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21st Century Metropolis and the System Thinker

21世纪的都市和系统思考者

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Abstract

The world is accelerating into the 21st century and will continue to be stressed by population increase. The metropolis must be part of the solution since 75% of the world's population will live in cities by 2050. Status quo design will not provide the required solutions in the metropolis - more integrated systems are required. Buildings, districts, and cities must be sustainably designed not only as individual components, but also as parts of larger networks. Increasing connectivity within cities will decrease resource consumption, despite the higher EUI of tall buildings, and lead to higher qualities of life that include longer life expectancies, higher productivity, and enhanced resiliency. More importantly, such cities can create positive feedback loops to further strengthen sustainability by creating silicon valleys of sustainable design.

Keywords: Connected Cities, Energy Usage, Resiliency

摘要

21世纪，世界正在加速发展并持续面临人口增长所带来的压力。到2050年，75%的世界人口将集中于城市，都市必须提供部分的解决方案。然而现有的设计方式很难为城市提供其所需的解决方案——我们需要实施更为整合的系统设计。无论是建筑、区域还是城市，在可持续设计中都不仅仅是独立的个体，更应作为庞大网络系统中的一部分来考量。城市间的联通性可以节省资源消耗，尽管高层建筑有较高的能耗密度，但这同时也成就了更高的生活品质，包括延长人的寿命，提高生产力，以及提高适应性。更重要的一点是，随着创造"硅谷"般的可持续设计都市，这些城市能够产生正面的反馈循环效应，从而进一步加强并促进可持续设计。

关键词: 联通的城市、能源使用、适应性

Introduction – Stressed Environment And Rising Cities

Humans are leaving a mark on the world. Forty two percent of Americans and over ninety percent of Europeans are exposed to unhealthy levels of ozone and particulate pollution (American Lung Association 2013) (European Environment Agency 2013). More waste is generated than ever before. Water is consumed at alarming rates. The world population continues to break records every day. The environment is under tremendous stress and calls out for relief. A key strategy for this relief has come through rising cities that leverage shared resources and greater connectivity to not only decrease resource consumption and increase quality of life, but lead to the generation of sustainability hubs.

This paper explores how people and the environment benefit from the increased connectivity within cities. First, reduced resource consumption within cities is discussed despite the high energy intensities of taller building typically found in cities. Nationwide data from the United States and a case study of 706 buildings in New York

前言 –紧张的环境和崛起的城市

人类活动在地球上留下了不可磨灭的印记。根据2013年美国肺科协会和欧洲环保局提供的数据，有百分之四十二的美国人和超过百分之九十的欧洲人生活在危害健康水平浓度的臭氧和颗粒污染中。人类垃圾产量之多史无前例，对水资源的耗费已达到引起警觉的程度，全世界人口每天都在打破新的记录。环境现状面临极大的压力，保护环境迫在眉睫。而保护环境的一个关键策略就在于充分利用新兴城市资源共享和城市联通的特性，在减少资源消耗、提高生活品质的同时孕育可持续发展的核心区。

文章探索了人与环境如何从更多的城市联通中获益的问题。首先，文章谈到了城市范围内更少的能源消耗，尽管城市高层建筑的能耗密度通常偏高。来自全美范围的数据和纽约市一项包括706栋建筑的案例分析均为上述观点提供了有力的佐证。其次，文章还探讨了不断提高的城市生活质量和适应性的问题。文章还利用有关社会经济指标如何在城市范围内发生变化的全球性研究以及美国国内的数据为世界范围内类似的发展趋势提供数据支持。重点阐述城市联通的两大好处后，文章的重心转

provide illustrative examples. Next, increased quality of life in cities and resiliency are explored. Worldwide studies on how socioeconomic indicators change within cities are presented and American data is analyzed and shown to support similar trends found in the global data. After highlighting these two broad benefits of connected cities, discussion shifts to how designers can further promote connectivity within cities to expand the benefits of urban life. Finally, a vision for creating positive feedback loops of sustainability is shared that can lead to silicon valleys of sustainable design.

Decreased Resource Consumption in Cities

Connectivity creates opportunities to share resources, especially in cities. Central Park provides green space for city dwellers rather than private yards. Denser populations can more easily justify the robust public transportation infrastructure required to slash transportation energy. This connectivity leads to compelling statistics: 56% of U.S. carbon emissions are generated in its largest 100 cities that account for 66% of the population and 75% of the economic activity (Brown et al. 2008). Per capita energy consumption in the one hundred largest cities (2.24 metric tons) is 86% of the national average (2.60 metric tons) (Brown et al. 2008). The one hundred largest U.S. cities use 23% less electricity in their homes than the U.S. average (Brown and Logan 2008).

These reductions exist alongside preliminarily counterintuitive trends. For example, taller buildings tend to use more energy per square meter due to elevators, HVAC pumping energy, infiltration, and increased exposure to solar gains (Leung and Ray 2013). Elevators travel further distances at faster speeds. Multiple pressure breaks in chilled and hot water lines increase pumping energy and reduce temperature differences of the water. Infiltration can increase based on the stack effect and higher wind velocities. Increased exposure to solar gains, because fewer surrounding buildings provide shading, can also increase cooling loads. Energy usage data from 706 office buildings in New York (see Figure 1) indicate an increasing Energy Usage Intensity (EUI) with the number of floors in a building until thirty floors, at which point a plateau is reached (Leung and Ray 2013). This plateau is further discussed elsewhere, but raises two interesting points related to connectivity. First, it illustrates how city dwellers do more with less. Despite higher EUIs in taller buildings, to a point, American city dwellers still use 86% of the national per capita energy consumption (Brown et al. 2008). Although part of the reduction is simply explained by the reduced spatial footprint per person within cities, the increased connectivity within cities also contributes to the reduction. For example, more easily shared utilities, public transportation, shorter commutes, and shared public space all help reduce the per capita energy consumption of city dwellers. The second point, and perhaps more important one to progress the vision for increased connectivity within cities, is that American city dwellers use 56% of U.S. carbon emissions to generate 75% of the U.S. economic activity (Brown et al. 2008).

Higher Quality of Life in Cities

Increased connectivity within cities not only enables more efficient resource utilization, but also enhances the quality of life of city dwellers. A partial explanation for this increased productivity and creativity has been suggested by studiers of the intricacies of biological and social complexities. Researching all types of animals, from the mouse to the elephant, they have found that larger animals need

向设计师应如何在将来进一步促进城市联通，令城市生活更美好的问题。文章还在最后对创造一个可持续设计的正面反馈循环进行了展望，目标在于打造一个硅谷式的可持续设计。

城市资源消耗的减少

联通性为资源共享创造了机会，尤其是城市内部的联通。中央公园为整个城市的居民创造了绿色空间，而并非是为个人准备的私人庭院。健全的公共交通设施是大幅度削减交通产业能耗所必须的途径，而高密度人口城市可以更容易的证明这一点。联通性所带来令人信服的统计数据: 根据Brown et al. 2008年的统计，美国56%的碳排量集中在人口占全国66%、经济活动占75%的一百个大城市里。这一百个美国大城市的人均能耗 (2.24吨) 是全国平均水平(2.6吨)的86%。而这一百个美国大城市的家庭用电量则少于全国平均水平约23%。

这种能源节省也发生在那些貌似与直观感受背道而驰的现象上。举个例子来说，高层建筑因为更多的电梯、暖通水泵能耗，漏风以及太阳得热增加等原因，倾向于在单位平方米消耗更多的能量(Leung and Ray 2013)。高层电梯以更快的速度运行更长的距离。冷冻水和热水管道中的多次压力断压转输增加了泵送耗能，并且减少了水的温差。烟囱效应和高风速会导致漏风的增加。因为周边能够提供遮阳的建筑过少，增加的太阳得热会加重制冷负荷。纽约706栋办公建筑的能源利用数据 (见图1) 显示了随着楼层的增加能耗密度也随之增加，在三十层达到一个平台 (Leung and Ray 2013) 平台的问题已在别处讨论，但是其中引出的两个有趣的问题点都和联通性密切相关。首先，这解释了城市人怎样消耗更少而产出更多。尽管高层建筑的能耗密度较高，但美国的城市人仅仅使用了全国人均能耗的86% (Brown et al. 2008) 。尽管部分原因可以简单的通过城市里每个人更小的空间足迹来解释，但城市里更好的联通性也对此作出了贡献。比如说，更便捷的市政设施共享、公共交通、较短的通勤距离以及公共空间的共享都有助于减少城市居民的人均能耗。第二点，美国城市仅利用了全美碳排放的56%就支撑全美75%的经济活动 (Brown et al. 2008) ，了解这一点或许也是促进了实现城市联通性之愿景更重要的一点。

城市中的高品质生活

城市联通性的增加不仅使资源利用更加有效，同时也提高了城市居民的生活品质。通过对纷繁复杂的生物科学以及社会复杂性的课题研究，部分解释了生产力及创造力的提高。根据West et al. 1997和West et al. 2001对各类型动物的研究发现，从老鼠到大象，

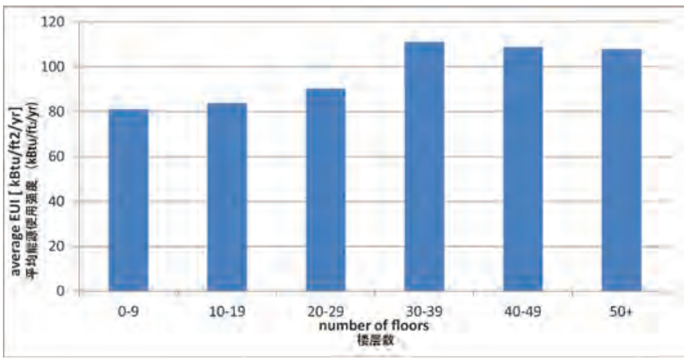

Figure 1. Average measured EUI in [kBtu/ft^2/yr] of 706 New York office buildings as a function of height, reported by the City of New York (The City of New York 2013). (Source: Stephen Ray)

图1. 纽约706座办公楼平均测量能源密度EUI [kBtu/ft^2/yr]与高度的变量关系，纽约报道 (来源: Stephen Ray) 。

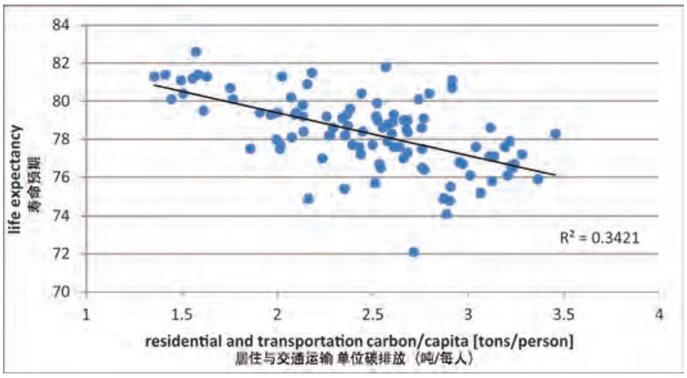

Figure 2. Life expectancy as a function of residential and transportation carbon use per capita (Brown and Logan 2008)(Southworth et al. 2008)(Social Science Research council 2011). (Source: Stephen Ray)
图2. 人寿命与人均居住和交通碳消耗的变量关系 (Brown and Logan 2008)(Southworth et al. 2008)(Social Science Research council 2011) 。（来源: Stephen Ray)

less energy per unit mass than smaller ones, in part because of the interconnectedness of the biological systems (West et al. 1997) (West et al. 2001). Although some exceptions exist to the observed sublinear power law scaling of energy use and mass, it holds for a wide spectrum of animals (West et al. 1997) (West et al. 2001). Some of the same researchers have turned their attention to cities under the hypothesis that the interconnectedness of systems within a city may lead to similarly interesting trends (Bettencourt and West 2010) (Bettencourt et al. 2010). Instead of the biological sublinear relationship, they have observed a superlinear power law scaling of many socioeconomic indicators with population (Bettencourt and West 2010) (Bettencourt et al. 2010). Researchers out of the Santa Fe Institute found that when cities double in population, nearly every available measure of economic activity increases by 15% (Lehrer 2010)(Bettencourt et al. 2010). This superlinear trend applies to everything from patents, to GDP, to crime, to number of AIDS cases in cities around the world (Lehrer 2010)(Bettencourt et al. 2010).

This global trend is explored within the United States through a different lens, using life expectancy as a proxy for quality of life. Life expectancy is a well documented and relatively consistent metric of quality of life. In this study, life expectancy data is collected from the Institute for Health Metrics and Evaluation from 2009 and made accessible through the Measure of America organization (Social Science Research council 2011). It is used to correlate life expectancy to various developmental and environmental parameters: mean income per capita, education index, and carbon emissions per capita. Mean income per capita data are expressed as 2010 U.S. dollars and were collected between 2005-2009 by the U.S. Census Bureau (U.S. Census Bureau 2009). Education index is based on two indicators: school enrollment of children, which is weighted by a factor of one-third, and educational degree attainment of people 25 years and older, which is weighted by a factor of two-thirds (Social Science Research council 2011). Carbon use per capita data accounts for the carbon emissions associated with residential and transportation sectors in the one hundred largest U.S. cities (Brown and Logan 2008) (Southworth et al. 2008). A rigorous methodology is used to collect, analyze, and normalize the carbon emissions data that originate with actual energy sold by all utilities for residential energy and vehicle-miles traveled as reported by the Highway Performance Monitoring System maintained by the Federal Highway Administration (Brown and Logan 2008)(Southworth et al. 2008).

Life expectancy depends on too many factors to fully explore in this paper. Moreover, these other factors are not all properly controlled in

体型更大的动物比体型更小的动物需要的单位质量耗能更少，部分原因是基于生物系统所具备的互联性。虽然上述有关能量消耗与质量成反比关系的次线性定律存在例外，该定律仍适用于广泛的动物族群 (West et al. 1997) (West et al. 2001)。这些学者中有些人将注意力从生物界转向城市，认为城市内的系统联通可能会遵循类似的趋势 (Bettencourt and West 2010) (Bettencourt et al. 2010)。他们的研究并非着眼于生物的次线性关系，而是城市中由人口和社会经济指标组成的超线性定律 (Bettencourt and West 2010) (Bettencourt et al. 2010)。Santa Fe 研究院的研究者发现，城市人口翻番的时候，几乎所有可量化的社会经济活动都只增加了15% (Lehrer 2010)(Bettencourt et al. 2010)。该超线性趋势适用于世界上所有经济生活指标，包括专利、国内生产总值、城市中艾滋病案例的数目等 (Lehrer 2010) (Bettencourt et al. 2010)。

生活品质(使用人的预期寿命作为大致的衡量标准)的全球性趋势在美国通过另一种视角进行研究。人的预期寿命是一个有详细备案并且相对稳定的用来考量生活质量的标尺。该研究中有关生命周期的数据资料由健康指标和评估研究所 (Institute for Health Metrics and Evaluation) 于2009年采集出来，并由美国测量 (Measure of America) (健康指标和评估研究所) 组织发布。从而将人的寿命和多种发展与环境参数联系起来，包括人均收入、教育指标、以及人均碳排放量。其中，人均收入是人口普查局2005-2009年统计出的数据，该数据以2010年美元计算。教育指数所依据的两个指标包括: 孩子入学人数 (占三分之一权重) 和25岁及以上人口的受教育程度 (占三分之二权重) 。并统计了一百个美国大城市中与居住和交通部门相关的人均碳排量数据。通过这种严谨的办法，实现收集、分析碳排放数据，并对其进行标准化处理，这些数据是根据公用事业单位实际售出的居民能源数量以及机动车行驶的里程数 (由联邦公路管理局使用的公路性能监控系统进行记载) 得出的。

由于决定人预期寿命的因素太多，无法在本文中一一展开，且所获数据中某些元素的处理方式不完全合理，但人的预期寿命与文中所考虑的发展和环境参数的仍然可以发现较强的相关性。根据普遍认可的观点，收入和教育水平会影响人的预期寿命，因此这两个因素和人的寿命间的判定系数 (r^2) 可以成为其他因素进行比较的基准。城市人均碳足迹与人的预期寿命有很强的线性相关性，r^2为0.34 (见图3)，远大于其他因素，如教育指数和收入的r^2 (分别为0.22和0.3) (见图4和图5) 。本文虽未考虑二者的因果关系，但城市内的联接可能影响居民的寿命。体育活动的增加，世界级医疗护理机构分布更密集，使碳足迹较少的城市居民的寿命得以延长。

这种类型的联接不仅仅有益于人的寿命。城市联接的增加也增强了适应能力。在面对灾难时邻里间更强的网络联系为社区成员提供了支援，而且根据这一点可以很容易的区分出相邻城镇的差距。1995年在芝加哥爆发的热浪中，有739名芝加哥人丧生 (Klinenberg 2013)，在面对这个危机的时刻，相邻城镇的处理方式截然不同。Englewood 和 Auburn Gesham都位于芝加哥南部，非常贫穷，主要是独居老人，所处微气候也不尽相同。然而，多年不与外界环境接触让Englewood的居民的生活更加闭塞，市政设施过少而无法实现与外界的联接(Klinenberg 2013)。而Auburn Gesham不同，通过促进街角咖啡店和街角小店增进了邻里之间的交流。增强的联接让Auburn Gesham比相邻小镇Englewood具备了更强的适应性。在Englewood每100,000个人中，热浪就夺走了33名居民的生命 (芝加哥范围里最严重的)，而Auburn Gesham只有3人 (芝加哥范围里最轻的) (Klinenberg 2013)。芝加哥市政府意识到了邻里联接所带来的适应性能的提高，启动了政策来更好的联系居民关系，包括为帮助弱势居民建立的电话网络，为公共社交提供的聚集场所(Klinenberg 2012)。上述的两个例子，虽然不是很详尽，但阐明了增加的城市联接有助于生活品质的提高。

the obtained data. Nonetheless, correlations between life expectancy and the considered developmental and environmental parameters can still provide insightful relationships. Income and education are commonly known to impact life expectancy, thus the coefficient of determination, r^2, between these two factors and life expectancy should provide a baseline correlation to which other factors can be compared. A city's per capita carbon footprint provides the strongest linear correlation to life expectancy with an r^2 of 0.34 (see Figure 3), which beats out other factors like education index and income that have an r^2 of 0.22 and 0.30, respectively (see Figures 4 and 5). While causality is not considered in this study, the connectivity of cities may impact their inhabitants' life span. Increased physical activity and greater concentrations of world-class medical care may extend the lives of city dwellers who tend to have smaller carbon footprints.

This type of connectivity reaches beyond only life expectancy. Increased connectivity in cities also increases resiliency. Stronger networks between neighbors support community members in the face of disaster and can vastly differ between two adjacent neighborhoods. During the 1995 heat wave in Chicago that killed 739 Chicagoans (Klinenberg 2013), two adjoining neighborhoods responded to the crisis in very different ways. Both Englewood and Auburn Gesham are located in the southside of Chicago, very poor, comprised predominately of elderly people living alone, and characterized by the same micro-climate. However, years of abandonment in Englewood had left its residents more isolated with less social infrastructure in place to foster connections (Klinenberg 2013). Auburn Gesham, on the other hand, promoted corner coffee shops and corner stores where residents could connect with one another. This increased connectivity in Auburn Gesham helped it respond more resiliently than its neighbor, Englewood. The heat wave killed 33 out of every 100,000 people in Englewood, one of the worst rates in Chicago, while it claimed only 3 out of every 100,000 people in Auburn Gesham, one of the best rates in Chicago (Klinenberg 2013). The City of Chicago noticed the increased resiliency from connected neighborhoods and created policies to better connect residents that include phone networks to cover vulnerable residents and increased social gathering spaces (Klinenberg 2012). These two examples of how increasing a city's connectivity improves its quality of life serve as illustrative, not exhaustive, examples.

Further Increasing Connectivity

Increasing connectivity within a city reduces its resource consumption and improves the quality of life of its inhabitants. How can designers and city planners inject these benefits into the cities of the future? They can design district level systems that take advantage of economies of scale. Chicago's central cooling plant cools over one hundred downtown buildings using ice created with off-peak electricity, centralizes capitol costs, and increases leasable space in downtown buildings. Toronto's district heating and cooling system reduces electricity demand for the city by 61 MW and eliminates 79,000 tonnes CO_2 per year (Enwave 2014). Copenhagen's district heating and cooling system heats 98% of the city and plans to double the use of biomass fuel, to more closely mimic a natural cycle of using waste as fuel (New York City 2011). SOM's Southworks Lakeside Master Plan in Chicago uses an urban park system to filter over 90% of stormwater and reuses waste heat from data centers to keep nearby residences warm (see Figure 5). Energy is recovered from sewage in Vancouver to provide over 70% of a neighborhood's annual energy (City of Vancouver 2014).

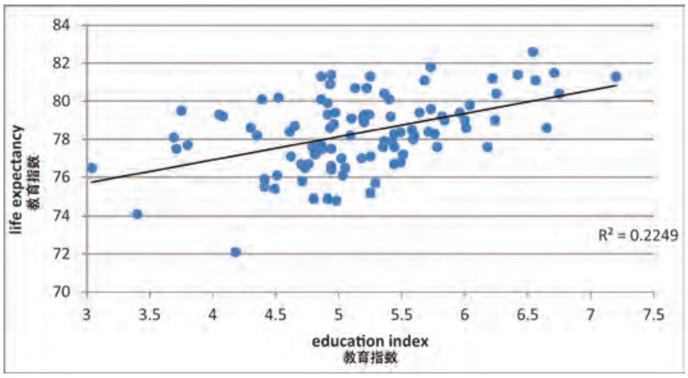

Figure 3. Life expectancy as a function of education index (Social Science Research council 2011). (Source: Stephen Ray)
图3. 教育指数与人寿命的变量关系 (Social Science Research council 2011) 。（来源: Stephen Ray)

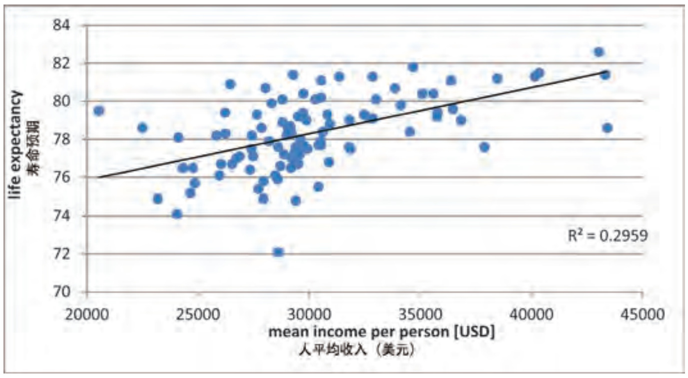

Figure 4. Life expectancy as a function of mean income (Social Science Research council 2011)(U.S. Census Bureau 2009). (Source: Stephen Ray)
图4. 平均收入与人寿命的变量关系 (Social Science Research council 2011)(U.S. Census Bureau 2009) 。（来源: Stephen Ray)

Figure 5. Urban park system that filters 90% of stormwater in the Southworks Lakeside Master Plan for Chicago designed by Skidmore, Owings & Merrill LLP. (Source: Skidmore, Owings & Merrill LLP)
图5. Skidmore, Owings & Merrill LLP设计的芝加哥南部湖畔总体规划项目中的城市公园系统过滤90%的雨水量。（来源: Skidmore, Owings & Merrill LLP)

Figure 6. Visualization of most traveled Divvy bicycle sharing routes in Chicago. (Source: Matthew Shaxted)
图6. 芝加哥Divvy自行车共享线路的可视化图像。（来源: Matthew Shaxted）

Bicycle sharing programs around the world, including the Chicago Divvy program (see Figure 6), are deterring congestion and reducing emissions. Social resiliency plans are being discussed by cities and nations. These strategies provide a small glimpse into the measures currently employed by cities around the world to further increase connectivity.

Beyond these strategies, though, lie important opportunities that have not yet been discussed in this paper. Digital connections through social media and other online communities are changing the landscape of how people interact and connect, including in cities. The growth of big data, particularly through increased access to utility service data, and the ability to process it are transforming how complex systems and interactions are understood. Nevertheless, certain key factors are still necessary for people to come together in cities to more efficiently use resources and enhance their quality of life. Basic security is essential. None of the benefits put forward in this paper will be realized if people are not safe and do not feel secure in their homes and communities. With basic security in place, an infrastructure that promotes connectivity will further help connect cities. Multiple modes of transportation, access to various economies, vibrant urban districts, and green frameworks must be integrated into a city's infrastructure to attract talented people who will contribute to its connectivity. Once an infrastructure is in place, nurturing a culture of connectivity will bring even more people together and help establish the city as a beacon of sustainability. These features create a positive feedback loop that first attracts people to a safe city with an intelligent infrastructure to share resources and increase their quality of life. As the city grows, more people are drawn to it and leverage the benefits of a connected city, which attracts even more people. Along the way, a silicon valley of sustainable design can emerge that fosters the development of new technologies, processes, and ways of life. Many of the details have been excluded from this paper and must be thoroughly considered to realize any of the outlined benefits. Even without these details, however, the basic framework of a connected city that decreases resource consumption while increasing the quality of life to create a positive sustainability feedback loop can prompt even small steps towards increasing the connectivity within cities.

联通性的进一步增强

城市内部增强的联通性节省了资源消耗并提高了居民的生活品质。设计师和城市规划者怎样才能将这些好处投射到城市的未来发展中? 他们可以利用规模效益设计区域系统。芝加哥中央制冷机房为超过一百座市中心建筑提供制冷，利用在非峰值电费时段制冰，集约化资金成本，并增加了市中心建筑的可租赁空间。多伦多的区域供暖和供冷系统为城市节约了61MW电力需求，并且每年减少79000吨二氧化碳排放量 (Enwave 2014) 。哥本哈根的区域供暖和供冷系统提供了98%的城市供暖，并且在计划将生物燃料的应用加倍，使得整个过程更类似于利用废物做燃料自然的循环[New York City 2011]。SOM在芝加哥展开的南部湖畔总体规划中，运用了一个城市公园系统来过滤超过90%的雨水，并且使用来自数据中心的废热来为周边居民供暖 (见图5) 。从温哥华的污水中得到的能量回收为周边提供了超过70%的年度能源需求 (City of Vancouver 2014)。包括芝加哥Divvy项目 (见图6) 在内的全球范围自行车共享规划减轻了拥挤并减少了排放。社会的适应性规划在城市和国家范围内被广泛讨论。以上讨论的策略只是当今世界增进城市联通方法中很小的一部分。

然而，除却上述策略，还存在许多文中未提及的重要机会。数字化连接正在通过社交媒体和其他网络社区改变着人们相互联系和交流的方式，在城市中亦是如此。大数据不断增多 (尤其是可获得更多的市政服务数据) ，我们已具备处理大数据的能力，这两点正在改变着人们对复杂体系和其交互方式的理解。然而，要把人才汇聚到城市中更有效地利用资源并提高他们的生活品质，某些关键因素必不可少。基本生活安全就是其中一个。如果人们的生活没有安全保障，或是无法从家里或所居住的社区获得安全感，那么文中提到种种益处均无法实现。如果安全问题能够得以解决，基础设施的建设将进一步实现城市的联通。必须将多种交通方式、多种经济形式、活跃的城市生活、以及绿色环保框架纳入城市的基础建设，才能引进人才，为实现联通作出贡献。在基础设施的建设完成后再培育一种联通的城市文化，则会吸引更多的人才，将城市建设成为可持续发展的灯塔。这些特征所创造出的正反馈环路会把先人才吸引到能提供安全保障的城市，再通过城市智能基础设施实现资源共享并提高人们的生活品质。随着城市的增长，更多的人会涌入城市，充分享受联通城市的好处，从而进一步吸引更多的人到城市生活。在此过程中，一个可持续设计的"硅谷"将应运而生，促进新技术、流程、和生活方式的发展。文中无法列出所有相关细节，而上述任一优势的实现均需充分考虑文中略去的细节内容。但是，就算不考虑这些细节，建立一个联通城市的基本框架也可以在提高人们生活水平的同时降低资源耗费，形成一个可持续的正反馈环路，(哪怕是渐进的) 促进城市联通性。

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