cities throughout the world and propose an innovative model city, which encompasses not only a circular pathway for products that keeps the highest and best use of materials for the longest duration possible but also strives to minimize the city's ecological footprint and loading of greenhouse gases.

In addition, a city must be truly inclusive and accessible to all individuals who are represented in the United States. In order to achieve this, a transparent participatory process is required at all stages of a city's formation: design, implementation, and ongoing maintenance. This will require a new way of thinking about stakeholder involvement because of the absence of an existing population to engage before groundbreaking. An iterative, collaborative planning approach can be used to pilot this type of participatory engagement to coproduce knowledge and successful solutions to create a model city.

Introduction

The goal of this report is to imagine and propose a new urban settlement in the United States that operates as a natural complex system to establish a sustainable, resilient, equitable, and regenerative urban environment that can be used as a model for redeveloping existing cities. Therefore, this report seeks to propose a new framework and model for how an urban settlement is imagined, designed, and managed, as well as how it serves its inhabitants to ensure the city's vision is actualized. This urban system includes the built environment, the natural environment, materials and the related expenditure of energy, individuals, and all of the nonmaterial items necessary such as governance, knowledge, the arts, and spirituality.

To accomplish this goal, this report first provides a summary of the current landscape of cities in the United States and definitions for the commonly used terms and then a brief review of the background and justification for the focus on cities. This introduction will be followed by describing a framework to consider and apply to a selection of urban development strategies. Each urban development strategy will display one example that is often highlighted in research or the media. The purpose of applying the framework to each urban development strategy is to piece together the best aspects of each to inform a model city for the future that is based on a resilient, equitable, regenerative, and circular material flow. Following this review, the report will consider recommendations for a pathway forward toward establishing a model city based on the lessons learned. This approach will propose how to rethink, restructure, and reconnect in the redevelopment, or creation, of new cities. In the conclusion, further considerations and areas for ongoing research will be discussed.

Current Landscape

A city is a large human settlement. It is a permanent, geographically defined area that contains a concentration of people, services, and government. For this report, we define cities as an incorporated area with governmental powers that are delegated by the state or county. As of 2018, there were 19,495 incorporated cities, towns, and villages in the United States. These range in size from those with populations below 5,000 to the largest, New York City, with over 8 million people.

Historically, the purpose of a city is to provide infrastructure and services to the population that lives within the city boundaries. This includes the streets, buildings, power, water, and necessary government. Cities have a significant influence on material inputs and outputs, including the directional pathway of how materials are consumed and discarded. Materials are defined in this paper as water, energy, human products and byproducts, people, and the components of natural ecological systems. In cities, food, water, energy, and consumer goods are constantly flowing in to support the needs of an urban population. These materials are typically discarded as waste after being consumed by the population. This is a predominant linear pathway of material flows that has resulted in unsustainable and inequitable societies.

All of the materials in our existing systems, including within our cities, are connected and interdependent. However, these connections and dependencies are not necessarily included in the current urban planning and design of cities. In addition, the city's geographic boundary typically defines the systems of materials that the city attempts to manage. However, a city itself is embedded within a set of larger systems that exist and extend beyond the city's actual footprint on the landscape (Wackernagel & Rees, 1996). Invariably, two phenomena are associated with city operations that seldom considered in a city's design. First, negative externalities are exported, which are then experienced by others, often far beyond the urban boundary. Second, cities are buffered by space and time from the natural regulating feedback loops that have emerged to avoid unsustainable pathways.

It is also important to note that cities are rarely, if ever, planned and built through a holistic process. Typically, city planning, and implementation is often balkanized by the various municipal departments delegated to ensure services are provided. In addition, cities evolve over time through incremental changes, with limited coordination.

Therefore, we acknowledge and realize the limitations of conceptualizing a "new" city versus focusing on how to structure redevelopment of an existing urban settlement. To be successful in any redevelopment goals, we must first imagine and sketch out what a sustainable, resilient, regenerative, and equitable city would look like. Employing this type of imagination is essential to creating the transformational vision and agency that is needed to redevelop a city such that it provides secure ecological, social, economic, and cultural well-being (Moore & Milkoreit, 2020). While this report will envision a new urban settlement, our intent is to apply the theory and framework that we have developed to existing cities in various pilot projects to understand how to implement the vision and goals of the model city effectively.

Traditionally, the purpose of a city is reflected in the municipal charter, which is granted by state legislature, or indirectly under general municipal corporation law. The charter is a legal document that defines the organization, powers, functions, and essential responsibilities of the municipal government. Many city charters start with a preamble, an introduction, which frames the intent of the charter in a subjective manner that is not enforceable by law. It is in these statements where a municipality can declare the values and goals of the city. Research in the public administration field suggests the need for the government to redirect its emphasis on providing services toward efforts to support quality of life for its citizens (Kirlin, 1996). The purpose and vision of a typical city does not take into account the implementation of sustainability, climate resilience, equity and social well-being, and ecosystem services and functions to create thriving, livable urban settlements that support meaningful lifetimes for the people that live and work there. To accomplish this, public participation must be incorporated in the design, implementation, and maintenance of the model city to ensure the inclusion of local knowledge, beliefs, attitudes, and values in the entire process (Gruber et al., 2015).

A transparent participatory process should be employed before the design process of a model city starts. Participatory processes that include authentic dialogue between stakeholders have been used successfully to engage the public in land-use planning and other social issues (Carson & Hartz-Karp, 2005; Patel et al., 2007; Kahane, et al., 2013;

Daniels, 2018). This type of method allows for the coproduction of knowledge that can inform and establish a successful urban settlement that is influenced by the populations that will live, work, and play there (McCoy & Scully, 2002).

Because the purpose of this research is to conceptualize a new city, with no current residents, a new approach must be adopted to ensure a participatory process. Many recently built cities have suffered from underrepresentation of the populations they originally seek to serve. In fact, many of these cities have become White enclaves of privilege amidst a larger region that does not demographically represent the new city (Ellis, 2002; Grant, 2006; Trudeau and Malloy, 2011). A possible option for overcoming this failure, piloting a participatory process in a city that has yet to exist, will be further explored in the Way Forward chapter of this report. This process relies on an iterative Collaborative Planning Approach (Gruber, et al., 2015) that can be adapted for creating the model city.

To apply the proposed framework to the development of a new city, a systems approach is needed. This type of approach requires stakeholders to expand their focus from the individual parts of a city toward a holistic view that includes how all of the parts work and operate together through their interconnectivity and relationships. Now, before describing the key metrics to consider in planning a city for the future, it is important to first clarify the various definitions that are commonly used in this reflection.

Definitions

There are numerous definitions of what "sustainable" and climate resilient development encompasses in the current discourse. In order to clarify what we are proposing in this paper, the following definitions should be used as a baseline for the vision of a sustainable, resilient, equitable and regenerative city in the future.

Systems Thinking

A system is a set of parts that are interconnected that produce a pattern of behavior over time. The behavior of a system emerges from its components but is greater than just the sum of its parts (Meadows 2008, p. 2). Therefore, even with detailed master planning, a model city will eventually self-organize into a system that is hard to foresee at the point of its conception. This is because systems are embedded within other systems, both temporally and spatially. Overarching systems may change slowly, but once they move to a new state of dynamic equilibrium, all of the systems that are embedded within the larger system shift, creating phenomena such as climate change and its concurrent effects on the embedded biodiversity, economic systems, and human infrastructure (Barnosky, et al. 2012). Moreover, uncontrolled, reinforcing feedbacks in a smaller system can create shifts in an overarching system, such as the loss of forests due to development reducing the sequestration of carbon, which in turn affects the changing climate (Sample, 2017). Imposing a narrow focus with respect to policy, or "fixed" rules for maintaining the status quo, leads to a system that increasingly loses resilience. As resilience diminishes, abrupt and unpredictable shifts in the system may occur (Gunderson and Hollings, 2002, p. 27). This implies that a city's system must engage in continual reevaluation, using an iterative, flexible planning process that recognizes system changes at multiple scales.

Sustainable Development

Sustainable development is the use of resources to improve society's well-being in a way that does not destroy or undermine the support systems that are needed for future growth. In 1987, the Brundtland Commission published its report, Our Common Future, and provided the oft-cited definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987, p. 43). Adopted by 193 countries in 2015, the Sustainable Development Goals (SDGs) are a global plan of 17 goals to end extreme poverty, reduce inequality, and protect the planet by 2030. Specifically, Goal 11: Make cities inclusive, safe, resilient, and sustainable is meant to address some of the most pressing challenges that cities face today (United Nations, 2015). The definition can be expanded and contracted temporally and geographically. When we reference sustainable development, we are using the definition provided above. Ultimately, we view sustainability as a process towards a goal rather than a state of being.

Climate Resilience

The Intergovernmental Panel on Climate Change (IPCC) defines climate resilience as the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation. (IPCC, 2014b, p. 1772)

Many practitioners at the local level have used the terms “climate adaptation” and “climate resilience” interchangeably. However, there are important distinctions between the two that need to be reflected in the local decision-making discourse. Climate adaptation is one option of achieving climate resilience. Many municipal decision makers tend to think of climate change preparedness as engineering resilience (Davoudi et al., 2013). They strive to return to or “bounce back” to what the community looked like and how it functioned prior to a disaster (Davoudi et al., 2013). This prior state may have included social injustice, inadequate public infrastructure and housing, other hazard vulnerability, and a weak local economy (Glavovic & Smith, 2014).

Therefore, it is important to recognize the aspects of resilience that involve “transformative sociopolitical change” (Davoudi et al., 2013; Glavovic & Smith, 2014; McEvoy et al., 2013). In application, this translates to urban planning that improves a specific social system. For example, instead of expanding existing drainage systems in a public housing complex, increased green space could be installed for stormwater retention that also increases psychological well-being (Wolch et al., 2014). This paper will use the socioecological definition of resilience: “resilience is not conceived of as a return to normality, but rather as the ability of complex socio-ecological systems to change, adapt, and, crucially, transform in response to stresses and strains” (Davoudi et al., 2013, p. 309).

It should also be pointed the interdependency of the concepts of resilience and sustainability. Resilience could be considered a necessary, but not sufficient condition for sustainability (Derissen et al. 2011). Where sustainability is an ongoing process towards a goal, resilience is often framed within the context of a shorter temporal horizon based on the best future projections at any moment in time.

Circular Economy

Kirchherr (2017) posits that there are at least 114 different definitions that have been identified for describing a circular economy. The variability in the definition provides a barrier to operationalization and may eventually result in the collapse of the concept. This parallels the history of the use of the word “sustainability.” Thus, one of the potential contributions of this project is to base metrics on core concepts that every definition should come to incorporate (Scheinberg et al., 2020). One of the most ambitious definitions of circular economy is from the same group of scholars:

> A circular economy describes an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. (Kirchherr et al. 2017)

A more straightforward description is put forward by Stahel (2019) by stating that a circular (industrial) economy manages stocks of materials that are manufactured into products such as infrastructure and buildings, vehicles, equipment, and consumer goods so as to maintain their utility for as long as possible and concurrently maintaining natural resources at their “highest purity and value.” This contrasts with a linear economy with objectives to use resources to develop products that may be used once. In addition, many situations where governments, or even businesses, have intervened to (re)cycle these materials circularity is still limited due to a focus of disposal as the ultimate path. Where the *linear* economy is reactive, responding to design and planning decisions, the *circular* economy proactively considers source, flows, interdependence, value-added, efficiency, and the justice effects of product use within the bounds of the city.

Cities create the “enabling conditions” for a thriving circular economy to emerge; therefore, circular thinking should be applied to other aspects of a city metabolism including maximizing the capture and reuse of water, ensuring the circularity of nutrients and sequestered carbon that are imported as food and horticultural products, and establishing infrastructure to maximize the energy cascades that use heating capacity to do work. Such thinking can also be applied to economic activity within a resilient model city, where businesses are linked so that nonproduct outputs from one become the inputs to another. Having the flow of money cycle through the local economy in a way that maximizes its purchasing power before the flight of capital from the region is equally important. Finally, circularity should be applied in assessing, revisioning, and implementing urban and economic development and the associated policies, which continues to build the resilience of the city and enhance the traditional ecosystem services of the region.

Social Equity

Equitable sustainable development ensures that all residents of a community are empowered to have a voice in design, implementation, ongoing engagement, and economic and social benefits of urban development. In the field of urban planning, all stakeholders must acknowledge and recognize that past and current planning practices have a direct influence on who benefits and who is systematically excluded from any benefits in community planning. This paper will define social equity according to the definition used by the American Planning Association, which defines equity as "just and fair inclusion into a society in which all can participate, prosper, and reach their full potential" (APA, 2019, p. 3).

Social equity infused in a model city would allow for a complete community where everyone is included, has access to all resources, and feels safe and equally valued. It is important to distinguish the differences between focusing on *equity* versus *equality* in sustainable development. While equality connotes sameness, equity's focus is on mitigating historic systematic differences in order to actively address fairness and justice. Therefore, it is a necessary component to design and plan a city not to repeat the mistakes of the past.

Until recent years, equity was often overlooked in sustainability efforts due to a focus on natural systems at the exclusion of social systems. The work of many environmental justice activists and other leaders has resulted in a broader lens that embraces equity considerations. This is starting to change the work of municipal sustainability initiatives and departments. Equity is no longer the forgotten E in the three Es of sustainability (environment, economy, and equity) and has even been center stage in some recent efforts such as the work in the City of Providence, RI.

Permaculture

According to Bill Mollison permaculture is "a philosophy of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless labor; and of looking at plants and animals in all their functions, rather than treating any area as a single product system" (Mollison et al., 1991). A more current definition of permaculture related to this report is "Consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fiber and energy for provision of local needs" (Holmgren, 2017).

Holmgren is considered the founder of the 12 permaculture design principles and ethics. The ethics ensure the principles are used in appropriate ways. These three basic ethics guide the designer to care for the earth, care for the people, and to ensure fair share (return surplus of what is needed to the earth. The permaculture design principles include: observe and interact, catch and store energy, obtain a yield, apply regulation and accept feedback, use and value renewable resources and services, produce no waste, design from patterns and details, integrate versus segregate, use small and slow solutions, use and value diversity, use edges and value the marginal, and creatively use and respond to change. These principles are founded on fundamental assumptions that require a systems thinking approach. First, humans are subject to the same energy laws that govern the material universe, the environmental crisis is real and will transform the earth, the reduction in biodiversity we are facing is unprecedented in the last few hundred years, and the depletion of fossil fuels will affect future generations in significant ways.

The application of permaculture design principles for developing urban landscapes includes principles of climate resilience, social equity, and a circular material pathway. The main obstacle to implementing permaculture principles is the lack of specific strategies for urban development at the city scale (Saumel, et al., 2019). The subsequent treatment of urban development approaches in this report will note that ecovillages, biophilic cities, and transition towns have permaculture as a guiding principle in their establishment and development.

Regenerative Design

While there is debate over the definition of regenerative design, there is consensus over the following: regenerative design is the use of resources to improve society's well-being in a way that builds the capacity of the support systems needed for future growth. It encompasses the basic tenets of sustainable development and takes the concept further to include the importance of restoring the capacity of natural systems to support human settlement (Mang and Reed, 2012). We propose incorporating the concept of regenerative design to holistically build and support earth's natural systems while accommodating human needs. A regenerative approach to design and development of the built environment requires a systems approach. Regenerative approaches recognize the need to reverse the current degradation of natural systems while establishing new human-centered systems that can exist and evolve with natural ecosystems.

Background/Justification

We now begin this section with providing the historical context of urban planning for sustainability, starting from the time of the Industrial Revolution, in order to set the stage to describe the overarching frameworks for a city of the future.

Historical Context

The Industrial Revolution is an important period in the evolution of cities. For the purposes of this research, it serves as the starting point in our search for a sustainable city. In the last few centuries, urban design and development has evolved from focusing on layout to include functionality and other human-valued considerations. These changes have often been made to meet the needs of citizens that reside in the urban settlements.

Many notable urban planning movements have emerged in the last hundred years to create a sustainable city. This ranges from the self-sufficient Garden City movement that was inspired by Ebeneezer Howard to the New Urbanist principles, proposed by the Center for New Urbanism. New Urbanist principles were established to create alternative mixed-use communities versus the dominant single-use low-density urban form. Many of the recent movements, such as Principles for Better Cities, Biophilic Cities Network, Circular Cities, and the recent Smart Cities model by New Cities and Sidewalk Labs will be discussed with respect to our proposed conceptual new city. However, many of these examples lack the components that constitute a holistic systems approach. While many of the movements above include various aspects of sustainability and resilience, there is no example that represents an entire city system. This tends to result from the prevalent urban development that we highlighted in the beginning of this report; it is extremely rare that a city is designed and constructed from a greenfield condition to a full urban condition. Typically, urban development occurs piecemeal, with limited coordination of visioning, planning, and designing the entire urban system.

Master-Planned New Cities

Humans have planned new cities throughout history. In this paper, we are defining new cities as urban projects that are intended to be physically separated from existing settlements and that contain their own industries. There are over 150 new cities in construction or planned in over 40 countries, not including China, since the mid-1990s (Moser et al., 2015). Throughout history, cities were primarily built as nation-building efforts. This differs from the recent new-city phenomenon, wherein city-building is primarily initiated by private entrepreneurs in collaboration with the public sector (Moser & Côté-Roy, 2021).

The intent for new city development is varied across the globe. Many of these experiments are a result of massive population growth and migration and are intended to serve a basic human need. However, a few of these cities are a result of small, privileged subsets of the population wanting custom-built, glamorous urban environments. The goal of many of these cities is to maximize profits, versus creating the model city that we envision in this report. Many recent examples of planned new cities include altruistic or even utopian purposes.

In the United States, we have seen new city development primarily in the Smart City and New Urbanist urban development strategies. It is important to note the differences between a planned Smart City and a New Urbanist city. While both might use information and communications technology (ICT) along with Internet of Things (IoT) in a new community, a Smart City is based on the premise that it is the technology that creates a vibrant community (Barlow & Levy-Bencheton, 2019), whereas a New Urbanist city believes that social capital is formed through the physical design of the city (Luka, 2018). While both the Smart City and New Urbanist models of development contain vital characteristics for creating a new city based on the framework we propose, both strategies lack some of the features that are necessary for a successful holistic urban settlement.

It is also important to note the majority of New Urbanist projects in the United States consist of *infill* development projects versus *greenfield* development (Trudeau & Malloy, 2011); thus, there is a lack of new city examples to evaluate as opposed to the multiple examples of Smart Cities. We have included New Urbanist strategies to the degree that we can highlight lessons learned that can be applied to any new greenfield development.

A Framework for the City of the Future

This section introduces five overarching frames that we will use to consider a city of the future: climate change, material circularity, scale, equity in realizing social well-being, and natural systems

The increasing demand for human settlement worldwide creates an opportunity to imagine, plan, and design new cities from scratch. Thinking about a holistic approach to a new urban environment can guide models for retrofitting existing urban areas. Based on the research and findings we gathered in this report, it appears that new cities that have been built from "scratch" in the United States have faced significant problems in their goal to be sustainable, resilient, and equitable communities. These cities are typically developed based on the New Urbanist or Smart City model. As seen in the example below of an exemplar New Urbanist city (Seaside, FL), there are numerous critiques regarding the sustainability, equity, and social capital aspects of these developments (Ganapati, 2008; Luka, 2019; Shin & Shin, 2012; Talen, 1999).

This section will begin to conceptualize a model city that encompasses a materials pathway that is sustainable, resilient, equitable, and regenerative. It will be based on a systems approach to all materials with respect to the following aspects: land use, design, municipal infrastructure (gray, green, and blue), urban intelligence, social systems, public health, economy. and the natural environment. The framework we propose below (Figure 1) includes the following components: Climate Change, Material Flow/Pathways, Scale, Equity/Social Well-Being, and Natural Infrastructure. The various components of the framework have a set of critical questions to address when exploring each of the existing sustainable urban development strategies. A draft matrix table is presented in Appendix A that can be further refined and used to begin reimagining future urban settlements.

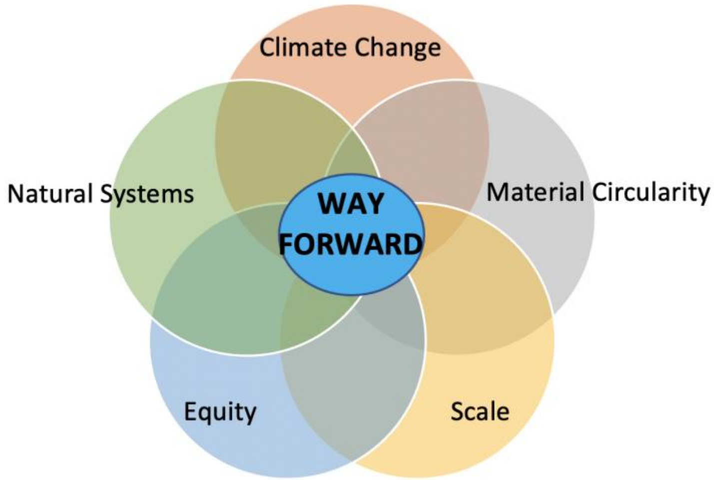

Figure 1. The Way Forward to a Model City Conceptual Framework
Note. Daniels & Simpson (2021).

Climate Change

Planning for any new urban development must be done with the awareness of a rapidly shifting climate system that is causing extreme weather events, sea-level rise, rising temperature, and the spread of vector-borne diseases. These issues have serious repercussions for cities and the services they provide. The influences of the changing climate are contextual in that what may be projected for the Piedmont region of the US will differ from projections for the Gulf Coast region or the Southwest or the Northeast. These contextual changes affect planning and the specific designs that are needed for establishing effective systems for infrastructure, housing, transportation, local economy, public health, and welfare in a city. Concurrently, cities should be viewed as potential primary contributors to the changing climate, and mitigating this potential is also a necessary objective in both urban planning and economic development.

This climate change component of the framework will evaluate how the strategy addresses and applies climate resilience, mitigation, and adaptation to an urban setting. Climate mitigation refers to how well the city plans and reduces greenhouse gas emissions from urban infrastructure, operations, and materials. It is also imperative for a city to plan and reduce the community's vulnerability to current and projected climate effects. Vulnerability refers to a city's exposure, sensitivity, and adaptive capacity with respect to climate-related changes and unforeseen events. Last, an urban settlement must strive to increase the climate resilience of its citizens. According to Folke et al. (2003), this would be evident in how well the city can live with disturbances and uncertainty, nurture diversity for reorganization and renewal, combine various knowledge types for learning, and create opportunities for self-organization.

The Stockholm Resilience Center proposes the following seven principles for applying climate resilience: maintain diversity and redundancy, manage connectivity, manage slow variables and feedback loops, foster complex adaptive systems thinking, encourage learning, broaden participation, and promote polycentric governance systems (Stockholm University, 2014). The following is an explanation of the principles above that need further clarification.

Feedback loops and variables are evident in all aspects of society. The management of slow variables and feedback loops is important to monitor because actions that are related to one variable can affect another variable in a reinforcing loop. Slow variables are factors that are harder to manage because they occur over a longer period and at larger scale and shifts may not be recognized until the process reaches a pivotal threshold for abrupt change. For example, if policies result in reductions in energy efficiency investments (the investment reductions constituting a slow variable), consumer energy costs are higher, resulting in lower profits, creating a reduction in further energy efficiency investments. It is important to identify these variables and feedback loops to disrupt the positive (reinforcing) trend that can occur to disrupt and change the outcome of the system, in the case above, energy efficient investment.

One aspect in building a city's adaptive capacity and mitigating risk to future disturbances, thus building resilience, is through a polycentric governance model (Carlisle & Gruby, 2019). This system of governance allows for multiple scales of governing bodies to collaborate for effective regulations and enforcement (Stockholm University, 2014). One main characteristic of polycentric governance is the acknowledgement of the inherent nestedness of different jurisdictional levels of government in order to create solutions that work holistically throughout all the levels of government (Ostrom, 2005).

An important aspect of effective polycentric governance is an adaptive management framework which begins with repeated monitoring of the components of resiliency of the system. The time horizon for such monitoring needs to consider the rate of change in the systems being monitored. If system shift is detected, then new planning strategies and associated designs need to be rethought and retooled. Concurrent with this process, is an informed citizenry that has a seat at the table as new strategies are developed.

The following questions will be explored to evaluate the extent to which climate resilience is incorporated into the strategy:

- How well does the example incorporate current and anticipated future effects of climate change in that specific location?
- How well does the example address the mitigation of greenhouse gas emissions?
- Does the strategy incorporate the climate-resilience principle, maintaining diversity and redundancy?
- Does the strategy incorporate the climate-resilience principle, manage connectivity within and between different scales of systems?
- Does the strategy incorporate the climate-resilience principle, manage slow variables and feedback loops?
- Does the strategy incorporate the climate-resilience principle, encourage learning?
- Does the strategy incorporate the climate-resilience principle, promote polycentric governance systems?
- Does the strategy incorporate the climate-resilience principle, foster complex adaptive systems thinking?

Material Circularity

It has been proposed that for the first time since agricultural settlements were established approximately 12,000 years ago, the aggregate scale of human economic activity has reached an inflection point that threatens to alter global biophysical systems and processes in ways that jeopardize both global ecological stability and geopolitical security (Rees and Wackernagel, 2008). Such a drive to extract resources at a rate that exceeds the carrying capacity of the stock, or the renewal rate of the flow, moves society closer to a bifurcation of the larger systems upon which society depends. In contrast, circular economic systems can ameliorate the projected increase in demand for natural resources to a level that matches the renewal rate.

Material flow analysis (MFA) determines the flow of materials through the city's metabolic pathways. In such an analysis, materials and energy are intimately linked. From extraction through processing and eventual product creation, energy is consumed. In short, the product is a reflection of this energy use, which has been characterized as a product's "embedded" energy (Simpson, 2020). From a life-cycle perspective, an MFA analysis recognizes existing, or potential material circularity, pathways that lead to less extraction of nonrenewable resources, which in turn reduces the sum total of embedded energy in the economy, which translates to a reduction in greenhouse gas emissions (Figure 2).

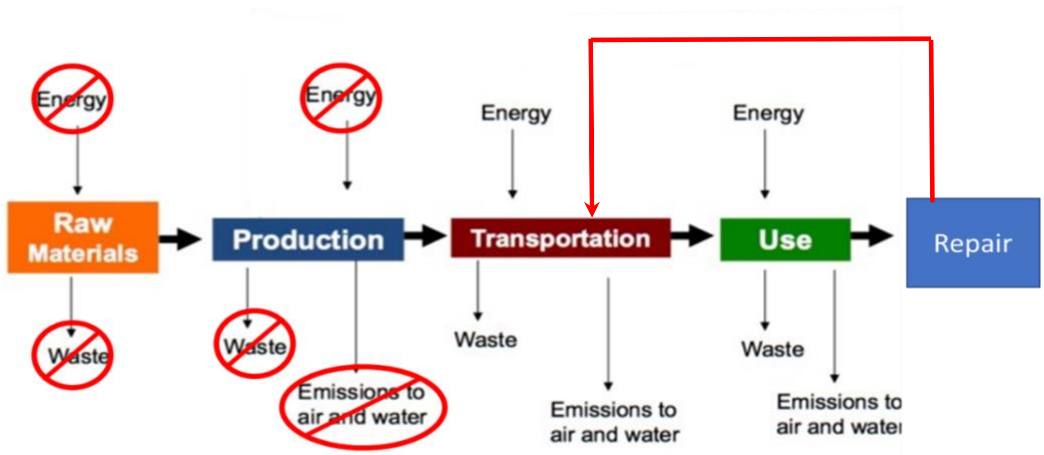

Figure 2. Avoiding Materials Extraction and Additional Energy Expenditures Through a Circular Pathway

Note. Simpson (2020).

MFA is a key component of industrial ecology that is often used in circular economy/city models. Every model of human settlement that is explored in this report will be evaluated for consideration of how material flow and pathways are managed and discussed.

Due to the historic lack (or perception) of the scarcity of materials, the flow of materials currently follows a linear pathway in the majority of human settlements. The traditional hierarchy in the United States of waste management has been to reduce, reuse, and finally recycle before disposing of materials. This still creates a "take-make-waste" linear model of pollution. Recycling, as conceptualized in the United States, has allowed for materials to be reused in manufacturing processes; however, it still requires intensive use of energy and has not made a significant reduction in material extraction from the earth (Krausmann et al., 2009).

In a circular economy, the service life of materials and their associated products reduces the flow-rate of materials through the economy and directly affects production volumes and end-of-pipeline waste volume. Assuming that demand for products is not increasing due to the growth of affluence or population, doubling the service life of goods halves both production emissions, energy use, and waste volumes.

The assessment of materials circularity considers how the city focuses on the maintenance of the stock of materials and associated products, with the resultant flow design of the materials to meet this end. Specific indicators to consider include the following:

- Are there easily accessible pathways for the consumer to direct materials to a reuse, repair, and refurbish economic pathway?
- Are there local policies (being) proposed to target specific materials/products flowing into the city that maximizes circularity?
- Has the waste management system been altered to maximize circularity?
- Does economic development target attracting businesses that can be compatible with respect to industrial symbiotic relationships?
- Is there an accounting system established for material extraction, embedded energy, and the avoidance of greenhouse gas emissions due to materials following a circular economic pathway?
- Are the city's metabolic pathways for the flow of water, nutrients, and energy maximizing circularity?
- Are there any policies/mechanisms for the circularity of nonphysical materials that enhance purchasing power, institutional knowledge, adaptive management?

Scale

When considering the application of a holistic design framework to a city, the issue of scale must be addressed. Foremost, a city is embedded within the larger environment, but there is also the culture and institutionalized social constructs of a region, state, and the globe (Figure 3). These larger systems provide inputs into the city and receive products, and associated emissions, from the city. Managing the city boundary is a necessary condition for maximizing a community's resilience.

The perspective of scale should also be considered in the context of the capacity to "scale-up" from the initial groundbreaking to the city vision that was conceptualized. Some of the visions for a future model city that are explored in this paper may not be possible due to scalability, or may not create the appropriate synergies beyond a certain population size or geographic footprint. In order to better understand this issue of scale, we have identified case study examples of existing cities that have instituted or are experimenting with some of the model city-frameworks identified in this paper.

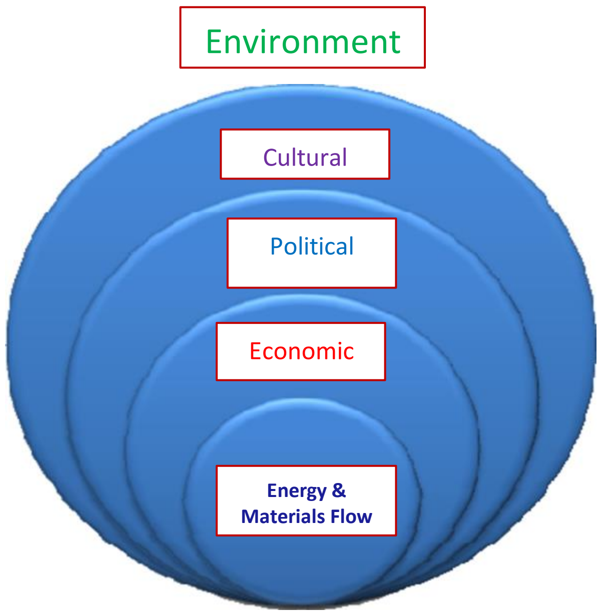

Figure 3. The City's Materials Flow is an Embedded System

Note. Simpson (2020).

A consideration of scale from planning through implementation needs to better balance the larger systems context of materials/product supply with the localized dynamic of human urban life (Berners-Lee, 2019). Historically the latter is often sacrificed by the former. The economy suffers from an idolatry of growth, which disenfranchises the value of the size of scale of human well-being. In short, a wholly new system based on attention to people, and not primarily goods, is required. The circular economy echoes this perspective of "production by the masses, rather than mass production" (Schumacher, 1973).

It also should be realized that the development of certain centralized functions and distribution infrastructure may need to be implemented for a larger footprint then one will see when the city is still in its nascent stages. Thus, modularity, redundancy and well-connected nodes must play a part if framing the city's design.

Questions that the city's leadership should consider in the planning, design, and implementation phases might include the following:

- At what scale is the proposed urban development most applicable?
- Is the plan for scaling-up detailed and reasonable from an initial groundbreaking to the projected maximum footprint of the urban development?
- Are multiple natural systems' scales recognized in both the urban and economic development, planning, and implementation?
- Does the projected population size for this urban development reflect the carrying capacity of the region in which it is being sited?
- Are multiple materials flow scales recognized in both the urban and economic development planning and implementation
- Is the location of the proposed urban development in line with the history and culture of the greater region in which it is being sited?

Equity/Social Well-Being

Sustainable development cannot be achieved without equity and social well-being being accessible to all members of a city. There have been systemic inequities in urban and land-use planning for centuries. Indigenous peoples and people of color have been especially subject to relocation, redlining, racial zoning, and blockbusting. While these practices have been classified as illegal, there are many other forms of discrimination in urban land-use planning today.

Recent research indicates significant variation in the extent to which cities focus on equity (Meerow et al., 2019). In addition, the words equity and equality are still often used interchangeably despite their differences. As stated in the definition section in the beginning of the report, we focus on equity as defined by the American Planning Association as it relates to urban development. Focusing on equity versus equality creates opportunities and ensures fairness in the planning and policies that are associated with urban development. It is important to recognize that sustainable urban development strategies can exacerbate issues of inequity in cities if they are not addressed throughout the entire process of planning, engagement, design, and implementation. Therefore, this framework will include an equity lens to examine how well the strategy addresses this factor.

Each urban strategy example will be evaluated based on the following factors to establish the degree to which equity and social well-being is evident:

- Does the planning and design of the urban development include active participation from the region's community wherein it is being sited?
- Does the strategy promote environmental justice with respect to an equitable share of environmental benefits for existing communities in the region in which the urban development is to be sited?
- Does the strategy promote and advance equitable economic opportunity?
- Does the strategy include policies or programs that allow anyone to live in the community (affordable housing, accessible transportation, healthy and accessible food, safe neighborhoods, and public health)?
- Does the strategy allow for meaningful engagement and participation of all community members?
- Does the strategy proactively address past city planning and design flaws that has shown to exacerbate inequality of the citizenry?

Natural Systems and Infrastructure

Providing food, energy, water, housing, and other goods and services while maintaining the ecosystem functions and biodiversity that underpin their sustainable supply is one of the great challenges for cities of the future. Worldwide, the UN states that the biosphere upon which we as a society depends is being "altered to an unparalleled degree across all spatial scales." Their projection is that one million plant and animal species will become extinct in the next few decades due to human-induced disruptions to their natural ecosystems (United Nations, 2019). Projections in the United States indicate that 25% of the 194 species that were analyzed are projected to lose more than 10% of their supporting ecosystems by 2051(Lawler et al., 2014). Preserving existing natural resources is the best strategy for maintaining the ecosystem services upon which society is dependent, with the awareness that in cases where the human footprint is expanding, city ecosystems will require management and repair-related efforts to ensure they become well established and self-regulating.

The integration of natural ecosystems into a city environment is a recognition of the role that nature plays as critical infrastructure. In places where the natural resources have been removed or severely degraded, *regenerative design* should be used as a whole-system approach that emphasizes the natural processes that restore, renew, or revitalize themselves. Similar to an intact and functional natural ecosystem, regenerative design challenges one to consider how human activity can plan for the long-term health and needs of socioecological systems (Benne and Mang, 2016).

A few established communities in Europe have guided their urban design through a permaculture process to ensure that natural systems are unharmed and ecosystem services are upheld. The permaculture process helps integrate human settlement within natural systems through a planning process that includes observation, envisioning, planning, developing, and finally implementing. In a region that is dominated by the built environment and traditional gray infrastructure, there is also an opportunity to integrate natural systems as living infrastructure that will provide critical ecosystem services.

The larger environment within which the city is sited has its own unique set of natural flows that support the ecological services of the region. Recognizing these natural flows of materials and energy allows for the city design to allow such flows to come into, through and leave the city so as to not create ecologically disruptive discontinuities. Such connectivity between the surrounding natural and urban environment not only provides a more sustainable city footprint but has multiple co-benefits from pollution amelioration, a more pleasing urban landscape and enhanced sense of well-being of the citizenry.

In the conceptualization of the scale and resultant footprint of the proposed city, the following factors should be considered:

- Does the spatial footprint for this urban development reflect the carrying capacity of the region in which it is being sited with respect to land, water, and energy use?
- Does the strategy integrate existing natural resources into the design and planning for this urban development to ensure ecosystem functions and services are maintained?
- Is there a commitment to regenerate lost or damaged natural systems?
- Does the design and planning of the city both replenish resources and maximize reuse of already extracted natural resources from the surrounding region?

Sustainable Urban Development Strategies

What follows is analysis of a selection of the most relevant current urban development strategies within the context of our proposed framework in regards to: a changing climate, material and associated energy circularity, the multiple scales of a city's footprint, the necessity of equity in realizing social well-being, and the ecological and physical laws that governs all natural, including human, systems. The urban development strategies that will be focused upon include examples of Biophilic cities, Biomimicry, Transition Towns, Smart Cities, Planned Communities (TND, Housing Trusts), Leadership in Energy and Environmental Design (LEED) and Green Buildings (Architecture and Design), New Urbanism, Circular Economy/Cities, Common Pool Land Ownership (Ostrom Model), Industrial Ecology, Ecovillages, and Cradle to Cradle.

From the list above, a limited number of strategies was selected for a deeper investigation into how the framework is applied in each setting. This is not an exhaustive list of model-city strategies, but these are the ones that are referenced most frequently in the literature as examples for new development. It is fair to say that the featured examples represent the spectrum of current thinking regarding urban development into the future.

Urban Development Examples

Below are the relevant urban development strategies and examples in practice that were selected for further analysis. Each of the strategies discussed are presented in the context of a representative example that is found in the literature. Included in the descriptions will be discussion of their foundational concepts and theories, as well as lessons learned through an evaluation of each within the framework we are proposing.

Lessons learned will include what is missing in practice, barriers to implementation, and how each urban development strategy addresses the framework components. The purpose of this application of existing urban settlement strategies to the framework is to piece together the best aspects of each urban settlement strategy to create a model city that is based on a resilient, equitable, regenerative, and circular material flow.

Following the critiques of the examples below, an expanded discussion will follow on the lessons learned to create a new model for urban development that incorporates each aspect of the framework that we propose.

New Urbanism: Seaside, Florida

New Urbanist cities are designed to reduce urban sprawl and the negative externalities that are associated with sprawl, through walkable neighborhoods that are intended to build social capital (Ghorbi & Mohammadi, 2019). The Congress of New Urbanism (CNU) was founded in 1993 by architects Duany and Plater-Zyberk, along with Calthorpe, Moule, Ployzoides, and Solomon. At the time of the movement's founding, a charter was developed asserting a common vision and principles guiding public policy, development practice, urban planning, and design to overcome interrelated community building challenges.

New urbanism posits that the built environment and infrastructure can have a direct effect on creating a sense of community and strengthening a city's social capital (Luka, 2018). Because the CNU charter did not specifically address the connections between their principles and sustainability, CNU adopted the Canons of Sustainable Architecture in 2009 to clarify the direct relationships. These canons address climate change, equitable development, renewable resource use, smart growth, green building, and a call for land stewardship for all human settlement. It is important to note the canons are a vision for development and do not require specific implementation.

Seaside, Florida is the first New Urbanist city in the United States that was built from a natural and previously undeveloped landscape (Fulton, 1996). It was designed by

Andres Duany and Elizabeth Plater-Zyberk for developer Robert Davis to create a resort beach town that would be differentiated from conventional master-planned communities often seen at that time.

The design of Seaside can be viewed as being based on neotraditional planning principles. Neotraditional planning, often called Traditional Neighborhood Development (TND), is a postmodern planning approach that draws inspiration from Ebenezar Howard's *Garden City Movement* (Howard, 1960) along with Frederick Law Olmstead's and John Nolan's work on landscape architecture. These principles focus on building architecture, pedestrian-oriented infrastructure, mixed use, and a variety of different types of housing for mixed incomes. TND is differentiated from New Urbanism in scale, as TND is usually smaller and limited to a neighborhood or town. One particular tool used by New Urbanist developments is the transect (Figure 4). This tool is used to envision the continuum of urban development from the rural to the urban to take a systems approach to urban planning wherein the whole (city) is greater than the sum of its parts (the individual pieces of a neighborhood).

Seaside is approximately 80 acres with 1,500 residents. The city was designed with the following goals: walkability, mixed-use development, vibrant street life and community spaces, inclusion of an urban village, natural sustainable landscaping, affordable housing, incremental development based on needs, and a form-based code approach to regulating development.

Seaside Florida is a good example that illustrates the pros and cons of applying New Urbanist principles to achieving a sustainable, resilient, circular, and equitable new city. However, as seen in the Background section of this report, there are no such specific requirements mandated in the charter for the New Urbanist movement.

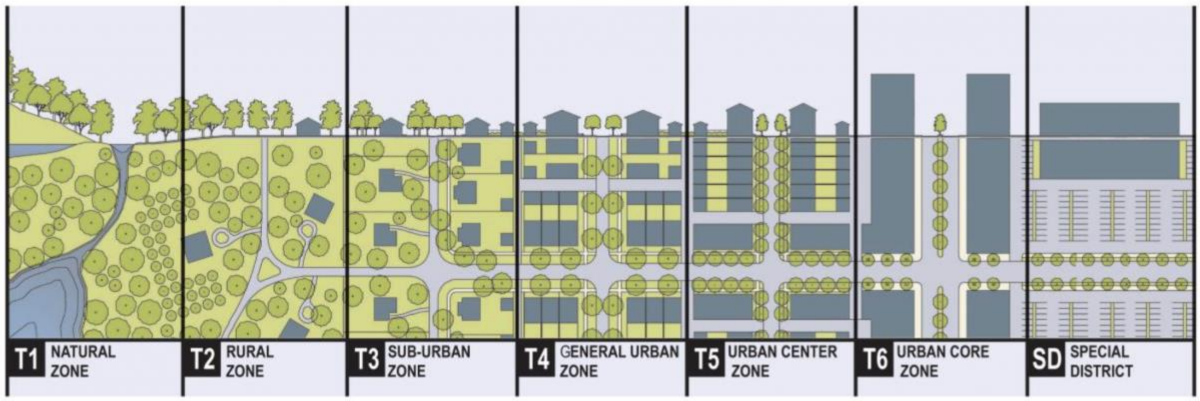

Figure 4. Transect Tool

Note. Duany (n.d.)

Climate Change

Subsequent to the establishment of the *Charter* for New Urbanism, a set of *Canons* were developed that included consideration of the effects of a changing climate. Although there is no evidence that climate change was a driving criteria for the development plan for Seaside, the city does reduce greenhouse gas emissions that are internal to the city by encouraging pedestrian mobility through the design of the city. New Urbanist towns and developments are designed and built to incentivize walking and other alternative forms of transportation, reducing personal vehicle use and the associated greenhouse gas emissions. However, one main criticism for Seaside is the amount of emissions generated by members of the vacation-homeowner population that live outside the city and travel to Seaside at different times of the year. The majority of residents of Seaside permanently reside in other cities such as Mobile, Alabama, and Atlanta, Georgia, and only visit the town as tourists in the summer (Bernstein, 2005). This negates the reductions in greenhouse gas emissions that are achieved through the design of a city with reduced car dependency.

In addition, the compact, mixed urban form of Seaside reduces embodied energy and materials through its infrastructure design. However, again, if the majority of the population has a permanent residence in another town or city, this does not reduce the embodied energy in housing overall in the larger system of the country.

Material Flow

New Urbanism does not directly address material flow in its charter or design principles. Indirectly, there are opportunities for district and shared energy, waste, and water systems based on the compact design of settlement. Waste management policies, with the hierarchy of reduction, circular economy incentives, and informed purchasing policies, are not included in the design or operating function of Seaside or any New Urbanist development.

Scale

Seaside is a small compact community of fewer than 2,000 individuals. There are also many examples of New Urbanist applicability to neighborhoods in large cities, such as Manhattan and Jersey City, NJ (Ellis, 2002). But there is no example to be found that demonstrates the efficacy of scaling up this approach, and many researchers question the successful upscaling of a New Urbanist small town or neighborhood to a large metropolitan city (Fulton, 1996). However, many of the basic principles of New Urbanism could certainly be applied to a model city, especially implemented at the neighborhood scale—for example, physically designing a city to include mixed use, mixed housing, walkability, and public spaces.

Equity

Seaside is not considered an affordable town to live in. Based on a recent real estate search for the costs of homes on Zillow, listings ranged from over $10 million for a Gulf-front home to $305,000 for a small inland condominium. High housing costs tend to characterize many New Urbanists towns, leading to homogeneous populations (Bookout 1992). These homogeneous populations can create privileged White enclaves that do not represent the larger regional demographics for an area (Ellis 2002; Grant 2006; Trudeau and Malloy 2011).

The Center for New Urbanism recommends using the *Charrette* format as a planning tool to include citizens, designers, and others to collaborate on a vision for development. However, there are no specific recommendations or strategies for ensuring that equitable representation is included when using the Charette design process. Seaside, as the first model new urbanist city, used the Charrette process, but it did not have significant public input. Robert Davis, one of the founders of Seaside, attributes this to the lack of zoning, building officials, and others that would normally participate in the Charrette process.

Natural Systems and Infrastructure

Seaside Florida was constructed on a greenfield. Any new development that is constructed on a greenfield will have an influence on the existing ecosystem and ecosystem services that exist prior to its development. This can be minimized by developing an ecological and cultural inventory before and after the alterations to the landscape are completed so as to develop a plan that maximizes the restoration of the ecosystem services that are affected (Keller et al., 2015). This type of inventory highlights how the natural systems currently support the landscape. At a minimum, this type of baseline allows for remediating disrupted ecosystem services through the construction process.

Seaside Florida was designed and constructed before CNU adopted the Canons of Sustainable Architecture. The Canons do recommend that "Design must preserve the proximate relationships between urbanized areas and both agricultural and natural lands in order to provide for local food sources; maintain local watersheds; a clean and ready water supply; preserve clean air; allow access to local natural resources; conserve natural habitat and to guard regional biodiversity" (CNU, 2009). However, there are no examples in practice of a city or neighborhood in the United States that is classified as New Urbanist that regenerates and replenishes natural resources in their geographic boundary and region.

Leadership in Energy and Environmental Design for Cities: Washington DC

A green building reduces or eliminates negative environmental effects through a whole-building systems approach. This systems approach takes into account the entire building's life cycle including, siting, design, construction, operation, maintenance, renovation, and deconstruction (Zuo et al., 2017). A green building is designed to use energy, water, and other resources efficiently; reduce waste, pollution, and environmental degradation; and protect occupant health and improve productivity. Global certification systems have been developed to certify and create common standards for what constitutes a green building. Developed by the U.S. Green Building Council (USGBC), Leadership in Energy and Environmental Design (LEED) is the most widely used green building certification system in the world. The LEED certification system was designed to be a transparent, third-party process for certifying green buildings.

The Center for New Urbanism, Natural Resources Defense Council, and USGBC collaborated to advance a green building certification process to be applied to in a community context. The result was that LEED for Cities and Communities was established in 2016. The certification was intended to be a new way forward for resilient, green, inclusive, and smart cities. The Arc performance platform allows a city to track and measure their progress across six LEED categories: natural systems and ecology, transportation and land use, water efficiency, energy and greenhouse gas emissions, materials and resources, and quality of life. This platform is a digital program that allows the user to benchmark, track, and measure improvements at any scale (from building to city) to meet LEED criteria. A city's score in Arc determines the city's certification level (Certified, Silver, Gold, or Platinum).

There are two guidebooks and scorecards for a city to use to achieve certification. One is designed for existing cities and the other for new or planned cities. The following will be in reference to the requirements and point system of the new and developing cities guidebook. The scorecard for obtaining LEED Cities and Communities certification requires acquiring 40 of a possible 110 points to receive LEED designation. There are criteria in each category that are prerequisites that any LEED city must meet, and then it remains up to the city to determine how they will create a cumulative score of additional points. Unfortunately, this approach falls short of a systemwide approach to achieving a model city based on the framework we propose. A city could achieve certification just by focusing on climate effects and social equity and addressing water quality, while giving scant attention to waste recovery or transforming to a low-carbon economy.

Thus, the point system creates a disintegrated approach to how materials are used and flow through the urban environment. The credit points have an indiscriminate weighting that results in projects being evaluated without incorporating externalities that are associated with ecological degradation. For example, installing a bike rack outside a building is weighted equally to bioremediation of a brownfield site. If a city pursues points in every category of the LEED certification, it is likely that it would be on track for approaching the ideal of a sustainable community as reflected by the intent of our proposed framework.

However, we believe there are a few considerations that first need to be addressed when considering the use of LEED for Cities to ensure the successful implementation of a sustainable plan. First, the scorecard for points should require the applicant to begin an integrative planning and design process before any construction of the new city begins. Second, the desired interactive process of continual improvement, which should be integral to any City-LEED certification, should necessarily include a transparent approach with the city's multiplicity of stakeholders so as to allow them to continually participate in this iterative process of assessment and improvement.

In 2017, the city of Washington DC was the first LEED Platinum-certified city designated by USGBC. At the time, the city had over 850 LEED-certified commercial structures and more than 546 LEED-certified residential projects. While the city has great examples of planning and implementing social equity, sustainability, and climate-resilience strategies, it omits a systematic approach to incorporate a circular materials flow to significantly reduce waste and emissions and to maximize maintaining the embedded energy found in products. The following is an assessment of Washington DC within the context of the metrics that are being proposed for our model city.

Climate Change

The city of Washington DC has incorporated current and future effects of climate change into urban planning and development. Climate Ready DC and Sustainable DC are the city's plans to mitigate and adapt to a changing climate. The city completed a vulnerability and risk assessment to identify specific climate effects and vulnerabilities. The plans address responses that the city can take across four sectors: transportation and utilities, buildings and development, neighborhoods and communities, and governance and implementation to mitigate and adapt to climate change. The District has also adopted a Green Area Ratio (GAR) that sets standards for landscape and site design to reduce stormwater runoff, improve air quality, and reduce the heat-island effect in the face of climate change.

However, it is less clear how well the city has addressed the seven principles of incorporating climate resilience into urban design and development. For example, while the city has a few projects and policies geographically scattered throughout the city, which might take into account the various principles, it is not applied systematically. For example, the DC district created an analysis tool to determine the climate resilience of their affordable-housing stock to gauge the potential for solar and battery storage to increase climate resilience. This attempt to create redundancy and diversity in energy usage is commendable, but it is not a policy that is implemented in other housing and commercial buildings throughout the city. This action does display the city taking leadership in the equity component of our proposed framework. Therefore, while it indirectly addressed climate change to a degree, it directly highlights an attempt by the city to address equity in their projects.

Material Flow

LEED for Cities and Communities version 4.1 included material circularity in the certification system. It provides points based on the material usage, life cycle, and transparency of materials used. The system evaluates waste, water, and energy based on a hierarchy of reduction, reuse, and recycling. LEED for Cities and Communities encourages cities to move toward achieving a zero-waste city through recycling, reuse, and reduction of waste generation as stated above. In the optional materials: Recycling Infrastructure category, the LEED 4.1 guidebook states that the intent of this possible credit is to "To encourage waste diversion of inorganic matter away from landfill and move towards 100% diversion from landfill." The guidebook further elaborates on the reasoning behind the stated intent above. It is in this section that the guidebook discusses the benefits of a circular economy and connects the credit to a city's pathway toward advancing the circular economy through recovery and restoration of materials.

While LEED does provide a framework for making informed decisions about material circularity, it still does not require a systems approach to the application of a circular material flow path. For example, in each category that deals with materials, one can find a stated intent to be zero water, zero energy, zero waste, and zero carbon. In addition, on further evaluation of the options to gain additional certification points, there still seems to be no clear framing for achieving a true circular material flow path. Specifically, the LEED framework does not address local policies that target the flow of desirable materials and products into the city, create incentives to ensure synergistic business relationships, emphasize economic development that target product-as-service business sectors, or establish accessible circular pathways that are as common as one sees for waste management pathways.

Washington DC does recycle materials, but well below the national average, and there is no evidence of a concerted effort to improve the circularity of materials because there are no other materials pathways being proactively developed by the District. In addition, the City provides subsidies to private waste haulers through the use of their trash transfer stations, which then direct more materials to incineration, without any energy recapture (Seldman, 2017).

Scale

The scale of the urban strategy can be applied to a whole city based on the new certification developed for LEED for Cities and Communities. Washington shows numerous examples of addressing the criteria we are putting forward with on-the-ground examples demonstrating that they can translate their vision and planning to implementation. However, as seen in Washington DC, receiving certification as a Platinum LEED city does not translate into an urban environment that is equitable, sustainable, and climate resilient, with a circular material pathway embedded in its operations.

To scale up these successes, seen peppered throughout the metro area, requires more than just counting points to meet the LEED certification for a community. It will require a transdisciplinary, integrated planning process, which necessarily incorporates input from the multiple stakeholder populations within the District.

Equity

The LEED for Cities and Communities rating systems address quality of life issues, as well as health, prosperity, equity, access, empowerment, safety, and education. There are 20 possible points awarded in the quality-of-life category for certification, with only a demographic assessment being required. Along these lines, Washington DC displays their commitment to equity and social well-being through numerous projects and policies that are evident in the urban infrastructure. However, despite economic growth in the city over the last few years, racial inequity has continued to grow, resulting in a lack of affordable housing and transportation, along with a decline in public health options for vulnerable populations (Frey, 2017; Ranganathan & Bratman, 2021). In fact, the city has major disparities based on race in the workplace and the local economy (Strauss, 2019).

Natural Systems and Infrastructure

LEED for Cities and Communities promotes the integration of ecosystem services into the built environment and requires an ecosystem assessment for certification. Green spaces, natural resource conservation, and restoration are all possible credits to pursue, but the certification process does not ensure their implementation based on how a city can accrue credits.

The District has an ambitious plan to attain a 40% tree-canopy cover, aligned with creating access to all parkland and natural space within a 10-minute walk of all residents. The city has numerous commitments and plans to conserve natural resources in various plans and programs.

Unfortunately, tree planting alone is not considered an effective strategy if there is no socioecological integration with respect to distribution and ongoing maintenance. A recent study in neighboring Baltimore, MD, showed that the effects of summer heat were disproportionately higher in areas with higher poverty rates. This difference was attributed, in part, to the lack of tree planting and shading in these low-income neighborhoods (Huang et al., 2011). This phenomenon may exist in Washington DC; a study inventorying trees in DC showed that low-density, higher-income, residential neighborhoods saw a tree density of 50.5 trees/acre, whereas the poorer medium- to high-density neighborhoods showed more than a 50% reduction in the associated tree density (Nowak et al., 2006). More recent research for Washington indicates that low-income neighborhoods in the District have a faster loss rate of preexisting trees versus new plantings and growth (Chuang et al., 2017). This leads to concern that the LEED certification point strategies may need deeper analysis in order to achieve multiple goals with a single policy initiative. In this example, urban forests can not only address the need to support ecosystem services and build resilience to climate-mediated urban heat-island effects but also do it in a manner that is just.

Ecovillages: Auroville, India

An ecovillage is an intentional community of any size that is created by a group of people who are consciously collaborating toward a shared vision on supporting ecosystem services. In most cases, a participatory process is used to design and construct the envisioned community, and the resulting physical space is a representation of the shared principles of the individuals involved.

The Global Ecovillage Network reports that many of these established communities are guided by design principles that include the four identified themes of regeneration (social, culture, ecology, and economy), and that a whole-systems design approach is embraced. This is often accomplished by using the permaculture design process (Figure 5) to best consider the site conditions and regional and social context and then articulate a comprehensive design of a human settlement that is modeled after the complexity of natural ecosystems. Ecovillages are also known to be living laboratories for experimenting with alternative and innovative solutions (Barani et al., 2018).

Figure 5. Permaculture Design Principles

Note. Holmgren (2017)

Auroville, India was founded in 1968 and has been under development since. It is the largest example of an ecovillage in terms of area and population, but it has not truly reached an urban form yet, which is a stand-alone governing entity that is completely independent from surrounding communities. At the time of this report, it consists of 120 settlements, 19 farms, and 6 Tamil (indigenous population) villages inside the area. In 2018, Auroville had a population of 2,800, but the vision for the community is to grow to a population of 50,000 residents. Over the 50 years of its evolution, Auroville has received the support of the Indian ministry and institutions like UNESCO.

Climate Change

Auroville is considered a model city as it relates to reducing the effects of climate change in a specific location. When Auroville was initially conceived in the 1960s, climate change was not at the forefront of urban development considerations. When founded, the area was a barren wasteland that was the result of grazing, deforestation, and land-use practices that degraded and eroded the soil. Since 1968, efforts have been underway to restore the vegetative cover and manage stormwater, and the efforts have been extremely successful. Initially intended as a means of improving living conditions in the immediate vicinity, the successful and ongoing reforestation project has since gained both local and national attention. Starting at the turn of the last century, climate change has taken a pronounced role in the development of ecovillages. According to the Global Ecovillage Network, ecovillages are designed to help implement the UN's Sustainable Development Goals and Climate Agreements on local levels.

Such a regenerative initiative highlights the benefits of forest cover in ameliorating the disruptions that can be exacerbated by a changing climate such as mediating excessive heat, sequestering carbon, capturing and storing runoff, reducing erosion, and cleaning the air of specific pollutants. The added benefit is an increase in biodiversity in the region.

Some renewable energy systems have also been developed and are in place, and multimodal transportation alternatives have been embraced by many residents. However, with a significant international population and summer temperatures that soar, large numbers of residents leave the community for part of the year to escape the heat, visit family, and earn additional income. This surely has social, economic, and environmental effects.

Auroville is an exemplary model for climate resilience with respect to disaster management and response. After the tsunami of 2004, Auroville created a Rehabilitation Center, a Knowledge and Coordination Center, and Palaam Community Groups to help with trauma counseling, livelihood projects, and ecological restoration (Wheeler, n.d.). Community member suggestions for resettlement patterns included open and shaded areas, increased ventilation, social interaction, cyclone shelters, rainwater harvesting, and solid waste management (Wheeler, n.d.).

Material Flow

Auroville has many ambitious initiatives that address waste minimization and avoid the use of pollutants. However, it is important to remember that the population is fairly small and a large land area is available to residents and visitors. This is unlike many densely populated urban scenarios.

One of the strategies that the community has employed effectively, and become known for, is the use of natural building materials. These nontoxic and locally available materials have been used to build the structures throughout the community. The materials for these structures have lower energy inputs, thus reducing greenhouse gas loading, and if made of organic material, they provide a stock of sequestered carbon. In addition, the economic benefit of this labor-rich country is that such a strategy relies more on human rather than manufactured capital. These structures can be easily adapted and repaired, and at the end of their useful life, they present no pollution risk or negative associated effects, which one experiences with human-created, chemically complex construction materials that have few alternative uses.

Many small businesses have been started in Auroville to produce goods locally. Some of these businesses repair and refurbish products and/or recover materials that are destined for disposal. However, some of the food and other essentials that are sought by residents are still being sourced from outside the community.

Scale

While Auroville serves as an inspiring example on many fronts, it raises questions about the ability of upscaling the ecovillage approach. Given the involvement of individuals in the formation and implementation of such an intentional community, and the many likely obstacles to success, this approach may remain more appropriate for neighborhood and village-scale development. This could be why the community still has a fairly small population after 50 years. Enough people are needed to share the workload and provide momentum, but large populations are unlikely to use such an overarching ecovillage decision-making and design structure.

For the future city, the ecovillage model provides elements of community building and collaboration that should be considered at the neighborhood or street level during design of any new urban development. This is also the case with the Transition Town model (addressed below), as these two approaches are very much aligned.

Geographically, it appears that the ecovillage model can fit in a very small and densely populated footprint or be spread out over a large rural area, as one sees with Auroville. However, the intent and initiatives found across the many ecovillage examples worldwide should serve as inspiration and should inform the design framework for a model city.

Equity

Ecovillages, and Auroville in particular, provide good examples of meaningful engagement of all community members, equitable economic opportunity, and affordable and accessible housing options. Human well-being, interconnection, and happiness are typically goals driving the creation of ecovillages. Because these communities are designed and developed using a systems perspective, the environmental benefits are shared within and often beyond the limits of the community. Most ecovillage examples also emphasize the production or sourcing of affordable healthy food for all of its citizens. Also, innovative transportation options are shared and promoted among community members, and the sharing economy is modeled on initiatives in many of the older ecovillages.

Income level is often touted as not being a barrier to becoming a member of an ecovillage. However, there seems to be a notable difference between the ecovillages of the developing South and those to the developed North. For the former, the intentionality of the ecovillage is often related to poverty alleviation and the isolation of dispersed rural populations. For the latter, even though there are often expressions of having a diverse community population, in looking at the existing communities' profiles they are often composed of homogeneous, mostly middle- and upper-class citizens (Dias et al. 2017).

Natural Systems and Infrastructure

Often in rural locations, ecovillages may have a greater opportunity for integrating natural resources and ensuring that ecosystem functions and services are maintained into the future. The same could also be said for a model city that is being planned in a greenfield location. Often the landscapes that are selected for Ecovillages are degraded and require regenerative design work. This, too, should be an inspiration for the model city rather than a pristine and intact natural area. Auroville in India and Crystal Waters in Australia are both examples of this, and the results are measurable in canopy growth and increases in biodiversity across these landscapes. The regenerative design and implementation efforts in these communities are an excellent example of how to protect and restore natural resources to ensure that ecosystem functions and services are available.

Transition Towns: Totnes, United Kingdom

The Transition Town movement evolved from a permaculture design. The overall intent was to retrofit existing communities so as to consume less fossil fuel and emit less carbon while building community and supporting the local economy (Taylor, 2012).

This movement began in Totnes, UK, in 2005, with the intent of "stepping up to address the big challenges they (communities) face by starting locally" (Neill, 2020). The effort emerged from a grassroots effort, but often in a coordinated fashion with the associated municipal government. Working together, community members have the ability to crowd-source solutions. Crowdsourcing allows for members in a community to cogenerate information to coproduce and create new sustainability solutions that can inform public organizations (Lenart-Gansiniec & Sułkowski, 2018). The initial vision for Totnes was about not only curtailing the negative effects of towns and cities but also maximizing the positive effects. This approach grew exponentially since it began and is now found across countries, towns, villages, cities, and academic institutions (Taylor, 2012).

The Transition Towns approach is based on eight principles that include respecting resource limits and creating resilience, promoting inclusivity and justice, decentralizing decision making, creating physical and psychological balance, fostering experimentation and learning, sharing ideas and power, collaboration, and positive visioning and creativity. These principles should be incorporated into the design and planning processes for the model city at its inception.

Climate Change

Reversing the effects of a fossil-fuel-dominated economy is a major aspect of the Transition Towns movement (See Figure 6); therefore, it concurrently supports the reduction of greenhouse gas emissions. To do so, these initiatives focus on new approaches to transportation, the local economy, and energy production.

An aspect of this is the decision to purposefully transition to a future that is more local and less reliant on outside inputs that have large energy and emissions inputs—the goal being communities that consume fewer energy inputs and emit less emissions. In the case of Transition Towns, this work is largely focused on retrofitting existing communities. The model city presents an opportunity to avoid the many barriers that Transition Towns encounter by redirecting existing institutional structures and decisions related to moving from fossil-fuel-driven infrastructure and food consumption and one-time use of energy-intensive products.

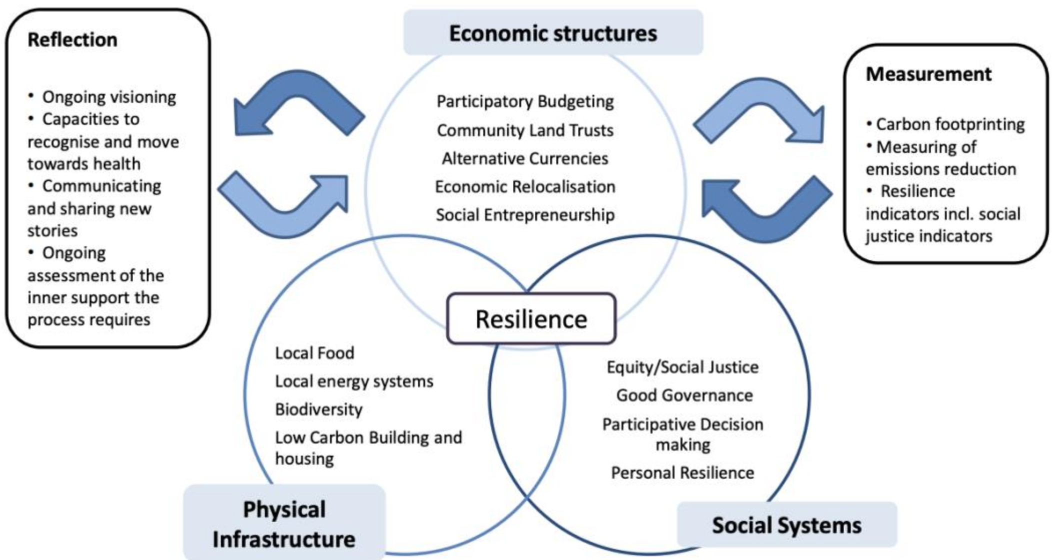

Figure 6. Community Scale Resilience in Practice for Transition Towns

Note: Banks, et al. (n.d.).

Material Flow

Transition Towns emphasize education and collaboration to reclaim the local economy, inspire entrepreneurship, reimagine work, and reskill the population over time. When fossil fuels are intentionally phased out and the community shifts to making and repairing the products needed to support the local population, material flow becomes an overarching consideration in decision making. Specifically for Totnes, forums, workshops, and collaborative groups to reskill and support local businesses and entrepreneurship have been initiated, but there has not been the development of an overall strategy focusing on implementing a circular economy. However, a society that reuses, repairs, and remanufactures goods and maximizes the usefulness of materials is a core aspect of the vision for Transition Towns. This philosophy and the corresponding strategies indirectly meet many of the indicators that are needed to create a circular material pathway for a model city.

Scale

The Transition Town movement, with Totnes as an example, seems to indicate that this model may be more applicable to smaller cities and communities. However, the mindset and central themes should be used to inform the design and management of new cities in the future, possibly at the neighborhood scale. There are examples of urban neighborhoods applying the transition model and of regional transition initiatives that encompass larger geographic areas than many cities. However, to translate this strategy to a larger urban settlement, modularity and interconnectedness of the neighborhoods or villages needs to be taken into account (Taylor, 2012). The Transition Town movement is based on self-reliant economies and decentralizing governance structures as stated in the summary above. At the larger city scale, neighborhoods or villages would still need to be interconnected with the larger urban system’s economic development goals but be allowed to foster diversity and networked polycentric forms of decision making at a more-local scale. Such an approach will need to be addressed in the initial city design process to ensure the delicate balance of smaller community units in the larger urban city system.

Equity

The guiding principles of Transition promote both inclusivity and social justice. This provides a mechanism or requirement to consider the needs of disadvantaged and often powerless people in society who may be the most affected by rising energy and food prices, resource shortages, and extreme weather events. The goal is to increase the opportunities for all members of society to live well, healthy, and with sustainable livelihoods.

Because the Transition movement is a grassroots effort that is informed by widespread community involvement, issues of equity can be directly identified and addressed. This is because each community takes ownership of the process themselves.

Transition initiatives have also modeled more comprehensive stakeholder engagement. These efforts recognize that individuals and organizations in all sectors have access to networks or people, funding sources, and different solutions. When they are invited to collaborate, new ideas and actions are possible.

Natural Systems and Infrastructure

Given that Transition Towns have largely been used as a redevelopment tool, this model acknowledges and respects the resource limits that are related to natural resources, both locally and globally. The Transition movement also advocates for creating more resilient communities with healthy natural systems. While regenerative approaches may not appear to be a major focus of the Transition Town efforts reviewed, there are isolated examples that illustrate the potential for more emphasis on this work.

Blue-Green Infrastructure: Vancouver, Canada

With the increased threat of climate change due to extreme weather events, maximizing the resilience of water infrastructures is necessary to reduce the vulnerability of cities. Even though the current (gray) water-conveyance infrastructure of existing cities already has embedded investments of materials, energy, and associated dollars, such a system has resulted in the increase of impervious surfaces on the landscape, which in turn reduces water infiltration.

This vulnerability of increased runoff due to increased impervious surfaces is particularly relevant in the current reality of urbanization in the context of more frequent extreme weather events (Kaluarachchi, 2020). The World Bank (2019) has highlighted the fact that current investment in gray infrastructure lacks the flexibility to respond to a rapidly changing climate, and the unavoidable investments into the future must look to integration of green infrastructure.

Blue-green infrastructure (BGI) is a needed component for achieving the model city. BGI is the interconnected system among designed and natural water bodies and associated green spaces (Lamond & Everett, 2019). Blue infrastructure refers to water elements such as rivers, wetlands, floodplains, marshes, and water treatment facilities. Green infrastructure includes trees, forests, fields, parks, and other green spaces.

The BGI concept seeks to replicate the need to control water resource management for a city, but to do so in a way that minimizes gray infrastructure and replaces it with the use of natural systems that can ameliorate the effects of stormwater runoff and provides the maintenance of its water quality. The co-benefits of a BGI approach is not only managing both water supply and water quality, but by incorporating 'green' landscapes, it also has multiple benefits with expanding such green infrastructure to serve also as a public space. An emerging concept with BGI is what is known as smart green infrastructure (SGI), which is seen to use technology and data in combination with information platforms to promote efficient water conveyance and treatment networks in a city. Networks that increase efficiency and save costs (Kaluarachchi, 2020).

BGI considers all four categories of ecosystem services identified by the Millennium Ecosystem Assessment (Monteiro et al., 2020). These include provisioning, regulating, supporting and cultural services. Provisioning would include products people in the city obtain from ecosystems such as water, food, fuel or fiber. Wetlands, and other types of ecosystems that offer flood protection or reduce urban heat would be classified as regulating services. An example of cultural services would include non-material benefits, such as recreation and emotional well-being that city dwellers obtain. Finally, supporting services are necessary for all the other categories of services. For example, soil formation for local food, or biomass production for energy.

Blue-green infrastructure recognizes and incorporates aspects of ecosystem services, especially by extending the usefulness of water in contexts of low-rainfall climates. However, not every example of BGI focuses on natural ecosystem remediation. BGI could be incorporated into multiple city infrastructure designs.

The city of Vancouver, British Columbia is one of the rainiest cities in Canada. In 2019, Vancouver took their green infrastructure plan a step further to designate rainwater as a valuable resource. The city created the Rain City Strategy to improve and protect water quality, create resilience, and enhance livability. Vancouver has an ambitious plan to capture and clean a minimum of 90% of their rainfall and implement a design standard that can capture and clean rainwater from a minimum of the first 48 mm (approximately 2") of any precipitation event.

Climate Change

The Rain City Strategy was born out of the city's concern of how to manage their stormwater which is expected to increase in runoff volume due to changing climate. The strategy specifically focuses on implementing blue-green infrastructure projects that will increase the climate resilience of Vancouver.

The city has various environmental plans and strategies under the Green Vancouver Initiative. This includes climate change mitigation and adaptation, zero waste, renewable energy, and a vision for a strong local economy and inclusive neighborhoods. By having a strong focus on implementing green infrastructure, the city has addressed many of the principles of climate resilience. As you will see below, this reinforces the importance of including blue-green infrastructure into your urban design, nonetheless still requires other synergistic urban development strategies to be implemented to create a model sustainable city.

Material Flow

Blue-green infrastructure examples in an urban settlement include items such as green roofs, constructed wetlands, bio-retention ponds, green vertical walls, bioswales, trees, and parks. Materials, such as water and heat (energy) are delayed in entering and exiting the urban system green-infrastructure. Instead of stormwater directed into rivers and gray sewer systems, a constructed wetland can capture and hold the water for an extended amount of time while recirculating part of the material (water) back into the vegetation. In effect, such closed loops for water (and associated heat) can be more efficient, and thus less costly, than using more traditional linear flow systems (Houle et al., 2011). This water can also be stored as a reservoir for those seasonal times that rainfall amounts are lowest.

Blue-Green Infrastructure projects in the city of Vancouver provide a modicum of circularity of material flow in the system; a stormwater mitigation framework does not specifically apply to the majority of materials circulating in North American cities. However, implementation of BGI throughout the city will obviate the need to utilize more materials to dig up and up-size the City's stormwater piping infrastructure (Simpson 2017). As an aside, in developing economies, there is a close link between storm and wastewater runoff and the ultimate disposition of materials associated with production of goods and services bought and consumed by community members (Ngoc & Schnitzer 2009).

In the city of Vancouver, we must look to the Zero Waste Strategic Plan to fully incorporate material flows into their urban development strategy. This plan does place an emphasis on avoidance of material used, however does not envision or lay out a circular material flow path for all of the materials we have included in the report.

Scale

Technically, blue-green infrastructure is designed at the project-level scale. However, it could be expanded to be a policy that is incorporated in all development in an urban setting, substituting the materials demand of traditional grey infrastructure with the greater resilience of the blue-green infrastructure (Roseen et al., 2011; Stack et al., 2014; Moore et al., 2016). In this case, there is no limit in geographic or population size or density to implement the strategy.

Equity

Blue-green infrastructure strategies can indirectly address equity and social well-being if strategically planned and implemented in areas of low income, and black, indigenous and people of color neighborhoods. These projects help address issues such as urban heat island, poor air quality, water quality issues and lack of social spaces to gather and experience natural systems. Unfortunately, in many cases, the distribution and accessibility of GBI tends to be inequitable and does not serve the most vulnerable populations (Thorne et al. 2018). While it was not specifically mentioned in the Rain City Strategy that BGI projects would be prioritized in vulnerable neighborhoods, the city has pursued a decision support mapping process for equitable access to green infrastructure. The Equity Initiative Zones map illustrates areas of Vancouver that have been historically underserved with green space. These maps are intended to focus investments in these underserved areas in the city.

Natural Systems and Infrastructure

A blue-green infrastructure policy or plan is based on replicating ecosystem services through utilizing, restoring, or building natural functioning systems. BGI integrates ecosystem functions and services into the built environment. The strategy can regenerate lost or damaged natural systems depending on where it is implemented and the history of the ecosystem service in question. Blue-green infrastructure application, along with conservation of urban ecosystems is a necessary component of achieving a model urban settlement.

Biophilic Cities: Singapore

E.O.Wilson defines biophilia as "the innately emotional affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature" (Wilson 1984, 31). There has long been a history of notable urban development planners to emphasize the vital importance to integrate nature and parks into urban settlements. This is evident in the work of Olmstead and McHarg (Linehan & Gross, 1998). Furthering this work are examples from Ulrich (1981) and Kaplan and Kaplan (1989) to Kellert (2005) and the European Union (2015) that showcase the psychological and physical healing power of integrating nature into our built environment.

Biophilic cities have come to represent a city that prioritizes nature in its design, planning, and management while recognizing and allowing for daily human contact with nature. Timothy Beatley is the founder and director of the Biophilic Cities Network. He reinforces the integration of nature and the city by explaining how a biophilic city is no longer a park in a city, but the city itself as a park.

The biophilic cities model is closely related to regenerative design. It includes many of the principles of permaculture, and a recognition of ecosystem services that are considered in blue-green infrastructure. Biophilic cities also focus on the importance of the human connection to nature. However, it never specifically talks about building the capacity of our ecosystem services beyond what is needed. The strategy also never explicitly considers the design flow of materials into and through an urban settlement.

Singapore has shown how it is possible to incorporate biophilic urbanism in a dense city setting. Since 2013, Singapore has been a Biophilic Cities member and has changed its motto from Singapore, Garden City to *Singapore, A City in a Garden*. The city has installed a comprehensive network of trails and pathways that connect to each other and the population. The city has also incorporated nature into various built infrastructure throughout the city.

Climate Change

A biophilic city designation does not include an assessment of climate change or a specific plan for mitigation or adaptation for greenhouse gas emissions. However, the implementation of nature and natural resources into a city leads to a city becoming climate resilient. Beatley and Newman (2013) present a conceptual diagram depicting the biophilic pathways to achieve resilience (Figure 7.).

A biophilic city could be designed to develop co-benefits from the growth of the green living infrastructure that not only improves residents' psychological well-being but also would address effects from a changing climate, such as excessive heat or precipitation, while obviating the need for energy-intensive cooling or stormwater runoff. In addition, the choice of vegetation could also supplement the diet of the population, attract wildlife, and mitigate climate related disruptions by providing a carbon-sequestration sink.

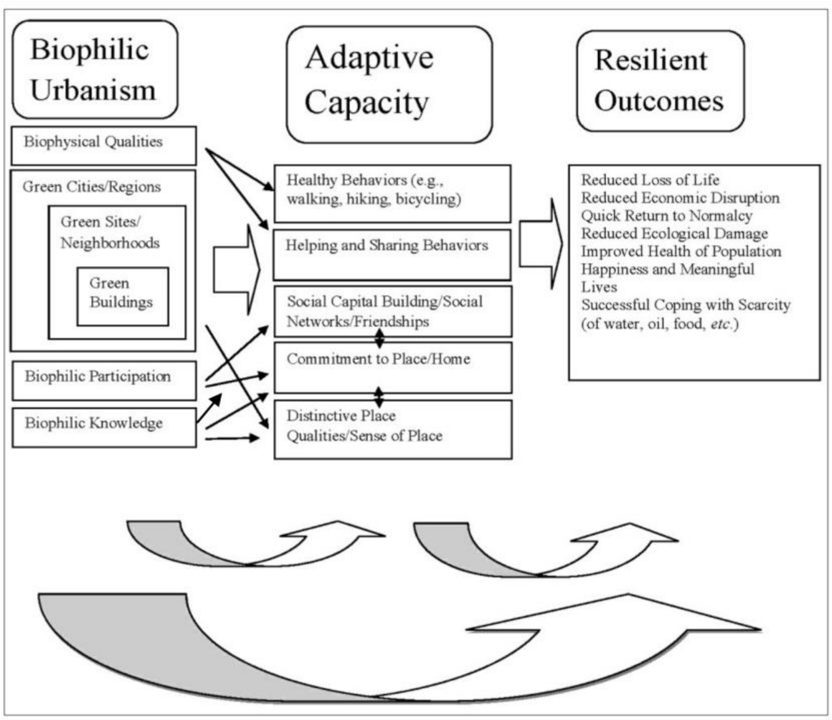

Figure 7: Biophilic Pathways to Urban Resilience

Note. Beatley and Newman (2013).

Material Flow

The biophilic cities strategy does not directly discuss material flow and pathways in the urban environment outside of the benefits of green infrastructure projects. As discussed in a previous example, green infrastructure projects are geared toward changing the linear flow path of materials such as water and the related use of energy. However, the biophilic-city concept does not address other areas in the linear input and output production cycle of materials used by community members.

One would assume that a city that puts vegetated space at a premium would also need to consider the flow of required water, nutrients, and soil amendments and the circularity of biomass and the associated carbon. For the latter, the prevalence of the growth and consumption of the organic material can be converted to local bioenergy or recycled to create soil amendment products that can be used to provide food to the city. Concurrently, this mediates the need for as much import of organic material that has a substantial reservoir of embodied energy from having been produced in a more energy-intensive manner, if for no other reason than that it must be delivered from a distance. The co-benefits of closing the loop locally are that the captured biomass provides a carbon sink, improves the city's soil structure, enhances the water-holding capacity of the natural landscape, and delivers macronutrients that create a reinforcing feedback to the greening of the city.

Scale

Biophilic cities are not limited to geographic or population size for applicability. The biophilic strategy could be implemented at any size or geographic location for a model city.

Equity

It has been shown that populations with greater exposure to green space experience lower mortality, a reduction of health inequalities, and improvements in psychological health and cognitive performances (Wang & Tassinary, 2019). However, biophilic cities do not lay out a governance structure to ensure equal access to the benefits of natural resources (Beatley, 2017).

Natural Systems and Infrastructure

The biophilic city strategy integrates existing natural resources into the built environment, ensuring some ecosystem functions and services. In many instances, this application can lead to regenerating lost or damaged natural systems. The intentional development of green areas and infrastructure in Singapore are regenerating the existing natural systems and also increasing biodiversity through this strategy (Newman 2014). However, a city would still need to formulate a plan or specific commitment to regenerate natural systems in the biophilic city strategy to ensure this outcome.

Industrial Ecology: Kalundborg, Denmark

It has been posited that industrial ecology envisions a synergistic relationship between businesses that strives to mirror the materials-flow dynamics noted within a natural ecosystem (Frosch and Gallopoulos,1989) . Such a framework seeks to create a paradigm where the output of one component of the system becomes materials, or a form of energy, for another in the same system, thus minimizing what are considered wastes by reframing the materials as resources to be used by another (Erkman, 1997). The flow of materials through such synergistic production-process pathways is designed with an appreciation of the greater system's natural resource constraints and ecological limits.

One can consider the concept of industrial ecology from different system levels (Lifset and Graedel, 2002). At the micro scale, it is the decision at the point of manufacturing to change supply-chain inputs, standard operating procedures, technology, or materials output to reduce emissions and energy loss, concurrently reducing liability so as to provide the same product/service for less input. At a macro level, whether at the regions or global scale, it is to consider resource and energy stocks and flows so that the use of both nonrenewable and renewable natural resources proceeds at a rate that maximizes the former and doesn't exceed the carrying capacity of the ability to replenish stocks.

At the intermediary scale of a city, materials flow into it from the surrounding region, with an associated expenditure of energy. These materials, once used, result in waste as either emissions or materials destined for disposal. Industrial ecology seeks to replicate the systems view of a circular material flow between businesses that are situated within that community. However, this is just one piece of the puzzle. Industrial ecology does not specifically strive to build the capacity of ecosystem services or nature's support services. To achieve a circular pathway for materials flow, this would be a necessary component for our model city.

The city of Kalundborg in Denmark is an often-touted example of an industrial ecology strategy applied at the community scale. The Kalundborg Symbiosis project (Figure 8) is based on an industrial circular economy model from the perspective that the by-product of one company becomes the raw material of another company. Such industrial symbiosis is not happenstance, it is the result of proactive planning to institute an industrial eco-park that improves the resilience and economic health of the surrounding city and agricultural region (Boix et al., 2015).

The Kalundborg project involves several businesses including a power station, oil refinery, biotech, plasterboard, and supports both agricultural initiatives and soil remediation. The initiative was scaled to a level that did not include the whole town, but a portion of the surrounding community benefits from industrial-sourced excess heat providing residential district-heating. It is important to note water scarcity contributed to the initiation of the project and did not initially take into consideration a multi-systems approach that included climate change and social equity.

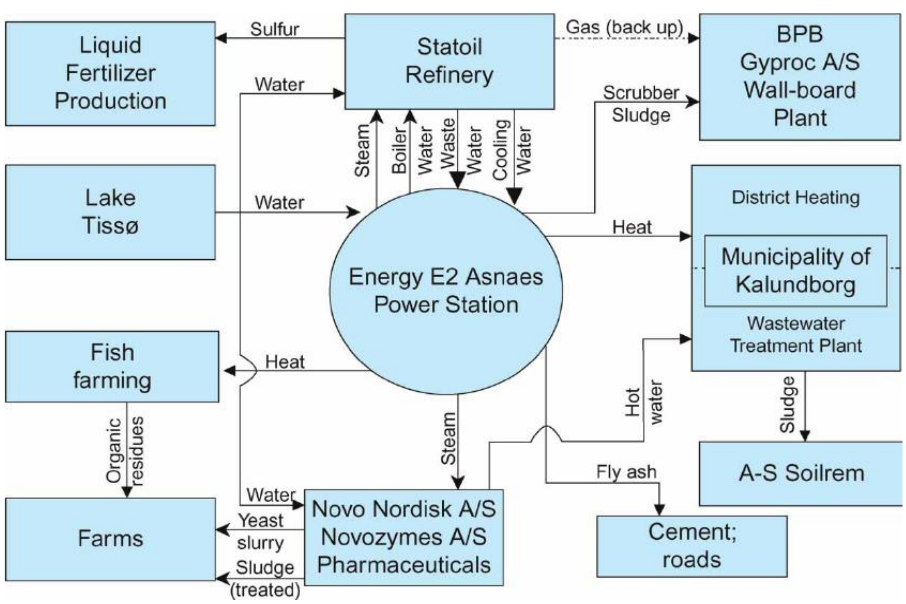

Figure 8. Industrial Symbiosis in Kalundborg

Note. Chertow et al. (2008).

Climate Change

The goal of the Kalundborg symbiosis is to reduce the environmental impact of industrial systems, which necessarily would include reduction of greenhouse gas emissions to mitigate climate change, but it did not strategically plan the development around climate change. Emissions are reduced due to the management of material flows in the system. Reducing energy use for delivery and disposal of the water in the various industrial processes results in lower greenhouse gas emissions. The management of material flow in the project also leads to greater climate adaptability. By linking material flow pathways, each component of the system is less at risk from climate disruptions because the inputs and outputs for production are geographically in close proximity. While the project addresses many of the principles of climate resilience, it does not foster complex systems thinking, encourage learning, broaden participation, or promote polycentric local governance systems.

Material Flow

Kalundborg, being an exemplar of an industrial ecology framework, necessarily advances the implementation of such concepts as MFA, life cycle assessment (LCA), and input–output analysis (IOA; Chester, 2020). This knowledge has subsequently led to innovative advances in understanding and managing urban metabolism. The example above is a model of managing material flow in a specific system. The symbiosis project was purposefully designed to eliminate waste and pollution from the initial point of production by reusing materials in another industrial process. Energy that is created will eventually be lost as heat (entropy), but before that, the energy is converted to forms that provide inputs to other aspects of the community not only for residential district heating but also for needed greenhouse and fishpond energy requirements.

The Kalundborg example is essentially a linear-cascading approach. For example, pure gypsum, a waste product from a coal-fired power station, is used as an input to a contiguous (gypsum) plasterboard manufacturer, which obviates the need to mine additional gypsum. But such a system is vulnerable to structural change, such as through an EU extended producer responsibility (EPR) policy mandate, plasterboard manufacturers are forced to take back their used products. In such a policy framework, the manufacturers will give preference to materials that follow this mandated circular flow rather than using the waste stream from the power plant (Stahel 2019, p. 4).

Scale

Nevertheless, such an industrial symbiotic approach might be expanded geographically to include additional linked industrial processes across a city and into the surrounding region. But it should be noted that such examples typically consist of business-to-business cooperation agreements and are not part of an overall economic-development vision by a city. Therefore, many examples of industrial ecology have been limited to specific industry mixes or single business park initiatives within a community (Vevela et al., 2016).

Equity

The strategy does not specifically address or mention issues of equity or social well-being. However, it could be expanded to include these considerations. In Kalundborg, heat from the power plant is diverted to district heating of homes. As such, industrial symbiosis design can lend itself well to sharing benefits of such by-products. With the appropriate planning intervention, this low-cost heat output could be directed to serving low-income or vulnerable residential populations. It is not unreasonable to expect that the social justice/equity needs can be part of the initial design and subsequent management of such a symbiotic partnership, not only between businesses but also including the local government.

Natural Systems and Infrastructure

The strategy does attempt to mimic the larger ecosystem system by mimicking how materials and energy flow through a natural system. However, there is no specific tie-in to using natural resources for providing ecosystem services or a commitment to regenerate lost or damaged natural systems.

Circular Cities: Brussels, Belgium

A circular city is rooted in the principles and practices of a circular economy, which shifts the value of the economic model from the material supply chain to one that puts the product use foremost. This would apply to both any goods manufactured within the city environs and products imported to support the city's infrastructure and citizenry.

In order to move to a circular city that is both resilient and equitable, the vision of focusing on extending the life of all products to minimize the extraction of additional materials and to avoid additional greenhouse gas emissions needs to be a foundational tenet of the urban planning, design, and implementation of how materials flow. This necessarily requires that the culture, and related social institutions, follow a path so that consumer behavior can adapt to new circular business models that can drive the circular transition.

The Ellen MacArthur Foundation (EMF) defines the circular economy as a system that "aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital." The foundation posits a circular economy composed of three basic principles: designing out waste and pollution, keep products and materials in use, and regenerate natural systems. The Ellen MacArthur foundation's goal is to build thriving, livable, resilient cities by embedding circular economy principles into their design and operations.

Cities are blessed with an abundance of innovative businesses and creative individuals that can be the engine for transitioning the economic model. This means they are ideally situated to turn the tide on the linear economy and foster circularity. In this respect, cities can restructure their form to more closely replicate the metabolic flows, interconnectedness, redundancy, and small feedback loops that are inherent in natural ecosystems. The concentration of producers, consumers, and intermediaries and the related material and waste flows create many opportunities to introduce new circular connections and pathways.

The circular cities strategy is built upon many of the other sustainable urban development models in this paper. It relies on the design philosophy of keeping assets at their highest value and moves to a skilled workforce that focuses on maintaining product use while minimizing waste emissions and energy loss. And although not put forward as a component of such an approach, a citizen-engagement process should be integrated into the conceptualization and planning for an equitable, resilient, and circular city that will contribute to equitable and just outcomes.

Cradle-to-cradle, which describes five criteria (material health, material reutilization, assessment of energy required for production, water usage, and social responsibility; Braungart & McDonough, 2009) is one framework that has been used to inform the circular city model. The EMF model draws on cradle-to-cradle to describe material flows as a series of instituted steps that maintains the value of the product through a cascade of circular loops until the product needs to be disaggregated to its component materials to be recycled (Figure 9). A circular city focuses on a service-as-product economy that optimizes the usability of products at their highest value, thus valuing labor over raw materials as the essential input to the economy (Stahl, 2010).

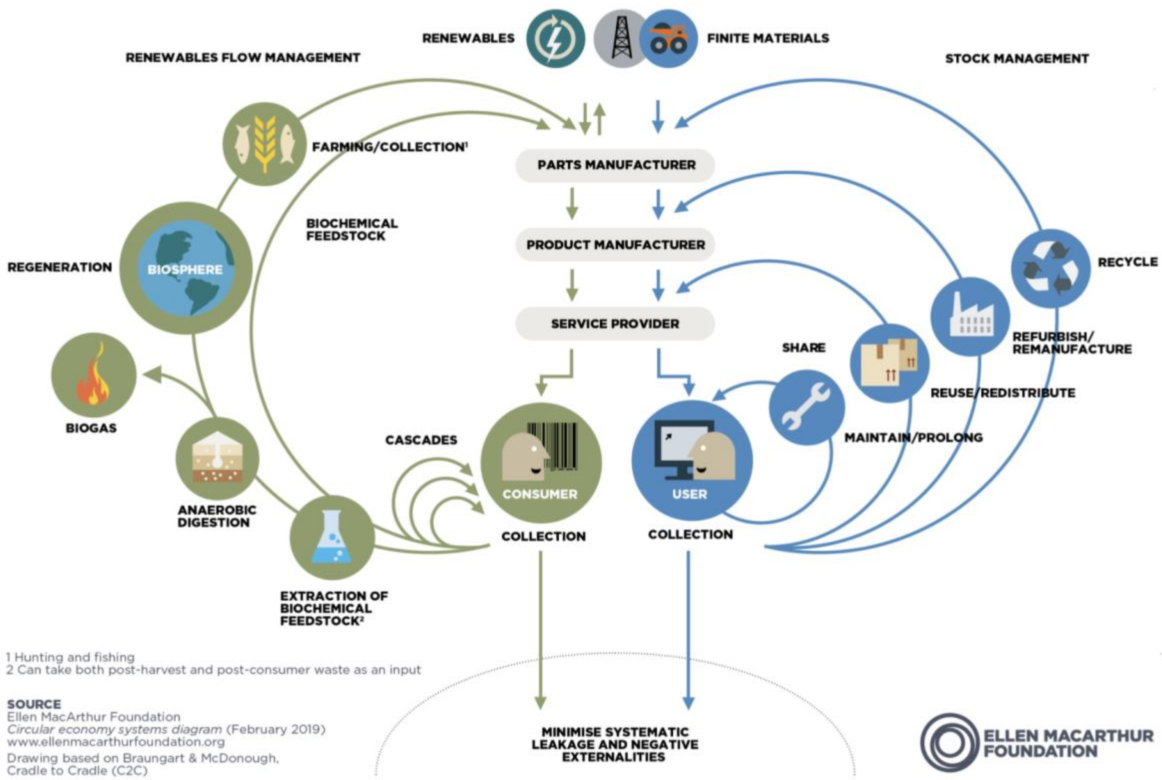

Figure 9. Circular Economy Systems

Note. Ellen MacArthur Foundation (2019).

While no circular city exists in the world, there are examples of aspects of circularity that are manifested within cities (Prendeville et al., 2017). However, there is still no consensus on what constitutes a circular city nor specifics on how to create, or retrofit, a city into a living example. Brussels is an example of implementing numerous concepts and principles of a circular city. The Brussels Regional Programme for a Circular Economy (BRCPE), commonly referred to as *Be Circular*, is Brussels's central circular economy initiative. The Brussels initiative focuses on six economic sectors: retail, logistics, waste and resources, food, construction, and the built environment.

Climate Change

The circular city vision aligns with the 2030 Sustainable Development Goals, including reducing greenhouse gas emissions and adapting to the effects of climate change. While Brussels's Be Circular does not have specific statements to assess climate change disruptions or conduct a greenhouse gas inventory, these goals are reflected in other climate plans for the city. A circular city meets a significant number of the climate-resilience principles through the design that embeds circular materials management principles. For example, this strategy creates a city where there is greater proximity where people live, work, and play. This reduces air pollution and greenhouse gas emissions from transportation and buildings (Condon & Yaro 2010; Roseland 2012). Creating these types of neighborhoods maintains diversity, manages connectivity, can slow disruptive feedback loops, and can broaden community engagement. The only principle excluded from the strategy is how to enable polycentric governance.

Material Flow

In a circular city, the layout and design of a city changes the way materials and products move around them. Instead of disposing materials in a landfill or having them incinerated for a one-time energy capture, a new distributed system of resource management, nutrient flows, and reverse logistics makes the return, sorting, and reuse of products possible. Brussels created a strategy that reviewed all existing materials, looked at the region's metabolic balance, and evaluated whether the material flows could be circular. The city of Brussels and the concept of a circular city do not include knowledge, human innovation, and social or financial capital as "materials" on which to focus.

Scale

A circular city is not limited to a specific geographic scale or population size. However, to adhere to the principles of a circularity of an economy, neighborhood, or community, nodes might need to be created that are modular and connected to each other through a network that is framed by an overarching set of economic-development principles. In addition, the city, as an urban area, lacks the resources that are acquired from the surrounding rural environs, so the maintenance of the circular city is dependent on supply chains that span the globe. Within this context, the circular city can maximize its internal circularity and develop sustainable collaborations within the larger region to enhance an external circularity.

Equity

The vision of the circular city from the Ellen MacArthur Foundation does not specifically address equity through any specific framework or guidance in the design, planning, and operations of a city. In many city examples, it is the major businesses, economic development organizations, or the solid-waste-management sector that frame a circular approach rather than the inclusion of citizen-stakeholder participants. To realize the vision of a sustainable, resilient, and equitable new city, a diversity of community members will need to be included in the design, creation, and maintenance of the model city (Prendeville et al., 2018).

Natural Systems and Infrastructure

In a circular city, valuable land previously dedicated to roads and car parking is freed up for green spaces, commerce, offices, houses, and recreation, thus helping to preserve natural systems. In the literature on circular cities, the words “restoration” and “regeneration” are often used. This is due to the embedded emphasis on reuse, repair, refurbishment, remanufacturing, and maintenance for products in the circular economy but not necessarily applied to natural systems and the ecosystem services provided (Morseletto, 2020). Because the term “regeneration” does not align with our definition of regeneration of natural systems used in this report, Brussels’s Be Circular initiative would need to be amended so that the regeneration of ecosystems would be given a priority.

Smart Cities: Lessons Learned from Various Examples

The Smart City initiative is included in this report because of its applicability to obtaining a sustainable, equitable, and climate-resilient city. In addition, many recent examples of planned new city development were initiated and promoted based on the Smart City lens. The Smart City movement has seen more promising results with respect to achieving model-city status.

However, the Smart City does not lend itself as well to an analysis similar to that which we presented for the previously reviewed strategies. There is a limitation of privileged information about these developments for the public to access. Many of these proposed, or existing, examples are led by centralized governments or private businesses that do not follow the traditional processes of municipal inception and development. Therefore, the Smart City approach is included in this report because of the lessons learned in creating new cities; however, the review is structured differently to capture important points that can be applied to our proposed framework.

There are numerous definitions of what a Smart City is according to the literature (Allam & Newman, 2018). These definitions agree on the basic concept of integrating Information and Communication Technology (ICT) and the Internet of Things (IoT) to manage and control a city's assets (Colding et al., 2020) and maximize efficiency (Silva et al., 2018). Initially, the concept of a Smart City was led by technology providers and lacked leadership by citizens and municipal governments (Allam & Newman, 2018). Nor were urban planners and designers included in the conversation of how such cities would actually function.

In this report, we propose Smart Cities to be urban settlements that are guided by citizen co-creation models that have a goal to make the city sustainable, efficient, equitable, and livable through urban intelligence via technology. To ensure that a smart city meets the goals of climate resilience and sustainability, they must be designed to include nature-based solutions in tandem with technology and must focus on enabling connections with nature for all the citizens of a city (Colding & Barthel, 2017). However, there are quite a few inherent flaws in the design and implementation of the few examples that exist of a city built from scratch based on the Smart City movement. In addition, all of the examples we explore below do not include citizen cocreation as a process for initiating the city planning process.

It is important at this point to characterize the difference between the purpose of new urban development models in the United States versus China and other Asian nations. Many new model cities in China are planned by centralized governments, with the primary purpose of relieving overcrowding of an adjacent city by promoting out-migration to the new urban development (Tan, 2010). In the United States, recent developments of new urban settlements are led predominantly by private initiatives.

The Toronto Sidewalk project (not a whole city), Shenzhen, China, Belmont, AZ, Bluetech Park, NV, Songdo, South Korea, Forest City, Malaysia, and Masdar, UAE are a few examples of Smart Cities that can be explored in the context of this report. Because we are exploring various examples of smart cities across the globe, this section will need to address components of the framework throughout each specific example.

Shenzhen, China is often referred to as a successful, well-planned, instant city. However, if one researches the origins of the city, the initial purpose of the city was to spur market-led economic growth for a failing national-planned economy (Hu, 2019). As discussed in the beginning of this report, aligning the purpose of a city with a sustainable urban development vision is vital to ensure that a model city is implemented. New town projects in China are often marketed with sustainable urban concepts such as ecocity, low-carbon city, and Smart City to justify (or label) their creation. Unfortunately, if you examine the reasons why scholars or the Chinese government would classify these planned cities as successful, like Shenzhen, they will not align with the principles that are needed for our proposed sustainable urban development model. In addition, because the Smart City concept is applied to a "new city" without existing residents, the design of the city is lacking input from an already-present population that can add diversity and complexity into city formation. While many Asian cities have incorporated aspects of designing nature into the city, the overall material pathways for these cities remain traditional linear take-make-waste flows.

Other examples of a touted Smart Cities include Songdo, South Korea, which was envisioned as a "weapon for fighting trade wars" and was also intended to attract multinational companies with "lower taxes and less regulation" (Kasarda & Lindsay, 2012), and Belmont, AZ, which is the brainchild of Bill Gates, intended to be a forward-thinking community that embraces cutting-edge technology with real-time data accessibility, autonomous vehicles, and logistics hubs (Cooke, 2020). Although Bluetech Park, NV incorporates energy-generating sidewalks, net-zero buildings, "super trees," workforce housing, and other green technologies, the driving purpose of the development by the developers is still unknown according to recent newspaper articles in the Architects Newspaper, Las Vegas Review Journal, and Miami Herald. All these examples of using ICT/IoT data-driven logistics can contribute to city resilience but is in no way a panacea for sustainability. The examples being proposed still beg the questions of how these new experiments will be governed, where the food that is needed by residents will be grown, and what the implications from climate change are for creating such development in the face of specific projected climate change effects where they are being located.

Although not a complete city, the Toronto Sidewalk Project is the only example that aspired to be a sustainable and affordable community that is dependent on innovations in technology and urban design. In 2017, Sidewalk Labs and Waterfront Toronto started a plan for the Quayside area, which consists of 12 acres in the eastern Bayfront region of Toronto. Sidewalk Labs is a Google-affiliated company with a mission to reimagine cities to improve quality of life. The project unfortunately ended in May 2020. According to Sidewalk Labs, this outcome was due to the unprecedented economic uncertainty in the real estate market.

However, since it first announced the project in 2017, there has been strong opposition to the project from local residents and others who are concerned about the profit motives of the tech companies that are involved and the lack of transparency around the plans. On paper, the project exemplifies sustainable urban development concepts for affordable housing, sustainable transportation, green job creation, and an attempt to reduce material flows in the system while implementing digital innovation and technology. However, issues of privacy and data use created insurmountable obstacles to obtaining the public support needed for the project to be implemented (Tusikov, n.d.). This issue of data and privacy will continue to be a barrier to actualizing Smart Cities in the United States.

Forest City, Malaysia is another planned city (in construction) that is marketed as a "smart and green futuristic city that combines environment, technology and cutting edge technology to create an ideal, idyllic and technology-driven living and working space ecosystem," according to the enterprise Country Garden Pacificview Sdn Bhd, which is a joint venture between Country Garden Group and the Malaysian-government-backed Esplanade Danga 88 Sdn Bhd. While adhering to certain urban sustainable-development model characteristics, this example fails to address the issues of equity and environment. An environmental impact assessment was delayed, and the majority of the development was created and intended for an elite class of the population.

Masdar UAE is a smart, sustainable city example that was started in 2006 as a private–public partnership between an investor, Abu Dhabi, Foster (architectural firm), and Mubadara Investment Company. The vision for Masdar City was to create a zero-carbon and zero-waste city that would be a model in sustainability. Unfortunately, partly due to the

2008 global financial crisis and other economic constraints, the original plan was scaled back to a goal of "low carbon" along with less ambitious waste-reduction goals (Griffiths & Sovacool, 2020). While there are many aspects in the initial design and vision of the project to apply to our proposed model city, there are still two vital issues with replicating the Masdar City project. First, the economic mandate of Mubadala prioritizes economic returns over environmental returns, causing a conflict with realizing the original vision of a zero-waste city (Griffiths & Sovacool, 2020). Second, a significant concern of Masdar City is the physical location selected for the city. Masdar City will be constructed in the desert, with significantly limited freshwater resources and extreme sandstorm events. The latter has curtailed the ability to tap solar power to drive the energy intensity that is demanded by the City's design (Prior, 2010)—a cautionary tale that any model city needs to take a systems approach in the location, creation, operations, governance, and maintenance.

We propose that the incorporation of the technology and ideals of Smart Cities needs to be a part of the model city. However, it is important to take the lessons learned in many of the examples above to avoid the same barriers for development of a robust model city. First, the issue of data and privacy access must be addressed and resolved. Second, the conceptualization, planning, and design of such new urban development must consider the projected effects from a changing climate. Third, a new city needs to be planned and envisioned in anticipation of the community members that will live, work, and recreate there. This could be accomplished with representative samples of future resident populations. It would be an iterative process, where aspects of the new city would be refined over time as new residents migrate into the city.

While there is no silver-bullet answer for overcoming the issues associated with Smart Cities, there are many opportunities to ensure trust and transparency in Smart City development. In addition, there must be thought given to what information is collected in a Smart City and how it will be given meaning. Different interpretations of how the data is interpreted will change the outcome of who benefits from the information. Possibly even more important, is the importance of place-based, cultural information that cannot be collected through technology. This type of information, for example traditional ecological knowledge, can increase the climate resilience of a community and cannot be collected and analyzed by computers or tech. In addition, it is imperative that any new urban development is imagined and envisioned through an engaging municipal community process versus a plan that is conceived by a private tech company.

As reported above, many of these new cities are designed based on goals or a purpose that are directly and indirectly in conflict with equity, sustainability, resilience, regeneration, and circular material flows.

A Way Forward

The previous section evaluated urban development strategies and applied our proposed framework to one example of the strategy in practice, except in the case of Smart Cities. A comprehensive bibliometric analysis has concluded that urban sustainability strategies need fine levels of distinction and frameworks integration to achieve true urban sustainability (de Jong et al., 2015). As seen above, many of the strategies addressed criteria in our framework either directly or indirectly. In some cases, our framework was not addressed at all in the existing development strategy. Appendix A will summarize whether, and to what extent, the existing urban strategy incorporated criteria from our proposed framework.

From Appendix A, one could surmise that the LEED City framework may be a good tool with which to consider how to develop a resilient and equitable future city. But there are two challenges with implementing this approach. First, the LEED model has been applied to existing cities and the framework for scoring is piecemeal, lacking the integration that would be desirable if a new city were sited on the landscape. Second, there is no weighting of the application of the criteria, resulting in a skewed view of the efficacy of options that are planned and implemented. But with this said, the existing scoring matrix for each LEED City criterion can provide guidance on how a new city might better conceptualize and plan the urban footprint.

This section of the report will define and suggest ways to reconsider circular material flow embedded in an urban development that also incorporates equity and systems thinking to build a city's resilience and social well-being. If the questions of the framework (Appendix B) are addressed, the new urban development will be closer to the sustainability of the ideal vibrant, robust, and resilient community. These questions emerge from investigating the previously explored sustainable urban settlement strategies and taking them to a higher level of systems thinking and material flow.

To achieve the model city for the future, a new way of thinking is needed for urban development. This can be achieved through restructuring and reconnecting people with the limitations and opportunities that are associated with natural systems and our physical environment. Leuphana University faculty (Abson et al., 2016) have engaged in relevant research to transform our systems and achieve true sustainability by addressing higher-level leverage points for system change. Their work is premised on Meadows's *leverage points*, which range from relatively easy interventions that change the amount or extent of a system's dynamics to more significant paradigmatic change that shifts a system toward sustainability (Meadows, 2010).

In today's society, changing numbers are typical intervention points for creating behavioral change. For example, increasing the miles per gallon of a car will reduce greenhouse gas emissions to a certain extent. This is because individuals primarily live in places where they need a car or another form of vehicular transportation to get to work, buy groceries, or just have fun. But economists have seen that such an energy-efficiency change may lead to more miles driven per car, obviating the benefit of lower mileage per gallon. This is often characterized as *Jevons Paradox* (Blake, 2005; Freir-Gonzales, 2015). However, eliminating the need to own a car because of the physical (re)development of a city has a much more profound effect on emissions.

Changes in the system's goal, organization, or structure are considered to be deeper and highly influential leverage points that can shift the overarching framework. Such leverage points are also considered the hardest to implement. For example, it is much easier to recycle waste through a solid waste system versus reengineering the design of all products to maximize reuse, refurbishment, or repair, a foundational attribute of a true circular economy. Historically, it seems evident that there has been a disproportionate focus and reliance on the easier-to-influence leverage points such as numbers, stocks, and flows. The structure of stocks and flows are viewed as having minimal influence for creating substantial changes because of the amount of time and resources needed to change physical infrastructure. You can see this evident in the time it takes for contaminants to be washed out of aquifers. The structure of the system would need to be completely changed to avoid the in-flow of pollutants into the water (stock). It is time to focus on Meadows's (2010) system-shifting leverage points to create the needed paradigm shift in the field of sustainability (Abson et al., 2016).

We can see various types of leverage points being addressed in many of the examples given in this report. While the resilient and circular city model envisions a system change of how materials flow in a process, many of the examples seek to make changes in the shallower, or less influential, leverage points. For example, regulating greenhouse gas emissions, increasing building efficiency, and increasing the amount of green space in a city all fall in the lower leverage points for sustainability. All of these actions deal with incrementally changing the existing systems versus changing the purpose of the overall system design.

To envision, plan, and design our model city, the goal and subsequent organization of the city must be rethought, restructured, and reconnected. The following is a nonlinear approach to applying the framework we propose to the purpose, design, and creation of cities from their inception through their development.

Rethink

We are at the threshold of major systematic shifts of our climate and our biosphere, both of which threaten social stability and limit the potential for future generations. This urgent situation, which we ourselves have created, requires us to learn to think in ways that are new, expansive, transdisciplinary, and empathetic. The thinking skills of the 21st century must embrace the power and capability of humans to transform the entire planet for ill, or good.

The city, as an ever growing human construct, is an appropriate place to intervene to shift how we think about future human settlement and its related ecological footprint on this planet. So, we must begin by how we vision and conceptualize the future city, not only in its structure and internal metabolic flows but also in how it is embedded on the larger landscape on which it is dependent. We must bring to the forefront of our deliberations that every decision within the city affects people and the ecological services, both up the supply chain and down the pathways of product flow. We must appreciate the practical and ethical benefits of closing loops closer to home so as to minimize growth without sacrificing well-being. Finally, we must always consider future generations and how to ensure that our decisions today do not limit their decisions in the future.

Purpose and Vision of the City

The goal and purpose of the city must be rethought to include a holistic systems approach for providing the infrastructure and materials that are necessary for people to live and work. We must necessarily include that the purpose of the city is to create equitable, meaningful, and fulfilling lives for the inhabitants. Beyond building resilience, equity, and social wellbeing and happiness, the purpose of the city should include a goal of supporting and regenerating the capacity of earth's natural systems.

Concurrently, we must acknowledge and explore how all materials and energy in our cities are produced and used. How do we envision our materials flow? Are products designed so that consumers have one-time use, which in turns reinforces a flow rate of the supply chains that hastens the limits to the carrying capacity of the very systems in which the city is embedded? It is time for us to rethink the linear flow path of materials, envisioning a culture where materials management is not just a waste management responsibility.

To begin this process, a community-driven design form of urban planning is necessary (Wilson, 2018). Such a design approach creates a space where power is equally redistributed for decision making, creativity is encouraged through deliberative processes, shared goals are highlighted and prioritized, and participation is honored and rewarded.

This type of participatory approach would be located at the highest rung of Arnstein's Ladder, which is "citizen control" (Arnstein, 1969). Arnstein's ladder was created as a guide to highlight who holds the power when making important decisions that affect the community. Environmental and resilience planning and design typically depend upon experts for crucial decisions on the outcome of urban development. However, in the model city we are envisioning, this information would be dependent on citizen participation for shared values and solutions to enhance the expert knowledge for an equitable, resilient, sustainable city.

To do this successfully, we propose adapting the iterative Collaborative Planning Approach (Gruber, et al., 2017) to gain stakeholder values, beliefs, attitudes, and knowledge to inform the development of the city (Figure 10). If one is proposing an entirely new city there would not be a citizenry at the point of conceptualization and subsequent groundbreaking. However, it would be recommended to initially gather a representative sample from the region to help inform the process.

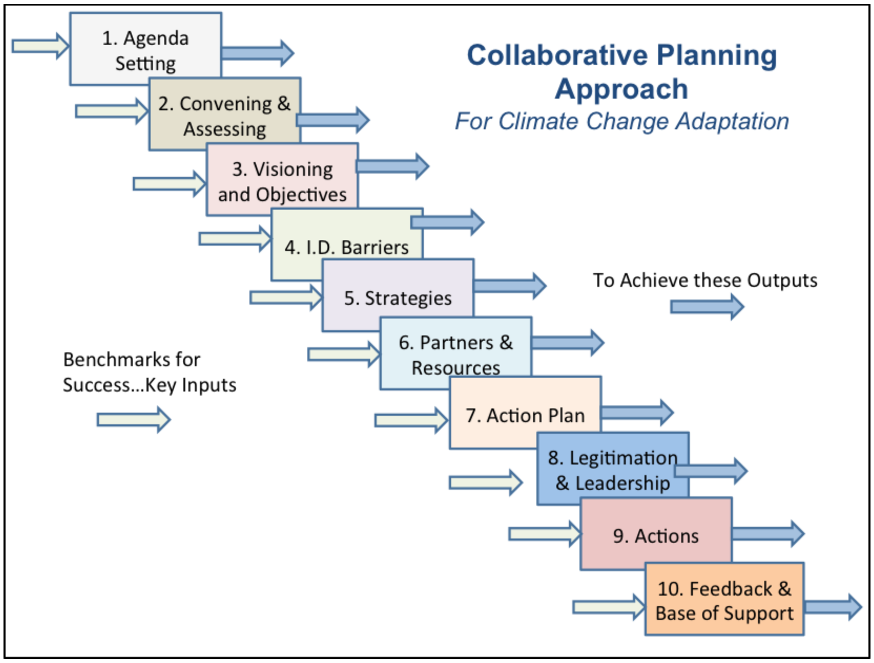

Figure 10. Ten-Stage Collaborative Planning Approach Model for Change

Note. Figure adapted from Gruber et al. (2017).

This approach is also applicable when redeveloping a city to include a more diverse population. This helps avoid the trap of being a community for a privileged subset of the larger population. As the design moves forward, additional stakeholders can be pulled into the process so as to cocreate the ongoing design, planning, and implementation of the urban development. This model overcomes many of the barriers that are encountered in the planned smart cities across the world. While technology and data innovation will certainly help our model city achieve its vision, these advances will need to be designed in partnership with the citizen participants and thoughtfully planned for their objectives and how they are managed.

Sense of Place

For this resilient and circular model to be implemented, we must rethink different aspects of urban development. This begins with reconceptualizing the purpose of the city by acknowledging the "sense of place" within which the urban development is located or proposed to be sited. Such an approach values the preservation of the historical, cultural, and ethical mores of a region and its people. It also acknowledges the specific natural systems on the landscape that the city is supplanting.

In addition to creating opportunities for authentic citizen participation, we must also rethink the scale at which we envision, design, plan, create, and operate the new model city. To frame the model city to maximize its resilience in face of the global challenges we see, there must be a balance between thinking globally and recognizing that the proposed urban footprint is cognizant of, and respects, an already existing landscape.

"Sense of place" transcends various disciplines and has foundations in both urban design and sociopsychological sciences. It is necessary to incorporate and foster a sense of place for an urban settlement to be a vibrant and livable, as well high quality with respect to the built environment (McMillan & Chavis, 1986; Puddifoot, 1995; Hu & Chen, 2018;). The subsequent planning and design of such a model city should develop in a manner to maintain already-existing natural assets and culture while concurrently developing an economy that contributes and enhances the quality of life of not only the urban inhabitants but also of the greater region's citizens (National Academies of Sciences, Engineering, and Medicine, 2016).

Such a sense of place encourages stakeholders in the urban development process to be cognizant of the shift of the larger climate systems and the associated projection of climate effects in a particular region. The specificity, frequency, and intensity of such effects vary with locale. Therefore, the design, planning, and implementation will vary with respect to what makes the community resilient. Failing to consider this shift in the climate system results in a flawed design, which will not only constrain the sustainable economic growth of a city but also possibly lead to inequalities within the citizenry, and may actually result in fatalities.

Empathy

A central concept of neoclassical economists is the concept of *Pareto Optimality*, which is a state where there is no opportunity to make changes in the economy that will make one better off while at the same time not making another worse off (Goodwin et al., 2005). This is an ideal to strive for but not reflective of our market system, which is far from perfect. But such a goal is honorable to hold in that it translates to ensuring equal distribution of economic benefits to all and at its core is predicated on an assumption of understanding and caring for others. Such empathy is also reflected in the Brundtland Commission's definition of sustainable development, which places a value on future generations equal to our own.

M. Berners-Lee (2019) posits that "our circle of concern needs to parallel our circle of influence". If brought down to a city-level perspective, the effects can be significant from replacing natural systems with an urban footprint, creating a hub of demand for materials and products that follow supply chains that span the globe, and exporting uncontrolled emissions and materials that are deposited on landscapes and people far from the municipal boundary. In short, the daily lives of a city's population do affect people on the other side of the globe. He summarizes his point by positing that we need to change the way we think; we need global empathy that exists beyond the timing of an electoral cycle and a city's limits.

The focus for the city's planners, designers, and leaders should stretch far beyond the physical boundaries of the urban settlement. No city on the globe acquires all that it consumes within its own environs; in fact, the ecological footprint of urban development is multiple times the space that the city occupies (Rees and Wackernagel, 2008). Thus, within their domain of influence, city leaders need to frame a working urban environment that minimizes the negative externalities beyond its borders and maximizes the positive effects of closing loops locally.

Restructure

Abson et al. (2017) propose restructuring our institutions to enable change, stability, and learning for sustainability. A view that harkens back to Meadows's (2010) system-shifting leverage points. Two essential structural systems to shift include the "balkanization" that occurs among professional disciplines and the traditional hierarchy of decision making in organizations and communities. Additionally, there must be restructuring of the production cycle and the associated flow pathways so as to maximize the useful life of already extracted materials and expended energy.

Balkanization and Decision-Making Hierarchy

The resilient and circular model city needs to develop an approach that allows both top-down framing, planning and design by producers that reflects bottom-up buy-in by the consumer, who ultimately makes the decision of how to handle a product once their use of it has passed. Top-down change is institutionally driven (in this case by the municipal/local government), such as economic-development decisions facilitating public-private partnerships that maximize material circularity. Alternatively, bottom-up change describes company collaborations (supply chains, product design), social movements, social innovation, and community/neighborhood based implementation (Prendeville et al., 2017).

A crucial factor of flattening and integrating the traditional hierarchy of decision making is to address the common "balkanization" of professional disciplines and material production. The process of developing a model city that uses a circular economy approach requires multiple disciplines including urban planning; economic development planning; architecture; engineering; water and energy resource expertise; and the professional disciplines within the transportation, public safety, education, and environmental protection domains, just to name a few. As has been seen in existing cities, the expertise that is required to operate the various city services are often separated into different departments, and collaboration among these different city operations is lacking a true transdisciplinary approach (Patel, 2015).

This has more recently been revealed as a barrier to effectively responding to the potential effects of a changing climate (Leiren and Jacobson, 2018; Uittenbroek et al., 2013). Thus, it is incumbent upon those who are championing the development of a new model city that during the initial phase of conceptualization, the visioning should be informed and refined by an inclusive process that brings the different professional perspectives into a common forum (Ekstrom & Moser, 2014). This would allow proposed ideas to be debated, critiqued, and refined so that subsequent planning, design, and implementation has a *shared vision* that emerges from the process. An additional necessary set of stakeholders to include in such a process are those whose region will be the recipient of the urban (re)development.

Because products and components follow a circular rather than a disposal pathway, it is important to recognize and address the balkanization inherent in the competitive marketplace. There is a propensity not to collaborate with those viewed as competitors. What collaboration that does exist is often relegated to business-to-business interaction along the supply chain and does not recognize the benefits of creating a horizontal collaboration that could be beneficial to all (Cao & Zhang 2010; Majava et al. 2013). Similarly, one often sees a silo mentality within a single business operation, such as when there is a common goal stated to address sustainability but the business functions of finance, marketing, and corporate responsibility fail to work together collaboratively (Hart et al., 2019).

M. Berners-Lee (2019) posits that there needs to be a new way of approaching the challenges that are threatening society. He characterized this as a need for a "Joined-up Perspective," meaning that any one perspective, such as science or engineering, only provides one of many frames of the complexity of our challenges. It is useful, but only up to a point, because it only provides a "complete explanation" within its own terms of reference. Nor can arts, philosophies, and spiritualties alone feed people, preserve the biosphere, or control a pandemic. Moving toward an environmentally sound, economically wise, and equitable city construct requires a transdisciplinary approach. The concurrence of multiple perspectives will build resilience and move us closer to the ideal equitable community.

Production and Pathways of Materials

Along with restructuring the hierarchy and balkanization of decision making, we must reorganize the production cycle. This includes restructuring the entire linear material flow pathway of the city. To do this, various principles need to be addressed and incorporated into the design of the model city. This restructuring will also require an overhaul of the traditional city planning, design, and responsibilities of departments such as public works and waste management. A priori, this requires a reframing of city-level policies, regulations, and approaches to economic development. This restructuring will enable and facilitate the creation of a circular economy for any urban settlement.

Creating, or redeveloping, for a resilient and circular city will also require a transformation in the physical design of our cities. If we have the option for designing a new planned urban settlement, we recommend using the five steps of permaculture design to envision the physical structure and placement of the city. These include observation, envisioning, plan, develop, and implement. The observation of a landscape is the most important first step for the physical design of an urban settlement in the permaculture approach. Individuals are needed to understand and watch the landscape to be cognizant of the solar gain of the area, how and where the water flows, what the various soil types are, climate, wind patterns, and all existing ecosystems and their services. This will help minimize and recirculate materials that are needed to heat and cool structures, obtain water and food efficiently, generate distributed energy, acquire natural resources onsite to be used in production, and determine how to manage precipitation and stormwater.

During the envisioning step, a structured and facilitated process is used to build community collaboration on how best to locate residential, commercial, and recreational city forms, along with municipal spaces that can enhance industrial ecology and mimic natural systems. Once such thoughtful systems-oriented envisioning is underway, the next crucial step is to restructure existing land use policies and regulations to support and incentivize the circular economy of the urban settlement. Nontraditional and innovative land-use planners with experience in form-based code, performance zoning, development impact fees, power purchase agreements, land banks, tax credits, transfer of development rights, and more will be necessary to achieve this circular flow path of materials.

Reconnect

For this resilient and circular model city to be actualized, we must foster interactions between people along with their relationships with nature. This can be accomplished by building social capital through governance structures and other forms of authentic community participation. In addition, we must ensure there are opportunities in the design of the urban landscape for all members of the community to have access to experience nature.

Social Capital Through Governance and Participation

Our model framework is dependent on connecting individuals with the community. The design and operations of the city must include opportunities for building relationships and networks among people to enable the community to function more effectively. This might be accomplished with the formation of polycentric governance systems that depend on community-driven participation. This type of governance system will create nested jurisdictions of collaborating levels of governance working together for the vision and goals of the new model city. A polycentric governing system would allow for multiple centers of decision making for different collective decisions. These types of governance structures include overlapping jurisdictions to account for outcomes that are systems dependent, overarching shared norms and values placed on natural systems, and high level of coordination between decision makers to internalize all externalities of decision-making outcomes. This type of polycentric governance will depend on a participatory-democracy method of stakeholder involvement wherein citizens are actively engaged in the management of the urban system.

In addition, technology could be a vital ally in accomplishing this reconnection. It will be important to incorporate lessons learned from other planned smart cities and use technology and data for maintaining a circular material pathway while it is being used to bolster social capital and adaptive capacity. The purpose of the technology that is used must always be aligned with the stated vision and goals of the proposed model city. These technological resources will be useful for providing feedback signals to make fast, efficient, adaptive changes based on the use and behaviors of urban systems. For example, real-time monitoring on building energy usage can help determine at what times of the day energy usage rises, helping the city institute incentives or policies to reduce consumer energy demand during peak energy load times.

Connection with Nature

E.O. Wilson (1984) posits that humans need to connect and affiliate with nature to be happy and healthy. Building on this, there is a growing body of research demonstrating the positive physical and mental health benefits associated with incorporating nature into home and work environments (Beatley & Newman, 2013). As seen in our Biophilic Cities example, a few leading cities around the world are attempting to change the current paradigm of developing isolated green spaces in a city where people must travel to experience nature to developing a city where nature is integrated into all aspects of urban design.

This type of integration has multiple benefits for urban development in addition to improved public health. These benefits include mitigating and adapting to climate change, building climate resilience, fostering "sense of place" among residents, increasing social capital, reducing energy demands, and lowering infrastructure costs. As we have recently seen through the current pandemic, green spaces and access to nature are a valuable, privileged resource. By incorporating nature into all aspects of urban design, the associated benefits are equitable and accessible to all community members.

A Few Closing Thoughts . . .

This conclusion begins with addressing some reflection on aspects of this thesis that should be mentioned in considering any conceptualization of a new model city. It closes with a proposed tool that could serve those who are initially conceptualizing any new urban (re)development.

Premises

Our analysis is framed from two overarching paradigms. The first is that we are imagining developing a new resilient and circular model city where, heretofore, there was no development. From a circular economy perspective, considering the investment in products and infrastructure of existing cities, our framework would be more apropos for re-urbanization. This would maintain the usefulness of materials that have been extracted and the related energy already expended. Also, there is the consequence of siting any new city footprint on the landscape in that it further reduces the natural ecosystem services on which society is dependent.

But with this said, if population growth and in-migration to cities from rural environs continue to increase, new city footprints may be unavoidable and as has been demonstrated here, governments and private initiatives are already in the process of developing such new communities.

A second premise, which is referenced in the introduction, is that our framing of resilience, circularity, equity, and regeneration are aligned with the United Nations' Sustainable Development Goals (SDGs) put forth in the Agenda 2030 for Sustainable Development. The goals that are specifically reflected in this analysis includes SDG 11, *make cities and human settlements inclusive, safe, resilient and sustainable*; SDG 12, *ensure sustainable consumption and production pattern*; SDG 13, *take (urgent) action to combat climate change*; SDG 16, *promote peaceful and inclusive societies for sustainable development*; SDG 15, *protect, restore, and promote sustainable use of terrestrial ecosystems* (United Nations, 2015).

A circular economy is a necessary condition for our resilient city model, and the circular materials-flow framework addresses the SDGs, including promotion of sustainable economic growth and associated industrialization; striving for full, productive, and decent employment; and fostering innovation to build resilient infrastructure in a manner that ensures equal access to affordable and reliable energy, water and sanitation.

Efficiency and Resiliency

Framing climate resilience as an important criterion for a model city assumes that redundancy, developing multiple linkages, and circular regulating feedback loops are necessary components. A city that is dependent on a single source for anything is vulnerable to the shifting systems in which it is embedded (e.g., climate, global economy, and resource availability).

At the scale of a city's economic actors, one often sees a drive by businesses to maximize efficiency by instituting standard operating procedures, such as just-in-time supply chains. The motivation is from a cost-savings, not revenue-assurance, perspective. But as COVID has shown, such efficiency decisions have led to businesses seeing their revenue decrease, their costs increase, loss of market share, and even closure due to lack of access to a once-dependable supply or a lack of capacity to reach their clientele and relationships to cash flow. This has been especially true for small businesses (Bartik et al., 2020).

A recent research report showed that a small group of resilient companies outperformed their competitors during the 2008 financial crisis. Although their revenue loss was on par with that sector's industry-average loss, by 2009 the earnings of the most resilient companies had risen 10%, whereas the non-resilient companies had gone down 15%. In this context, resilience was characterized in the frame of preparation for possible futures by mapping supply-chain possibilities and developing alternative strategies to just-in-time procurement and access to capital (Sneader & Sighasl, 2020).

This lesson in resilience can be also seen at the city scale. After Hurricane Katrina hit New Orleans, an analysis of what went wrong with respect to city/regional planning was released by a review panel. This study concluded that with respect to a changing climate, there was a clear lack of thinking globally in order to act locally. The report went on to say the city failed to build resilience into their systems and lacked the necessary redundancy that was required to reduce the city's vulnerability (ACSE, 2007). An important implication of this report may be that efficiency can translate to more product and service output for the same input, but this will be a moot if a systematic shift outstrips the resiliency that the efficiency has compromised.

Another lens on the same dynamic has been developed by the Federal Emergency Management Agency (FEMA) regarding extreme events that are mediated by the changing climate. It has been found that after natural disasters many businesses within communities, especially small businesses, are not resilient to such disturbances. FEMA has seen that 40% of small businesses never reopen after a disaster and another 25% that do reopen fail within a year (McKay 2018).

Building resilience is important not only to a business's bottom line but also to the city's economic health and the well-being of the city's workforce. This is particularly important for a city that strives for a circular economy—one which focuses on highly skilled workers in a multiplicity of smaller business enterprises that maintain the usefulness of products.

AI: the Good and the Bad

With respect to efficiency, there is large potential for artificial intelligence (AI) to play a significant role in supporting a circular economy within our model city. This is at the point of production of goods as well as the systems-oriented functions of routing materials flows, using autonomous vehicles, installing smart electric grids, and even having AI-powered health care systems.

This does not mean that AI is material and energy neutral. Infrastructure that supports AI can be made up of the majority of the elements found on the chemical periodic chart, which are very hard to recapture once integrated into a product. AI, being energy intensive, can be a significant emitter of greenhouse gases, particularly when the required electricity demands are not supplied by nonrenewable resources (DeWerrdt, 2020). And, a server-based AI without redundancy becomes a system vulnerability, to not only hacking but also the vagaries of a climate system that can affect AI-related infrastructure (Vinusesa, et al., 2020).

However, AI can be used to magnify the competitive strength of circular economy business models by supporting the complexity that is associated with a product-as-a-service business economy (Vermut et al., 2019). By combining real-time and historical data from products and users, AI can help increase product circulation and asset utilization through pricing and demand forecasting, establish predictive maintenance, and provide smart inventory management. In addition, AI can optimize the circular economy by building and improving the reverse logistics infrastructure that is required to "close the loop" on products and materials, specifically through establishing systems to process, sort, and disassemble products, remanufacture components, and recycle materials (Mckinsey & Company, 2019).

But society may not be ready for an AI-driven smart city, where copious amounts of data are collected to maximize efficiency. There is the specter of mistrust of those who collect and control such information. From Orwell's *1984* to Stritmatter's recent *Harmonizing Artificial Intelligence for Social Good*, the zeitgeist of an ominous "big brother" remains a part of our socialization, as is evident in the example of the Sidewalk Lab's innovative urban development attempt in Toronto (Bliss, 2018).

Responsibility

One must ask who holds the responsibility for ensuring the handling, routing, and disposition of the materials that are by a city. For a circular economy, it has been stated that responsibility for the circularity of a product lies with the consumer (whether a citizen or a business). Once the consumer has made use of the product, the decision to follow a circular path or a disposal path lies with them (Stahel, 2019).

To follow circular pathways, there needs to be system options for circularity as easily accessible as there are for a disposal pathway. It is in this role that the city must be a significant driver, not only through its urban and economic development but also through messaging, education, and collaboration with its citizenry. From the urban development side, circular paths for products, both spatially and temporally, must be equally accessible for all. From the economic-development perspective, the responsibility needs to start with facilitating the location of businesses that have shown to minimize inputs of materials and energy. It is also important for businesses to move proactively from a design of planned obsolescence to maximizing use. Businesses need to avoid designing a product's linked goods that are specialized and should consider establishing universal standards for component and accessory use. The design phase should envision component replacement and eventual disassembly, establish universal coding to recognize component parts to facilitate materials tracking, and support a more efficient marketplace for the sale and acquisition of such components.

Synthesizing a New City Model

As identified through our research, not one of the current urban development strategies reviewed represents a holistic approach to a sustainable development. Each of the strategies has essential characteristics and principles that need to be coalesced and synthesized into an all-inclusive new city model. To help move our assessment framing to application, the table (Appendix B) below is a first iteration of a guide to inform consideration of any future (re)urbanization. This approach should help guide envisioning, planning, and designing a model urban settlement.

The matrix uses the climate change, material flow, equity, scale, and natural-resource lens and has associated questions that can be applied to assess past urban development efforts or used to help conceptualize new urban development. Our ideal model city will score a 5 in every question to approach the goals of a resilient, equitable, and circular-material-flow city. The matrix, along with a systems approach in participatory planning, will foster the way forward to a new paradigm for a successful vision toward a new city model.

Appendix A: Urban Development Strategies

Urban Development Strategies	Framework Criteria: Directly Addresses (DA), Indirectly Addresses (IA), Does Not Address (DNA)				
	Climate	Materials	Scale	Equity	Natural Systems
New Urbanism	IA	DNA	IA	IA	IA
LEED for Cities	DA	DA	DA	DA	IA
Ecovillages	DA	IA	IA	DA	IA
Transition Towns	DA	IA	IA	DA	IA
Blue-Green Infrastructure	DA	IA	IA	DNA	IA
Biophilic Cities	IA	IA	DA	DNA	DA
Industrial Ecology	IA	DA	IA	DNA	IA
Circular Cities	IA	DA	IA	DNA	IDA

Appendix B: Framework Matrix

Climate Change	
Questions	**Rating (1–5)**
How well does the example incorporate current and future effects of climate change to that specific location?	
How well does the example address mitigation of greenhouse gas emissions?	
Does the strategy incorporate the climate-resilience principle, maintain diversity and redundancy?	
Does the strategy incorporate the climate-resilience principle, manage connectivity?	
Does the strategy incorporate the climate-resilience principle, manage slow variables and feedback loops?	
Does the strategy incorporate the climate-resilience principle, foster complex adaptive systems thinking?	
Does the strategy incorporate the climate-resilience principle, encourage learning?	
Does the strategy incorporate the climate-resilience principle, promote polycentric governance systems?	
Material Flow/Pathways	
Questions	**Rating (1–5)**
Are there easily accessible options for the consumer to direct materials to a reuse, repair, and refurbish economic pathways?	
Are there local policies (being) proposed to target specific materials/products flowing into the city that maximize circularity.	
Has the waste management system been altered to maximize circularity?	

Does economic development target attracting businesses that can be compatible with respect to industrial symbiotic relationships.	
Is there an accounting system established for the material extraction, embedded energy, and greenhouse gas avoided due to materials following a circular economic pathway?	
Are the city's metabolic pathways for the flow of water, nutrients, and energy maximizing circularity?	
Are there any policies/mechanisms for the circularity of nonphysical materials that enhance purchasing power, institutional knowledge, and adaptive management?	
Scale	
Questions	**Rating (1–5)**
At what scale is the proposed urban development most applicable?	
Is the plan for scaling-up detailed and reasonable from an initial groundbreaking to the projected maximum footprint of the urban development?	
Are multiple natural systems' scales recognized in both the urban and economic development planning and implementation?	
Does the projected population size for this urban development reflect the carrying capacity of the region in which it is being sited?	
Are multiple materials-flow scales recognized in both the urban and economic development planning and implementation?	
Is the location of the urban development in line with the history and culture of the greater region in which it is being sited?	
Equity/Social Well-Being	
Questions	**Rating (1–5)**
Has the planning and design of this urban development included active participation from the region's community in which it is being sited?	

Does the strategy promote environmental justice with respect to an equitable share of environmental benefits for existing communities in the region in which this urban development is to be sited?	
Does the strategy promote and advance equitable economic opportunity?	
Does the strategy include policies or programs that allow anyone to live in the community (affordable housing, accessible transportation, healthy and accessible food, safe neighborhoods, and public health)?	
Does the strategy allow for meaningful engagement and participation of all community members?	
Does the strategy address overall human well-being and happiness in the design?	
Natural Systems/Infrastructure	
Questions	**Rating (1–5)**
Does the spatial footprint for this urban development reflect the carrying capacity of the region in which it is being sited with respect to land, water, and energy use?	
Does the strategy integrate existing natural resources into the design and planning for this urban development to ensure that ecosystem functions and services are maintained?	
Is there a commitment to regenerate lost or damaged natural systems?	
Does the design and planning of the city both replenish resources and maximize reuse of already-extracted natural resources from the surrounding region?	

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