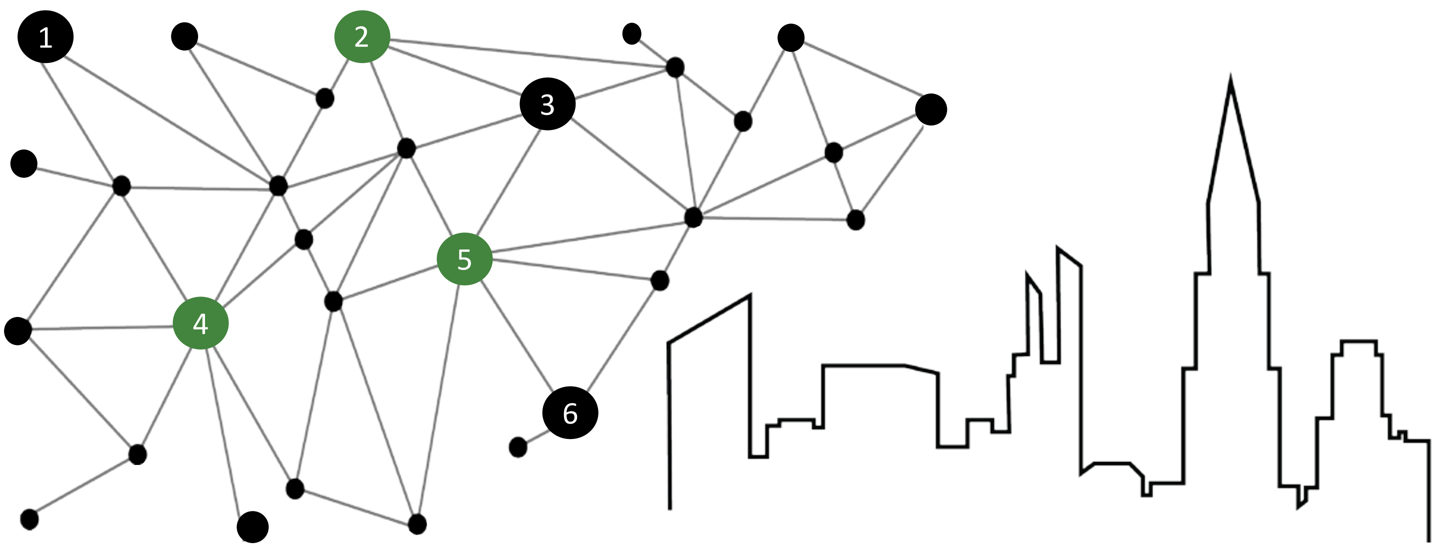

SIX SMART GUIDELINES

CDBC'S GREEN AND SMART URBAN DEVELOPMENT GUIDELINES

OCTOBER 2015
DRAFT FOR COMMENT

国开金融
CHINA DEVELOPMENT BANK CAPITAL

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GREEN & SMART

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SIX SMART GUIDELINES
AUTHORS:

- CC Huang, Energy Innovation
- Edward Qu (曲景东), Green and Smart Urbanization Task Force, HK Parkview Group

FOREWORD

At the United Nations General Assembly session in September 2015, President Xi Jinping committed China to being a global leader in tackling climate change. Green, low-carbon, and smart new-type urban development will play an important role in alleviating climate change. This development strategy has also been the core objective of China Development Bank Capital's (CDBC) efforts towards new-type urbanization in the past few years.

As urban development practices have evolved, we profoundly feel that the ideals behind green and smart development have already become common belief. Everyone wants to realize these ideals, but there is still the question of how it can be done. Not only are there no successful case studies in China, there are few internationally, and many of these experiences have been limited and dispersed in scope. We need to integrate existing domestic and international experience with the conditions of China's new-type urban development to create a comprehensive and working model. Only then can we rapidly expand this model and achieve significant progress.

Hence, two years ago, CDBC's International Advisory Group for Green and Smart Urbanization began work on *CDBC's Green and Smart Urban Development Guidelines* with the intent to create a benchmark for green and smart urban development to be used in China and internationally. In these two years, we have gathered input from over a hundred urban planners, mayors, developers, experts, and other industry players. We also surveyed international best practices in the context of China's unique economic, environmental, and social conditions. With this foundation, we created the *12 Green Guidelines* and the *Six Smart Guidelines*. We were careful not to create a long list of desirable options, but instead focused on the most critical and foundational design elements of green, smart, livable, and economically successful urban development. The design elements featured in the *Green and Smart Urban Development Guidelines* are already in practice in a number of cities in both developed and developing countries. A well-designed city can reduce congestion, improve air quality, reduce noise pollution, and decrease energy use. It can create enjoyable spaces for everyone, from children to the elderly, and increases options for daily life. It makes neighborhoods more attractive and livable, and creates cities with more vitality and economic prosperity.

These guidelines include two case studies, one on the Pearl District and Brewery Blocks in Portland, Oregon and the other on Hammarby Sjöstad in Stockholm, Sweden. These two cases show that our guidelines can achieve both economic and environmental benefits. The case studies detail the process to success, including the regulatory, financing, and technical mechanisms that were part of each urban area's development strategy.

12 GREEN GUIDELINES

The *12 Green Guidelines* fall into three key categories: urban form, transportation, and energy and resources. These guidelines are measurable and practical, and they concisely describe the foundations of sustainable urban development:

- **Urban Form:** Urban growth boundary, Transit-Oriented Development, Mixed-Use, Small Blocks, Public Green Space
- **Transportation:** Non-motorized Transit, Public Transit, Car Control

- **Energy and Resources:** Green Buildings, Renewable and Distributed Energy, Waste Management, Water Efficiency

SIX SMART GUIDELINES

The *Six Smart Guidelines* are designed to optimize the green guidelines. "Smart" provides for more optimal ways to achieve green results. When done in addition to the *12 Green Guidelines*, smart technologies can capture additional economic, environmental, and social benefits. The *Smart Guidelines* fall into six key categories:

- Smart Telecommunications
- Smart Mobility
- Smart Energy Management
- Smart Governance
- Smart Public Services
- Smart Safety

The *Six Smart Guidelines* emphasize the importance data analysis and optimization. We focus on case studies with returns on investment to demonstrate the application of these smart technologies.

As our time and experience is limited, this edition of *CDBC's Green and Smart Urban Development Guidelines* is still in development. Particularly as global green and smart practices evolve, these guidelines will need to be added to and improved on. CDBC is an important player in China's urbanization, and we hope to collaborate with other players in China and internationally to put these guidelines into practice and advance, for the long-term, the sustainable urban development of China. Moreover, we hope that Chinese and international partners will continue to introduce us to global best practices and potential collaborators. We hope to expand the perspective of Chinese urban developers and involve world-class international developers in China's urbanization process to create opportunities and achieve mutual benefits.

Zuo Kun

Vice-President, China Development Bank Capital

October 2015

CONTENTS

FOREWORD II

INTRODUCTION 6

FIRST GREEN, THEN SMART 7

WHAT IS “SMART” URBAN DEVELOPMENT? 12

WHY SMART? AN OPPORTUNITY TO OPTIMIZE CITIES 13

OVERVIEW OF SMART GUIDELINES 14

RESPONSIBILITIES IN THE DEVELOPMENT PROCESS 19

MASTER PLANNING 20

PHASE 1 (LAND DEVELOPMENT) 22

PHASE 2 (PROPERTY DEVELOPMENT) 23

OPERATIONS AND MAINTENANCE 23

1. SMART TELECOMMUNICATIONS 1

RECOMMENDED TECHNOLOGIES 1

BENEFITS 7

2. SMART MOBILITY 9

RECOMMENDED TECHNOLOGIES 9

BENEFITS 20

3. SMART GOVERNANCE 22

RECOMMENDED TECHNOLOGIES 22

BENEFITS 25

4. SMART ENERGY MANAGEMENT 27

RECOMMENDED TECHNOLOGIES 27

BENEFITS 31

5. SMART SAFETY 32

RECOMMENDED TECHNOLOGIES 33

BENEFITS 34

6. SMART PUBLIC SERVICES 36

RECOMMENDED TECHNOLOGIES..36
BENEFITS 42
CONCLUSION 43
REFERENCES 44
ACKNOWLEDGEMENTS... 54

INTRODUCTION

Chinese urbanization has entered into a new phase. By providing an assortment of case studies, these guidelines hope to expand developers and investor's perspectives on smart city development. The guidelines aim to showcase successful international examples and aim to inspire local governments, developers, investors, and other contributors to urban development in China. The *Six Smart Guidelines'* key goal is to help cities choose the right technologies to optimize urban development, improve livability and comfort in cities, and advance sustainable economic, environmental, and social development.

The *Six Smart Guidelines* consider the perspective of developers and operators and integrate the unique conditions of China's current urbanization patterns. Hence, we divide technologies and case studies into telecommunications, mobility, energy, governance, safety, and public services. These categories consider the development process in China and each contain information on the environmental, economic, and social benefits. We also explain the connection between green and smart urban development. Overall, the *Six Smart Guidelines* and *12 Green Guidelines* aim to improve sustainable urban development in China.

These Guidelines have the following characteristics:

1. Show the newest trends in green and smart urban development internationally. Smart cities use the appropriate technologies and products to better city operations, improve living conditions, and advance sustainable development. Internationally, many cities are using smart technologies to achieve green goals.
2. Show the importance integration of urban planning, maintenance, and management. The Smart Guidelines consider information, land management, planning, construction, city governance, green space, roads, transportation, emergency prevention, and other departments. These guidelines encourage having one platform for operations and interdepartmental collaboration. International case studies show the efficiency gains in having different government departments work together.
3. Show the importance of coordination and communication between government departments and companies in the development process. These guidelines show examples of having government, corporations, research organizations, and implementation companies work together.
4. These guidelines show various business models for the various technology solutions. Smart projects must be economically viable. These guidelines hope to show through case studies the economic, environment, and social benefits that must come from green and smart urban development.

The six key categories of the Smart Guidelines are:

- Smart Telecommunications
- Smart Mobility
- Smart Governance
- Smart Energy Management
- Smart Safety
- Smart Public Services

At this point, China's smart city construction is still in its early stages, and the priorities of each city vary. These guidelines offer a number of technology solutions, and readers can pick relevant technologies to do further evaluation of based on their needs. For example, a city that has insufficient access to water might invest more heavily in smart water technologies.

FIRST GREEN, THEN SMART

China Development Bank Capital's *Green and Smart Urban Development Guidelines* call for the Green Guidelines to be the foundation for every city. The *Smart Guidelines* will be most effective when used in support of the *Green Guidelines*. For example, cities should encourage non-motorized transit first by having a dense network of walking and biking paths, according to the *Green Guidelines*. Beyond that, based on recommendations from the *Smart Guidelines*, the city could also use smart bike-sharing systems or smart parking meters to further help achieve the goal of increasing walking and biking.

Smart technologies can advance green development, for example:

1. Save land: Through smart technologies, cities can increase mixed-use and land efficiency and also advance development along transit corridors.
2. Decrease energy: Through using an energy-efficient smart lighting system, building management system, or Internet of Everything (IoE) technology, cities can create an integrated platform to implement demand response, smart grid, renewable energy, combined heat and power and other balancing measures to improve over energy efficiency;
3. Save water: Through IoE technology and other water saving technology, cities can improve water efficiency through smart storm and flood control equipment and water re-use technologies. Cities can also better detect for leaks and decrease water loss.
4. Improve transportation efficiency: Through combining IoE technology with data on traffic and people flows, smart traffic light systems,, transportation efficiency can be improved. Public transit and non-motorized transit can also be increased with smart parking and smart public bike systems.
5. Environmental protection: Through IoE and environmental monitoring technology, cities can track air quality, provide information to the public.
6. Improve quality of life: Through building automation technologies, air quality can be improved; through smart lighting, smart safety, and fire safety technologies, residents can also enjoy a safer living environment.
7. Improve economic efficiency and convenience: Through analysis of big data, the city can improve city management and public service provision. Companies can also use applications to improve commercial services and increase profits.

Moreover, smart technologies can ensure that cities capture the benefits of the Green Guidelines. For example, even if a developer constructs a building with green materials and technologies, the building may not realize its full energy savings without proper energy management. Hence, it is important for the property owner to install building energy management systems to guarantee energy savings. The same is true for other green mechanisms or technologies. With data and analysis, cities can better ensure performance improvements.

There are also technologies in the Smart Guidelines that might not have a direct relationship with the Green Guidelines but can still aid in achieving their goals. For example, public wireless can increase the livability and attractiveness of public spaces. Smart safety technologies can make walking and biking at night more appealing. Table 1 below gives more information on the relationship between the Green and Smart Guidelines.

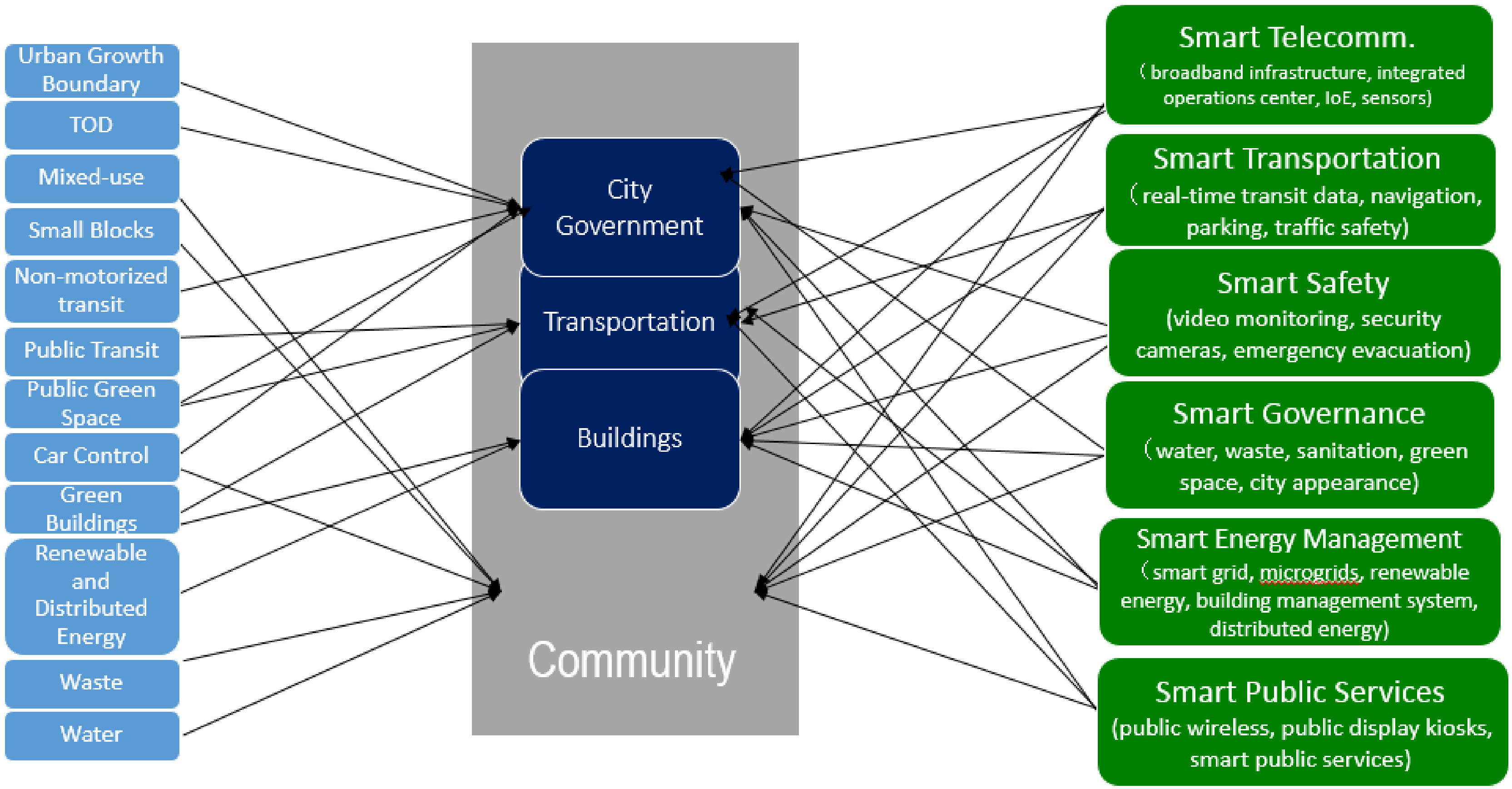
This table shows how the Smart Guidelines work in addition to the Green Guidelines. This table is not exhaustive but provides a general look at the constructive relationships between the items in the two guidelines.

Table 1. Relationship Between Smart and Green Guidelines

Smart Guideline	Relevant Green Guidelines	Relationship	Relevant Smart Technologies
Smart Telecommunications	All	An integrated operations center combined with a comprehensive data platform allows improved decision-making on all facets of the Green Guidelines. Cities can apply sensors in a number of ways to understand use of anything from resources to roads.	Wireless Sensors, Broadband Internet, Integrated Operations Center
Smart Mobility	Transit-oriented Development	These smart technologies can use data to help people find the best route and integrate various modes of transportation to reach their final destination. Higher density areas are much easier to navigate when cities implement these technologies in conjunction with transit-oriented development.	Smart Bike-sharing Systems, Smart Traffic Management and Congestion Pricing, Smart Parking, Transit Data and Smart Payment
	Mixed-use	Mixed-use neighborhoods make travel distances much shorter and more walkable by having clear commuting districts. However, smart bike-sharing systems can offer a faster way to get to locations outside the neighborhood but within the commuting district.	Smart Bike-sharing Systems
	Non-motorized Transit	A great transit system integrates various transit options to allow users to optimize their routes—in other words, it is multi-modal. People are also more likely to combine walking with public transit, or biking with public transit, if transit systems offer accurate information and accessible payment systems. Smart bike-sharing systems can making biking more attractive and improve the bike-rail connection.	Smart Bike-sharing Systems, Transit Data and Smart Payment Systems
	Public Transit	Smart mobility technologies improve public transit services, increase ridership, and improve energy efficiency of public transit systems.	Transit Data and Smart Payment Systems
	Car Control	In addition to improving public transit or non-motorized transit systems to encourage people to drive less, smart parking can price parking more appropriately or shift more driving to off-peak hours through dynamic pricing.	All Smart Mobility technologies
	Small Blocks	Smaller blocks (hence more intersections) combined with smart traffic management system increases the flexibility in timing traffic signals to alleviate congestion and also adds more potential intervention points if the city chooses to use congestion pricing.	All Smart Mobility technologies
Smart Governance	Water	Using data to manage water in an urban area can greatly improve efficiency by detecting leaks or identifying the most inefficient water users.	Smart Water Management

	Waste	Optimizing waste routes or understanding when to empty public waste bins can save on fuel and labor costs associated with waste management.	Smart Waste Collection
Smart Energy Management	Renewable and Distributed Energy	Smart energy management technologies help to improve decision-making and even automates many decisions, which improves energy efficiency. Smart grid technologies help integrate a diverse mix of renewable and distributed energy sources to the grid and gives grid operators the flexibility to use the most efficient sources as conditions change throughout the day.	Smart Lighting Systems; Smart Grid Technologies
	Green Buildings	Even if a building is equipped with all the right energy efficient fixtures, building management systems can ensure that buildings actually capture these efficiencies. Otherwise, many green buildings end up operating at a much lower efficiency due to lack of robust management.	Building Management Systems
Smart Safety	Non-motorized Transit	A robust security system can make sidewalks and biking paths more appealing to use, especially for children and the elderly. A smart emergency response system can direct residents on sidewalks or public areas towards safe havens.	Smart Surveillance Camera; Smart Emergency Response System
	Public Green Space	The city can make public areas more safe and attractive with smart safety technologies. A smart emergency response system can help minimize damage in high-density areas when disasters or accidents do take place.	Smart Surveillance Camera; Smart Emergency Response System
	Mixed-use	Public service kiosks can help residents or visitors navigate a mixed-use neighborhood to take advantage of all the amenities and services within walking distance.	Public Service Kiosks
Smart Public Services	Public Green Space	Public wireless can make public green spaces more useful and appealing while also improving information access to a greater number of people.	Public Wireless
	Non-motorized Transit	Public service kiosks can alert users of nearby amenities and services within walking or biking distance and offer information on the best route.	Public Service Kiosks
	Car Control	Remote patient services and digital learning can often reduce the need to travel to a facility to get medical services or education. This can decrease car use.	Remote Patient Services; Digital Learning

Figure 1. Relationship between Green and Smart



WHAT IS "SMART" URBAN DEVELOPMENT?

Many new and innovative technologies promise benefits through better optimization of urban systems. "Smart" urban development selects the best of these technologies to solve cities' most pressing challenges, such as loss of mobility due to traffic congestion, air pollution, energy inefficiency, and crime. However, these smart technologies are not the end-all of urban development. Ultimately, they must serve the purpose of creating an urban system that works better for people.

For these guidelines, "smart" is defined broadly as using digital or internet and communications technology (ICT). The items in the Smart Guidelines, like the 12 Green guidelines, must meet three conditions to qualify:

1. **BENEFICIAL:** The technology must have the capability to enable various urban services and offer economic, environmental, and social benefits;
2. **MEASURABLE:** The technology's benefits must be measurable in terms of the actual economic, environmental, or social benefit accrued. For example, the city should be able to measure the success of the technology in terms of the measurable benefits, instead of using the number of units of a particular technology being installed as a success indicator.
3. **PRACTICAL:** The technology must demonstrate market maturity by having successful and completed projects where these benefits have been measured and accounted for.

Achieving these economic, environmental, and social benefits is also the primary goal of the Green Guidelines. The opportunity for Green and Smart to work together and produce positive feedback is immense and these guidelines highlight such opportunities.

Most of the recommended smart technologies in the case studies involve three key processes: data collection, analysis, and optimized decision-making. Smart technology entails frequent, if not real-time, adjustments to new information. There is an iterative aspect to such system optimization:

1. **Data Collection:** In general, smart technologies require the collection of data to help organizations improve decision-making. Parking data can help cities automate payments. Data on electricity use can improve demand management systems. Water use data can help a city identify leaks and other infrastructure problems.
2. **Analysis:** Analysis refers to the algorithms or software programs that allow users to better understand the relevant system. For the most successful technologies, these algorithms and programs either automate decisions or give decision makers actionable pieces of information.
3. **Optimization:** Ultimately, better information and insightful analysis should lead to smarter decisions. Iteration is one important aspect of optimization: new data should lead to new analysis and calibration because our cities are always changing. The process of information intake and optimization should be continuous.

Many types of decision makers use new insights that come from improved data and evaluation. They could be a resident trying to better navigate a transit system and save commuting time, or a city official trying to improve how residents can offer feedback to the city government. In some instances, there will be no person making a decision per se because the improved control will be automated. It is important that the local government create the internal and external capacity to act on these information technologies. This could be through educating residents about energy efficiency programs, informing property owners about their ability to sell electricity from rooftop panels back to a smart grid, hiring new talent to manage complex data systems, or incubating businesses that focus on smart technologies.

WHY SMART? AN OPPORTUNITY TO OPTIMIZE CITIES

> "Life in smart cities will be defined by (these) dynamic, adaptive systems that respond in real time to changing conditions at the very small and very large scale simultaneously.
>
> Anthony M. Townsend, Author of "Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia"

Smart technologies have already become an important development strategy in a number of the world's most livable cities. In the United Kingdom, for example, the city directs about 8% of expenditures toward information technology. Chicago has shown that publicly available data can aid in better policy design in everything from shoveling snow to preventing foodborne illnesses. Barcelona's 22@Barcelona has been dubbed the "Innovation District" and offers smart lighting, sensors for parking, trash bins with radio frequency identification (RFID) technology, and even smart irrigation of public parks. After New York City's efforts in smart street lighting and smart traffic lighting cut costs and alleviated congestion, the city decided to expand these projects.

In China, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and the Ministry of Housing and Urban-Rural Development (MOHURD) are pursuing smart city initiatives. The biggest of the group is MOHURD, which has selected 193 local governments and economic development zones as official smart city pilots and lined up a more than $10 billion loan facility from the China Development Bank, into these projects as of 2013 (Johnson 2014). By 2014, 202 local governments and economic development zones had been approved for smart city projects—nine more areas than initially planned. China Development Bank Capital, a wholly owned subsidiary of China Development Bank, and the Chinese Society for Urban Studies are also going to advance funding for smart cities (China Development Bank 2013).

The International Data Corporation (IDC) estimates that China's smart city market totals about $13 billion, and by 2020 the total value will more than double to $28 billion (Zhang 2013). Moreover, the company estimates that, while the total government investment in smart cities currently occupies about 70% of the market, this will decrease to 20% by 2020 (Zhang 2014). This shows that the opportunity for private companies to take more a leading role and work with local governments is growing, perhaps through public-private partnerships.

There has been some success in China with smart city projects. For example, Zhenjiang has been working on enhancing city bus technology with IBM so that buses now constantly report their position and operating characteristics to a smart dispatch control center. According to the city, the system saves $2.7 million in fuel costs per year due to the scheduling efficiencies. Buses also have 4G wireless internet for riders, and a half-million riders per day are checking real-time bus arrival information using their phones (Johnson 2014). This smart technology application is helping to manage more than 1,000 public transportation vehicles and more than 80 city bus routes (IBM 2012).

However, a number of challenges in China remain, including tracking the actual benefits associated with installation of smart city technologies. For example, Chinese cities often talk about smart city technology success in terms of penetration (i.e., 70% of companies have smart technologies installed, 90% of communities are covered by smart technologies), instead of the actual benefits accrued (Hangzhou Smart City Plan). While penetration can be one measure of success, it is also important for Chinese cities to look at social, environmental, and economic metrics in the forms of improved or innovative services made possible by those smart technologies, as in the Zhenjiang example. Only through measuring these services—either civil services provided by public sector, or value-add services by private sector—will smart city technologies deliver tangible benefits to urban residents and thus become a scalable, replicable, and commercially feasible investment. In order to encourage this type of benefits accounting, the case studies in this document all contain specific social, environmental, and economic benefits from the use of smart city technologies.

OVERVIEW OF SMART GUIDELINES

These guidelines divide smart technologies into six key categories. The case studies under each category provide specific examples of how to integrate some of the technologies and provide value-add services with viable business model to support its operation. The six key categories are:

- Smart Telecommunications
- Smart Mobility
- Smart Governance
- Smart Energy Management
- Smart Security
- Smart Public Services

Each category has three to five recommended technologies that have shown to be practical and advantageous, either in China or internationally. Each technology has a short discussion on the **returns on investment** for that technology and **case studies** where the technology is succeeding under real world conditions. The report then looks at the economic, environmental, and social **benefits** of the technologies in each category.

Before going into each of the categories, this report offers a section on how the local government can best be aware of the possible technologies in the development process. This section looks at each of the key development phases – Master Planning, Phase 1 (Land Development), Phase 2 (Property Development), and the operations and maintenance after development is over.

The report bases the information on each of the technologies on real-world examples with proven benefits. There is a plethora of smart technologies available, but this report highlights the ones with the most potential to lead to social, economic, and environmental benefits. Not every technology will be appropriate in every circumstance, but every project should consider them for inclusion.

To generate the most value, smart technologies must often be integrated with one another. As a result, the categories in this report often overlap. For example, smart mobility and smart energy management can overlap; there is the opportunity to create a demand response function and vehicle-to-grid system with smart charging networks serving electric vehicles (EVs). Additionally, the same sensors used for a smart lighting system can be integrated with air pollution measurement devices. Some of the case studies will show how the integration of different technologies has provided value to cities.

The table below shows the technologies we have identified for each of the six categories:

Table 2. Technologies Included in Six Smart Guidelines

CATEGORY	RECOMMENDED TECHNOLOGIES
Smart Telecommunications	• Integrated Operations Centers and Data Platforms • Wireless Sensors • Broadband Infrastructure
Smart Mobility	• Smart Traffic Management and Congestion Pricing • Real-Time Transit Data and Navigation Tools • Smart Bike-Sharing Systems • Smart Parking • Electrical Vehicles and Charging Networks
Smart Governance	• Smart Water Management • Smart Gas Grids • Smart Waste Collection
Smart Energy Management	• Smart Grid Technologies • Smart Lighting Systems • Building Management Systems
Smart Security	• Smart Surveillance Camera • Smart Emergency Response Systems
Smart Public Services	• Web-based Public Services • Public Wireless • Public Service Kiosks • Remote Patient Monitoring • Digital Learning

Within each technology, we discuss **returns on investment**. Financing for smart technologies in China has mostly come from the government; for example, the $10+ billion allocated to MOHURD from China Development Bank. This report does not cover the financing mechanisms[1] that generate returns on investment, but instead focuses on where the city can recover value through these smart technologies. This includes direct energy savings and indirect benefits, such as lower labor and maintenance costs due to optimization, or less congestion and air pollution. We identify how each technology creates long-term value for cities and offer examples of implementation structures that can capture these benefits. In this

[1] There are a number of excellent reports on financing mechanisms for sustainable and smart technologies. Local governments should look into innovative financing models such as green bonds, various guarantee structures, and energy performance contracting.

report, returns on investment are defined quite broadly. Financial cost is just one aspect. Benefits such as improved health, air quality, and user satisfaction are also included and quantified, where possible.

Under each recommended technology, the **case studies** in this report will focus on examples that illustrate the benefits of smart technologies. Case studies are collected from cities all over the world and reveal the economic calculus behind the selection of a particular smart technology.

The table below gives an overview of all the case studies covered under each technology.

Table 3. Overview of Case Studies in Smart Guidelines

Category	Technology	Location	Description
Smart Telecomm.	*Integrated Operations Center*	Rio de Janeiro, Brazil	Integrated Operations Center aimed at minimizing impacts from emergencies and incidents.
		Chicago, Illinois, United States	Data analysis of everything from foodborne illnesses to crime.
		Santander, Spain	Wireless sensors that measure temperature, luminosity, carbon monoxide, and noise.
		Busan, Korea	Public cloud system with platform as a service (PaaS) and integration of public and private data.
	Wireless Sensors	Nice, France	Connected Boulevard project that uses smart parking, smart street lighting, smart waste management, and environmental monitoring.
		South Carolina, United States	Use of sensors to understand the condition of bridges through monitoring overweight vehicles on bridges, bridge strength, and wind speed.
		Barcelona, Spain	Barcelona's Smart City initiative that includes a smart telecommunications network, smart lighting, smart irrigation, smart parking, and expansion of electrical vehicle use.
	Broadband Infrastructure	Singapore	Nationwide broadband network that connects almost all of Singapore's residents to an ultra-high speed network
Smart Mobility	*Smart Traffic Management and Congestion Pricing*	Seoul, Korea	Touch-card payment system that also collects smart traffic data through installing a GPS system in over 25,000 taxis.
		Stockholm, Sweden	A city-wide camera network that maps the precise journey of every vehicle, allowing the government to charge road tolls passed on distance driven and time of day of the trip.
		New York City, New York, United States	A congestion management system with sensors that measure flow and occupancy, electronic toll collection reads, and traffic video cameras.
		Melbourne, Australia	An on-ramp metering algorithm that manages traffic demand and reduces travel time on Melbourne's busiest freeway.
	Transit Data and Smart Payment Systems	London, United Kingdom	Transport for London's use of contactless payment systems and real-time travel information through a website called TrackerNet.
		Zhenjiang, China	A upgraded bus network that uses data analysis to manage traffic patterns for more than 80 routes in the city.
	Smart Bike-sharing Systems	Phoenix, Arizona	Smart-bike sharing service that includes solar-powered, GPS-enabled locks that allows users to park the bikes anywhere.
		Copenhagen, Denmark	An electric bike system that has an Android tablet attached to each electric bike that offers GPS, public transit data, and the ability to buy tickets.
		Taipei, Taiwan	A smart bike-sharing system that uses an integrated electronic ticketing system connected to metro, bus, taxis, and even convenience stores.
	Smart Parking	Los Angeles, California, United States	Smart parking meters and low-power sensors that allowed users to pay for parking on their mobile phones and allow the city to use dynamic pricing.

		Nice, France	Smart parking sensors that allow users to find the best available parking spot, kiosks that allow the public to pay for parking and also access services such as bike- and car-share.
	Electric Vehicles and Charging Networks	Paris, France	An electric vehicle system with about 1,750 electric vehicles and more than 5,000 charging stations.
		Geneva, Switzerland	An electric bus system that uses boost charging that can fully recharge buses in 3-4 minutes.
Smart Governance	*Smart Water Manageme nt*	Barcelona, Spain	A smart irrigation system with sensors that provides data on humidity, temperature, wind velocity, and sunlight that helps gardeners determine the optimal amount of water to use on plants.
		Singapore	A smart water management system that detects leaks, troubleshoots, and even creates water demand predictions.
		South Bend, Indiana, United States	A system of sensors and smart valves that can act dynamically based on economic algorithms, weather and water data, and also historical data in heat maps to optimize water use.
	Smart Gas Grids	France	A smart gas meter that measures gas use in residential homes with radio communication so that the utility can collect and act on gas use data.
	Smart Waste Collection	Philadelphia, Pennsylvania, United States	Solar powered trash compactors that reduce trips needed to empty waste bins.
		Stillwater, Oklahoma	A GIS-based fleet optimization software for waste collection fleets that can optimize around route times, areas, and service days.
Smart Energy Management	*Smart Grid Technology*	Italy	An automated electricity management system that reads and manages energy readings through meters remotely with an operations center that manages the acquisition of the meter data.
		United States	Nest, a learning thermostat that collects energy use information from consumers directly through a wireless connection and optimizes energy consumption based on energy use habits.
		Amsterdam, Holland	Vehicle-to-grid technology that allows electric vehicles to integrate with the electric grid and provide power during peak hours.
	Smart Lighting Systems	Oslo, Norway	Smart lighting system that provides maintenance data, allows for dimming, and allows officials to control streetlights through computers, tablets, and even phones.
		Guancheng, China	A system that retrofitted Guancheng’s streetlights with LED lights and allow officials to monitor and manage the entire network through software.
	Building Manageme nt Systems	Microsoft Headquarters	Building management system that increases energy efficiency by detecting faults and reduces unnecessary energy use.
		Washington D.C., United States	Building management system that allows real-time energy management that improved understanding of how energy in building was being used.
Smart Safety	*Smart Surveillance Cameras*	Mexico City, Mexico	A comprehensive security system that involves license plate recognition cameras, surveillance drones, gunshot sensors, and emergency call points.
	Smart Emergency Response Systems	New York City, New York	A system called FireCast that organizes data based on a number of risk factors for buildings to prevent and help firefighting forces better respond to building fires.
		Japan	An emergency response and coordination system that helps manage the impacts of earthquakes.
Smart Public Services	*Web-based Public Services*	Stockholm, Sweden	A web platform that provides a number of services for residents including applying for school, scanning radon gas levels, and booking weddings.
		Barcelona, Spain	A web platform that provides services such as accessing parking ticket information, car-towing destinations, and even requesting public subsidies for non-profit activities.
	Public Wireless	Vancouver, Canada	A public wireless system that is combined with smart parking technology.

	Public Service Kiosks	Barcelona, Spain	A system of kiosks located throughout the city that help citizens to resolve administrative requests. The services from the kiosks are also offered online.
		Kansas City, Kansas, United States	A system of kiosks that offer information, can act as alert systems in the case of an emergency, and offer advertising services.
	Remote Patient Monitoring	Texarkana, Texas, United States	Remote patient monitoring for care transition patients that were transitioning from hospital care to at-home monitoring.
	Digital Learning	Los Angeles, California, United States	A blended learning curriculum that changed the classroom model to include more small group teaching and individualized education.

Finally, the **benefits** section under each category describes the economic, environmental, and social benefits that accrue due to successful implementation of the smart technologies. Most of the technologies lead to benefits across all categories, but some have concentrated benefits in just one or two of the categories. These benefits range from improved public health, to lower carbon emissions, to lower operation costs for the municipal government. This report extracts the evidence for the benefits from case studies and real-world examples.

RESPONSIBILITIES IN THE DEVELOPMENT PROCESS

Infrastructure planning for smart cities should be integrated into the urban planning process. Especially at certain points in the urban planning process, there can be value captured in coordinating planning processes. This can prevent departments from having to take on projects by themselves, complete unnecessary work, or have projects lag behind.

For example, with smart safety systems, cities can take advantage of Phase 1 development to install smart transportation technologies (such as cameras that detect speed, traffic data collection, or street light management) as well. These technologies can be integrated and the following economic and social benefits can be accrued from this integration:

- Improve the efficiency of departmental collaboration in the event of an emergency;
- Extract big data from the system to have a better understanding of the city's population and improve services and management;
- Decrease costs of installation and maintenance and decrease amount of labor needed.

CHONGQING CASE STUDY: On November 22nd, 2010, the Chongqing Government and China Electronic Technology Corporation signed a general contracting agreement on Chongqing's Public Video Information Management System. The agreement has plans to build and expand video surveillance sites and update existing video monitoring systems. The goal is to create a video system that covers the entirety of Chongqing with at least 500,000 monitoring sites. The system can use the city's existing public telecommunications system and optical network and take advantage of Internet of Everything technology to create a city-wide smart platform. This project can support public safety management, city management, transportation management, and emergency management. It can also issue warnings for emergencies and aid in environmental monitoring. With this type of centralized platform, the city can:

- Emergency alerts and response: A city emergency response center can use real-time video data in emergency or unexpected situations to control traffic systems, evacuate cars and people, and arrange for rescue forces.
- Safety management: Public security personnel can quickly find suspects based on video footage.
- Traffic management: Based on traffic cameras, the city can better optimize traffic lights and improve traffic flow.
- City management and environmental protection: The city can place law enforcement personnel based on the camera system, better monitor for environmental indicators, obtain evidence, and enforce the law.

Based on initial estimates, the project will cost a total of 5 billion RMB. In principle, the project will adopt a build-transfer model where the local government and relevant district governments will purchase the equipment after the project is set up.

If these projects are completed in the initial stages of urban development, then the cost of laying cables and excavation can be decreased by 30-55%, just the cost of excavation can be decreased by at least 40-50%.

The following sections looks at key points to consider for smart city development at different stages in the development process.

MASTER PLANNING

Master planning is both the first stage and the most important one. This phase of work includes: regulatory and site/detailed planning. Regulatory planning is based on the master plan or district plan and it determines zoning, land-use density, road and pipeline networks, and also regulation and control of the environment. During the planning phase, it is important to use smart technologies that can accomplish the goals of saving land, water, energy, and improving mobility.

In this stage, there must be coordination between the planning department, the local development and reform commission, and the information management departments to handle transportation, governance, and landscaping and vegetation. The following planning and design tasks must be taken into consideration at this stage:

1. SMART TELECOMMUNICATIONS: Based on the population, scale of land development, land-use of the land to be developed, zoning, city center, district center, and other key elements, the relevant departments must determine the location, capacity, and scale of the integrated operations and data center. Moreover, after the relevant departments completes the planning for the following five smart city technology categories, they must create a plan for a district-wide Internet of Things (IoT), fiber optic network, wireless network, and data center.

2. SMART MOBILITY: According to the scope of the planning and the layout and scale of the transportation system, the relevant departments should determine the capacity, directions, and lengths of the communication line as well as the location and capacity of the main communication nodes. The following aspects are related to the transportation system:

a. Railway hub, ports, airports
b. Distribution of subway, light rail and other transit stations
c. Primary and secondary arterials, non-motorized transportation system and layout, intersections, and other urban form considerations;
d. Location and capacity of parking including motor and non-motorized parking;
e. Traffic signal lighting

3. SMART GOVERNANCE: Based on the scope of planning and public services needed at the time of planning, the relevant departments should determine the capacity, directionality, and length of communication lines, as well as the location and capacity of relevant facilities. The departments should also provide proposals for a smart system to manage government facilities, smart water technologies, flood management, smart waste management (including waste management and reduction). More specifically, the departments should consider the following:

a. Water supply, drainage and flood control, gas, heating, sanitation, urban lighting
b. Lakes and rivers
c. Flood control and any waterlogged fields along the coast and river
d. Environmental monitoring, ensuring completion of certain benchmarks, and pollution prevention measures

4. SMART ENERGY MANAGEMENT: Based on the population, layout, zoning, industrial composition, and environmental factors like sunlight, water bodies, the relevant departments should establish standards for clean energy, energy efficiency, combined heat and power, and district cooling. The departments should complete the planning for smart grids/microgrids and any distributed energy systems.

5. SMART SAFETY: Based on the city's needs in disaster prevention, fire prevention, air defense, and other types of disaster management, the relevant departments should plan for the demand and application of the Internet of Everything and cable layout and capacity.

6. SMART PUBLIC SERVICES: Based on the space and layout of public buildings, community districts, commercial districts, education centers, medical centers and other public service facilities, plan the capacity and location of the data center, telecommunication cables, and wireless internet's operational range. The following elements will also require careful consideration to establish a reasonable goal for the plan:

- Based on natural conservation areas and cultural or historical sites, ensure there is a plan for the IoT system's layout and capacity;
- Determine the layout and capacity of green space and plan for the layout and capacity of any relevant smart infrastructure or cables.

After going through the steps above, the relevant departments must still complete a thorough assessment to optimize the layout and division of uses. They should produce two documents, "Standards for Regulatory Planning in Smart City Development" and "Contents of Smart City Development," and integrate these into the local urban economic and social development plan.

A leader from the government should be the committee leader for the steps above. Leaders from the local national development and reform commissions, the information management department, and the city planning department can serve as deputy leaders and help with organizing relevant departments to complete the design and planning process together.

For example, in the construction of smart roads, the following departments must participate: the Bureau of Land and Resources, the Planning Bureau, the Municipal Department of Economy and Information Technology, the Communications Management Department, the Construction Committee, Transportation Management Department, Police Force, heating companies, water provision companies, water treatment companies, environmental companies, transportation companies, electricity companies, etc. There are a total of over 20 departments and companies that must participate in the process. Since each company or department is responsible for a specific part, if there is one party that does not agree with the plan, the results will be affected.

"Goals and Metrics for Regulatory Planning in Smart City Development": This document mainly contains the goals and metrics for smart city construction by stages. For example, the capacity of the data center per 1,000 people, the amount of data transferred per 1,000 people, the length of the fiber optic network per square kilometer, or the amount of sensors per 1,000 people.

"Content of Smart City Development": This should include the main projects that will be a part of smart city development. The information should include specific proposals and an understanding of the relationship between projects. It should also clarify investors and funding sources.

PHASE 1 (LAND DEVELOPMENT)

Phase 1 development refers to when the companies that are working with the local government undertakes land acquisition, demolition, resettlement, and provides compensation for any state-owned land or land owned by rural collectives. They will also complete any infrastructure and ensure that the land has leveled ground, roads, electricity, and water supply. Other requirements for this phase include water, electricity, heat, gas, sewage, internet, telecommunication, and closed circuit television. In this phase, the land and resources management department, local development and reform commission, planning, transportation, and environmental department will have an integrated evaluation meeting. These departments will provide suggestions for the proposal in terms of land use, industrial policy, urban planning, building certification, transportation and environment.

During Phase 1 development, it is important to determine key objectives and metrics for any smart technologies in the regulatory planning. 1) It is important to implement large-scale excavation and other basic infrastructure projects. For example, it is important to set up cables and lines for any roads, bridges, green space, government facilities, and transit junctions; infrastructure for smart grid and microgrids must also be implemented. 2) Based on the financial situations, it is also important to complete any necessary fiber and communication network related to smart city construction, including bidding, construction, and project selection. 3) Any other excavation beyond the red line should be completed at this phase. The projects that must be completed and pass inspection include:

- Main fiber optic lines;
- Smart-grid/micro-grid;
- Lines for Internet of Everything and equipment and facilities for municipal facilities
- Equipment and facilities for Internet of Everything on roads, transit stations, bus stations, and parking areas;
- Internet facilities for gardening, greening and city municipal construction

There are probably a number of investors involved in these projects, such as government, private sector, or joint ventures. The local development and reform commission and information management department can draft and approve of public-private partnerships (PPP) or technical proposals. For example, in order to ensure that the developer (or smart technology provider) has a reasonable profit margin, the local government should, under proper supervision, provide them with an Internet service provider (ISP) license.

Final approval of the work in Phase 1 should be lead by the information management department in collaboration with the land and resources management, the local development and reform commission, and the planning department.

PHASE 2 (PROPERTY DEVELOPMENT)

In general, Phase 2 development is when real estate developers who have already obtained land development rights finish construction of their buildings and then transfer these land rights to property buyers. In this phase, the relevant departments should implement projects under the regulatory plan which are outside of the red line, while any projects within the red line should be completed by construction companies (real estate developers) and coordinated with any projects outside of the red line. Usually, this involves the following:

- Data center development and construction
- Multi-route high-speed Internet access
- Internet of Everything- Building energy efficiency system
- The Internet of Everything- Public safety system
- The Internet of Everything- Public utility management system
- The Internet of Everything - Transportation management (including parking information)
- Any necessary software adjustments for the systems above

If the investors are Phase 2 developers, they should complete the design and construction. Any equipment that is relevant to city government or transportation should also be completed by the relevant entities. Planning and construction management departments should track records and complete evaluation. In this phase, the main tasks are: 1) Final adjustment of any systems outside the red line; 2) Certification of any systems in need of approval from the planning or information department; 3) Coordination and adjustment of any systems that need to be connected.

The construction department, local development and reform committee, and information department can provide tax breaks, subsidies or other incentives and rewards based on national or local policy (or create their own local incentives) to better motivate Phase 2 developers. For example, developers who use smart technologies to reduce energy use can be rewarded. For more information on these rewards, please take a look the green certification programs from MOHURD.

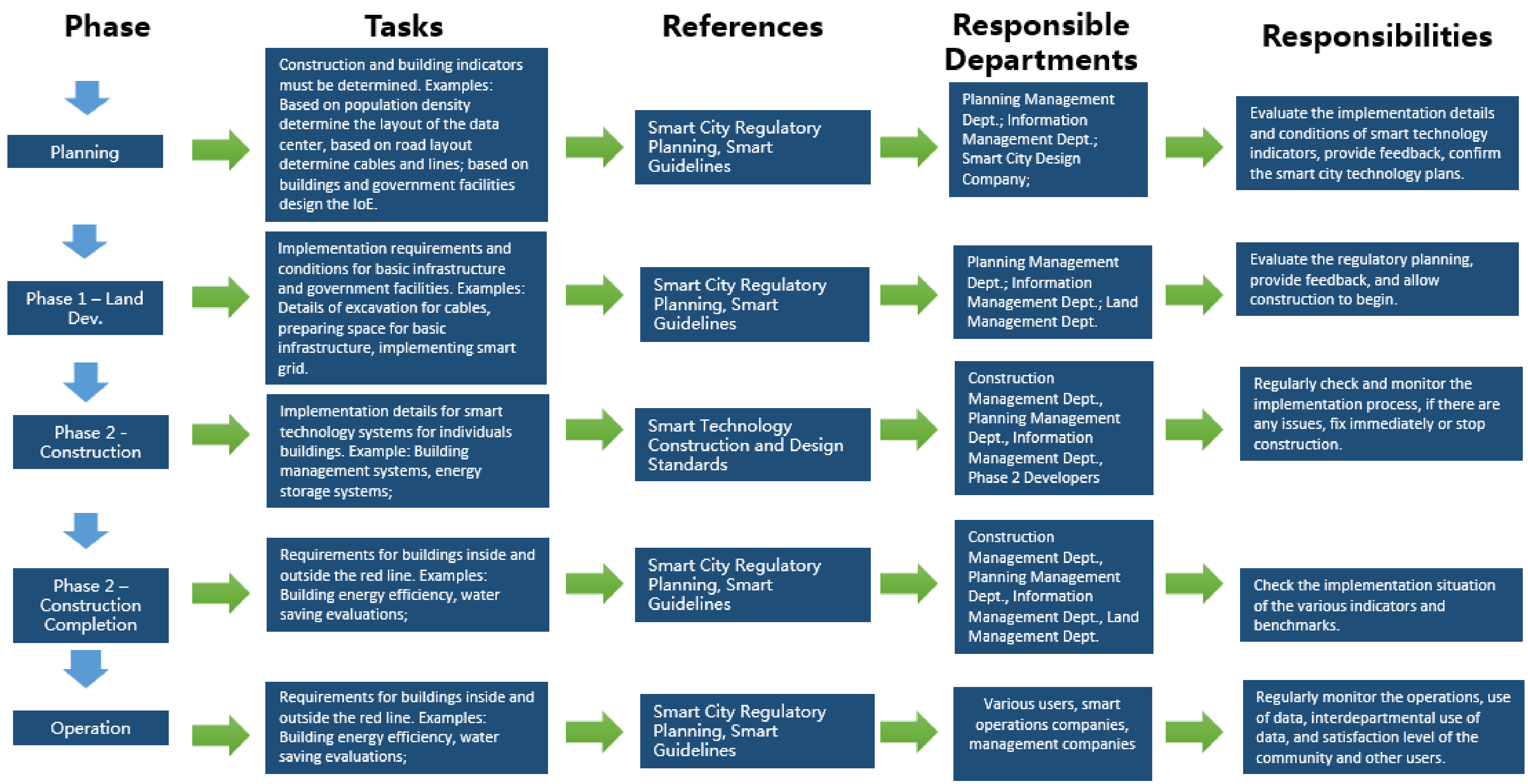
OPERATIONS AND MAINTENANCE

In the operations phase, the main purpose is to complete projects so that they best serve the final users. There are two types of projects – market-oriented projects and public service-oriented projects. Market-oriented projects are when users agree to pay for a service, and public service oriented projects are for public infrastructure services, the main users of these projects are roads, communities, local government, the city's appearance, green spaces, public safety, emergency prevention, transportation and other departments or companies. The key responsibilities in this period include: 1) Complete all projects, operation and maintenance, and create a data platform. Users should see value-added from the services. Through analysis of big data collected, continue to improve services and results; 2) While improving the efficiency of the technology, consider the social and economic realities of the area and consider expanding technologies or projects in order to solve any emerging problems and meet the demands of development.

If the local government has the financial capacity, they can construct a integrated operations center that combines all functions relating to data application and use. This center can integrate the personnel of all the different departments and improve efficiency and technical capacity. This can also be outsourced to an external company and have this company provide technical support to the various government departments. It's also possible to attract more talent in the process, which also increases efficiency. Beyond improving operating efficiency, and integrated operations center can also encourage more inter-departmental collaboration in the local government and improve service provisions and satisfaction.

SINGAPORE E-GOVERNMENT: With the foundation of an open data platform, Singapore's E-government created a collaborative government. Over 60 government departments have released over 8,600 datasets online, and have completed smart city projects, sometimes through inter-department collaboration. For example, they used this comprehensive platform to understand flows of people in the city (how many people, when they move, where they move to, etc.). With this information, they can better optimize transportation routes and other mobility tools. Also, with information on green spaces and parks, they can better plan green space. They can also monitor the environment, sanitation, adjust the number of sanitation workers, and even use text messages to provide tax information to individuals or companies. Through this integrated and open source data platform, they were able to improve their management and service provision ability.

Figure 2. Smart City Construction and Operations Process



1. SMART TELECOMMUNICATIONS

Smart telecommunications serves as the basis for many of the other smart city applications. For this report, smart telecommunications refers to the ability for a city to have a system of networked devices that can interact and communicate with each other (Hamaguchi et al. 2012). Smart data collection using sensors can help cities optimize and improve efficiency in a number of areas. Moreover, the cost of telecommunications technologies has dropped significantly within the last ten years—by 50% for sensors, by a factor of 40 for bandwidth technologies, and by a factor of 60 for processing technologies (Jankowski et al. 2014).

This section recommends three key technologies:

- Integrated Operations Centers and Data Platforms
- Wireless Sensors
- Broadband Infrastructure

The most effective smart telecommunications system is integrated and scalable (Cisco 2012). An integrated operations center that uses a comprehensive data platform is one of the most fundamental aspects of a smart telecommunications system. Rio de Janeiro's Operations Center is a great example of this and described below. For these operations centers to work, they need a network of sensors that collects data as well as a strong wireless or broadband infrastructure that helps the sensors send data. Smart telecommunications systems can connect people in a number of ways: human-to-human, human-to-machine, and machine-to-machine.

There is some overlap between smart telecommunications technologies and the other technology categories in this report. For example, smart parking can be considered a form of smart telecommunications since the city can install wireless sensors in the parking meters to detect violations or measure how long cars are parked for.

RECOMMENDED TECHNOLOGIES

Integrated Operations Centers and Data Platforms

These operation centers allow the government to improve city governance and give public organizations or companies a chance to use data collected on the city's operations to develop their own applications. These centers can include the ability to analyze data on any aspect of a city, including transit, weather, crime, business, and public health. There is a global trend toward cities providing data on open platforms. Cities that make their data available are seeing innovative and useful applications from start-up businesses and researchers. Rio's Operations Center integrates a large amount of data to help the city make important decisions. Barcelona and Chicago both host events that encourage public use of their municipal data, while Busan in South Korea offers a development center for engineers and entrepreneurs to work on new applications of the data. The benefits of creating an easily accessible open-source platform have proven to be substantial.

Returns on Investment

An integrated operations center provides a number of opportunities for optimization from which a city can obtain returns on investment. Integrated operations centers can help with disaster response, public security, traffic management. Returns on investment for these technologies are a bit more indirect, but there are enormous gains in having an overall improved governance mechanism as well as the ability to integrate other services easily when the city identifies additional challenges.

The data platform is a core component of the central operations center. Most smart technologies will inevitably involve data collection, and an open data platform usually puts this information online and in an easily accessible format. While the data collection itself might be expensive, cities can recover costs directly through other smart technologies such as smart parking and smart lighting (discussed later in this report). The additional cost of making this data publicly available or available across different government departments is quite low. Making data that the city has already collected available online does not require much capital. For example, Pittsburgh only spent $20,000 to build a website that allows the public to look at city finances (Zullo 2015). OpenGov, a California-based company that provides data platforms for about 250 state and local governments, runs the service. This example also shows how a government can contract out the technical requirements for managing a database to an external organization if they do not have the in-house capacity. However, a number of cases have shown that internal government capacity can determine the ultimate success or failure of smart city projects.

Most importantly, collecting data and making it publicly available often allows external actors to innovate and develop solutions to municipal challenges, which can improve quality of life and spur local business creation. While these returns are more difficult to quantify, creating a city that boasts transparency and trust from its residents is an invaluable asset.

Case Studies

This section covers case studies on these operation centers and how they are used in Rio, Chicago, Busan, and the Spanish city of Santander.

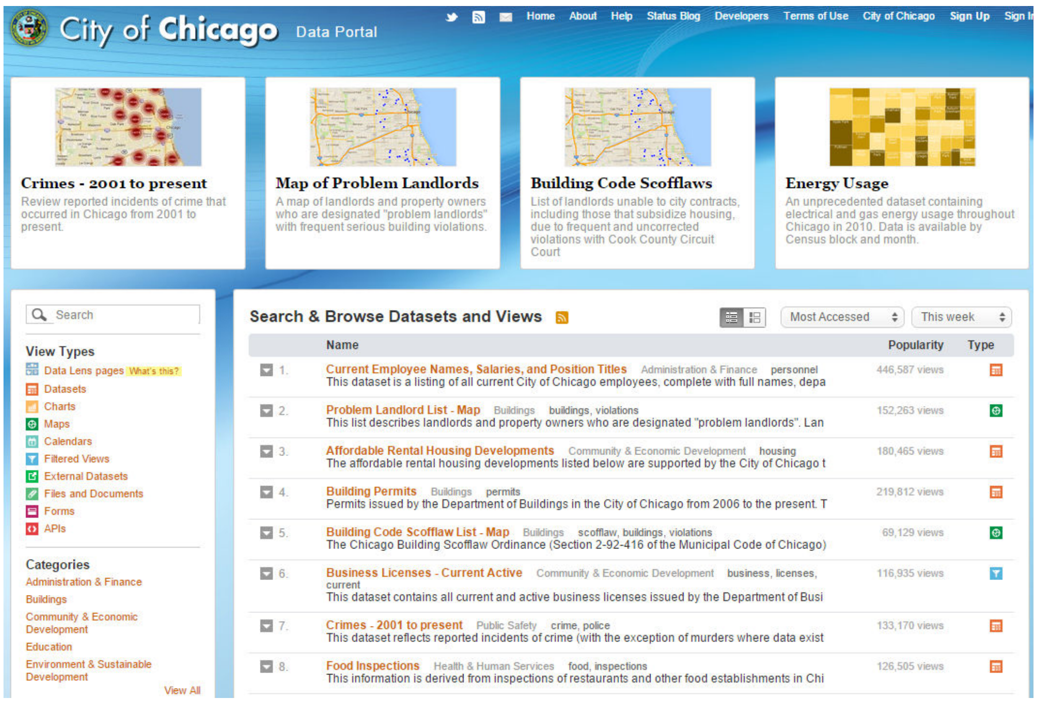
RIO'S OPERATIONS CENTER: This center integrates information from around 30 municipal and state entities. The main goal of the center is to minimize the impact of emergencies and incidents by coordinating all city agencies and ensuring their communication with one another. Rio built the center after floods, landslides, and avalanches caused more than 300 deaths in 2010 (Cisco 2014b). Three pillars define the initiative: 1) Collection of information from sensors, such as rain gauges, radar, bus GPS systems, images, social networks, and other sources; 2) Analysis of information to make operational decisions; 3) Dissemination of information to the public to alert them of disasters and other problems (Cisco 2014b). The center shows the importance of inter-agency communication. In this case, the control room coordinator holds meetings to ensure that all agencies are communicating about the latest incidents in the city (Cisco 2014b).

CHICAGO'S OPEN DATA INITIATIVE: Chicago has been a leader in combining open data with predictive analysis to improve city governance. Chicago has been making all types of municipal data public, everything from energy use to crime data.

One area where Chicago has been particularly innovative is its food inspections dataset. With the help of volunteers from the Civic Consulting Alliance and Allstate Insurance, Chicago's health department and

Department of Innovation and Technology designed a predictive model using open datasets to understand which food establishments were the most likely to be the site of a foodborne illness outbreak. A randomized trial showed that inspectors who used the data from the predictive modeling program identified 5% more critical violations (Wold 2015).

Moreover, Chicago is using social media to analyze complaints about possible foodborne illnesses. A total of 193 complaints were filed through the platform and resulted in 133 restaurants being inspected. From these inspections, 16% of restaurants were closed after failing inspection, and 2% of restaurants passed but had critical or serious violations. With a smart learning algorithm, the program could parse which tweets contained the words "food poisoning" to identify specific instances to investigate (Harris et al. 2014). The open data project also sped up the process of identifying and inspecting suspected restaurants by seven days (Goldsmith 2015).



SMART SANTANDER'S OPERATIONAL CAPABILITIES: The government of Santander equipped the city with more than 1,100 wireless sensors that measure temperature, luminosity, carbon monoxide, and noise. In all, the network involves a total of 20,000 fixed and mobile devices (Belissent 2013). The city was divided into 22 separate Wireless Sensor Networks, each with a node as a gateway that stores the data in a database and transmits the data via 3G or Ethernet to web servers in the cloud. The data from the sensor network creates a database covering air pollution, environmental noise, and free parking spaces (Simpli-city).

The city invested nearly $12 million into the project, which was largely funded by the European Commission (O'Connor 2013). Libelium, the Spanish company behind Smart Santander, has expanded into a wide range of services, including radiation monitoring in Japan, traffic restructuring in Spain, and public transportation improvements in Serbia. This case study shows the ability for a local pilot project to help local businesses expand their reach globally.

PUBLIC CLOUD IN THE CITY OF BUSAN: The Busan government installed a cutting-edge public cloud system that connects the metropolitan government, local universities, and a mobile application development center. Eventually, the project will also include kiosks, digital signage, and mobile services. The public cloud will create a shared platform as a service (PaaS) for mobile application development and training to spur economic development. Moreover, the intelligent aggregation of public and private data (traffic, facilities, and emergency management) optimizes city operations (Cisco Consulting Services 2014). Since the opening of the Busan Mobile Application Development Center, the local development community has grown from 500 to 1,500. In the first year, 840 people registered for professional development courses and seven businesses have registered as start-ups (Cisco 2012).

Wireless Sensors

Wireless sensors can be attached to physical objects to collect data on everything from humidity to carbon monoxide to the status of a parking space. These objects can link through wired and wireless technologies, providing data for computers to analyze.

These technologies can be applied in a variety of ways, and other technologies mentioned in this report can also rely on advances in sensors.

Returns on Investment

Initially, these projects might require upfront funding from the government. In the case of Nice's Connected Boulevard project public funds paid for the initiative due to the strong backing of the mayor. In the case of Barcelona, government investment in the wireless sensors has led to significant private sector investment in the city that has exceeded costs of the initial investment. Investment in basic infrastructure can also attract private investment to use the infrastructure in other, more advanced ways. Smart parking stations, for example, can provide public wireless access. Many applications (as shown in later sections) also have ways to recover costs, such as smart parking, smart lighting, and smart waste collection. For more details, please see the returns on investment information for each of these technologies. In general, the local government should consider investing in these technologies due to the potential savings on the maintenance and labor costs of complex infrastructure systems.

Case Studies

The case studies in this section look at broader applications of sensor networks, with the goal of helping local governments and developers understand that many of these applications can be easily packaged. The case studies also target city-level projects covering a spectrum of technologies that can be implemented together. The case studies in this section include Nice, France; Barcelona, Spain; and South Carolina, U.S.

CONNECTED BOULEVARD IN NICE, FRANCE: Nice's Connected Boulevard project incorporates various smart technologies in addition to sensors, including smart parking, smart street lighting, smart waste management, and environmental monitoring (Cisco 2014c).

The platform works through four layers:

- Layer 1: Sensors and networked devices with wireless technologies
- Layer 2: Data capture, processing, storage, and analytics at distributed points across the city

- Layer 3: Central data collection, including storage, computing, and analytics
- Layer 4: New and innovative applications and services that can be developed and integrated for both city managers, businesses, and residents (Berst 2013)

The program started with smart parking as its pilot application. The technology allows drivers to see what parking is available and see real-time information on public transit via a mobile application. Cisco estimates that the project reduced congestion by 30 percent, increased parking income for the city by 35 percent, and reduced air pollution by 25% (Lange 2013). Moreover, the Connected Boulevard program shows how technology selection can minimize costs. In a sensor-rich system, the replacement of sensor batteries makes up a large proportion of the maintenance costs. Connected Boulevard relies on low-power sensors to measure physical properties such as temperature, humidity, and luminosity. Low-power sensors often function by not needing to be turned on at all times and instead having scheduled data transfer time points, which significantly reduces the need for battery replacement (Weiss, Yu, and Simon 2013). Later, the city also implemented smart lighting, smart waste management, and environmental monitoring. By packaging these options, smart technologies that involve some sort of cost recovery, such as parking, waste, and lighting, can balance out technologies that lack a cost recovery mechanism, such as environmental monitoring (Corsaro 2014).

USING SENSORS ON INFRASTRUCTURE IN SOUTH CAROLINA: This case study demonstrates how sensors can be used in larger infrastructure projects. In South Carolina, eight bridges have carrying capacity monitors that are measured 24 hours a day. The monitors reduced the need for in-person physical inspections, which tended to underestimate bridge strength. The real-time information allows South Carolina to keep bridges in service for an extra five years before they must be replaced. More specifically, data from the monitors has led the state's Department of Transportation to solve a bridge's problems using a retrofit that cost $100,000 rather than spending $800,000 to completely replace the bridge. The sensors can alert officials of overweight vehicles on bridges that are particularly damaging to the lifespan of a bridge. They also provide data on wind speed, which allows the bridge authority to close the bridge without having to send an employee to the site (Chieppo 2014).

BARCELONA'S SMART CITY: According to Cisco, Barcelona's Smart City initiative created $3.6 billion in value through 1,500 new companies and 44,000 new jobs. The initiative includes the use of wireless sensors in Barcelona to set up a new telecommunications network, smart lighting, smart irrigation management, smart parking, among other planned measures, such as EVs. Cisco's analysis shows that smart lighting created $47 million, smart water created $58 million, smart parking created $67 million, teleworking created $199 million, and finally mobile collaboration created $1.6 billion (Department for Business Innovation and Skills 2013).

Broadband Infrastructure

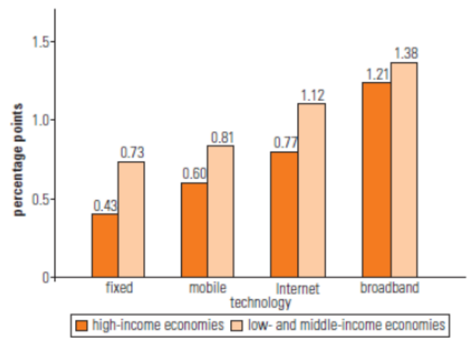
Access to high-speed wireless internet has become a foundation of modern societies. Fast internet connections are a requirement for businesses to communicate with customers, for workers to telecommute, and for individuals to enjoy the full benefits of the internet. For example, with Google Fiber's implementation in the U.S., there is evidence that some businesses are even willing to relocate to access faster internet speeds. In Kansas City, Missouri, 121 businesses have launched or relocated to the Google Fiber area (Rogers 2015).

Returns on Investment

Compared to other public spending stimulus options, broadband investment is fiscally sound. The financing is mostly market-led and much of the initial funding can come from the private sector. This is the case in Australia and Korea, where the government has funded 11% and 4% of the total cost of a broadband network, respectively. In Portugal, the government helps by providing a credit line to the operators. As long as the government helps with some of the upfront costs, case studies show that users are very willing to pay for the service once the infrastructure is in place and costs can be recovered.

The growth effects of ICT infrastructure are known for countries at every point on the development spectrum.

Figure 3. Growth Effects of ICT infrastructure



Source: Qiang 2009.

Note: The y axis represents the percentage-point increase in economic growth per 10-percentage-point increase in telecommunications penetration. All results are statistically significant at the 1 percent level except for those for broadband in developing countries, which are significant at the 10 percent level.

When a local government is making financing decisions, they must take into account the ripple effects of ICT infrastructure investment. Broadband can help with the development of small businesses, improve education and health care, optimize public safety, and improve the provision of social services ("Broadband's Benefits"). Widespread broadband infrastructure can also act as a foundation for other smart technologies.

Case Study

The case study in this section focuses on Singapore's Nationwide Broadband Network.

SINGAPORE'S NEXT GENERATION BROADBAND INFRASTRUCTURE: Singapore's Nationwide Broadband Network is a fiber-to-anywhere project that connects 99% of Singapore's residents to an ultra-high-speed network via cabling. The broadband network aims to "transform Singapore into an intelligent nation and a global city powered by info-communications" (Infocomm Development Authority of Singapore, n.d.). Private partners provide home- and business-based services. Public-private collaboration made the broadband infrastructure possible. The government pledged $250 million toward the installation of the broadband infrastructure. Private providers covered the remaining costs associated with installation and maintenance, and now own and manage the network (Cisco 2014a).

Three different types of industry players make up the broadband infrastructure:

1. **The Network Company:** Responsible for the design, building, and operation of the passive infrastructure, including the dark fiber and ducts
2. **The Operating Company:** Commits to offering wholesale network services over the active infrastructure that involves the switches and transmission equipment
3. **The Retail Service Provider:** Sells services to end users and industry in a competitive market that offers services such as Internet and Voice over Internet Protocol (VoIP) (Infocomm Development Authority of Singapore 2012)

As of June 2014, there were more than 550,000 subscribers to the broadband network, which has quintupled since January 2012. The network provides download speeds of up to 1 Gbps (Gigabits per second) and speeds of up to 500 Mbps (Megabits per second). These speeds are becoming critical for many industries in Singapore, especially finance, software, engineering, data centers, and gaming.

BENEFITS

ECONOMIC

ENCOURAGES INNOVATIVE NEW BUSINESS DEVELOPMENT: Information infrastructure increases productivity and profitability in cutting-edge businesses. Software-as-a-service and storage-as-a-service companies will have lower capital costs since the broadband network already offers access to fast service (Infocomm Development Authority of Singapore 2012). Busan encouraged entrepreneurs to start businesses by offering a public cloud combined with facilities for business development (Cisco 2012). A broadband network can also catalyze new business development, which is part of the strategy for Singapore's broadband network (Infocomm Development Authority of Singapore 2012). Apart from the direct support for technology companies that such investments provide, more effective information flows will more broadly support high-value and creative economic activity, from product design to marketing.

CREATES JOBS: A U.K. study estimated that investing in ICT infrastructure would create jobs, with broadband investment alone creating 280,500 jobs (Liebenau et al. 2009).

ENVIRONMENTAL

CREATES A FOUNDATION FOR MUCH MORE EFECTIVE ENVIRONMENTAL MONITORING: Wireless sensors makes it possible to perform certain environmental activities such as air and water pollution monitoring. By investing in the basic infrastructure, the local government enables the advanced technologies to improve air quality, clean up water supplies, and decrease carbon emissions.

ENCOURAGES INNOVATIVE SOLUTIONS TO ENERGY AND ENVIRONMENTAL CHALLENGES: By making data on carbon emissions, air quality, and energy use widely available, both the private and public sector can develop better applications and technologies to solve these problems and even create new businesses. For example, in Chicago, the availability of parking data lead to the creation of a company called SpotHero that helps users find open parking spaces. This company has now grown and operates in a number of cities.

SOCIAL

IMPROVES RESPONSE TIME TO PUBLIC COMPLAINTS: The government of New Taipei City set up a system using ICT infrastructure to respond to public complaints by streamlining all requests, and this has reduced redundant work (Microsoft 2015).

IMPROVES PROVISION OF PUBLIC SERVICES: Broadband infrastructure enables the expansion of technologies in health and education as well. For example, fast and reliable internet connections make cost-saving technologies, such as remote consultations and monitoring, possible (Dini, Milne, and Milne 2012).

IMPROVES ABILITY TO RESPOND TO EMERGENCIES: These technologies improve local government's interactions with the public, and they help the public communicate better with government officials, both of which are beneficial in the event of an emergency.

2. SMART MOBILITY

The smart mobility market in China will be one of the world's largest due to the economic costs that congestion is imposing, according to Navigant Research (Woods 2012). China is building more public transit systems than the rest of the world combined. Without intelligent management, Chinese cities will find it difficult to cope with their transportation demands (Woods 2012). This section covers the following technologies:

- Smart Traffic Management and Congestion Pricing
- Transit Data and Smart Payment Systems
- Smart Bike-Sharing Systems
- Smart Parking
- Smart Charging Networks and Vehicle-to-Grid

In general, smart mobility is about making existing transit services more efficient, while also increasing multi-modal trips and making them more convenient. For example, Copenhagen's smart bike-sharing program gives users direct information on access to public transit, making it easier for cyclists to travel long distances since they can incorporate mass transit into their trip planning. Reducing congestion has been another major goal of smart mobility technologies, whether by reducing the amount of time drivers spend looking for parking, or by imposing tolls to discourage driving during on-peak hours and encourage use of public transit.

RECOMMENDED TECHNOLOGIES

Smart Traffic Management and Congestion Pricing

Smart traffic management and congestion pricing includes technologies such as sensors that can track vehicles, dynamic traffic signals, congesting pricing technologies, and traffic data collection technologies.

Smart traffic management and congestion pricing have become necessities for many of the world's largest cities that face heavy congestion. This technology increases revenue, reduces traffic congestion, leads to savings by decreasing the need for road expansion, and reduces CO_2 emissions (Bradley et al. 2013).

Returns on Investment

Smart traffic management and congestion pricing have reliable and direct payback mechanisms. However, the city needs an initial capital investment and must perform detailed analysis to understand how quickly costs can be recovered. The city has flexibility in setting the price for tolls and there are various pricing approaches (tiered, on-peak versus off-peak, monthly versus daily) that can also optimize revenue gains. Smart congestion pricing can be a boon for municipal revenue. For example, London's program has reduced traffic by 10% and garners about £200 million in revenue a year (Litman 2011). By putting a price on congestion, the city can use the revenue it generates to address congestion-related externalities, such as pollution, health problems, and infrastructure costs. Local financing mechanisms can play a critical role in successful smart mobility projects.

While tolls can often lead to public resistance, London, Singapore, and Stockholm's experience shows that pilot projects for congestion pricing can gain public support by demonstrating positive effects. Pilot projects often do not induce as much public resistance since they are not permanent and often have a re-evaluation period. By showing drivers that tolls improved the driving experience, the majority of the public became supporters and the pilot project became a permanent program ("How to Solve Traffic Jams" 2014).

While it is difficult to quantify the investment returns due to improving congestion, studies have more clearly shown the high costs associated with congestion in many major cities. In Rio de Janeiro and São Paulo, Brazil, congestion costs accounts for 8% of municipal GDP (Lobo 2014).

Case Studies

The case studies in this section look at a number of more specific strategies that cities have adopted to manage congestion, including collecting congestion data from taxi drivers in Seoul, charging drivers for the amount they drive in Stockholm, installing sensors and measurement technologies in New York, and creating a smart metering scheme in Melbourne.

SEOUL'S SMART TAXI TOUCH CARD PAYMENT SYSTEM: Seoul has been trying to capture real-time traffic data for years to improve congestion. The city originally invested millions of dollars to install sensors embedded in roads. However, the traffic data was unreliable and not useful. Seoul found a simpler solution: in 2012, the city's 25,000 taxis introduced a touch-card payment system that uses GPS. This technology gave the city the smart traffic data it needed at a fraction of the cost. Seoul's experience, according to Jong-Sung Hwang, former CIO of the Seoul Metropolitan government, shows that "a smart city can now use smart technology and solve problems without changing the city's infrastructure" (Smedley 2013).

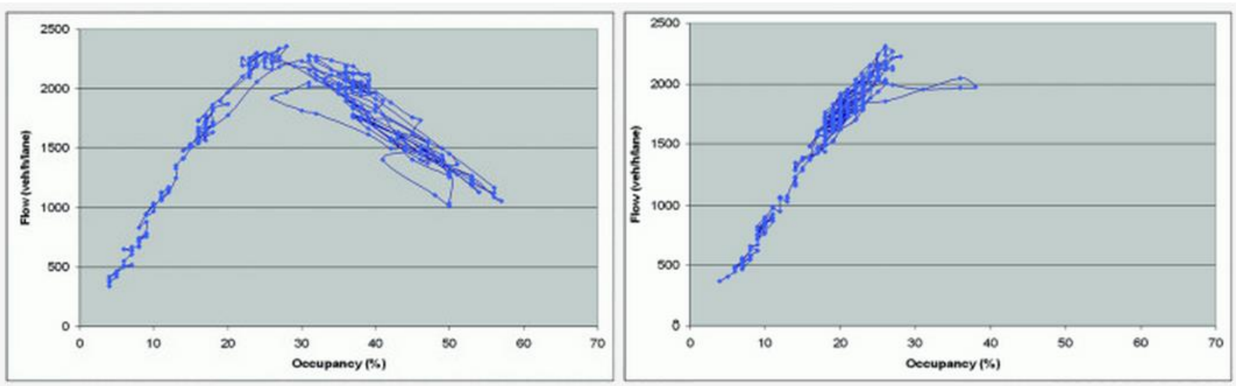
STOCKHOLM TRAFFIC CONGESTION: Stockholm voted to implement a road toll scheme powered by an IBM system that uses a city-wide camera network to photograph vehicles and map their precise journey. This allowed the city government to charge people more accurately for the distance and time of day they traveled through a toll collection system. The traffic system helped Stockholm cut gridlock by 20%, reduce emissions by 12%, and increase the use of public transportation dramatically.

NEW YORK'S MIDTOWN IN MOTION: This congestion management system allows engineers to identify and respond to traffic conditions in real-time. The project cost $1.6 million, with city government supplying $1 million and the federal government providing $600,000 (Office of the Mayor 2011). The project installed 100 microwave sensors that measure flow and occupancy, placed electronic toll collection (ETC) readers at 23 intersections to measure travel time in segments within the zone, and added 32 traffic video cameras for verification and further monitoring (2011). The system then used this data to respond to congestion levels by adjusting traffic signal patterns to improve traffic flow. After implementation, according to Siemens, travel times improved by 10% on the avenues in the project zone, and average travel speed increased from 10.5 km/hour to 11.6 km/hour (Siemens 2014). The system has won a transportation technology award from the Intelligent Transportation Society of America. The project's success is leading the city to expand the system to more than 270 additional square blocks (Solomon and Mosquera 2012).

STREAMS ITS IN MELBOURNE: The city of Melbourne worked with Transmax to improve congestion and traffic flow on its busiest freeway. Transmax implemented STREAMS ITS to deploy on-ramp metering to manage the traffic demand so it wouldn't exceed the freeway's capacity. VicRoads, the local transportation authority, worked with Transmax to implement a ramp-metering algorithm, known as HERO/ALINEA. The project reduced accidents by 30% on the motorway and 60% in the City Link Tunnel. It also reduced travel time by 42% on the motorway and 48% in the tunnel, increased sustainable peak flows by 50%, and reduced fuel consumption and costs.

The figure below shows that after the city implemented STREAMS, overall traffic flow increased and occupancy rates decreased during peak hours.

Table 4. Impact of STREAMS on traffic flow (Source: City of Melbourne)



Melbourne peak traffic flow before STREAMS

Melbourne peak traffic flow after STREAMS

After the system was implemented, the peak hour flows increased by 10% and the average speed of vehicles using the freeway improved by 20 km/hour during the peak travel period. The daily economic benefits were $94,000, and drivers saved travel time and vehicle operating costs. This means it took just 11 days to recover costs of the $1 million project investment.

Transit Data and Smart Payment Systems

Transit data can be beneficial to riders as well as those that control and operate the transit systems. The system can offer riders more data on when transit arrives, explain how to navigate multi-modal transit systems, or provide accurate estimates of travel times. The transit authority, in turn, can collect data on usage to optimize routes. If a city government wants to use data to improve a transit system, there are many opportunities to package this with other technologies. For example, smart payment systems can make collecting data on public transit much easier. Offering real-time transit data can also improve ridership and shift users away from using private cars.

Returns on Investment

There are options to monetize real-time transit data and payment systems to save on potentially high capital costs. For example, in the London case study below, using an existing Microsoft system to use contactless payment and offer real-time transit information allowed the government to save millions of dollars on the initial investment.

By linking real-time transit data with a smart payment system, a city government can also better understand the transit system and decrease its costs. For example, in the Zhenjiang case study below, the city's optimized transport network reduced fuel costs due to more efficient routing.

The city government can charge riders directly for payment cards by collecting fees. Cities can also work with companies to decrease costs and share risks. For example, in New York, collaboration with MasterCard allowed the city's transit authority to leverage their resources for risk management and technology upgrades. The program, PayPass, will begin in 2020 (Smart Card Alliance 2006). The city can also share revenue from a co-branded bank card or usage fees (First Data Government and Transit Task Force 2010). In 2010, the project began linking transit agencies so that users can use PayPass in New York and New Jersey. This upgrade shows how programs can expand in scope beyond a local transit system (Metropolitan Transit Authority 2010).

Finally, it is often cheaper for these smart transit systems to maintain an open system for payment, as opposed to a closed-loop system. A closed-loop system only allows transit payments to occur where other transactions, such as credit cards, can integrate in an open-source system. For example, London spent $148 million a year to maintain its closed-loop Oyster system (First Data Government and Transit Task Force 2010). Closed-loop, or proprietary systems, cause high maintenance costs (especially when systems start becoming obsolete), lock in transit authorities to one vendor which constrains their flexibility in technology upgrades, and reduce revenue opportunities for transit authorities due to usage fees or revenue sharing from co-branded bankcard interchange (First Data Government and Transit Task Force 2010).

The city government should also look at opportunity costs when making financing decisions. If, for example, there is an option to widen a road or invest in public transit, the city should account for the external costs of pollution, congestion, emissions, and health problems. Making public transit more convenient through better data and payment systems can also increase ridership, which helps the city recover its costs (Tanga and Thakuriahb 2012).

Case Studies

The case studies in this section look at upgrades to transit systems in London and Zhenjiang.

TRANSPORT FOR LONDON: Transport for London has collaborated with Microsoft to improve the city's public transit system in a number of ways.

First, they have begun using "contactless" payment for public transit, which improves access to transit since users no longer need to carry an extra public transit card (Microsoft UK 2015). Transport for London is now the fastest growing contactless merchant in Europe (Cameron 2015). This case shows the importance of utilizing existing IT infrastructure and collaborating through an efficient public-private partnership that delivers a smart solution.

Second, their TrackerNet website, which provides real-time travel information, now receives more than 2.3 million hits daily, up from 1,000 daily hits previously. By collaborating with Microsoft and using their existing software, Transport for London saved millions of pounds it would have spent developing its own

IT infrastructure (Microsoft 2011). The Journey Planner helps users route around delays and is receiving about 750,000 requests a day (Perez 2015). The technology goes beyond the capabilities of a platform such as Google Maps by incorporating data from traffic cameras, bike-sharing stations, and public transit schedules.

SMARTER ZHENJIANG: Working with IBM, Zhenjiang implemented an intelligent transportation solution to provide city managers with a consolidated view of the local network. The "Smarter Zhenjiang, Smarter Tourism" project has replaced and upgraded more than 400 bus stations and more than 1,000 public transit vehicles. They have created a new bus scheduling system that is using sophisticated data analysis to manage traffic patterns and more than 80 transit routes across the city (Richards 2014). A sensor system collects data from devices in buses and bus stations for use by IBM's Intelligent Operations Center for Smarter Cities. IBM China Research Laboratory is also working with the city to create a Transit Route Network Optimization Planning System (Woods 2012). The city estimates the technology has saved $2.7 million USD in fuel costs per year (Johnson 2014).

Smart Bike-sharing Systems

China's bike-sharing systems have proliferated in recent years and are some of the largest in the world. There is now an opportunity to use smart technology to better integrate these bike systems with public transit to make them more useable. Bike-share provides more mobility options by facilitating connections to metro or light rail, or by allowing travelers to use a ride-sharing service for the return trip. In general, bike-sharing systems can decrease congestion, improve public health, and improve mobility.

The following upgrades can improve bike-sharing systems:

- Provide information through a mobile application or a panel on the bike that shows public transit times, availability, and a GPS map
- Provide electric bikes to increase ridership and allow people to travel farther
- Incorporating geo-location, geo-fencing, and built-in locking technology into bikes so that they can operate independently of expensive docking stations
- Use sensors or other tools (such as a mobile application) to understand how the bikes are being used so systems can be upgraded

For a smart bike-sharing program to be truly successful, the city must implement it in conjunction with, or after, the development of a dense network of biking paths. Again, this is a key example of where a smart technology must be done on top of the Green Guidelines. Without a great network of biking paths, even the most advanced bike-sharing technology will be difficult for residents to use.

Returns on Investment

The city government often provides financing for smart bike-sharing systems. The city can either charge for use on a monthly or daily basis, or sell advertisements on bike parking stations to recover some of the costs. The city can also share risk with a private company by contracting out the project. In these cases, the city can expect to provide some of the initial funding to get the project running, but the private company is responsible for later additions and smart technology upgrades. The GridBikes program in Phoenix is a good example of using innovative financing solutions, such as having local businesses co-sponsor bike parking stations.

Case Studies

The case studies in this section cover bike-sharing systems in Phoenix and Copenhagen, which are two very different programs that have both increased bicycle use in their respective cities.

GRID BIKE IN PHOENIX: GridBikes is an excellent example of a private company providing a smart bike-sharing service. Pheonix has contracted with CycleHop, LLC to establish and operate a bike share network that will eventually include 500 bikes in Phoenix, and another 500 in neighboring Mesa and Tempe to follow. Users can make reservations, purchase day passes, or buy longer-term memberships. These bikes are equipped with solar-powered, GPS-enabled locks and can be parked at special kiosks or traditional bike racks, which gives users immense flexibility and convenience (City of Phoenix). The program works with the private sector by creating innovative sponsorship opportunities. Businesses have two options: host a bike-sharing station on their property, or advertise through the Grid bike-sharing system (either on the bikes, at bike-parking stations, etc.) (Grid Bikes). Businesses can improve their public image and accessibility by hosting bike-sharing stations, while the program can earn revenue to support the system's health. This case study shows: 1) The flexibility of using smart technologies: the solar-powered, GPS-enabled locks give travelers unlimited options because they do not have to park at a special docking station, and 2) The effectiveness of innovative financing in allowing for sustainable business models and successful private-public partnerships in bike-sharing systems.

COPENHAGEN'S SMART E-BIKE SHARING PROGRAM: Each of Copenhagen's electric bikes features an Android tablet that offers built-in GPS, real-time train departures (for optimized bike-rail integration), and the ability to buy tickets through the tablet directly (VisitCopenhagen). Users pay about $3.50 USD per hour or buy a monthly pass for around $8.85 USD. Cykel DK is a non-profit organization operated by the cities of Copenhagen and Fredericksberg, as well as DSB (Denmark's national railway system). There will eventually be 1,260 bikes available at 65 stations and the service will be available 24 hours a day, 365 days per year (VisitCopenhagen).

Table 5. Smart Bikes in Copenhagen

[2]

TAIPEI'S YOUBIKE PROGRAM: Currently, there are over 6.4 million users of Taiwan's YouBike program with 40,000 rentals a day and 1 million a month. There are over 160 bike stations in Taipei, each with its

[2] (Shahan 2013) http://cleantechnica.com/2013/08/19/copenhagen-bike-sharing-program-to-be-most-high-tech-bike-sharing-program-yet/

own service kiosk. Users must use an EasyCard, Taiwan's most used electronic payment system that is integrated with the metro, bus, taxis, convenience stories, and other locations (JA Travel Solutions 2013). As of 2014, Giant, the Taiwanese bike company helping to run the system, wants to expand the bike-sharing system to Changhua County, Greater Taichung, and New Taipei City. Giant says that running a public bike program will not directly generate high profits since the cost of accessing the bike rental programs must be kept relatively low for the public. That said, Giant's overall sales in Taipei rose after launching the YouBike system (Kao 2014).

Smart Parking

Smart parking technologies can involve dynamic pricing, sensors, meters, and data dissemination that point people to open parking spots, as well as electronic or mobile payment systems that make parking more convenient and reliable. Smart parking captures the value of data to optimize parking revenues while reducing congestion. For example, smart parking can involve smart parking meters that are connected to a central data system. City administrators can then implement dynamic pricing, by changing parking prices based on the time of day.

Smart parking can be integrated with other smart technologies. For example, Streetline's wireless network can also obtain data on road surface temperature and noise levels (Yusuf 2014). Road surface temperature can help identify where tree planting can reduce heat island effects. Lowering the road surface temperature can also reduce building energy usage and improve air and water quality ("Road Surface Temperature"). Noise level sensors can help detect levels of traffic and help the city manage noise pollution (Office of Planning, Environment, & Realty (HEP) 2011).

Returns on Investment

Parking is one of the easiest applications of the smart technologies and has a short payback period. Parking is typically the second or third highest revenue source for a city, at least in the U.S., so there is a high probability that these investments can increase revenue and decrease labor costs. With smart parking systems, the city can not only control the costs of congestion, but also increase government revenues. Smart parking also gives the city the ability to charge tiered prices for parking and raise parking costs during the busiest hours at certain zones to discourage driving and generate more revenue.

Case Studies

SMART PARKING IN LOS ANGELES: Los Angeles installed low-power sensors and smart meters to track the occupancy of parking spaces in the Hollywood district, one of its most congested areas. The technology was produced by Streetline (Kessler 2011; Streetline). The sensors are about the size of a coffee cup lid and are embedded into the asphalt. The meters, which let users pay with their mobile phones, provide data to the city and allow it to adjust parking prices to the level of demand (Kessler 2012). The information also alerts enforcement officials about expired parking meters or other parking violations, thereby reducing operating costs. An app called Parker provides users with real-time data on the location of unoccupied parking spots. According to Streetline, Los Angeles recouped this investment in just three months (Streetline).

SMART PARKING IN NICE, FRANCE: The city of Nice installed smart parking sensors on 8,500 on-street spaces and 19 multi-story parking structures. The introduction of smart parking has reduced operational parking costs by 30%, reduced congestion and pollution by 10%, and provided a quick two-year payback period.

The project also includes a mobile application that helps residents find the best available route to an open parking spot. Additionally, Nice installed 570 multi-service kiosks that let the public pay for parking, but also access services, such as bicycle- and car-sharing. These kiosks are an excellent example of smart integration: they allow citizens to give the city feedback on potential problems and obtain information on local businesses. Finally, the data collected from the smart parking system allows Nice to adjust fees to cover negative externalities, such as congestion and pollution (ACT Government 2015).

Electric Vehicles and Charging Networks

Vehicle sales in China are still increasing, despite many caps on car purchases in major cities, so it is more important than ever for local governments to set up the infrastructure to encourage residents to buy electric vehicles (EVs). A car purchasing decision can lock in energy consumption and emissions for over a decade. Because it is difficult for drivers to transition to EVs after purchasing a non-electric vehicle, it is important for cities to integrate EVs into the grid as early as possible (Xinying Tok).

Battery prices are also decreasing, and at an even faster rate than originally predicted in 2013. In 2015, a study that looked at 85 cost estimates of EV batteries found that 2013 estimates of battery prices from the International Energy Agency were already outdated. They found that the electric car industry had already reached the goal of cell costs falling to $300 per kilowatt-hour (Edelstein 2015). Consequently, the consumer demand for EV's is projected to increase and the need for government subsidies to encourage EV purchases will decrease.

In places that get more energy from hydropower and renewable energy, it is especially important for cities to encourage EV use since they already have a clean electricity source. Energy security concerns are also pressing, and a higher percentage of EVs on the road is part of a more resilient transportation system.

Many cities still lack the necessary infrastructure for EVs. Once EV charging networks are established, there are a number of options for how these charging networks can be used and how EVs can interact with the electric grid of a city.

EVs are more expensive than their internal combustion counterparts, but battery prices are decreasing and the volatility of oil prices make them an attractive option. Local governments can improve charging infrastructure in cities—a necessary component of successful EV adoption.

In China, unlike the U.S. or some areas in Europe, many residents do not have their own garages, which makes the availability of charging stations in residential complexes, workplaces, and public areas all the more important. Local governments should encourage new residential developments to include EV charging stations, in addition to encouraging deployment of charging stations at these other locations. There are a few charging options for EVs:

- **Battery swapping:** Recently, Tesla been focused on this technology, it has supported battery swapping in its Model S and has announced that it will pilot swapping stations in the U.S. Battery swapping was piloted by Better Place, though the company went bankrupt in 2013.

- **Wired charging:** The most dominant form of charging. In Europe, there are about 20,000 charging stations and about 1,000 DC fast-charging stations (as opposed to AC charging stations, which are slow but cheaper to install).
- **Induction ("wireless") charging:** In operation at a few pilot locations, but not commercially viable yet.

There are also different strategies for EV use. For example, the local government can encourage companies to have more EVs in their corporate fleets, in which case charging stations can be linked with workplaces. Alternatively, the goal can be to encourage inter-city travel using EVs, in which case charging stations can be designed as an integral part of highway systems. In general, encouraging travelers to use EVs for commuting makes the most sense because EVs often have a smaller range (i.e., the BYD E6 has a range of about 200 km, the Tengshi is about 300 km, while the Tesla Model S has a range of about 426 km).

Returns on Investment

While Level 1 charging stations (AC charging) are relatively inexpensive to install, Level 2 and Level 3 (DC charging, which is much faster) are quite expensive even though they are much more useful. However, new business models and technologies are constantly emerging to make installation easier and cheaper. For example, smart EV management with demand response capability, such as using less costly off-peak energy, can decrease the costs of charging infrastructure (Aunedi 2015). Green eMotion finds that the cost of supplying EVs with no smart charging is about €200 per EV per year, but with smart EV management, this decreases to €5-100 per vehicle per year, depending on the system and EV penetration. This study calculates the return on investment for the whole utility system, and not just the individual charging stations. This cost calculation includes the proportional cost of infrastructure and generation needed to support the EV in addition to the cost of new infrastructure. Hence, technological innovations such as smart grid technologies can make an EV charging network much more cost-effective.

Moreover, different pricing schemes can help shift the burden of payment off the government. For example, the government can charge users an upfront cost or a monthly fee to use the charging infrastructure. Of course, the downside is that this might discourage consumers from purchasing an EV, especially when subsidies are not sufficient to make them cost-effective.

With destination charging at home or work, there is less need for fast charging. Trip continuation charging (DC fast charging) is more expensive. Local governments should create systems in which destination charging captures the majority of charging needs, but there are still trip continuation charging opportunities scattered throughout the city (Siemens 2011). The other option is to create incentives so that corporate fleets serve as an anchor load[3] for EV charging stations and the local government can then partner with companies to decrease costs. The government can identify larger corporations with a higher number of workers that drive EVs to guarantee that a certain number of drivers will use the charging stations.

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[3] An anchor load in this case is what will provide sufficient demand for charging stations to allow the local government to install charging stations at an optimal scale.

The table below summarizes U.S. EV charging costs. One takeaway for China is that U.S. labor costs are especially high, so the Chinese experience could be considerably less expensive. It might also be strategic for Chinese cities to install the basic infrastructure early before labor costs rise further.

Table 6. Cost Breakdown for EV Charging Stations in the United States (Argenbroad and Holland 2014)

	Level 2 Home	Level 2 Parking Garage	Level 2 Curb-side	DC Fast Charging	Description/Key Assumptions
Charge station hardware	\$450–\$1,000	\$1,500–\$2,500	\$1,500–\$3,000	\$12,000–\$35,000	
Electrician Materials	\$50–\$150	\$210–\$510	\$150–\$300	\$300–\$600	• \$1.50–2.50/ft for conduit and wire, plus misc other materials • \$50–80/hour (per dist?) • \$500–1000 if new breaker is required • Assume 2x electrical cost for level 3
Electrician Labor	\$100–\$350	\$1,240–\$2,940	\$800–\$1,500	\$1,600–\$3,000	
Other Materials		\$50–\$100	\$50–\$150	\$100–\$400	• \$25–100/ft for trenching/boring—depends on surface, soil, and underground complexity • Mounting, signage, protection, and restoration also included here, but don't usually contribute more than a few hundred dollars
Other Labor		\$250–\$750	\$2,500–\$7,500	\$5,000–\$15,000	
Transformer	NA	NA	NA	\$10,000–\$25,000	• 480V transformer installed by utility
Mobilization	\$50–\$200	\$250–\$500	\$250–\$500	\$600–\$1,200	• Home: 1–3 hours of electrician time for a home installation • Public: \$250–500 of time for 1–2 electricians and other labor. We found that the work could usually be completed in a single visit from each contractor.
Permitting	\$0–\$100	\$50–\$200	\$50–\$200	\$50–\$200	• Varies city to city, often a flat fee for one or several stations

Investing in EVs also produces indirect returns, such as decreasing emissions, improving energy security via reducing reliance on oil imports, and creating a foundation for integrating more renewables onto the grid. There is even the potential for advanced vehicle-to-grid technology, such as the system in Amsterdam. Before more and more people choose internal combustion vehicles, the local government should capture the opportunity to lock in lower emissions from cleaner EVs.

There is also innovation in charging points, which will eventually drive down costs and make charging points easier to install. For example, BMW has created technology that uses streetlights as charging points for EVs (BMW Group 2014). Drivers can charge through the streetlight using a standard charging cable. The first pilot project in Munich was slated to begin in spring of 2015 (BMW Group 2014). Cost information has not been released yet, but the integration with streetlights has the potential to reduce costs and quickly expand the number of charging points in a city (Taylor 2014).

Most experts agree that adoption of EVs is inevitable; it is just a matter of how quickly. Producers of smart EVs can continue to work on the right pricing strategy to accelerate EV adoption through effective private-public partnerships. This way they can leverage green financing and government incentives. Local governments can benefit from this innovation by supporting a robust and useful charging infrastructure at the outset to create the foundation for a clean energy vehicle system.

Case Studies

These case studies show there are a number of benefits for using EVs and installing EV charging infrastructure, including reducing peak demand (Amsterdam's vehicle-to-grid project), providing vehicles for tourists, or providing charging at workplaces and commercial destinations. The case studies also discuss new charging technologies, such as BMW's streetlight charging systems.

AUTOLIB'S EV SYSTEM IN PARIS: In 2011, Paris introduced a three-door car named the Bluecar, an electric vehicle that could be rented at 250 stations in the city. The goal was to have a low-carbon alternative to public transit and private vehicle ownership. By 2012, the program had grown to 1,750 EVs and more than 5,000 charge points at 710 stations in the Paris metropolitan area. There are a number of local incentives that have made the service popular: preferential parking, road tax exemptions, registration tax exemptions, and access to bus lanes. Various municipalities in the Paris area manage the program and a company called Bolloré is responsible for operations. The system is still dependent on public financing, but Bolloré has recently received €75 million from the European Investment Bank to expand the project. As of now, the service has obtained about 38,800 subscriptions. Bolloré estimates that it will take 80,000 subscriptions for the service to be no longer dependent on public financing.

The environmental returns on the project are substantial. Autolib drivers in Paris can save about €7,000 a year by using the service rather than buying a car. In general, mobility-as-a-service is more efficient than owning a private vehicle. In general, cars in Paris are parked 95% of the time, which means that Bluecar can provide about 15 times the use of a privately owned vehicle (University of Cambridge 2014).

GENEVA'S ELECTRIC BUS SYSTEM: Geneva has been working with energy company ABB on a new boost charging technology for electric buses. The organizations working together include the Geneva public transport authority and operator, the Office for the Promotion of Industries and Technologies, the state-owned electricity provider of the city of Geneva (SIG), and the Geneva plant of ABB Secheron Ltd (ABB 2013).

The large capacity electric buses can carry as many as 135 passengers. The bus can be charged directly at certain stops with a 15-second energy boost while passengers enter and exit the bus. At the end of the bus line, a 3- to 4-minute boost enables the batteries to fully recharge. The buses have an innovative electric drive system, and power from the roof-mounted charging equipment can be stored in compact batteries. This flash charging technology allows buses to run all day on clean electricity (hydropower). The pilot project runs between Geneva's airport and the city's international exhibition center, Palexpo.

The photo below shows the electric battery charging mechanism. The system uses a laser controlled moving arm, which connects to an overhead receptacle for charging at bus shelters (ABB 2013).

Figure 4. Electric Bus Charging in Geneva (Source: ABB)

BENEFITS

ECONOMIC

CONGESTION PREVENTS ECONOMIC SUCCESS. For prosperous cities, traffic congestion and the loss of mobility handicaps greater economic productivity. Successful cities create jobs and attract new residents, so smart mobility is crucial to managing economic growth. Smart traffic management can improve traffic flow considerably. For example, New York City estimates it loses $13 billion yearly due to traffic congestion and has invested in smart transportation solutions to alleviate it. Moreover, smart parking technologies can reduce time wasted looking for parking. According to UCLA professor Donald Shoup, 8- 74% of traffic in congested downtown areas is due to people looking for parking (Shoup 2006). This finding is also supported by the National Highway Traffic Safety Administration, which estimates that 30% of driving in business districts is spent hunting for a parking spot (Bilton 2013).

INCREASED GOVERNMENT REVENUE: Cities are losing up to 40% of possible parking revenue due to inefficiencies (Streetlines, n.d.). Smart congestion toll systems can both improve traffic flow and act as an additional source of revenue for the government. The revenue can then be reinvested in public transit systems to further improve transportation for the city. Barcelona's city government has increased parking revenues by $50 million through smart parking-fee revenues (Cisco 2014e).

IMPROVED LOCAL BUSINESS: Ellicott City, Maryland, implemented a smart parking system that resulted in a 9.5% increase in parking turnover, which correlated with a 12% increase in local business revenue from the improved parking situation (Shaw, n.d.).

ENVIRONMENTAL

DECREASED ENERGY USE AND COMBUSTION EMISSIONS: Smarter technology leads to higher utilization rates, which is necessary for efficient and effective transportation. The space inefficiency of vehicles with single occupants that sit empty the majority of the time is evident around the globe. Using the STREAMS ITS system, the daily fuel savings on the Montreal freeway totaled about 16,500 liters of petrol and greenhouse gas emissions were reduced by 11% ("City of Melbourne," n.d.).[4] Moreover, in Los Angeles, a traffic signal synchronization program improved vehicle throughput enough to save 38 million gallons of fuel (Shaw, n.d.).[5] Real-time public transit information systems can also increase use of public transit, as shown in Seattle (Ferris, Watkins, and Borning 2010).[6]

IMPROVED AIR QUALITY: There is also an opportunity to shift to cleaner systems that directly address pollution problems. EVs are an example of a smart solution that directly shifts the system to cleaner transportation fuels. All electric-drive transportation has zero tailpipe emissions, but for transportation electrification to be truly green, the generating source for the electricity also must be clean. Smart bike-sharing is another way to shift transportation toward space-efficient, pollution-free, and health-promoting transport modes.

SOCIAL

IMPROVED SAFETY: Transmax's intelligent solutions system in Melbourne reduced accidents by 30% on the motorway and 60% in the City Link Tunnel ("City of Melbourne," n.d.).

REDUCED STRESS AND INCREASED COMFORT: By improving traffic flow, these transportation systems can reduce stress and increase user comfort while driving on busy roads ("City of Melbourne," n.d.). A system that allowed for dynamic traffic signals in Pittsburgh, Pennsylvania reduced travel time by 25%. This system included monitors that could measure incoming traffic by the second and send that data to each downstream intersection (Shaw, n.d., iii).[7]

INCREASED SATISFACTION WITH PUBLIC TRANSIT: Providing real-time public transit information in Seattle produced a number of positive outcomes, including greater satisfaction and more transit trips per week (Ferris, Watkins, and Borning 2010).

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[4] ("City of Melbourne," accessed 10/23/15) https://www.transmax.com.au/cms/streams-intelligent-transport-system/case-studies/city-of-melbourne-vic-roads-case-study

[5] (Shaw, n.d.) http://digitalenergysolutions.org/dotAsset/933052fc-0c81-43cf-a061-6f76a44459d6.pdf

[6] (Ferris, Watkins, and Borning 2010) http://homes.cs.washington.edu/~borning/papers/ferris-chi2010-onebusaway.pdf

[7] (Shaw, n.d., iii) http://digitalenergysolutions.org/dotAsset/933052fc-0c81-43cf-a061-6f76a44459d6.pdf (p. iii)

3. SMART GOVERNANCE

Smart governance a wide range of technologies, including water, waste, and gas management. Most of these technologies are primarily used by municipal utilities, but often they require citizens and residents to engage with the technology and change behaviors to realize natural resource savings. Many of these technologies can benefit from first considering the key recommendations in the Green Guidelines. For example, smart waste collection will be much easier and more effective if residential and commercial waste sorting is already in practice.

This section covers:

> Smart water management
> Smart waste collection
> Smart gas grids

RECOMMENDED TECHNOLOGIES

Smart Water Management

Smart water technology is similar to smart grid technology in that it uses smart meters, data, sensors, and more informed users to decrease water use, improve detection of leaks, and make the water system more efficient and cost-effective. This technology can reduce labor and maintenance costs, improve the accuracy of readings, decrease water consumption, and lower meter-reading costs (Bradley et al. 2013). For water management to be the most effective, investors should first ensure that all water fixtures are low-flow and already water efficient, as per the Green Guidelines.

Returns on Investment

Smart water management has a direct cost recovery mechanism through water savings and decreased maintenance costs. The case studies below show that smart systems not only save water, but also identify leaks and other costly problems. There is also the possibility of increasing water rates for users to support smart water meters, with the expectation that users will save even more money by using the technology. This is the model for financing the smart gas grids in France. Smart water management can also prevent unnecessary investment in larger facilities, as seen in South Bend, Indiana (Rocky Mountain Institute). An important caveat: one cannot assume residents with more information will necessarily use less water because behavioral changes often take more than just installing technology (Robinson 2014). The best case scenario is It is difficult to calculate potential water savings from a smart water system because the gains lie at the intersection of behavior and technology. Hence, cities should use pilot projects or small-scale interventions to understand how smart water management can induce behavioral changes.

Case Studies

The case studies in this section will cover smart irrigation in Barcelona, a smart water management system in Singapore, and a network of smart sensors and valves in South Bend, Indiana.

SMART IRRIGATION IN BARCELONA: In Barcelona, an internet-controlled system connects 178 irrigation points. In a city where water scarcity is a real issue, the smart water system provides live data on humidity, temperature, wind velocity, sunlight, and atmospheric pressure, which allows gardeners to make better decisions and avoid overwatering. The system automatically stops when it rains and adapts to the wind so that water does not fall outside the irrigation area. The staff of Barcelona Parks and Gardens uses a tablet to inspect the health of the vegetation every day ("Telemanaging Irrigation"). The first phase of the project cost $382,200, but the city has cut water use by one-quarter and saves $555,000 USD per year. The payback period for this technology was less than a year (Laursen 2014).

WATERWISE IN SINGAPORE: WaterWiSe is a technology that can be used by utilities to improve system management and operation by providing integrated measurement and analytics. WaterWiSe uses data from WaterWiSe multi-probes (or other in-situ sensors), SCADA (supervisory control and data acquisition) data, and operational information (valve closures and pump schedules) to perform analytics and pinpoint problems. The probe can sense hydraulics (pressure, flow), acoustics (hydrophone), and water quality (pH, oxidation reduction potential, and conductivity). If there are any abnormal events, the system sends an email or text message to each subscriber. Data is transmitted at 5- to 15-minute intervals. The system can also create demand predictions, analyze water age and water source, and valve operation simulation. In Singapore, WaterWiSe has been useful in the key areas of

- Pressure anomaly detection and localization
- Post event analysis to understand what may have contributed to a particular burst or leak event
- Pressure characteristic analysis – Singapore's PUB has been able to see the characteristics of any normal or abnormal events;
- Troubleshooting – Real-time data has given informative feedback to help quickly isolate complaints of low pressure. For example, a commercial customer complained of lower pressure but the WaterWiSe node did not detect any abnormal activity. It was quickly determined that the customer's building tank was too small to supply during peak consumption.
- Real-time modeling and sensor placement (MIT).

IMPROVED WATER MANAGEMENT IN SOUTH BEND, INDIANA: South Bend began investing in smart valves and sensors at 116 locations in 2006. However, the amount of data and processing needed to make use of the data exceeded the staff's capacity. The city wanted to optimize its water distribution and treatment system, which includes 600 miles of piping and 550 miles of sewers, so its planners worked with IBM and a professor to automate and improve the city's ability to use the data. These measures include:

- Develop economically based algorithms that can be proactive in monitoring weather and optimize the flow of waste water
- Program the smart valves so they can dynamically act on data from weather and water sensors
- Deliver real-time and historical data in heat maps and historical graphs so that workers without statistical knowledge can still use the data
- Deploy the IBM Intelligent Operations Center so that the city can dedicate fewer workers to the IT infrastructure

These upgrades generated immediate benefits. According to Nucleus Research, the payback for this project was 1.3 years with a return on investment of 123%. On average, the city saves $326,321 per year, due to four key benefits:

- Reduced maintenance costs because the city could now take action on sewer problems before they reached critical limits
- Avoided costs of building new storage facilities because the city could monitor the system in real-time
- Reduced number of incidents that incurred government fines from 30 to only one or two incidents per year
- Improved public health and safety by reducing dry weather overflows by 95% and increasing capture and treatment by 23% (Rocky Mountain Institute).

Smart Gas Grids

Gas monitoring connects the household gas meter to an Internet Protocol (IP) network and provides remote information on usage and status. Similar to smart water management, this can reduce labor and maintenance costs, improve the accuracy of readings, decrease gas consumption, and lower meter-reading costs (Cisco 2014e). There are predictions that the global smart gas market will be worth $11.3 billion by 2019, with a compound annual growth rate of 11.4% (Rohan).

Returns on Investment

Financing for smart gas grid technology is very similar to that for smart water or smart grid technologies. There is a cost recovery mechanism through decreased gas use, but these would mostly benefit residents and not the government. The smart gas grid in France was financed by a slight increase in gas rates. As with the metering of any resource, decreased use also depends on behavioral changes. Hence, this technology could be paired with an awareness campaign to encourage residents to conserve gas.

Case Study

GAZPAR – SMART GAS GRID IN FRANCE: The Gazpar smart meter measures gas use in residential homes. In France, they plan to install 11 million meters equipped with a radio communication module by 2022. This will be managed with a communication infrastructure system and information system that can manage meter readings every day. The financing mechanism for this project will be through a distribution tariff that is about 0.3% of each customer's energy bill. However, field tests of the gas meter in the United Kingdom and France showed that the meters save 2-3% of gas consumption, which more than makes up for the tariff cost for the gas users (Metering International 2013).

Smart Waste Collection

Waste is already costing cities in China a significant portion of government revenue. In Beijing, the cost of waste management accounted for 2.1% of municipal revenue in 2014.

Smart waste collection can include a number of technologies. One of the most commonly used technologies is fleet optimization to cut down on the cost of waste collection. Another one of the more recent and successful are trash bins with sensors, notably BigBelly's, which use sensors to alert waste pick-up fleets when to collect trash from the bins. Fleet optimization and the technology from BigBelly are covered as case studies below.

Returns on Investment

Smart waste collection can offer direct returns on investment through fuel savings and decreased labor costs. It is important for the municipality to analyze the costs because there have been cases where smart waste collection did not save money. These cases often involve smaller cities or university campuses where the number of trash bins might not warrant the upfront costs. It might also be the case that urban areas that are extremely dense find that trash pick-up must be so regular that optimization only garners marginal improvements.

Case Studies

The case studies in this section cover BigBelly trash compactors in Philadelphia and the application of fleet optimization software in Oklahoma.

BIGBELLY TRASH COMPACTORS: In 2009, Philadelphia replaced 700 public wire trash baskets with 500 BigBelly solar trash compactors. Before, the city government was making 17 trips each week to empty 700 regular baskets throughout the city center, at an annual cost of $2.3 million. With the 500 solar-powered compactors, the city now only makes five trips a week, at a much lower annual cost of $720,000. This means annual cost savings of 70%. The city will save $13 million in cumulative collection cost savings over the next 10 years, net of the equipment cost (The Joint U.S.-Brazil Initiative on Urban Sustainability 2012). In general, BigBelly's solar trash compactors have a payback period of about 3 years (Kramer 2011).

FLEET OPTIMIZATION IN STILLWATER, OKLAHOMA: Stillwater's Waste Management Division services 13,000 trash pick-up points. FleetRoute is a GIS-based modeling software for routing. It can optimize around route times, area routing, and service days. It can reduce the cost of updating routes and also integrate with customer billing and service systems (GBB 2015). Before using FleetRoute, Stillwater's Waste Management Division's drivers primarily completed routes based on memory. By optimizing routes, Stillwater was able to increase the number of homes serviced per day by 30%. The division has also saved fuel and balanced the use of labor on their various routes (GBB 2015).

BENEFITS

ECONOMIC

REDUCE OPERATING COSTS OF UTILITIES: For smart water management, utilities can see payback periods of 3-5 years by installing smart water systems, especially those with high meter-reading costs, according to Luis Pizano, a Principal Consultant with Black and Veatch (Pizano). Costs can decrease due to streamlining billing processes, designing better rate structures, and improving leak detection (DeLay). Smart waste collection can cut costs by reducing the number of times that the municipality must pick-up waste.

ENVIRONMENTAL

> **REDUCED WATER USE:** Data from smart water systems can improve leak detection, boost efficiency, enhance rate design, and create behavioral incentives to use less water (Boulos

and Wiley 2013). For example, Barcelona is saving $58 million annually from using smart water technology (Cisco 2014e).

REDUCED ENERGY USE FROM TRASH PICK-UP: Smart waste collection technologies can minimize trash pick-ups by alerting officials when to collect trash from full bins. In the example of BigBelly, the city cut trips from 17 per week to five per week. This reduces fuel costs and vehicle emissions.

DECREASED USE OF LANDFILLS: Smart energy recovery can divert waste away from landfills and use it instead for energy generation, like waste gasification.

SOCIAL

MORE EFFICIENT MANAGEMENT OF USER COMPLAINTS: In both Washington D.C. and Singapore, customer complaints are better managed with automated meter readings and/or smart water technology. This can also decrease water authority costs because they need less staff time to deal with both user and system problems (ITU News 2014). Data also gives utilities a more granular look into user data, which in general can help better serve customers (DeLay, n.d.).

4. SMART ENERGY MANAGEMENT

Smart energy management will allow cities to take advantage of valuable decentralized energy resources to make the grid more reliable, affordable, and environmentally clean. New smart technologies allow customers to integrate their building heating, car charging, and other electricity end-use with grid management. When paired with on-site generation or storage, customers become both energy producers and consumers that can interact in real-time with the utility and other customers (Rohling 2015).

Increasing penetration of renewable and distributed resources can greatly aid in the effectiveness and use of smart energy management. Hence, cities should consider any ways in which renewable and distributed resources can be added to their energy mix first, as per the Green Guidelines, before considering smart energy management technologies.

New technologies like home automation, distributed generation, or battery storage can provide the same—and in some cases better—grid services as more traditional technologies (i.e. power plants, distribution infrastructure), but at much lower cost. Capitalizing on the full potential of these technologies can help customers save money.

According to PricewaterhouseCoopers study, 94% of the world's energy suppliers believe that business models for energy will be significantly altered or transformed towards smart grid technologies by 2030. This section covers the following technologies:

- Smart Grid Technologies
- Smart Lighting Systems
- Building Management Systems

RECOMMENDED TECHNOLOGIES

Smart Grid Technologies

There is an array of different smart grid technologies that can be implemented at a number of levels. For cities, the distribution level, and consumption level technologies are all possible options.

- **Transmission level:** Enhanced integration of synchronized phasor measurement units, high temperature superconductor cables, flexible AC transmission, advanced relay protection, and high voltage DC.
- **Distribution Level:** Advanced metering infrastructure, advanced sensors, automated reclosers, automated voltage/VAR control, and substation energy storage.
- **Consumption level:** Home area networking, autonomous demand response, smart appliances, plug-in hybrid vehicles, distributed generation, and integrated building controls.

Smart grid technology vendors can cover a wide range of services.

A survey of local governments and private companies found that smart electric grid technologies were the most important technology that cities should incorporate, with building management systems ranking second.

Better rate design that captures the full value of smart grid technologies is one key to optimizing electricity use. This value varies based on time of production or demand, location, and physical attributes (Glick, Lehrman, and Smith 2014). For example, time-of-use pricing will encourage high-energy consumption customers to use less energy when it is most expensive and reward low-energy consuming consumers. Smart technologies like Nest thermostats can help customers take advantage of these pricing programs without constantly monitoring their energy consumption.

Capitalizing on the full potential of these technologies can help customers save money. However, before any of this can happen, the regulatory framework and market structure must be developed. Another key component of effective smart grid technology will be good software that can help utilities manage electricity use.

Utilities and municipalities also have roles to play in enabling system optimization by upgrading grid infrastructure. For example, a smart meter program can lay the groundwork for the kind of dynamic pricing that saves customers money. Distributed resources such as microgrids can be useful for critical infrastructure like hospitals. Grid managers should ensure that distributed resources remain connected to the grid by providing a platform for rewarding their full value and coordinated management (Rocky Mountain Institute). Electricity systems function best when there is a broad portfolio of resources that can be managed in an integrated manner.

Returns on Investment

One problem that utilities constantly face is procuring electricity that is more expensive during peak hours, which drives up the cost of service and may threaten reliability in extreme shortages. Smart grid technologies can be especially helpful in this area. By making demand more elastic, smart technologies give utilities increased flexibility to hedge against price spikes by shaving energy use during peak hours, or even avoid service disruptions. Even better, utilities that take advantage of elastic demand as a resource can also avoid building additional generators, which can require very capital-intensive investment. Pairing better rate design through differentiated and dynamic pricing is critical to make smart grid technologies cost-effective.

Case Studies

SMART METER USE IN ITALY: ENEL, a utility in Italy, operates a system that manages more than 30 million electricity meters. The ENEL Automated Meter Management system was developed in 2001 and consists of four main elements:

1. Electronic meters that read and manage energy readings remotely;
2. Data concentrators installed in every medium- and low-voltage station that collects data from the meters connected to it;
3. Central system that manages and collects the data from the data concentrators;
4. Operations center that manages the acquisition of measurement data and all contracts.

The total investment of the system amounted to more than €2 billion (Giordano et al. 2011). ENEL benefits by being able to offer more types of services, and now provides a number of tailored tariffs to the final user to improve system management. Tariff measures and energy savings are helping ENEL recover its costs (Ludwig-Bölkow-Systemtechnik et al. 2012). More specifically, the project encouraged 57% of customers to change their energy consumption behaviors in the form of delaying use of appliances until evening (29.3%), avoiding simultaneous use of different appliances (11.9%), switching off appliances instead of leaving them in standby (7.5%), and using less of their larger appliances (6.6%). Moreover, the ability to introduce time-based rates can reduce energy consumption by 5-10% and shift 1% of the energy demand to non-peak load times (Jozef Stefan Institute). A number of countries in Europe plan to have 100% smart meter installation by 2020.

NEST LEARNING THERMOSTAT: The Nest Learning Thermostat is a way to leapfrog many of the "smart meter" technologies by collecting energy use information from consumers directly through a wireless connection rather than having the utility install a meter. The Nest Learning Thermostat works by learning about your energy use habits and preferences and then programming a schedule it follows for controlling the user's HVAC system (Nest 2015). Three studies of Nest Learning Thermostat (two independently funded, designed, and evaluated and one conducted by Nest) found heating use savings of 10-12% (Nest Labs 2015).

AMSTERDAM'S VEHICLE-TO-GRID: Research shows that vehicles are only used for driving 4% of the time (Bohnsack, Van den Hoen, and Oude Reimer 2015). The logic behind a vehicle-to-grid system is that in the remaining 96% of the time, EVs could be used for a secondary function: integrating with the electric grid. Amsterdam's goal is to balance solar energy use and consumption by employing the batteries of EVs to store energy generated during the day and then use it during peak hours in the evening (Larson 2015). This is done by having solar PV's charge electric vehicle batteries during the day. This can also increase an individual's use of renewable energy from 30% to 60%. Before the program was implemented, only 17% of the energy consumed by participants was clean energy, but by March 2014, after program implementation, the percentage rose to 73% ("General Results"). The program is working with not only EVs, but also electric boats.

Smart Lighting Systems

Smart lighting systems are some of the most commonly installed smart technologies. They allow the city to control streetlights from a centralized system and can integrate with other smart technologies, such as sensors or even public wireless. Smart lighting systems usually include capabilities for dimming and often coincide with the installation of highly efficient light bulbs. Success rates have been high and almost every city has the ability to save energy costs while improving their public lighting systems.

Returns on Investment

Smart lighting systems have relatively quick cost recovery times due to direct energy savings. These systems also save municipalities a significant amount of labor and maintenance costs as well. For example, rather than having to check every streetlight in person for maintenance, a smart lighting system alerts the municipality when a light goes out. Smart lighting systems also allow cities to improve the urban environment by having brightness options, which can improve safety and livability.

Case Study

SMART STREET LIGHTING IN OSLO: The system began in 2011 and includes 650 process stations that monitor more than 65,000 streetlights. The stations and lights allow officials to control lighting levels and timing of light adjustments through computers, tablets, and even phones. The system also gives officials maintenance data so they can better service the system. Previously, city officials had to drive to a light to see if it was still on; now, officials can check the status of all 65,000 lights via their computers, which reduces maintenance costs. Moreover, the city can save energy by dimming lights throughout the day, depending on the amount of natural light; the previous system was either fully on or off. One challenge for the city was ensuring that the process stations were rugged enough to withstand the harsh winters in Oslo, but that was solved by reconfiguring the cable layout. The total cost of the system was $3-3.3 million USD and the city is now saving about $1.3 million USD on electricity costs per year. Hence, the payback period for the system is less than 3 years, not including the lower maintenance costs (Cisco 2014f).

GUANCHENG'S STREET LIGHTING RETROFIT: The Dongguan Guancheng Utility Service Center was responsible for replacing 12,500 street and alley lights. The utility engaged in an energy performance contracting model with Guangdong Rongwen Energy Service and Technology Group (Rongwen). Under this agreement, the utility pays Rongwen 90% of the energy savings each month. Monthly savings are used to offset the cost of the retrofit, which allows officials to remotely monitor and manage the entire street lighting network through software, as well as manage individual lights. Each LED streetlight's data is sent to a server through a public wireless network.

The 12,500 LED streetlights decreased annual energy use by 70%, lowered installation costs by 20%, and reduced maintenance costs by 40%. The project also delivered qualitative benefits, such as improving lighting quality, improving safety, beautifying the city, and enabling the ability to notify the public of emergency situations via the streetlights (LonMark International).

Building Management Systems

Building management systems have been proven again and again to ensure that energy savings in buildings, particularly green buildings, are fully achieved. Building management systems may simply control lighting or may also include the HVAC system.

Returns on Investment

Building management systems can have reasonable payback periods and help property managers improve overall building operations. For regions with high heating or cooling bills, building management systems can easily recover costs through technologies such as detecting room occupancy to set the amount of climate control needed. Especially for property management companies that operate across a larger number of buildings, scaling efficiencies can make smart building management very cost-effective.

Case Studies

COMMERCIAL BUILDINGS IN WASHINGTON D.C.: A case study of three large commercial buildings in Washington D.C. found that large amounts of electricity in commercial office buildings do no useful work and do not contribute to the operation of the building or to the tenant's needs. Real-time energy management led to a 13.2% reduction in electricity use in each of the three commercial buildings. The project cost for year one is $144,320 and the recurring cost is about $65,520 per year, while the energy management initiative saves the buildings $218,703 per year, meaning costs are recovered even in the first year of implementation. This case study shows that using real-time energy management initiatives is not always based on installation of advanced technology, but also depends on a better understanding of how energy in the building is used (Henderson and Waltner 2013). A key part of the initiative was the installation of a new building management system in one of the commercial buildings. The cost of this system is $79,000 and the payback period is 10 years.

BENEFITS

ECONOMIC

DEMAND-SIDE POLICIES YIELD ENERGY SAVINGS. Smarter energy consumption can avoid wasteful energy use, which results in consumer savings on energy bills. This also can reduce capital costs by helping to avoid peak power spikes, which every electricity system must be built to accommodate.

GREATER ENERGY RELIABILITY AND QUALITY: Smart grid technologies can reduce power interruptions and provide a higher quality (more stable) electricity supply (Electric Power Research Institute 2010).

GREATER COST CERTAINTY: Microgrids that rely principally on renewable energy avoid the price variability inherent in reliance on fossil fuels.

CAPTURE SAVINGS FROM GREEN BUILDINGS: Building management systems enablegreen building managers to capture the full energy and water savings potential of their properties.

ABILITY TO IMPLEMENT DYNAMIC PRICING STRATEGIES: Smart meters in particular allow utilities to impose more rational pricing policies, which lead to reductions in energy use and, oftentimes, more revenue for the utility.

ENVIRONMENTAL

ABILITY TO OPTIMIZE ENERGY SYSTEMS IN WAYS THAT USE MORE VARIABLE RENEWABLE SOURCES: Smart grid technology allows energy sources that have more variability, such as solar and wind, to be intelligently connected to the grid (2010).

DECREASED EMISSIONS: Smart electricity technologies can decrease electricity consumption while also increasing the use of renewable and clean sources.

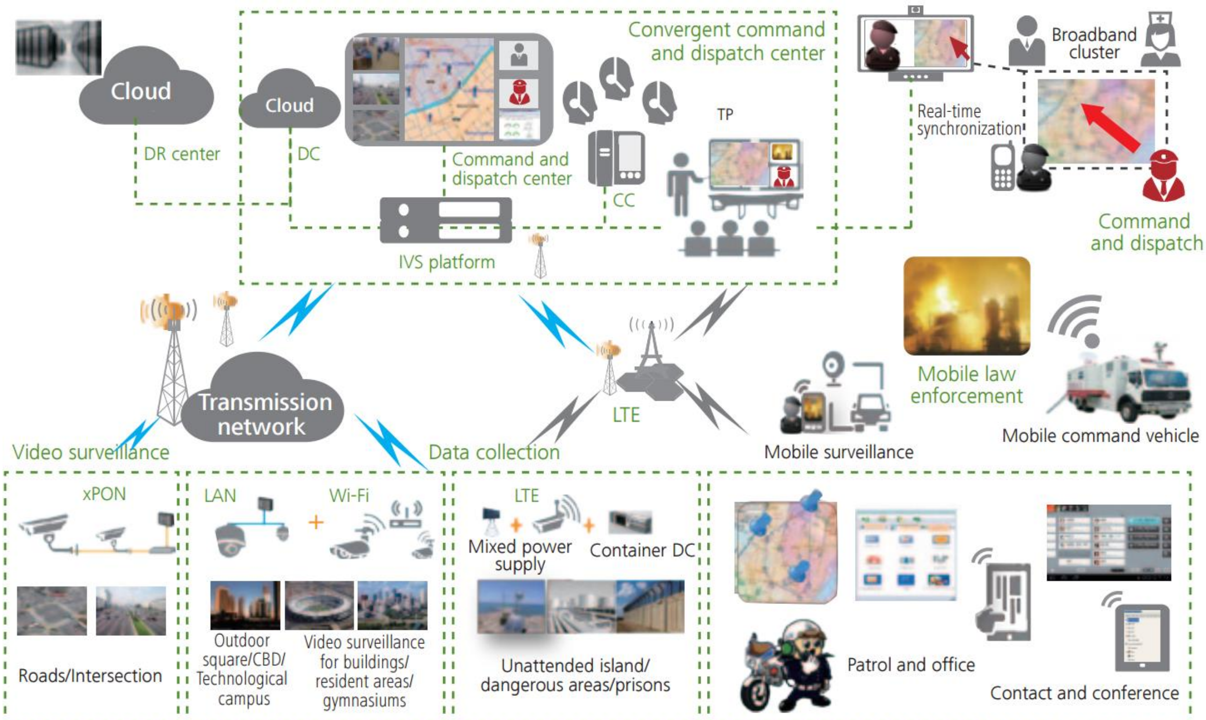
SOCIAL

IMPROVED RELIABILITY OF ENERGY: Local generation can improve reliability. For example, in New York City, backup generators and islanded mini-grids helped parts of the city maintain electricity after Hurricane Sandy (Pyper 2013).

5. SMART SAFETY

Smart safety can mean targeted monitoring of a specific neighborhood, or it can mean a security system that covers an entire city. Cities have the option of scaling a smart safety system to suit their needs. The graphic below shows a comprehensive smart safety system as suggested by Huawei.

Figure 5. Comprehensive Smart Safety System (Source: Huawei)



Moreover, police are often overstretched and crime can be difficult to predict. Smart technologies can be used to monitor high-crime areas and increase safety in public spaces. They can also improve urban resilience to natural disasters or fires, which can impose huge economic costs if a city is unprepared. This section covers two main technologies:

- Smart surveillance cameras
- Smart emergency response systems

These technologies are relatively mature, but must be tailored to individual cities. For example, cities might be vulnerable to different kinds of natural disasters or plagued with different types of crime. It is important that the local government first identifies the challenge the city is facing, then selects the right technology to respond to that challenge.

RECOMMENDED TECHNOLOGIES

Smart Surveillance Cameras

Smart surveillance cameras can optimize the capacity and response time of emergency services, improve safety conditions of mass events, and provide surveillance of public places.

Returns on Investment

It is difficult to put a value on crime, but it costs cities in a number of ways. Increasing blight, decreasing property values, and lower business investment also make cities a less attractive place to live. Hence, safety is an invaluable asset in which cities should invest. Smart surveillance technologies can help cities create safe spaces while decreasing labor and operation costs.

Case Study

INTEGRATED SECURITY IN MEXICO CITY: Thales, a private company, and telecommunications operator Telmex have implemented a security system that includes 8,000 video cameras, gunshot sensors, automatic license plate recognition cameras, aerial surveillance drones, and emergency call points. These subsystems are controlled by five local centers that report to one city-level C4I (command, control, communications, computers, and intelligence) center. According to Telmex, the system has generated substantial benefits: crime in the metro area has fallen by 80%, car thefts have decreased by 8%, and criminal activity is down 35% in previously neglected areas of the city (Thales Group).

Smart Emergency Response Systems

Smart emergency response systems use data to improve a city's ability to preempt, mitigate the effects of, or respond to an emergency. Smart emergency response systems may involve:

- Use of sensors on the fire ground to assist in situational awareness and personnel location
- Increased collection and utilization of data before the incident to aid in effective use of personnel and equipment
- Enhanced interoperability between data systems
- Development of intelligent systems to assist with decision-making (Fox 2015)

Smart emergency response systems can be set up to respond to fires, earthquakes, flooding, and other emergency events.

Returns on Investment

Emergencies can be catastrophic for cities, both socially and economically. For cities with relatively frequent natural disasters, a smart emergency response system can be a very strategic investment that will pay off over the long term. For emergencies such as fires, a city can compare current costs of responding to these emergencies with the cost of upgrading to a smarter system. For example, the cost of fires in New York in terms of building damages and firefighter's lives warranted the development of a more sophisticated system.

Case Studies

This section covers case studies from New York and Japan.

NEW YORK CITY'S FIRECAST 2.0 SYSTEM: The New York City Fire Department has been using the Risk-Based Inspection System, an Oracle-based program that possesses data-mining capabilities. The centerpiece of the tool is an algorithm called FireCast, which organizes data from five city agencies and 60 different risk factors. This algorithm is then used to create lists of buildings that are most vulnerable to fire (Heaton 2015). An upgrade to the system, FireCast 3.0, is expected to be released before the end of 2015. FireCast 3.0 will analyze 7,500 factors. FireCast 3.0 will also look at the characteristics of each of the city's 49 battalion districts (Roman 2014). With the collaboration of key government agencies—the departments of Health, Finance, and Environmental Protection—the city has created a central data hub to which all the departments can feed information. Previously, much of the data on the buildings was stored in a non-electronic card system and the different departments had incompatible data structures. After FireCast 2.0 was implemented, the number of building violations in the city went up by 19%, and after the first 60 days, the number of violations was still up 10% (Roman 2014). Moreover, since FireCast 2.0 was implemented, 16.5% of new fires were in buildings that had been inspected within 90 days, meaning FireCast was able to predict which buildings are more at-risk for fires (Roman 2014). The fire department also expects that FireCast will help them identify how and why fires start, which can eventually improve laws and regulations.

EMERGENCY RESPONSE AND COORDINATION IN JAPAN: For earthquake impact management, Japan's solution, developed with NEC, includes observation systems, information gathering capabilities, data analysis, decision-making aids, and an intelligent warning system. An important aspect of this management system is Japan's comprehensive emergency warning system, which captures data from observation systems and feeds it into data processing platforms. This system then generates accurate information that can be transmitted to individuals and companies. Emergency response services (policy, fire, hospitals) can use this information to proactively respond to emergency situations (GSMA and Japanese Meteorological Agency 2013). In March 2011, the system detected primary waves (P-waves, the first shockwave) which gave Japan a window of 29 seconds before the S-waves (secondary waves) struck. The system allowed Japan to notify mobile users, broadcast information via television and radio, and alert trains and airplanes. The response ensured that no trains derailed, all flights landed safely, and no bridges collapsed (2013).

BENEFITS

ECONOMIC

> **LOWER OPERATING COSTS FOR POLICE FORCES:** Integration of police forces can reduce redundant work and help different police forces work together.
> **LOWER IMPACT FROM EMERGENCIES:** Japan's earthquake system allows it to minimize impacts by rapidly alerting transit, flights, and infrastructure agencies of shocks before they happen.
> **LOWERED PROPERTY DAMAGE:** Smart firefighting systems, such as FireCast, allow firefighting departments to better understand and anticipate fire emergencies (Roman 2014).

SOCIAL

REDUCES DANGER IN CASE OF FIRE: As shown above with FireCast, firefighters are safer when they have information on the layout of the building and when buildings are properly inspected. The same applies to people who are in the building at the time of the fire (2014).
REDUCE CRIME AND VIOLENCE: Research shows cameras reduced crime in Baltimore and Chicago. In Baltimore, violent crimes were reduced by 22% due to installation of surveillance cameras (La Vigne et al. 2011, vii). In Chicago, the smart video system saved the city four times the cost of the system (La Vigne 2013).
IMPROVES RESPONSE TIME FOR POLICE FORCES: By consolidating information and communication platforms, police forces can decrease response times. Neighboring jurisdictions can use shared information to catch criminals even when the crime occurred in a different area. In Mexico City, a smart security system improved response times by a factor of three (Thales Group).
IMPROVED ABILITY TO COOPERATE WITH NEIGHBORING JURISIDICTIONS: By consolidating information and communications platforms from neighboring jurisdictions, police forces can better cooperate and improve law enforcement.

6. SMART PUBLIC SERVICES

Particularly for large cities, citizens and residents need a way to communicate with the government. Smart public services can help people communicate with their local government in addition to expand the local government's ability to understand and better serve its people. This section will cover five technologies:

- Web-based Public Services
- Public Wireless
- Public Service Kiosks
- Remote Patient Monitoring
- Digital Learning

RECOMMENDED TECHNOLOGIES

Web-Based Public Services

Improving communication between residents and the local government can greatly enhance living conditions in a city. Web-based public services can make residents more likely to report issues and use government services.

Returns on Investment

The returns on providing web-based public services for the local government can come in the forms of increased labor, reduced operation and maintenance costs, increased resident satisfaction, and expansion of services provided. The level of return can wholly depend on the frequency of use and effectiveness of the web-based services. For many of the services in the case studies outlined below, the government was also able to cut down on paper processing and increase automation in responding to service requests.

Web-based services can also be a way for the residents to communicate directly to the local government. For example, many cities use mobile-based applications for residents to report potholes, burnt out streetlights, trash, or any problems in public spaces. For these services, resident participation is a way to outsource government responsibilities and make them more efficient.

Moreover, urban residents can gain greatly in terms of time saved from web-based services. Instead of having to make a trip to accomplish something in person, they have more flexibility by being able to do it over the internet.

Case Studies

The case studies in this section will cover Stockholm's e-services for residents and Barcelona's mobile public services.

STOCKHOLM'S E-SERVICES FOR RESIDENTS: The City of Stockholm spent about $90 million USD over five years in website development to provide e-services for its citizens. Based on the project's analyses, the e-services program will pay for itself within four to five years. The launch of the platform included a phase where only a beta version was released, and users could vote for the services most useful to them, offer opinions, and ask questions. This beta method attracted a lot of attention and the city was able to address many of the initial issues with the website. The service re-launched in 2012 and the city offered a new slew of services including applying for residential parking permits, scanning radon gas levels in residences, applying for pre-school and kindergarten, and showing vacant housing in Stockholm. Services like booking one's wedding at the City Hall and applying for pre-school were especially popular, and 90% of weddings are now booked online and 90% of parents are now applying to pre-school online as well (New York City Global Partners 2012).

BARCELONA'S MOBILE PUBLIC SERVICES: Barcelona provides a number of services through a mobile application: Citizens can access information about parking tickets, car-towing destinations, and even request public subsidies for non-profit activities ("Presidents, citizen relations"). To create this, the government developed Urban Habitat, a government-wide management structure that collaborates across water, energy, human services, and environment agencies. The Smart City Personnel Management Office further cemented the collaboration, which centralized authority of all projects related to smart city applications. Companies also have access to augment the web-based services. For example, FabLab Barcelona, an organization oriented towards incubating new technologies, offers a private platform that promotes the use of electric vehicles with Barcelona Urban Innovation Lab and Dev (BUILD) through a public-private platform.

Public Wireless

Public wireless systems can make public spaces more attractive, allow people to better engage with each other and local businesses, and expand equity in the telecommunications sphere to underserved communities.

Returns on Investment

Public wireless systems can be completed in collaboration with the private sector. There are a number of opportunities for selling advertisements or pairing the hotspots with advertising monitors that give users information about local businesses. Local governments should seek the option of either working with private companies or selling advertising or other components to fund public wireless systems.

Case Studies

COMBINING WIRELESS SERVICE AND SMART PARKING: This case study shows the ability to package multiple smart technologies. Located in Vancouver, Photo Violation's high-tech parking meters use high-bandwidth to transmit license plate photos. The photos sent to a parking management system would then be used to track parking times and violations. To get the bandwidth needed, Photo Violation combined their smart parking meters with providing wireless service at the parking meters. This made the technology more appealing to the municipal government while also improving Photo Violation's business model since they could now also charge the city a fee for providing wireless (Cisco).

Public Service Kiosks

Public service kiosks are not an end-all for helping government interact with residents, but it is a productive entry point for the local government to better understand the needs of its residents. Public service kiosks can be multi-functional. They may answer inquiries, sell public transit tickets, or serve as emergency response systems. In general, public service kiosks have been paired with mobile applications so that users have access to special features. Kiosks can also help people who lack access to mobile phones.

Returns on Investment

Public service kiosks can have simple returns on investment through advertising or collaboration with local businesses. For these transactions, kiosks can collect small fees to pay for the convenience of the transaction. Local businesses might also be interested in helping deflate the costs of public kiosks since they can use them for advertising. There is potential for the local government to create public-private partnerships to implement public service kiosks. For example, kiosks could sell concert tickets, help users book tables at restaurants nearby, or sell public transit tickets. This could mean increased revenues for these relevant businesses and organizations. Moreover, kiosks can reduce local government's costs by streamlining residents' requests, which in turn can identify problems and improve quality of life.

Case Studies

CITIZEN ENGAGEMENT IN BARCELONA: Barcelona's "e-government" appears in the form of kiosks that improve citizen engagement. There are 11 kiosks in the city that handle an average of 4,500 daily users. These kiosks are situated at different points in the city and allow citizens to resolve most of their administrative procedures. The requests from the kiosks represent 60% of the all city requests received. The kiosks allow citizens to interact with the government, even outside normal business hours, which helps the government better understand the needs of citizens. The services and procedures available from the kiosks are also available online (Barcelona Smart City Tour).

KANSAS CITY'S KIOSKS: This case study includes installing 25 kiosks with information, such as city news and announcements, services, current events, transportation services, local business information, and entertainment in collaboration with Cisco. The kiosks can also become alert systems in the case of emergencies. A smart phone application can link to the kiosks so users can finish transactions on their own devices if there is an interruption of kiosk use. The kiosks will also have advertising, which means a new revenue source for the city, especially the Kansas City Streetcar Authority (City of Kansas City 2015).

Remote Patient Monitoring

One challenge studies show is that patients will choose not to seek care when care is too far away. Key technologies that address this issue are remote patient monitoring and telehealth. While remote patient monitoring and telehealth cannot replace the presence of a high-quality hospital, they can augment existing medical services. These technologies are proven to be cost-effective in a variety of contexts, but it is still important for local governments and hospitals to identify the best context for this technology to be used.

Returns on Investment

Returns on investment vary for remote patient monitoring and telehealth technology, but in general seem to be favorable for the investor. The returns are based on which specific technologies are used, the types of patients to which the technology applies, and the existing infrastructure with which the technology is used. In general, hospitals that offer in-home patient care can save costs on transportation and labor, as nurses and doctors do not have to be paid for the time spent travelling to see the patient.

For patients that live far away from where they obtain care, or if their illness makes travel to the hospital difficult, remote patient monitoring can improve the likelihood that they get the follow-up care that they need. Case studies also show that since remote care is easier to access, patients with remote monitoring have improved more quickly than patients without access to the technology.

Case Study

REMOTE PATIENT MONITORING FOR CARE TRANSITION INTERVENTION (CTN) PROGRAM: This pilot program in Texarkana, Texas was undertaken to reduce hospital re-admissions of high-risk patients diagnosed with chronic illnesses such as congestive heart failure, coronary artery disease, and hypertension. The Care Transition Intervention Program teaches patients new skills for self-care when they are transitioning from the hospital to the home. The program was overall successful but they still faced key challenges. Some patients did not want a medical practitioner coming into their homes, while others lived so far away that the CTN practitioners might spend hundreds of hours total on all of the commutes. Another hurdle was that the CTN practitioners often did not get sufficient face time with the patients, which affected the quality of their care. By using a Remote Care Management Platform, patients used Bluetooth-enabled personal health devices (weight scale, blood pressure monitor, and pulse oximeter) and an Android tablet to send biometric data and communicate with caregivers. The return on investment for the 44 patients who completed the program was about $2.44 for every $1 spent. The average cost of care for the patients also dropped to an average of $1,231 from $12,937 per person. Most importantly, 95% of patients adopted the technology, of which 95% reported overall patient satisfaction (Webster, Clifton, and Ford).

Digital Learning

There are a variety of terms to describe digital learning: e-learning, virtual learning, online learning, and blended learning. Blended learning, which combines face-to-face learning with online and digital resources, is the most common way that digital learning is used.

Typically, schools subscribe to or buy online curricula, or use open-source platforms to create their own curriculum.

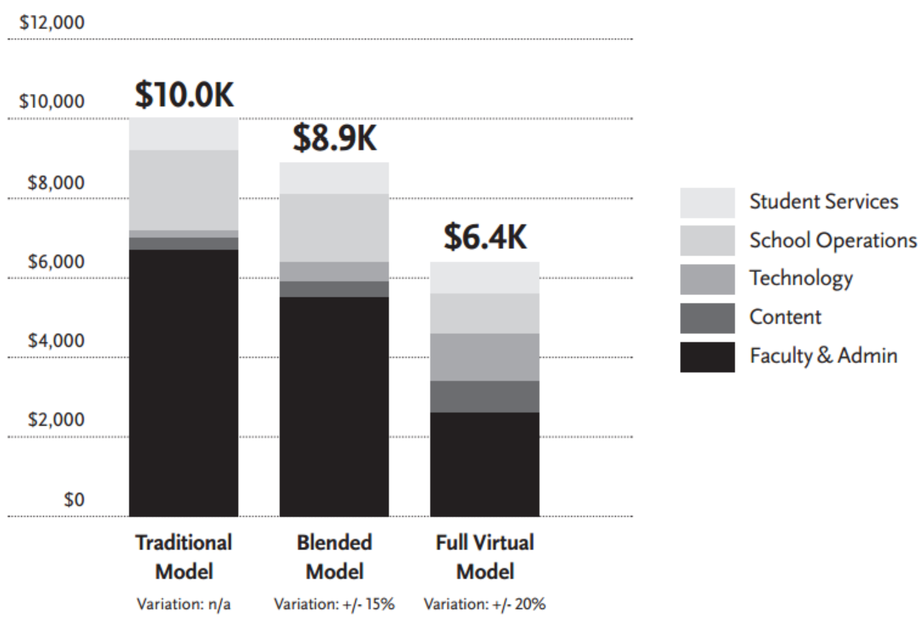
There is also a large spectrum in how much time schools decide to allow their students to spend using online resources as opposed to face-to-face learning. In the United States, teachers commonly express interest in integrating online learning into their curriculum, though there are also school-wide efforts to improve technology integration. Existing case studies seem to focus on short-term application of digital learning, making it difficult to extrapolate long-term effects (i.e. 5-10 years) of students that use more digital resources than others do.

Returns on Investment

The format of teaching has not changed in decades. Typically, there is one teacher at the head of a classroom responsible for teaching a number of students. The logic of online learning is typically to help teachers cut down on this type of classroom time by turning to online and interactive resources. This way, teachers can spend more time in groups or one-on-one, maximizing their time with a smaller number of students. There might be transition costs in helping teachers switch to this new type of classroom model.

The figure below shows the cost of a traditional model of education (all face-to-face), a blended model (face-to-face and digital), and virtual (fully digital). The biggest difference in cost between the three different models is the cost of labor for faculty and administration, though this might vary in China.

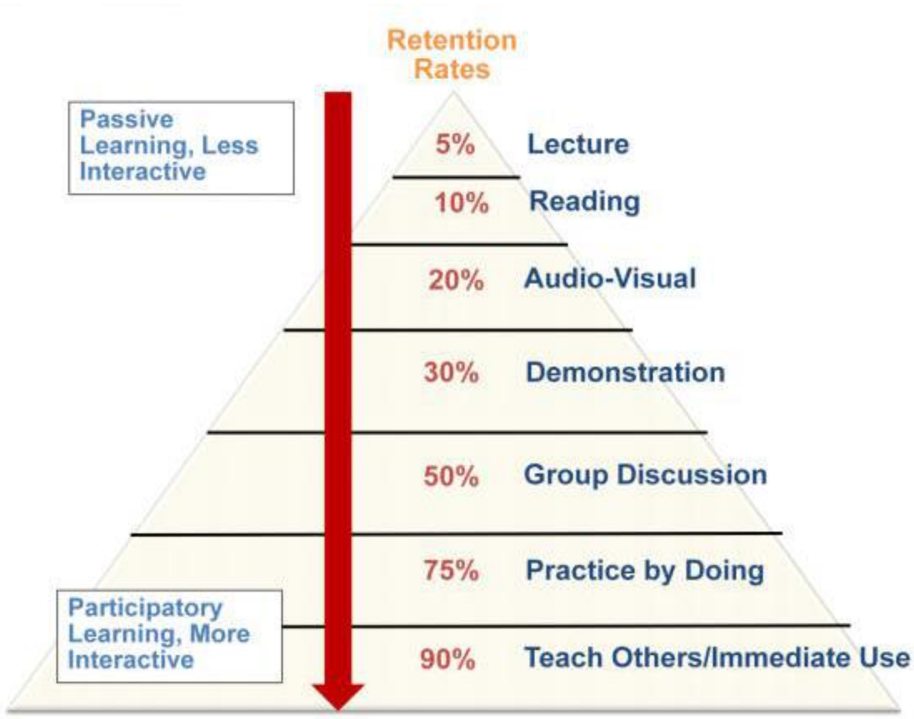
Figure 6. Estimated Per-Pupil Expenditures of Digital Learning Program (Battaglino, Halderman, and Laurans 2012)



More so than many of the other smart technologies, human behavior and response plays a very large role in online learning. The quality of the teacher, the quality of the curriculum, and the enthusiasm of the students can all have a huge impact on the outcomes. The amount that schools choose to spend on each of these components will also influence the cost-effectiveness of a digital learning program.

Hence, when evaluating return on investment with digital learning, local governments and schools should consider what their goals are. For instance, studies have shown that retention rates are higher when schools use methods other than lecture to teach students. Digital or blended learning allows the teacher to free up time to engage in more group discussion and learning-by-doing activities. Digital or blended learning can also increase the amount of demonstration and audio-visual types of teaching. Hence, another key return on investment is the potential for increased learning retention.

Figure 7. Learning Retention Rates by Type of Teaching (Source: World Bank)



Case Studies

KIPP LA AND BLENDED LEARNING: KIPP Empower worked with consultants to create a blended learning curriculum for four kindergarten classes. This case study shows how integrating digital learning can be done in parallel with a re-vamping of the classroom model. The figure below shows the classroom setup that KIPP has integrated with their digital learning technologies:

Along with the use of technology, KIPP also uses a differentiated staffing model where a lead teacher, an intervention teacher, and an instructional assistant intervene at different points in a student's day. The intervention teacher and instructional assistant lead small groups and tutoring while the lead teacher focuses more on full-class teaching and mentoring to less experienced teachers.

KIPP created a rotational, blended classroom model where students cycle through different in-person and online instructional stations over a class period. As a result, the teachers at KIPP say they have a greater understanding of each student's learning experience. The teachers also have the ability to tailor content to each student's needs (Bernatek et al. 2012).

In terms of costs, the blended model has allowed KIPP to obtain more state funding but also spend less on teaching. The blended model has meant that KIPP can hire one less Lead Teacher per grade. The table below shows the overall financial impact of KIPP's blended learning model. Overall, KIPP expects to gain $965 per student per year (without counting upfront investments).

BENEFITS

ECONOMIC

> **IMPROVES EFFICIENCY AND CUTS COSTS:** Both remote patient monitoring and digital learning technologies can help schools and hospitals cut costs while improving health and education outcomes.
>
> **INCREASED LEARNING RETENTION RATES:** Returns on investment in education can increase when retention rates increase, which many case studies suggest can be a result of digital learning (Bernatek et al. 2012a).

ENVIRONMENTAL

> **IMPROVED MONITORING OF ENVIRONMENT:** Web-based public services can help residents more frequently communicate to the local government when there is an issue with greenery, pollution, or public spaces.

SOCIAL

> **IMPROVED EDUCATION AND HEALTH SERVICES:** Remote patient monitoring and digital learning can improve overall quality of education and health, as shown in the above case studies.
>
> **IMPROVED PUBLIC SPACES:** Applications that allow anyone, anywhere to notify public agencies of safety, sanitation, or other concerns can make public spaces more attractive, thereby increasing neighboring property values.
>
> **ABILITY FOR PUBLIC TO PARTICIPATE AND IMPROVE URBAN ENVIRONMENT**: Applications on public kiosks can allow anyone to communicate with the relevant government authority when they notice a problem or issue with waste, water, or public spaces. This also improves the government's ability to manage the public domain.

CONCLUSION

Currently, there are still many technologies with huge potential to help solve urban problems and optimize urban operations. Developers and operators of cities must work together and design the direction and goals of smart city development. They must choose the right technologies and achieve different goals at different phases of development. These guidelines focus on a few select technologies from successful case studies to push forward green and smart urban development.

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