



IMPACT OF POPULATION SHIFTS ON CRITICAL INFRASTRUCTURE

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SCOPE

The U.S. Department of Homeland Security (DHS)/Office of Cyber and Infrastructure Analysis (OCIA) produces Critical Infrastructure Security and Resilience Notes in response to changes in the infrastructure protection community's risk environment from terrorist attacks, natural hazards, and other events. This product examines the potential risks posed to critical infrastructure from shifting populations.¹ OCIA is specifically interested in determining whether population increases and decreases cause system strain on critical infrastructure in the Energy, Transportation Systems, and Water and Wastewater Systems Sectors and how that strain burdens communities and commercial entities. Examples in this note are drawn from open-source research of past and current population shifts and their effects on critical infrastructure assets.² Further analysis is under way to determine how lessons from these limited examples can be applied to other cities and regions of the United States experiencing population shifts.

OCIA has coordinated this Critical Infrastructure Security and Resilience Note with DHS/National Protection and Programs Directorate/Office of Infrastructure Protection/Sector Outreach and Programs Division, and Argonne National Laboratory.

KEY FINDINGS

- **Rapid population growth may increase the stress on an area's critical infrastructure when usage increases faster than new infrastructure can be built and existing infrastructure can be improved or retrofitted. Rapid domestic population growth in 2014 most commonly occurred in the South, the West, and in areas with shale oil production operations.**
- **Persistent population declines may shrink tax bases and decrease funding available to maintain, repair, and replace infrastructure. Persistent population declines are most commonly found in the Northeast and Midwest, especially along the Rust Belt.**
- **Population increases, which can occur rapidly, are difficult to predict. Population decreases can last for extended periods and affect infrastructure systems built decades earlier. Strategic planning, innovation, and timely mitigation plans can alleviate the sudden and long-term negative effects from population shifts.**

¹ For this study, "Population Shifts" are defined as local and regional increases and decreases in population caused by migration.

² Anecdotal evidence was identified through open source research to provide insight into past and current effects on critical infrastructure for three lifeline sectors: Energy (specifically Electric Power and Natural Gas Subsectors), Transportation Systems (specifically Highway Infrastructure and Mass Transit Subsectors), and Water and Wastewater Systems (specifically Water Distribution Systems Subsector).

OVERVIEW

The U.S. Census Bureau estimates that during the 1990s, the U.S. population grew by 13.2 percent and during the 2000s, by 9.7 percent.^{3,4} In 2010, the census estimated the population to be greater than 300 million.⁵ As of 2014, the census estimated the population to be 318 million.⁶ As the U.S. population grew from 1990 to 2010, certain regions experienced faster population growth than others, while other areas saw their populations decrease (Figure 1). More recently, between April 1, 2010, and July 1, 2014, 96 of the 381 U.S. metropolitan statistical areas had a growth rate of 5 percent or higher, whereas 48 metropolitan statistical areas experienced population declines.^{7,8}

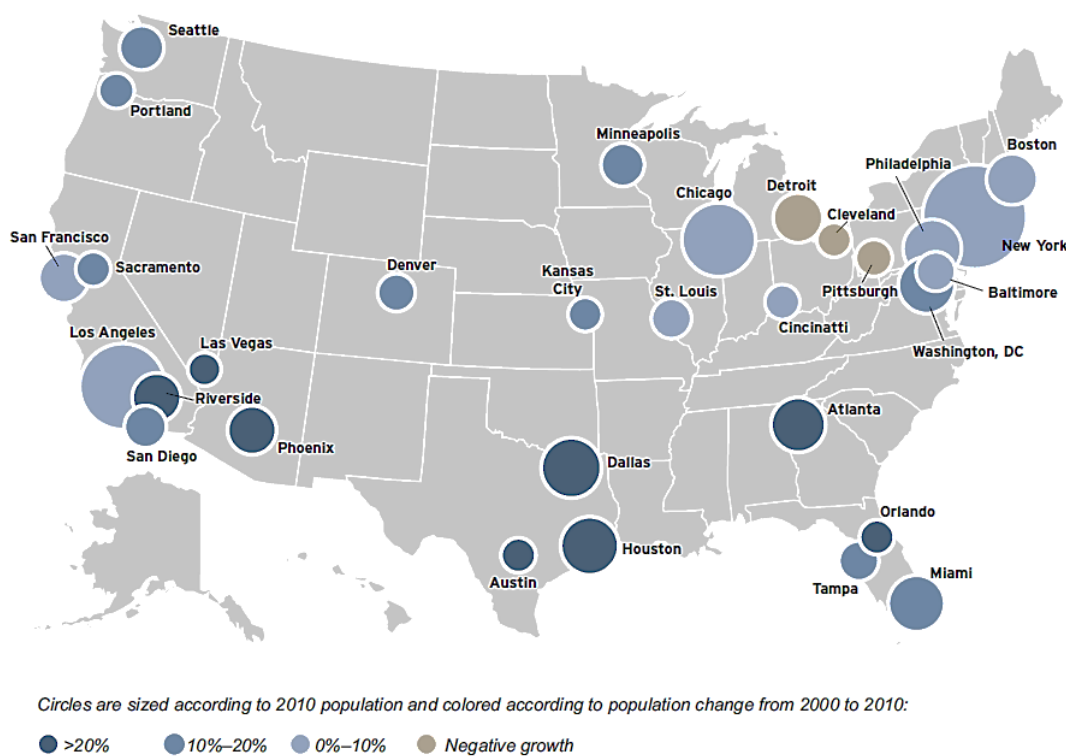


FIGURE 1—POPULATION GROWTH IN METRO AMERICA 2000 TO 2010⁹

³ Frey, William H., The Brookings Institution, “Population Growth in Metro America Since 1980: Putting the Volatile 2000s in Perspective,” http://www.brookings.edu/~media/research/files/papers/2012/3/20-population-frey/0320_population_frey.pdf, accessed 4 February 2015.

⁴ For this study, OCIA defines “Rapid Population Growth” to be positive growth rates that exceed the national average of 1 percent since the 1980s. The current average population growth rate for the United States is .7 percent. Population growth is measured by subtracting death and emigration rates from birth and immigration rates for areas of interest (city, state, region, country). Throughout most of human history, population growth rates have been close to zero, and birth and death rates have been closely aligned. Since the 1980s, some parts of the country have experienced growth higher than 10 percent year after year. (The World Bank, “Population Growth [annual percentage],” <http://data.worldbank.org/indicator/SP.POP.GROW/countries/US?page=4&display=default>, accessed 24 June 2015).

⁵ U.S. Census Bureau, “U.S. Census Bureau Projections Show a Slower Growing, Older, More Diverse Nation a Half Century from Now,” Newsroom, <http://www.census.gov/newsroom/releases/archives/population/cb12-243.html>, accessed 25 February 2014.

⁶ U.S. Census Bureau, “U.S. Population Clock,” <http://www.census.gov/popclock/>, accessed 17 June 2014.

⁷ U.S. Census Bureau, “Estimates of the Components of Resident Population Change: April 1, 2010, to July 1, 2014 – United States – Metropolitan Statistical Area 2015 Population Estimates,” http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2014_PEPTCOMP&prodType=table, accessed 14 April 2016.

⁸ Metropolitan and micropolitan statistical areas are geographic entities defined by the U.S. Office of Management and Budget for use by Federal statistical agencies in collecting, tabulating, and publishing Federal statistics. A metropolitan area contains a core urban area with a population of 50,000 or more. A micropolitan area contains a core urban area with a population of at least 10,000 but less than 50,000. Each metropolitan or micropolitan area consists of one or more counties and includes the counties containing the core urban area, as well as any adjacent counties that have a high degree of social and economic integration with the urban core.

⁹ Frey, William H., The Brookings Institution, “Population Growth in Metro America Since 1980: Putting the Volatile 2000s in Perspective,” http://www.brookings.edu/~media/research/files/papers/2012/3/20-population-frey/0320_population_frey.pdf, accessed 4 February 2015.

Population shifts (increases and decreases) can lead to stresses on critical infrastructure and may increase the risk of failure. Population shift effects on critical infrastructure can cost metropolitan areas millions of dollars in maintenance, replacement, and construction costs, while increasing financial and personal burdens on residents and private corporations. Sustainable fiscal policies supporting infrastructure improvements in metropolitan areas need to overcome several challenges:

- Population growth can outpace planning and construction for infrastructure, and because revenues for improvements may not be available until after the population increases, effects may not be effectively mitigated.
- Areas with decreasing populations may not have revenues sufficient to adequately manage or maintain existing infrastructure, let alone increase investment in major projects.
- Tax revenue receipts are not linked to the locations of the effects—residents who live and work in different cities do not provide the same tax revenue; yet, they continue to benefit from city infrastructure (externalities).^{10,11}
- Volatility in the revenue streams impairs the planning and implementation processes.
- Jurisdictions with decreasing populations may be unable to attract skilled service providers.¹²

Since the end of the 20th century, U.S. Census information shows populations shifting from the Northeast and Midwest to the South and West, where several new migration trends have been observed. Between 2011 and 2012, 40 of the 50 fastest growing metropolitan areas in the United States were in the South or West.¹³ The new growth is in part because of high-technology magnet areas in the West and South, energy development of shale gas and shale oil in rural areas throughout the country, and regrowth in cities in the South and West with housing-led reversals. This growth is also partially because of lower costs of living, potentially including lower tax rates.¹⁴

The growth of domestic shale oil production has led to localized population increases around shale oil regions, a trend that OCIA assesses may continue as state and local governments develop hydraulic fracturing policies and regulations. Apprehension exists concerning fracking—mineral rights, water rights, and environmental concerns—which makes the future of fracking uncertain. States and localities that limit fracking might experience localized population decreases.

Although the U.S. population is increasing as a whole, metropolitan and micropolitan areas have witnessed a decline in population ranging from 25 to 60 percent from their peak populations during the past 30 to 40 years.¹⁵ Persistent population declines are most commonly found in the Northeast and Midwest, especially along the Rust Belt.¹⁶ In total, the populations of seven Rust Belt cities (Youngstown, OH; Detroit, MI; Cleveland, OH; St. Louis, MO; Buffalo, NY; Baltimore, MD; and Scranton, PA) have decreased by more than 1.2 million residents since 1980.¹⁷ Urban areas in the Northeast and Midwest regions have been affected by slow, persistent declines as their populations moved to suburbs or relocated to different regions. These population declines have been fueled

¹⁰ Infrastructure often provides benefits to those who do not pay for them, and failure of infrastructure often affects those who are not involved in decisionmaking. (Nechyba, Thomas J., "Microeconomics: An Intuitive Approach," Cengage Learning, 2011).

¹¹ U.S. Department of the Treasury, "A New Economic Analysis of Infrastructure Investment," Washington, DC, 2012, <https://www.treasury.gov/resource-center/economic-policy/Documents/20120323InfrastructureReport.pdf>, accessed 14 April 2016.

¹² The World Bank, "Planning, Connecting, and Financing Cities—Now: Priorities for City Leaders," 2013, <http://siteresources.worldbank.org/EXTSDNET/Resources/Urbanization-Planning-Connecting-Financing-2013.pdf>, accessed 23 April 2015.

¹³ U.S. Census Bureau, "Oil and Gas Boom Driving Population Growth in the Great Plains, Census Bureau Estimates Show," March 14, 2013, <https://www.census.gov/newsroom/press-releases/2013/cb13-46.html>, accessed 12 May 2014.

¹⁴ Frey, William H., The Brookings Institution, "Population Growth in Metro America Since 1980: Putting the Volatile 2000s in Perspective," http://www.brookings.edu/~media/research/files/papers/2012/3/20-population-frey/0320_population_frey.pdf, accessed 4 February 2015.

¹⁵ Mallach, Alan, "Depopulation, Market Collapse, and Property Abandonment: Surplus Land and Buildings in Legacy Cities," Chapter 3, *Rebuilding America's Legacy Cities: New Directions for the Industrial Heartland*, A. Mallach (ed.), http://americanassembly.org/sites/default/files/download/publications/chapter_3_and_case_study.pdf, accessed 25 April 2014.

¹⁶ An area in the Midwest and northeastern part of the United States where industry was prominent during the early to mid-1900s, from Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, to New Jersey. Rust Belt is a slang term for a geographic region stretching from New York through the Midwest once involved in steel production and manufacturing. This region is called the Rust Belt because the decline in industrial work has left many factories abandoned and uncared for, rusting from their exposure to the elements. Investopedia, "Rust Belt," <http://www.investopedia.com/terms/r/rust-belt.asp>, accessed 29 October 2014.

¹⁷ U.S. Census Bureau, "Estimates of the Components of Resident Population Change: April 1, 2010, to July 1, 2014 – United States – Metropolitan Statistical Area 2015 Population Estimates," http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2014_PEPTCOMP&prodType=table, accessed 14 April 2016.

by divestment in industry, corporate mergers, reliance on single industries, regional fragmentation, and emigration trends.¹⁸

EFFECTS OF POPULATION INCREASES

Rapidly increasing populations are likely to increase demands for services, increase infrastructure usage, expand seasons of consumption, or decrease available *downtime* for maintenance and repairs. These factors may increase system stress and the likelihood of critical infrastructure failures. Growing regions are further challenged fiscally because funding for infrastructure projects to meet the increased demands may not be available until after the population increases, which is too late to mitigate effects.

In cities experiencing rapid population growth, new infrastructure often cannot be installed, and existing infrastructure cannot be retrofitted fast enough to account for the increased demand. Capital- and time-intensive infrastructure projects, such as energy supplies and connections, roads and bridges to accommodate increased vehicle traffic, and water and wastewater systems, can be vulnerable to logistic constraints or budget shortfalls.²² These demands increase system stress and may increase the number of system failures such as power outages or pipeline ruptures.²³ Metropolitan and micropolitan areas can be reluctant to invest in construction of new infrastructure because of uncertainty about the duration and magnitude of population increases and the additional population's usage of existing infrastructure.

Rapid increases in population can result in severe traffic and heavily rutted, crumbling rural roadways requiring expensive reconstruction and maintenance—especially in those micropolitan areas experiencing energy booms. Those areas have roads designed for agricultural and local traffic. Although cities in the southern United States are experiencing rapid population increases, they have the lowest rates for access to mass transit systems.²⁴ Because of the high cost of constructing and maintaining mass transit systems infrastructure, public transportation options do not exist within some metropolitan areas. This lack of public transportation infrastructure limits opportunities to support local economies and reduce traffic congestion from personal and commercial vehicles.

In Houston, TX, the aging water pipeline system loses billions of gallons of water every year. Officials estimate 15 percent of Houston's water supply is lost annually because of water main breaks.¹⁹ In 2012, Houston spent \$54 million on permanent fixes to about 1 percent of its pipelines, and \$31 million went to patching leaks.²⁰ In addition, nearly 45 percent of Houston's revenue from water sales is allocated to repaying its existing infrastructure debt.²¹

Population increases may further exacerbate issues affecting water and wastewater systems. Water and wastewater treatment providers must comply with increasingly stringent public health standards. In addition, while they are providing additional capacity as the number of customers served increases, the quantity of the water supply decreases. The added stress caused by rapid population growth may increase the frequency and severity of disruptions to water and wastewater systems. Consequently, infrastructure assets that depend on water to maintain operability may experience degradation in their capability to provide services.²⁵ These potential consequences can also increase costs of managing water and wastewater systems, which can be transferred to customers.

¹⁸ American Assembly of Columbia University, "Reinventing America's Legacy Cities, Strategies for Cities Losing Population," Detroit, MI, April 14–17, 2011, http://www.achp.gov/docs/Reinventing_Americas_Legacy_Cities_0.pdf, accessed 25 April 2014.

¹⁹ Horswell, Cindy, "Texas Losing Billions of Gallons to Annual Water Leaks," *Houston Chronicle*, December 23, 2013,

<http://www.houstonchronicle.com/news/science-environment/article/Texas-losing-billionsof-gallons-to-annual-water-5086902.php>, accessed 16 May 2014.

²⁰ *Ibid.*

²¹ Tresauge, Matthew, "Planning for future water use a conundrum for Houston," September 9, 2014, *Houston Chronicle*, <http://www.houstonchronicle.com/news/houston-texas/houston/article/Houston-news-5742472.php>, accessed 1 July 2015.

²² OCIA, "National Risk Estimate: Aging and Failing Critical Infrastructure Systems," December 2014.

²³ Infrastructure Failures from system strain are a normal occurrence, but can occur more frequently with increased strains from other factors such as over utilization, under funding, and lack of maintenance. OCIA, "National Risk Estimate: Aging and Failing Critical Infrastructure Systems," December 2014.

²⁴ American Society of Civil Engineers, 2013 Report Card for America's Infrastructure, "Transit: Conditions and Capacity," <http://www.infrastructurereportcard.org/a/#p/transit/conditions-and-capacity>, accessed 4 February 2015.

²⁵ City of Watford, ND, Vision West ND, "Watford Municipal Infrastructure Needs Assessment," www.visionwestnd.com/pdf/ia/Watford_City_Infrastructure_Assessment.pdf, accessed 12 November 2014.

CASE STUDY: THE OIL AND NATURAL GAS SHALE REGIONS

Much of the growth in U.S. oil and gas and mining industries in North Dakota and West Texas can be attributed to the Bakken and Eagle Ford Shale Oil regions.^{26,27} Harvesting natural resources in underpopulated regions where those resources were previously unexploited can trigger rapid population growth, thereby increasing stress on infrastructure systems. Because of the previously low population in many of these new industrial areas, the present infrastructure might be inadequate requiring new infrastructure to support the growth.

BAKKEN

Many of the municipalities in the Bakken area of North Dakota experiencing rapid population growth are wary of repeating the boom-and-bust cycle they experienced in the 1980s. The boom-and-bust cycle was marked by the building of infrastructure in anticipation of growth that did not occur.³¹ In 1980, Williston, North Dakota, invested in infrastructure to prepare for a supposed oil boom. However, the anticipated growth did not occur, and the subsequent drop in oil prices left Williston \$28 million in debt without the expected tax base to pay for it.³²

From July 2012 to July 2013, the population of Williams County, North Dakota, grew by 10.7 percent, the fastest growth of any county in the United States.^{28,29} According to the 2014 census, 6 of the 15 fastest growing counties in the United States were in North Dakota—McKenzie, Williams, Stark, Dunn, Divide, and Mountrail—all of which are in the Bakken Shale region.³⁰

As the Bakken Shale region continues to experience growth, the current and future demand for electricity will increase. Additional stress on unreliable and overburdened electric grids can result in brownouts and blackouts. Williston residents purchased backup generators to prepare for brownouts and blackouts from increased electricity demands during winter months.³³ Additional strain on the electric grid may increase unreliability, potentially affecting infrastructure that depends on electricity. Consequently, less reliable electric power service may negatively affect infrastructure sectors that rely on electricity, including hospitals, water treatment plants, and wastewater pumping stations.

Most areas experiencing significant growth in the Bakken region have low population densities and limited access to public transportation, which leads to increased traffic congestion, because the population relies heavily on personal vehicles. Micropolitan areas in North Dakota are experiencing unprecedented effects on their transportation infrastructure related to increased industrialization in the Bakken region. These effects include potholes, rutting, shoving, alligator cracking, blinding plumes of dust, steep drop-offs, and other pavement and roadway issues.^{34,35} In 2011, Mountrail County, North Dakota's 1,600-mile road system became so overloaded and

²⁶ Frey, William H., The Brookings Institution, "Population Growth in Metro America Since 1980: Putting the Volatile 2000s in Perspective," http://www.brookings.edu/~media/research/files/papers/2012/3/20-population-frey/0320_population_frey.pdf, accessed 4 February 2015.

²⁷ Hess, Alexander and Sauter, Michael, "Top States with the Fastest Growing Economies," *USA Today*, June 15, 2013, <http://www.usatoday.com/story/money/business/2013/06/15/states-with-the-fastest-growing-economies/2416239/>, accessed 5 February 2015.

Tresaugue, Matthew, "Planning for future water use a conundrum for Houston," *Houston Chronicle*, September 8, 2014, <http://www.houstonchronicle.com/news/houston-texas/houston/article/Houston-news-5742472.php>, accessed 1 July 2015.

²⁸ Goldstein, Steve, *Market Watch*, March 27, 2014, <http://blogs.marketwatch.com/capitolreport/2014/03/27/people-flocking-to-shale-boom-as-north-dakota-county-sees-fastest-population-growth/>, accessed 8 April 2015.

²⁹ U.S. Census Bureau, "South, West Have Fastest-Growing Cities, Census Bureau Reports; Three of Top 10 Are in Texas Capital Area," May 22, 2014, <http://www.census.gov/newsroom/press-releases/2014/cb14-89.html>, accessed 2 September 2014.

³⁰ U.S. Census Bureau, "Estimates of the Components of Resident Population Change: April 1, 2010, to July 1, 2014 – United States – Metropolitan Statistical Area 2014 Population Estimates," http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2014_PEPTCOMP&prodType=table, accessed 25 June 2015.

³¹ Boyd, Danny, "Soaring Oil Production Spurs Infrastructure Growth Across Booming Bakken Play," *The American Oil & Gas Reporter*, May 2012.

<http://www.aogr.com/magazine/cover-story/soaring-oil-production-spurs-infrastructure-growth-across-booming-bakken-pl>, accessed 14 April 2014.

³² Ibid.

³³ Dragseth, Debora, "Help Wanted: The North Dakota Boom," *New Geography*, December 26, 2011, <http://www.newgeography.com/content/002501-help-wanted-the-north-dakota-boom>, accessed 14 June 2014.

³⁴ Oldham, Jennifer, "North Dakota Oil Boom Brings Blight with Growth as Costs Soar," *Bloomberg*, January 25, 2012, <http://www.bloomberg.com/news/2012-01-25/north-dakota-oil-boom-brings-blight-with-growth-as-costs-soar.html>, accessed 28 May 2014.

³⁵ Cohen, Sharon, "The Promise, The Growing Pains of Oil Boom Town," *The Associated Press*, <http://bigstory.ap.org/article/promise-growing-pains-oil-boom-town-0>, accessed 21 May 2014.

deteriorated that officials ran out of “road closed” signs, and postal carriers were unable to deliver mail to some addresses because of heavily rutted road conditions.^{36,37}

Population increases can exert significant pressure on municipal water and wastewater systems. According to the 2010 census, the population of Watford, North Dakota, was estimated to be 1,744, but the city is projected to grow to 15,000 by 2017.⁴⁰ However, as of 2014, Watford’s water distribution system is capable of serving a population of only 7,500 with storage capacity for a population of 3,500.⁴¹

The city of Watford is transitioning toward purchasing water from the Western Area Water Supply Authority at monthly rates close to \$20 per thousand gallons; the national average for water is \$2 per thousand gallons.^{38,39}

From 2006 to 2011, the population of Williston, North Dakota, grew from approximately 12,500 to an estimated 22,000. In 2012, Williston’s sewers were overloaded, and its water supplies were strained, prompting the county to ban construction of new temporary worker housing until water and wastewater systems could be expanded.⁴²

EAGLE FORD

According to the North American Electric Reliability Corporation, the isolated electricity grid in Texas faces serious challenges in meeting future demands.^{43,44} The electricity infrastructure supporting the Eagle Ford Shale region in Texas is outdated and requires significant maintenance and upgrades.⁴⁵ Because of the lack of electricity transmission infrastructure in remote regions and lengthy lead time to build new transmission and distribution lines, new oil wells and pumps that extract oil are often powered by generators rather than the electricity supplied by the electric grid. Using generators for operations can cost up to three times more than using electricity supplied by an electric utility. Some corporations are even considering building their own electric power infrastructure to offset those costs.⁴⁶

The Texas Water Development Board oversees the water planning efforts and assesses activities such as water supply development and treatment, usage, and other management processes. This planning and assessing requires an understanding of issues related to water resources, especially the effects of population increases.⁴⁷ After 2010, 3 years of drought adversely affected Texas aquifers and reservoirs challenging its capability to adequately provide water and wastewater services for its increasing population.⁴⁸ Oil drilling activities in Texas, especially those in the Eagle Ford Shale region, exacerbate the effect of droughts. Each of the estimated 7,000 oil wells uses between 3 and 7 million gallons of water (for the life of the well) during operations.⁴⁹

³⁶ Oldham, Jennifer, “North Dakota Oil Boom Brings Blight with Growth as Costs Soar,” *Bloomberg*, January 24, 2012, <http://www.bloomberg.com/news/2012-01-25/north-dakota-oil-boom-brings-blight-with-growth-as-costs-soar.html>, accessed 28 May 2014.

³⁷ Cohen, Sharon, “The Promise, The Growing Pains of Oil Boom Town,” *The Associated Press*, <http://bigstory.ap.org/article/promise-growing-pains-oil-boom-town-0>, accessed 21 May 2014.

³⁸ Vision West ND, “Watford Municipal Infrastructure Assessment,” www.visionwestnd.com/pdf/ia/Watford_City_Infrastructure_Assessment.pdf, accessed 12 November 2014.

³⁹ Environmental Protection Agency, “Water On Tap: What You Need To Know,” http://water.epa.gov/drink/guide/upload/book_waterontap_full.pdf, accessed 18 February 2015.

⁴⁰ City of Watford, ND, Vision West ND, “Watford Municipal Infrastructure Needs Assessment,” www.visionwestnd.com/pdf/ia/Watford_City_Infrastructure_Assessment.pdf, accessed 12 November 2014.

⁴¹ *Ibid.*

⁴² Oldham, Jennifer, “North Dakota’s Oil Boom Strains Its Infrastructure,” *Bloomberg BusinessWeek Magazine*, February 2, 2012, <http://www.businessweek.com/magazine/north-dakotas-oil-boom-strains-its-infrastructure-02022012.html>, accessed 21 May 2014.

⁴³ Ragan, John, “Ragan: Time for Texas to Add to State’s Electric Grid,” *Houston Chronicle*, June 11, 2013, <http://www.chron.com/opinion/outlook/article/Ragan-Time-for-Texas-to-add-to-state-s-electric-4594395.php>, accessed 30 May 2014.

⁴⁴ Galbraith, Kate, and Batheja, Aman, “Infrastructure Constraints Loom as Texas Grows,” *The Texas Tribune*, May 17, 2013, <http://www.texastribune.org/2013/05/17/texas-grows-infrastructure-constraints-loom/>, accessed 5 May 2014.

⁴⁵ Pickrell, Emily, “Shale Boom Leads to Electrical Demand,” *MySanAntonio.com*, June 27, 2013, <http://www.mysanantonio.com/news/article/Shale-boom-leads-to-electrical-demand-4624353.php>, accessed 8 April 2014.

⁴⁶ Reuters, “In Texas Shale Patch, Drillers Bring Power to the Pump,” June 28, 2013, <http://www.reuters.com/article/2013/06/28/power-eagleford-idUSL2N0EN28420130628>, accessed 25 May 2014.

⁴⁷ Center for Community and Business Research, The University of Texas at San Antonio, “South Central Texas Region L, Population Projection Study,” <http://ccbr.iedtexas.org/south-central-texas-region-l-population-projection-study/>, accessed 14 April 2014.

⁴⁸ Galbraith, Kate, and Batheja, Aman, “Infrastructure Constraints Loom as Texas Grows,” *The Texas Tribune*, May 17, 2013, <http://www.texastribune.org/2013/05/17/texas-grows-infrastructure-constraints-loom/>, accessed 22 May 2014.

⁴⁹ Jervis, Rick, “Oil! New Texas Boom Spawns Riches, Headaches,” *USA Today*, January 15, 2014, <http://www.usatoday.com/story/news/nation/2014/01/15/texas-oil-boom-fracking/4481977/>, accessed 22 May 2014.

MITIGATION OPPORTUNITIES FOR REGIONS WITH RAPID POPULATION GROWTH

Increases in population can also have positive effects on the Energy, Transportation Systems, and Water and Wastewater Systems Sectors. Cities and organizations are trying to increase the benefits and decrease the negative effects on these Sectors with strategic planning and public-private partnerships. Flexibility is also important, because existing policies and regulations may not be sufficient during rapid population growth.

STRATEGIC PLANNING

Foresight and strategic planning are critical for meeting rapid increases in demand, because significant lead-time is often necessary to obtain financing; design and plan infrastructure projects; obtain regulatory approvals; and construct new power plants, transmission lines, substations, and distribution lines. For example, Southern Company was granted a construction and operating license for two new nuclear power reactors in February 2012, 4 years after it filed a license application. Its goal was to bring the reactors online in 2016 and 2017.⁵⁰

States, cities, and companies are strategically planning for the future in several ways. Some places, such as Texas, require a portion of the income from growing industries to be invested in infrastructure. In November 2014, Texas approved a constitutional amendment that dedicated some of the tax revenue collected from the oil boom to fund transportation infrastructure.⁵¹ In Williston, North Dakota, the 2013 Williston Impact Statement recommended that \$213.6 million be set aside for expanding storm water, wastewater, and drinking water systems infrastructure. However in 2014, the city planned less than \$50 million for water and wastewater systems projects to be completed over 18 months.^{52,53} Some areas have initiated long-term energy supply studies to identify paths forward for addressing an increasing demand for electricity.

PUBLIC-PRIVATE PARTNERSHIPS

Public-private partnerships increase the participation of private investors in the development and operations of public infrastructure projects. In many cases, public-private partnerships are designed as an investment for a private company since infrastructure can offer long-term revenue streams. In some rapidly growing regions though, especially ones where the growth is primarily because of a single company or industry, states and cities are passing laws requiring companies to invest in local infrastructure. In 2014, Texas approved legislation that requires oil companies to pay for new infrastructure to support localities most affected by nearby oil field development.⁵⁴ In North Dakota, some cities are requiring developers to build added water and wastewater systems infrastructure for their projects to protect the city from debt if the oil boom does not continue.

⁵⁰ Mufson, Steven, "NRC approves construction of new nuclear power reactors in Georgia," *Washington Post*, February 9, 2012, https://www.washingtonpost.com/business/economy/nrc-approves-construction-of-new-nuclear-power-reactors-in-georgia/2012/02/09/gIQA36wvIQ_story.html, accessed 23 March 2016.

⁵¹ Batheja, Aman, "Texans to Vote on Plan to Boost Road Funding," *The Texas Tribune*, May 30, 2015, <http://www.texastribune.org/2015/05/30/texans-vote-plan-boost-road-funding-billions/>, accessed 29 December 2015.

⁵² Van Loon, Benjamin, "Feeling the BOOM," *American Builders Quarterly*, Jan/Feb/Mar 2014, <http://americanbuildersquarterly.com/2013/williston-nd/>, accessed 22 May 2014.

⁵³ Williston Economic Development, "Williston Impact Statement, 2014," http://www.willistondevelopment.com/usimages/williston_impact_statement.pdf, accessed 14 April 2016.

⁵⁴ Texas Department of Transportation, "Proposition 1 Funding," <http://www.txdot.gov/government/legislative/state-affairs/ballot-proposition.html>, accessed 16 July 2015.

EFFECTS OF POPULATION DECREASES

Population decreases can shrink the tax base and create funding shortfalls for infrastructure maintenance and repairs. Households below the poverty line and retirees who typically pay little to no annual income tax and residents who are delinquent in paying taxes also contribute to the funding shortfall.^{55,56,57} This shortfall potentially increases the stress on an area's critical infrastructure and the likelihood of infrastructure failures.^{58,59} Lack of adequate investments can lead to increases in service disruptions and costs for individual customers.

In addition, underpopulated areas of cities are often concentrated and characterized by large numbers of vacant or abandoned houses, industrial facilities, and commercial facilities.⁶⁰ Pockets of under-population directly affect the local economies and can contribute to further decline of neighborhoods as small businesses move away from residential areas.

Underpopulated areas can reduce housing-market demand in neighborhoods where the local economies are likely too weak to prompt market-driven revival.⁶¹ In neighborhoods with larger populations, real estate markets are typically stronger.⁶² Real estate market strength results in residences that sell quicker at higher prices and appreciate over time, thereby strengthening local economies. Real estate values can change how occupants and property owners choose to invest in their properties.⁶³ Vacancy rates, tax delinquencies, and foreclosure numbers also decline in strong real estate markets, which buttress the local economy.⁶⁴

CASE STUDY: THE LEGACY OF THE RUST BELT

One-industry towns, such as Youngstown, Ohio, with its dependence on the steel industry, or Detroit, Michigan, with its dependence on motor vehicle manufacturing, developed suburbs with low-density, detached single-family homes during prosperity. The Youngstown metropolitan area once had 30 steel mills operating in a 20-mile industrial corridor; as of 2013, only one mill was operating.⁶⁶ Detroit had large automotive assembly plants and supplier factories in the surrounding area; but as of 2016, many of these facilities are abandoned. The loss of jobs has been a key factor leading to population declines.

Loss of jobs can lead to uneven population densities throughout a city, resulting in high volumes of vacant structures and numerous areas with low population levels compared with the rest of the city.⁶⁷ For instance, although

Certain large metropolitan areas, as well as micropolitan areas, have had their populations decrease 25–60 percent from their peak.⁶⁵ Legacy cities are metropolitan areas experiencing population declines and decreasing economic bases. Many legacy cities are industrial cities in the Rust Belt area. These legacy cities grew outward from the core in a continuous and largely interconnected functional grid or network of streets, electric and gas lines, and water and sewer lines, and much of this infrastructure is now underused and underfunded but still requires regular maintenance.

⁵⁵ Detroit Blight Removal Task Force Plan, "Property Tax Reform," Chapter 7, <https://s3.amazonaws.com/detroit-blight-taskforce/CHAPTER+07.pdf>, accessed 18 February 2015.

⁵⁶ Mallach, Alan, "Can Youngstown Make It On Its Own?" National Housing Institute, *Rooflines*, March 19, 2014, http://www.rooflines.org/3638/can_youngstown_make_it_on_its_own/?utm_source=March+25%2C+2014&utm_campaign=March+25+Weekly&utm_medium=email, accessed 26 June 2014.

⁵⁷ Mallach, Alan, "Rebuilding America's Legacy Cities: New Directions for the Industrial Heartland," Chapter 3, Mallach, Alan (ed.), http://americanassembly.org/sites/default/files/download/publications/chapter_3_and_case_study.pdf, accessed 25 April 2014.

⁵⁸ Ryan, Brent, D., "Rightsizing Shrinking Cities: The Urban Design Dimension," *The City After Abandonment*, M. Dewar and M. Thomas (eds.), Philadelphia: University of Pennsylvania Press, http://web.mit.edu/bdr/www/Ryan_Rightsizing_the_Shrinking_City.pdf, accessed 28 April 2014.

⁵⁹ Mallach, Alan, "Rebuilding America's Legacy Cities: New Directions for the Industrial Heartland," Chapter 3, Mallach, Alan (ed.), http://americanassembly.org/sites/default/files/download/publications/chapter_3_and_case_study.pdf, accessed 25 April 2014.

⁶⁰ *Ibid.*

⁶¹ *Ibid.*

⁶² *Ibid.*

⁶³ *Ibid.*

⁶⁴ *Ibid.*

⁶⁵ *Ibid.*

⁶⁶ Ansberry, Clare, *The Wall Street Journal*, "Left for Extinct, a Steel Plant Rises in Ohio," August 2, 2011, <http://www.wsj.com/articles/SB10001424053111904233404576462562705511704>, accessed 19 February 2015.

⁶⁷ Mallach, Alan, "Rebuilding America's Legacy Cities: New Directions for the Industrial Heartland," Chapter 3, Mallach, Alan (ed.), http://americanassembly.org/sites/default/files/download/publications/chapter_3_and_case_study.pdf, accessed 25 April 2014.

approximately half of Buffalo, New York, neighborhoods have a 10 percent housing vacancy rate, some neighborhoods have vacancy rates as high as 50 percent.⁶⁸ The corrosive effect on city infrastructure escalates with the rise in density of unsecured vacant houses. Large tracts of vacant homes can result in increased thefts of private and public water, electric, and gas piping and wire. These thefts dismantle the distribution system and lead to service rate increases, service disruptions, and resource loss. Roughly half of the land area in Youngstown is considered a housing market “dead zone.” Detroit is in a similar situation with 27 percent of all residential parcels vacant.⁶⁹

As legacy cities experienced growth, their transit systems were constructed for larger populations, and neighborhoods developed commensurately with adjacent commercial corridors. Many cities have also seen the movement of middle-class residents to the suburbs, leading to lower population densities. These areas were supported by transportation systems moving residents easily within the city and to various nearby places. When populations decline, the extensive transportation system may require more maintenance than can be supported by the tax base. Suburbanization may therefore compound the issues that legacy cities with declining populations face, because the scale of most transit systems ceases to match the needs of the populations they serve. This makes maintenance difficult and affects these cities’ capability to develop efficient and coordinated fixed-route, multiple-stop transit systems.^{70,71}

Legacy cities face a litany of water and wastewater system infrastructure challenges because of the age of physical infrastructure: system designs that no longer comply with current regulations, high maintenance costs, frequent disruptions in service, and a need for significant equipment replacements. To comply with regulations, cities and their residents face several billion dollars in costs and possible civil penalties for noncompliance. Declining populations can exacerbate already stressed and aging water and wastewater systems; smaller-than-optimal tax bases can prevent funding of necessary projects. For example, Detroit’s population decreases have prevented necessary maintenance on its water and wastewater systems. In addition, approximately 50 percent of Detroit’s water users are chronically delinquent in paying bills.⁷²

Historically, most metropolitan areas relied on combined storm water and sewage systems. Consequently, during heavy precipitation, wastewater treatment plants often overflowed. This resulted in discharges of billions of gallons of untreated wastewater and storm water into area lakes and waterways after storms.^{73,74} The Clean Water Act of 1972, Safe Drinking Water Act of 1974, and many state regulations require the separation of sewer and wastewater components and the upgrade of infrastructure systems.

Despite regulatory requirements, Detroit has a combined wastewater and storm water system—which treats both simultaneously. It costs \$400 to produce 1 million gallons of Detroit drinking water, whereas wastewater is treated at a cost of \$800 per 1 million gallons.⁷⁵ However, Detroit’s 30,000 vacant structures are vulnerable to having their pipes removed by metal scavengers, which can allow treated drinking water to run unabated to wastewater collection locations where it is retreated before discharge. This increases water treatment costs with no customers to pay for the treatment and delivery services.⁷⁶

⁶⁸ Ryan, Brent, D., “Rightsizing Shrinking Cities: The Urban Design Dimension,” *The City After Abandonment*, M. Dewar and M. Thomas (eds.), Philadelphia: University of Pennsylvania Press, http://web.mit.edu/bdr/www/Ryan_Rightsizing_the_Shrinking_City.pdf, accessed 28 April 2014.

⁶⁹ Mallach, Alan, “Rebuilding America’s Legacy Cities: New Directions for the Industrial Heartland,” Chapter 3, Mallach, Alan (ed.), http://americanassembly.org/sites/default/files/download/publications/chapter_3_and_case_study.pdf, accessed 25 April 2014.

⁷⁰ *Ibid.*

⁷¹ American Assembly Columbia University, “Reinventing America’s Legacy Cities: Strategies for Cities Losing Population,” Detroit, Michigan, April 14–17, <http://americanassembly.org/events/reinventing-americas-legacy-cities-strategies-cities-losing-population>, accessed 19 June 2014.

⁷² City of Detroit, “Proposal for Creditors,” June 14, 2013.

<http://www.detroitmi.gov/Portals/0/docs/EM/Reports/City%20of%20Detroit%20Proposal%20for%20Creditors1.pdf>, accessed 16 April 2014.

⁷³ City of Buffalo, “Buffalo’s Comprehensive Plan,” http://www.ci.buffalo.ny.us/files/1_2_1/mayor/cob_comprehensive_plan/section_2459212234.html, accessed 16 April 2014.

⁷⁴ Detroit Future City, “The City Systems Element: The Sustainable City,” 2012, http://detroitfuturecity.com/wp-content/uploads/2014/02/DFC_CitySystems_2ndEd.pdf, accessed 24 March 2014.

⁷⁵ Associated Press, *SFGate*, “Detroit’s Ravaged Pipes Draining Water, Money,” 11 December 2013, <http://www.sfgate.com/nation/article/Detroit-s-ravaged-pipes-draining-water-money-5056676.php>, accessed 18 June 2015.

⁷⁶ *Ibid.*

MITIGATION OPPORTUNITIES FOR REGIONS WITH POPULATION DECLINES

Decreases in population can also have positive effects on the Energy, Transportation Systems, and Water and Wastewater Systems Sectors. Cities and organizations are trying public-private coordination and strategic planning to increase the likelihood of benefits while decreasing the likelihood of negative effects.

PUBLIC-PRIVATE COORDINATION

Much of the critical infrastructure in the United States is owned by private companies. Companies often require state or local government approval to take certain actions, including building or repairing infrastructure, or changing rate structures to be able to invest in infrastructure. Therefore, private companies' coordination with state and local governments is critical.

- For example, 38 states have programs in which public utility commissions and operators collaborate to accelerate replacement of natural gas distribution pipelines that meet certain criteria.⁷⁷ Programs like these, which could be effective across sectors and states, help companies replace their most vulnerable infrastructure in a timely manner, rather than resorting to “replacement by failure.”

STRATEGIC PLANNING

In addition to collaborating, public and private organizations need to be planning far into the future to ensure that infrastructure will be cost-effectively built, maintained, and replaced to meet a city's or region's future needs. Strategic planning is especially important in regions with declining populations. A city needs to be able to meet its current needs and minimize its costs by realigning infrastructure projects and services in declining population areas.

- In Ohio, some natural gas companies have implemented long-term initiatives to improve the state of their pipeline infrastructure, which may also help mitigate the effects of decreasing populations.⁷⁸ In 2002, Duke Energy was granted approval by state regulators to begin a 15-year, \$716 million replacement program for approximately 1,200 miles of pipeline.⁷⁹ Dominion East Ohio, operating in Cleveland, is involved with a 25-year, \$3.4 billion program to replace 4,000 miles of pipeline.^{80,81}

Many research initiatives, including the 2011 White House Strong Cities, Strong Communities (SC2) initiative, have been undertaken in an attempt to understand the reasons for persistent population declines. SC2 goals include agendas and options for reinventing, rightsizing, rebuilding, managing, sustaining, and piloting strategies for legacy cities.⁸² States and cities are also developing innovative management strategies, such as selling excess output or capacity of certain infrastructure assets, leveraging data, and realigning public services through new organizational authorities in declining population areas. These efforts could reduce the debt of cities and result in a more effective sharing or allocation of services and costs.^{83,84}

⁷⁷ American Gas Association, “Get the Facts: Pipeline Safety,”

<http://www.mudomaha.com/sites/default/files/AGA%20Pipeline%20Safety%20Fact%20Sheet%202014.pdf>, accessed 14 June 2016.

⁷⁸ Kowalski, Kathiann, M., *Midwest Energy News*, “Ohio utilities replacing thousands of miles of gas pipelines,” April 21, 2014,

<http://www.midwestenergynews.com/2014/04/21/pipeline-replacements-lay-new-groundwork-for-ohios-infrastructure/>, accessed 19 February 2015.

⁷⁹ The Public Utilities Commission of Ohio, “Natural Gas Pipeline Safety in Ohio,” <http://www.puco.ohio.gov/puco/index.cfm/be-informed/consumer-topics/natural-gas-pipeline-safety-in-ohio/#sthash.5j7sQgLV.dpbs>, accessed 25 March 2014.

⁸⁰ *Ibid.*

⁸¹ The Public Utilities Commission of Ohio, “Natural Gas Pipeline Safety in Ohio,” <http://www.puco.ohio.gov/puco/index.cfm/consumer-information/consumer-topics/natural-gas-pipeline-safety-in-ohio/>, accessed 25 March 2014.

⁸² Zuckerman, Mark and Russell, Racquel, White House Office of Urban Affairs, “White House Council on Strong Cities, Strong Communities Announces New Executive Director,” June 19, 2012, <http://www.whitehouse.gov/blog/2012/06/19/white-house-council-strong-cities-strong-communities-announces-new-executive-director>, accessed 19 February 2015.

⁸³ Fox, Radhika, K., and Treuhaft, Sarah, 2006, “Shared Prosperity, Stronger Regions: An Agenda for Rebuilding American's Older Core Cities,” *PolicyLink*, <http://www.policylink.org/sites/default/files/sharedprosperity-corecities-final.pdf>, accessed 25 April 2014.

⁸⁴ American Assembly of Columbia University, “Reinventing America's Legacy Cities, Strategies for Cities Losing Population,” Detroit, Michigan, April 14–17, 2011, http://www.achp.gov/docs/Reinventing_Americas_Legacy_Cities_0.pdf, accessed 25 April 2014.

CONCLUSION

Population shifts (both increases and decreases) can result in stresses and failures, costing metropolitan areas millions of dollars in maintenance, replacement, expansion, and construction costs while increasing financial and personal burdens on community residents and private corporations. Opportunities exist for declining population centers and growing population areas to create sustainable and resilient communities by proactively partnering in energy efficiency, renewable energy, and resource conservation projects with corporations and governments.

The consequences of forecasted or realized significant population shifts can motivate public and private stakeholders to partner on long-term investment planning. This investment can include maintaining or replacing aging infrastructure retrofits or funding new capital expansion projects benefitting the Energy, Transportation Systems, and Water and Wastewater Systems infrastructure Sectors. Metropolitan area planners need strategic planning, innovation, and timely implementation to minimize strain, stress, and problems affecting infrastructure sectors.

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