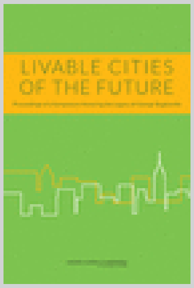

Livable Cities of the Future: Proceedings of a Symposium Honoring the Legacy of George Bugliarello

ISBN
978-0-309-30009-4

176 pages
6 x 9
PAPERBACK (2014)

Mohammad Karamouz and Thomas F. Budinger, Editors; National Academy of Engineering; NYU Polytechnic School of Engineering

LIVABLE CITIES OF THE FUTURE

Proceedings of a Symposium Honoring the Legacy of George Bugliarello

Mohammad Karamouz and Thomas F. Budinger, *Editors*

NATIONAL ACADEMY OF ENGINEERING
OF THE NATIONAL ACADEMIES

NYU | POLYTECHNIC SCHOOL OF ENGINEERING

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street NW Washington, DC 20001

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This project was supported by funding from New York University Polytechnic School of Engineering and the National Academy of Engineering Fund. Any opinions, findings, or conclusions expressed in this publication are those of the symposium participants.

International Standard Book Number 13: 978-0-309-30009-4
International Standard Book Number 10: 0-309-30009-6

Copies of this report are available from the National Academies Press, 500 Fifth Street NW, Keck 360, Washington, DC 20001; (888) 624-8373 or (202) 334-3313; *www.nap.edu*.

For more information about the National Academy of Engineering, visit the NAE homepage at *www.nae.edu*.

Printed in the United States of America

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Preface

Livable Cities of the Future, a symposium honoring the legacy of George Bugliarello, was hosted October 26, 2012, by the Polytechnic Institute of New York University[1] (NYU-Poly) in the Pfizer Auditorium of the Bern Dibner Library of Science and Technology. The event brought together more than 200 engineers, civic leaders, educators, and futurists to discuss how George Bugliarello's vision manifests itself in innovative urban planning for the cities of tomorrow.

The symposium objectives were to cultivate ideas for best practices and innovative strategies for sustainable urban development and to facilitate the evolution of New York City to a real-life laboratory for urban innovation. Participants heard the perspectives and experiences of representatives from private and public service operators, infrastructure agencies, and the academic community. Elected officials and other stakeholders in urban and other sectors examined issues critical to resilient and sustainable cities, such as energy, water supply and treatment, public health, security infrastructure, transportation, telecommunications, and environmental protection.

The event was organized in three parts (the program is reproduced in the Appendix). Part I opened with welcome remarks by Jerry Hultin, NYU-

[1]On January 1, 2014, Polytechnic Institute became the New York University Polytechnic School of Engineering.

Poly president and symposium chair, and an introduction by symposium cochair and session moderator Mohammad Karamouz, who presented the symposium objectives and reflected on George Bugliarello's intellectual courage and innovative thinking about the integration of engineering, the biosphere, and society. This was followed by a keynote speech by the Honorable Robert K. Steel, New York City deputy mayor for economic development, and reflections on the legacy of George Bugliarello by Ruth David, president and CEO, Analytic Services, Inc., on behalf of the National Academy of Engineering (NAE), and by Richard S. Thorsen,[2] NYU-Poly vice president emeritus.

Part II, on fundamental needs and emerging challenges in large cities, was divided into two sessions. The first addressed infrastructure renewal for water, energy, and transportation, with presentations by Patrick Foye, executive director of the Port Authority of New York/New Jersey (delivered on his behalf by John Ma, his chief of staff); Andrew W. Herrmann,[2] president of the American Society of Civil Engineers; Craig S. Ivey, president of Consolidated Edison Company of New York; and Daniel (Pete) Loucks, professor of civil and environmental engineering at Cornell University. Ilan Juran,[2] director of the NYU-Poly Urban Infrastructure Institute, moderated the session, which was followed by luncheon speaker Honorable David Miller, former mayor of Toronto. The second session, moderated by John C. Falcocchio,[2] director of the NYU-Poly Intelligent Transportation Systems Center, concerned sustainability, information technology, and the environment, with presentations by Joan McDonald, commissioner for the New York State Department of Transportation; Ruthie D. Lyle, with IBM's Smart Cloud for Social Business; Upmanu Lall, director of the Water Center at Columbia University Earth Institute (text not included in this volume); and Carter H. Strickland, Jr., commissioner for the New York City Department of Environmental Protection.

Part III, a panel discussion of challenges to the way forward, was moderated by Paul Horn,[2] New York University Distinguished Scientist in Residence and senior vice provost for research. The panelists were Steven E. Koonin,[2] director of the Center for Urban Science and Progress (CUSP); Gerard M. Mooney, vice president of IBM Global Smarter Cities; Thomas D. O'Rourke,[2] Thomas R. Briggs Professor of Engineering at Cornell University; and Theodore (Ted) S. Rappaport,[2] NYU-Poly David Lee/Ernst Weber

[2] Member of the Symposium Steering Committee. The complete lists of Steering Committee members and Symposium sponsors are in the Appendix, pages 159–160.

Professor of Electrical and Computer Engineering. Closing remarks were delivered by Katepalli R. Sreenivasan,[2] NYU-Poly provost and NYU senior vice provost for science and technology.

We are indebted to Symposium Chair Jerry Hultin, Honorary Chair Paul Soros, and the members of the Steering Committee, whose dedicated efforts ensured the breadth and success of this important event. In addition to those identified above, the committee benefited from the expert guidance of Lawrence Chiarelli, interim head of the NYU-Poly Department of Civil and Urban Engineering; Lance A. Davis, NAE executive officer; Kristen Day, head, NYU-Poly Department of Technology, Culture, and Society; Rose J. Emma, former assistant to George Bugliarello; Ivan T. Frisch, former executive vice president and provost, NYU-Poly; Kathleen Hamilton, director, NYU-Poly Marketing and Communications; Charles M. Vest, NAE president and president emeritus, Massachusetts Institute of Technology; Wm. A. Wulf, NAE president emeritus and former University Professor and AT&T Professor of Engineering and Applied Sciences, University of Virginia; and Rae Zimmerman, professor of planning and public administration, Robert F. Wagner Graduate School of Public Science, and director, NYU Institute for Civil Infrastructure Systems (ICIS).

We also gratefully acknowledge the support of the symposium's generous sponsors: the American Society of Civil Engineers, National Academy of Engineering, NYU-Poly Department of Civil and Urban Engineering, NYU Center for Urban Science and Progress, Forest City Ratner Companies, University Transportation Research Center, Hardesty & Hanover, NYU alumni Walter Bell, Virginia Bugliarello,[2] Robert Dalziel,[2] and Craig Matthews, and former colleague and University of Pittsburgh professor Tin-Kan Hung.

This volume opens with an overview of George Bugliarello's accomplishments and research, followed by a summary of each session and 18 papers based on the speakers' presentations. We are grateful for thoughtful editing by Cameron Fletcher, NAE senior editor, and for her role in shepherding these proceedings to publication. We also appreciate the assistance of Rose Emma and NYU Environmental Engineering Program graduate students Bianca Caraballa, Jatin Rathi, and Sally-Jeanne Watkins in the preparation of the proceedings.

This effort is intended to become a biennial symposium with the purpose of continuing to expand on the contributions toward urban resiliency that George Bugliarello spearheaded. The NYU-Poly Civil and Urban Engineering Department is determined to take a lead role in promoting collaborations among institutions and agencies for a better New York City, and future events will include national figures in policy and decision making, urban planning, resource allocation, and economics as well as cultural and social issues.

Mohammad Karamouz, Symposium Cochair
NYU Polytechnic School of Engineering

Thomas F. Budinger[3]
University of California, Berkeley

[3] NAE Home Secretary and member of the Steering Committee.

Contents

The Legacy of George Bugliarello: A Review of His Vision and Contributions

Mohammad Karamouz
Polytechnic Institute of New York University

In this volume we remember the professional career of George Bugliarello, who made significant impacts in the lives of many and changed the shape and character of downtown Brooklyn permanently. He was resourceful and instrumental in a variety of academic, administrative, professional, and personal endeavors. He was a kind and giving man, and he enjoyed a variety of roles—colleague, mentor, educator, humanist. He was dedicated to making a difference wherever he was involved, sharing with the world a vision of something better and acting as a driving force in support of realizing that vision.

George Bugliarello's interests and expertise transcended many disciplines—civil engineering, biomedical engineering, urban development, science policy, water resources, computer languages, fluid mechanics, and environmental science. His vision of the role of science, innovation, and education, coupled with a passion for turning his vision into reality, is reflected in today's urban communities, forged through academic and industry interactions in ways that spur economic growth and societal well-being while respecting the quality of human life and the environment. His understanding of these interactions was represented in his many works on the concept of *biosoma*,[1] a complex adaptive system with myriad components in the *bio*logical, *so*cial, and *ma*chine domains.

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[1] This and other terms—adaptive response, DUMBO, MetroTech, and urban knowledge park—are listed in a Glossary on page 20.

The following section presents an overview of George Bugliarello's professional career and his accomplishments while at NYU-Poly (formerly Polytechnic University). Next is a review of his scientific, engineering, and professional contributions, including the biosoma, his rethinking of urbanization and engineering for a sustainable future, urban security and adaptive response, and the urban knowledge park, exemplified by Brooklyn's MetroTech. We then offer personal reflections from George's distinguished academic, professional, and administrative collaborators.

OVERVIEW OF GEORGE BUGLIARELLO'S PROFESSIONAL CAREER

George Bugliarello—president (1973–1994), professor, and chancellor (1994–2003) of Polytechnic Institute of NYU—was an engineer and educator with a broad background, as indicated in the list of subjects above. He held a doctor of science degree in engineering from the Massachusetts Institute of Technology and was awarded honorary degrees from Carnegie Mellon University, the University of Trieste, the Milwaukee School of Engineering, the Illinois Institute of Technology, Pace University, Trinity College, Rensselaer Polytechnic Institute, and the University of Minnesota.

At the time of his passing, Dr. Bugliarello was serving his second four-year term as foreign secretary of the National Academy of Engineering (NAE), to which he was elected in 1987. He was a lifetime national associate of the National Academies and served as chair of the NAE Council's International Affairs Committee. He was also active in many National Academies projects and activities. He chaired the study on Sustainable Habitats: Innovation and Technology to Meet Megacity Challenges, Committee on the US-Iran Workshop on Science and Technology and the Future Development of Societies, Board on Science and Technology for International Development, and Board on Infrastructure and the Constructed Environment. He was also a member of the Committee on Counterterrorism Challenges for Russia and the United States, Joint Consultative Committee for the US-Egypt Program, Committee on Science Education K–12, and Committee on Human Rights.

For the American Association for the Advancement of Science, he chaired the National Medal of Technology and Innovation Nomination Evaluation Committee, Advisory Panel for Technology Transfer to the Middle East of the Office of Technology Assessment, and Committee on Science, Engineering and Public Policy.

Dr. Bugliarello's international experience included consultantships abroad for OECD, as reviewer of the science policy of several countries, and for UNESCO; services as a specialist for the US Department of State in Central Africa; a NATO Senior Faculty Fellowship at the Technical University of Berlin; and membership on the Scientific Committee of the Summer School on Environmental Dynamics in Venice. He was the US member of the Science for Stability and Science for Peace Steering Committees of the NATO Scientific Affairs Division.

He was cofounder and coeditor of *Technology in Society–An International Journal* and interim editor in chief (1997–2011) of *The Bridge*, the quarterly publication of the National Academy of Engineering. He also served on several editorial advisory boards, authored over 300 professional papers, and was the author, coauthor, or editor of numerous books.

He was a member of the Council on Foreign Relations and a fellow of the American Society of Civil Engineers, American Society of Engineering Education, American Association for the Advancement of Science, New York Academy of Sciences, and Biomedical Engineering Society, and a founding fellow of the American Institute for Medical and Biological Engineering.

HIS ACCOMPLISHMENTS AT NYU-POLY

George Bugliarello joined the then Polytechnic Institute of Brooklyn as president in 1973 and served in that capacity for 21 years.

George knew that in order for Poly to grow, the physical and economic character of its neighborhood needed to change as well. He saw this problem and converted it into an opportunity by carving a path to revitalize downtown Brooklyn with Poly in a leading role. He proposed the development of a technology park, an idea that paid off in 1989 when ground was broken for MetroTech, the first modern university-industry research and technology park in the United States. The project—15 years from concept to completion—required working with the city administrators and the corporate sector to renew the area surrounding Polytechnic. The resulting Metropolitan Technology Center, or MetroTech, grew to a workforce of more than 20,000 employees in financial, utilities, and communication sectors (including the 911 emergency system for New York City).

Among George's key decisions was the creation in 1982 of the Center for Advanced Technology in Telecommunications (CATT), which continues to receive funding from the state of New York in return for disseminating technological research to New York companies for new applications. He also formed a Center for Technology and Financial Services at Poly in 1994, with teaching and research functions and a strong focus on users of technology in the financial industry. This fostered the first US master's degree program in financial engineering.

The success of MetroTech was such that it became the catalyst that George believed would transform downtown Brooklyn into the vibrant place that it is today. In 1994, he was honored with the New York City Mayor's Award for Excellence in Science and Technology.

HIS SCIENTIFIC, ENGINEERING, AND PROFESSIONAL CONTRIBUTIONS

The Biosoma

The biosoma, illustrated in Figure 1, is an entity created by the interaction of a *bio*logical component (a city's inhabitants and other forms of life such as vegetation or microorganisms), a *so*cial component (the collective activities, ideas, and organizations of the inhabitants), and a *ma*chine component (artifacts, tangible and intangible, that support the life of the city) (Bugliarello 2000, 2001). The schematic representation in Figure 1 belies its complexity.

The biosoma concept helps provide a comprehensive picture of the interaction of living systems and society with machines and with the environment, whether one looks, for example, at cities, where half of the world population now lives, or at natural and anthropogenic environmental challenges and disasters (Bugliarello 2007).

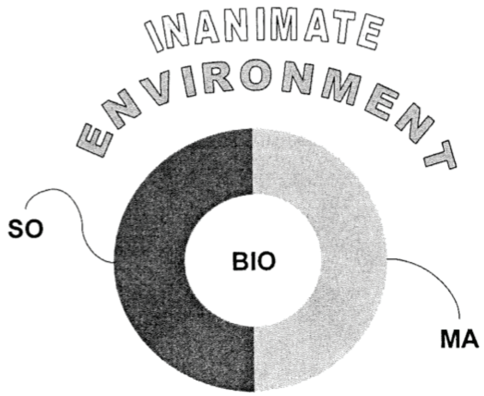

FIGURE 1 The Biosoma (Bugliarello 2000, 2001)

Balance among the three biosomic components is important to maintain a city's positive characteristics while reducing its dysfunctionalities. Balance considerations have far-reaching implications in making a city livable and manageable. A totally automated city becomes an inhuman city (Bugliarello 2001).

Human actions on the environment fall into two often synergistic categories: transformation and utilization. The origin of life itself is the transformation from inanimate materials and energy in the environment into biological organisms. The environment is also affected by tradeoffs between the hierarchy of elements of the matrix, such as energy-materials, energy-information, or materials-information (Bugliarello 2007).

George Bugliarello's writings on the biosoma have been cited in a number of scientific papers. For example, his article "The Biosoma: The Synthesis of Biology, Machines, and Society" (Bugliarello 2000) has been cited by Thomas et al. (2003), Cathcart and Čircovič (2006), Amadei (2003), and Sandekian et al. (2007). Benedikter (2010) cited his 1998 work "Biology, Society and Machines."

Rethinking Urbanization and Engineering for a Sustainable Future

The accelerating urbanization of the world is a recent phenomenon: at the beginning of the 20th century an estimated 5 percent of the world population lived in cities, whereas now half is urbanized. An understanding of this phenomenon in all its dynamics and implications is still missing, from the question of how the sustainability of cities affects the overall sustainability of the globe, to that of the long-term impact of urban living on society (Bugliarello 2011).

In the area of engineering for economic sustainability, the challenges are to design technologies and systems that can facilitate global commerce, cultivate technological innovations and entrepreneurship, and help generate jobs while alleviating environmental impacts and using resources efficiently (Bugliarello 2010a). Urban sustainability is multifaceted and encompasses security, economics, environment and resources, health, and quality of life (Bugliarello 2010b). It can be viewed as the intersection of two extremely complex and not yet fully understood processes, urbanization and global sustainability, which will increasingly overlap as urban populations continue to grow (Bugliarello 2010b). Effective policies are critical for addressing urban sustainability, and must be politically realistic in deciding on appropriate balances, such as centralized versus decentralized systems, "soft" versus "hard" solutions, local versus regional focus, agriculture versus pollution, and free markets versus interventions (Bugliarello 2008).

George Bugliarello's work on urbanization and engineering for a sustainable future has been cited in numerous journal papers. His work "Engineering: Emerging and Future Challenges" (Bugliarello 2010a) has been cited by Amadei et al. (2009) and Amadei and Sandekian (2010); "The Engineering Challenges of Urban Sustainability" (Bugliarello 2008) has been cited by Erickson and Stefan (2009). Bolay and Kern (2011), Sobrino (2012), and Amadei et al. (2009) cited "Megacities: Four Major Questions" (Bugliarello 2009). And Oliver-Solà et al. (2011), Ejechi and Ejechi (2008), Agudelo-Vera et al. (2011), and Blasi et al. (2008) cited his article "Urban Sustainability: Dilemmas, Challenges and Paradigms" (Bugliarello 2006).

Perspectives on Urban Security and Adaptive Response

In the United States, cities of over 100,000 inhabitants account for 80 percent of the country's population, which makes them major potential targets of terrorist attacks—on their infrastructures, government installations and operations, business sites, housing, chemical plants, and people—because all of their systems are interdependent and the vulnerability of one system can have a major impact on others (Bugliarello 2003). Threats from nuclear, biological, chemical, and radiological attacks are of greatest concern, as well as cyber, electromagnetic, and psychological attacks (Bugliarello 2005).

Given the complexity of possible target systems in a city, a comprehensive system is needed that explicitly addresses the interdependence of urban components and vulnerabilities (Bugliarello 2003). Cities must also become adaptive to survive changes in their environment (whether physical, social, or economic) and thus improve performance or seek new niches. The capacity to adapt may be developed exogenously, by design from outside the entity, or, in the case of self-adaptation, endogenously (Bugliarello 1999).

George Bugliarello's 2005 paper "Urban Security in the United States" was cited by Németh (2010) and "The City as an Adaptive Entity" (Bugliarello 1999) by Mayer (2007).

The Formation of MetroTech: An Urban University-Industry Park

The second half of the last century saw the emergence of a new phenomenon, the knowledge park, exemplified by the Research Triangle Park in North Carolina and the complex around Stanford University in California. These environments combine industry, business, or government operations with a knowledge institution such as a college, university, or specialized laboratory. As parks become a critical element for the economy, social development, and the workforce of the future, their location cannot be left to historical accident but needs to be rationalized (Bugliarello 2004).

MetroTech, in Brooklyn, New York, is a case where a university played a key role in creating a technology complex in an urban setting (Bugliarello 1997), and George Bugliarello was instrumental in its development (Figure 2). MetroTech is an early example of how science and technology programs can influence a region. It is located one subway stop from Wall Street, across the East River, and comprises 14 buildings (Figure 3), with academic, business, industry, and government occupants (Bugliarello 1997, 2004).

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George Bugliarello: Mastermind of Metrotech

By Barbara Confino

A man who stands at the crossroads between the theoretical and the practical, George Bugliarello is a visionary thinker with the rare capacity to see the relation of the parts to the whole. Translate that into layman's terms, and you describe someone who understands how urban conditions, economic realities, and technical innovations interconnect in our world. With a doctorate in engineering from MIT and a broad background ranging from computer languages to biomedical and civil engineering, to a serious interest in history, Bugliarello has a passion for information and a desire to know everything.

The President of Polytechnic University, he arrived on the scene seventeen years ago when the old Brooklyn Polutechnic was in deep financial trouble and the current Brooklyn renaissance hardly a dream. Almost immediately he began overseeing a merger with the engineering school of NYU, thus transforming Brooklyn Polytechnic into Polytechnic University, now one of the major technological institutions in the country.

His earlier experience as Dean of Engineering at the University of Chicago had given him a glimpse of the possible role a large engineering school could have in a major city; this experience buttressed by a study done for the National Science Foundation researching ways the university could be more responsive to the state resulted in a book called: *Technology, The University, and The Community.*

At Polytechnic, Bugliarelo quickly realized how critical was the relationship between the university and its downtown Brooklyn environment. "We could not

George Bugliarello — Photo by Barbara Confino

'I wanted to see those buildings come out of the ground.'

Polytechnic we established a venture capital fund called Polyventures. We are the technical partners, who can technically evaluate new ideas, and they are the business partners. So far it has invested about 20 million dollars in the fields of electronics, mechanics, and aerospace."

The relationship between the city and technology exists almost by definition for George Bugliarello. "Cities are the product of technology," he declares. "The modern city is only possible because of transportation, water supplies, elevators, that is to say, civil engineering. Today cities are major centers of services with telecommunications enabling you to communicate with factories, consulting engineers, or other professionals who can now interact in real time across the world. The SIAC building, for example, was designed jointly by U.S., Israeli, German, and Japanese engineers all working on the same set of drawings at the same time thanks to telecommunications."

New York, he believes, must remain constantly on guard vis à vis the competition from Tokyo and London. "I once said jokingly to someone in the stock market that really an exchange could be a micro-chip with peripherals. Thank God it isn't but there's always the danger. New York must look at its competition even in an area where it is strong, because it is a technology that can be anywhere. All you need is a very powerful telecommunications network."

We need to re-evaluate our public works policy as well. "Are we simply going to repair what is old, which we are doing now, or are we going to have new designs and new structures?" Overspecification in design is another obstacle

FIGURE 2 Excerpt from *Brooklyn Progress*, September 1990

FIGURE 3 MetroTech's Building Layout

PERSONAL REFLECTIONS

The following personal reflections are presented here on behalf of some of George Bugliarello's close friends and colleagues.

Daniel Berg, University of Miami

President George Bugliarello had a fantastic career with an enormous impact on both engineering and education. Even as an assistant professor, at Carnegie Tech in Pittsburgh, he was ahead of his time in starting a bioengineering research program well ahead of the academic engineering community's recognition of this important field. His record on engineering and education is very well known and deserved.

But a very important aspect of him, known primarily to his colleagues, was his gentlemanly, thoughtful, and sensitive approach to people.

One illustrative small personal anecdote: After a lengthy session with him and his colleagues at Polytechnic University about possible collaborative projects connected to homeland security involving Rensselaer Polytechnic Institute, George insisted on escorting me to the subway to make sure I caught the correct subway train to Penn Station to catch the Amtrak train to Albany-Rensselaer! That was just one small example of the many thoughtful kindnesses he showed me as well as his other colleagues locally, nationally, and internationally.

Peter D. Blair, National Research Council

George Bugliarello was among the most remarkable people I have ever known. The more I came to know and work with him over the years, the more remarkable his life as an engineer and even more as a person became to me. Our conversations over the years were often as much about art, language, culture, and politics as about science and engineering. Inevitably after a session with George I realized how little I really knew about the world and how much I would learn from him in even the most casual conversations.

In George's role as foreign secretary of the National Academy of Engineering, his lifelong international perspective on how science and engineering can shape and improve the human condition revealed him to be the quintessential renaissance engineer/statesman. His passion for Poly and for creating MetroTech was a realization of his lifelong vision of how cities could be reshaped for the future.

But above all I will remember George's engaging personality and his vision and inspiring passion for a better world throughout his life. He directed his powerful intellect, his compassionate nature, and his nurturing spirit to all his endeavors and his interactions with colleagues, friends, students, and everyone who had the good fortune to know him. We all miss him deeply.

Robert Dalziel, AT&T Global Networks (ret.)

George was one of those rare human beings with both vision and the management skill to make visions happen.

As a Poly board member, I enjoyed watching a skilled executive in action. He did a superb job of balancing the interests of faculty, administration, and students. I especially appreciated the support he gave to our efforts to improve student life and student retention. As my wife Mary Lou said, "He was a gentleman and a scholar, in the finest sense of the phrase."

George and Virginia were good friends and good people to be with. We miss him a lot.

Rose J. Emma, former assistant to George Bugliarello

When I think of George, I think of the person who could, with great speed, put into motion the most complex projects—starting a new venture as soon as another was finished and, more often than not, juggling numerous undertakings simultaneously. George was always on a mission and seemed to live in his own time warp. I recall times when he would call me to say he was on his way back to the office from Midtown—and show up at the office seemingly ten minutes later.

George had an uncanny ability to bring out the best in everyone with whom he worked. In the most difficult situations, he always knew what to do and what to say—intelligence and diplomacy incarnate. Amidst all the frenzy of high-level projects, constant writing, and a travel schedule that made everyone who knew him marvel at his stamina, he never failed to find the time to chat with any student, staff, or faculty member who stopped by the office or met him in the hallways.

I fondly recall being chastised for using a knife on my fettuccini, and for mispronouncing the name of a town in Sicily to which he was headed. It still amazes me that he was able to read—*upside-down*—the bizarre shorthand I had invented to keep up with his rapid-fire dictation (in which he often included the punctuation!). His remarkable writing often took a Dickensian turn, with lengthy phrasing that never missed a grammatical beat.

George's effect on students was extraordinary and watching him in class was an experience. I knew he had reached his major classroom goal when, after he passed, so many of his students approached me in the halls to tell me they had learned from George *how to think*.

The memories are abundant and I feel like a Lotto winner, for what are the odds of meeting, let alone working with, someone of George's caliber? He was truly a shining star, with a brilliance surpassed only by his compassion for everyone around him. I miss him.

John Falcocchio, NYU-Poly

George was a humanist and an engineer with a deep understanding of how science and technology can improve and sustain the quality of urban life. He was an exceptional visionary with an unusual gift for pragmatic approaches in solving societal problems. There was no boundary to his capacity for understanding complex issues and contributing realistic solutions. I miss George at our departmental faculty meetings, where he always infused positive energy in our deliberations. His positive energy was very contagious.

Ivan Frisch, NYU-Poly (ret.)

George Bugliarello was a visionary classicist. Pursuing his activities for Polytechnic, MetroTech, the NAE, and his myriad other constituencies, he worked everywhere in his own handwriting, continually scripting on pads, in margins, and on scraps for his trusted assistant to type as elegant prose. Elegance was his hallmark.

His warmth and versatility were unrivalled. He once arrived at an overseas conference with his speech written in Italian, only to discover the conference was in Spanish. He delivered it in Spanish.

He brought to the enormously challenging job of president grace and humanity that enlightened and broadened everyone. Primarily he was an educator, continuing in his last years to inspire his students in a freshman class as well as all of the rest of us who had so much to learn from him about urban society and the world.

James Garrett and Mitchell Small, Carnegie Mellon University

George Bugliarello was a renaissance man, advancing knowledge and technology in fluid mechanics, biotechnology, urban systems, and technology innovation. In his 11 years as professor of civil engineering at Carnegie Mellon (1959–1969), he studied mechanisms of blood flow in our fluids laboratory and was a founder and first director of the CMU Biomedical Engineering program. His 1970 paper with Andrew K.C. Wong, “Artificial Intelligence in Continuum Mechanics,” appeared in the *Journal of Engineering Mechanics* and helped to seed and foreshadow CMU’s emergence as a leader in AI and related computer-aided methods for engineering design and analysis, as well as his own out-front thinking on social intelligence and globally linked computer systems. We continue to be influenced by his vision, leadership, and joy for learning.

Ilan Juran, NYU-Poly

George was an elite humanistic explorer, whose creative scientific work and educational dedication were often inspired by a holistic quest for understanding the universe of the complex and intertwined relationships among biological, societal, environmental, and technological systems. For him, engineering was the art of creating technology solutions and systems as the processes that human societies devise to modify or preserve nature for their sustainable development, and the capability of their strategic integration in the design of the metropolis to address future societal needs.

I have personally deeply appreciated and enjoyed our unforgettable renaissance culture–style brainstorming sessions on the emerging challenges facing fast-growing metropolitan centers in both industrialized and developing countries. Working closely with George on shaping a new vision for the development of the Civil and Environmental Engineering Department (CEE) and creatively building an urban-focused nationally recognized research program was an inspiring endeavor and a greatly stimulating learning experience.

His vision of the university's core mission was anchored in the belief that Poly, as the prime urban engineering and science university of New York, should creatively build dynamic partnerships with metropolitan stakeholders, government agencies, and urban utilities for accelerating the development and assessment of state-of-the-art technologies and innovative urban solutions to metropolitan renovation and sustainable development challenges. This universitywide initiative involved a great diversity of interconnected disciplines and supported the development of several academic centers, such as the New York State–sponsored Center for Advanced Technology in Telecommunications (CATT; 1982), the fast-expanding graduate program in financial engineering, and the CEE research program, which was initiated with his personal commitment and support.

George's vision of environmentally sustainable urban development was greatly inspired by his deep global understanding of rising societal needs in a wide diversity of cultural contexts, his assessment of the critical role of technology innovation in shaping the future of cities and enhancing their resiliency, and his concrete grasp of current infrastructure needs to support renovation and extension of their urban systems. With an extreme passion for turning his vision into reality, forged through academic and industry interactions, George carved a path to create the first modern university-industry research and technology park for revitalizing downtown Brooklyn and placed Poly in a leading role to guide its renaissance.

Bill McShane, NYU-Poly (ret.)

My first memory of the new president, George Bugliarello, was at a gathering in the faculty lounge: he was so enthusiastic that he wanted to speak to the gathering while seeing everyone, so he used a chair to stand on a table, to see and be seen. That fire, enthusiasm, and outreach were the hallmark of his many decades contributing to Polytechnic and a very apt first impression.

Move ahead to the era of the Brooklyn Campus Redevelopment Committee, which became the MetroTech initiative. It was a concept that seemed too far-fetched to be serious in the minds of many. Even the codeveloper—Forest City, now a regional presence—had to be enticed from Cleveland. Suffice it to say that MetroTech is a reality, and surrounds and shapes us.

Move ahead again to his years of engagement with students, chatting at George's home at various gatherings he and Virginia had, or as he finished his class and I began mine in the new Jacobs Building.

Others can speak to his scholarship, his travels, and his presence. I focus on these memories, and on the smile and the energy.

Roger Roess, NYU-Poly

When I was dean I was often asked to speak to prospective students at recruiting events. One year, I was to follow George, who was giving a general welcome. I usually use cards to remind me of the main points I want to make in a presentation. On this particular day, as George did his welcome, I sat there quietly discarding card after card: George, in a five-minute welcome, had covered virtually every point I was going to make. To this day, I can't quite remember what I said during my 15-minute talk, but I have never forgotten how George distilled the essence of why students should come to Poly into a crisp and eloquent 5-minute welcome.

When I first became dean, we had our regular ABET accreditation visit only a month later. With no hotels in Brooklyn at the time, the visiting team was housed in Manhattan. They were supposed to arrive at 8:00 AM on a Monday morning. George and I, dressed in our Sunday best, were waiting for them at the front door. Unfortunately (and unknown to us), the team was stuck in a vicious traffic jam in lower Manhattan, and didn't arrive until two hours later. As we waited, George and I noticed that people entering the building were giving us very strange looks. Later, the union made a formal complaint, believing that George and I were standing there to observe the arrival time of employees! It always gave us a humorous moment to share over the years.

George was always a charismatic leader. I was only 34 years old when he asked me to accept the position of Dean of Engineering. I have always treasured the faith he placed in me, and the fact that he was always there to provide help, support, and advice when I needed it, which was pretty often in the early days. His vision of MetroTech and his tireless work to make it happen truly saved Polytechnic from extinction. With all of the difficult times he had to lead us through, however, he remained a very accessible president and a most personable one. I am very lucky that I was able to work for him for so many years, and to work with him as a treasured colleague in civil engineering.

Richard Thorsen, NYU-Poly

George had a passionate commitment to the welfare of Polytechnic and saw a role for the institute in shaping the city and the world. In 1973 he became the first president of the newly formed institution that arose from the merger of Polytechnic Institute of Brooklyn and the New York University School of Engineering and Science, and the eighth president of Polytechnic.

By 1976 he was convinced that it would take multiple decades for a great institution to emerge. He saw three principal phases:

- Rebuilding our local environment—urban decay replaced by MetroTech
- Refurbishing and building our own facilities and infrastructure
- Rebuilding the intellectual capital of the institute

The first was largely completed during his presidency, the second by his successor with seeds planted by George, and the third is the process in which we are now engaged with our new relationship with New York University.

MetroTech not only gave Poly an urban campus but was the catalyst for the rebirth of downtown Brooklyn. Without the success of MetroTech there would be no waterfront development (including DUMBO[1]), no residential towers, and no Barclays Center. These all grew out of George's recognition that the future of humanity was in its cities.

George showed great courage in building a strong and enduring relationship with Donald Othmer in the face of opposition to investing [fundraising] resources during eras of financial stress for Poly. This investment paid off after George had left the presidency with a $175 million gift from the Othmers, making possible our new building and refurbishing Rogers Hall.

The third leg of George's view of Poly's future, building her intellectual capital, is what we are now engaged in. George would love to have seen this process mature, particularly in the area of urban studies and research, something he was a proponent of from the first day of his presidency.

So much of what we are today and what we are poised to become have their roots in George's presidency. We are all in his debt and society will reap the benefits.

Lucio Ubertini, Sapienza University of Rome

It was the 2nd of June 1992 when George Bugliarello, president of Polytechnic University, and Giancarlo Dozza, president (*rettore*) of the Università degli Studi di Perugia, signed the "Agreement of collaboration between Polytechnic University (USA) and Università degli Studi di Perugia (Italy)." The program was presented during a memorable seminar on September 20 and 21, 1993, hosted by the Italian Cultural Institute of New York and Polytechnic University. The presentation document concludes: "The first major initiative resulting from these agreements will enable civil engineering students in Italy, who have completed the fourth year of the five-year *Laurea* degree, to attend the Polytechnic University for their fifth year. With this arrangement, they will receive both the *Laurea* degree from the Italian university and the master's degree from the Polytechnic University. It is expected that this program will be extended to include other opportunities for Italian-American faculty and student exchanges and other interesting modes of cooperation between universities." The achievement of the program was "providing for collaboration in teaching, research, studies, and other academic activities in fields of mutual interest, thus encouraging the exchange of different experiences and points of view."

Today we can say that thanks to the tremendous vision of George Bugliarello there has been an incredible growth of that initiative; in fact, in 2004 at Sapienza University of Rome we created H2CU (www.h2cu.com), the Honor Center of Italian Universities. Currently 21 Italian universities and three Italian National Research Council (CNR) institutes are related to H2CU. The Center has allowed more than 200 students to be enrolled and obtain the *doppio titolo* (dual degree) at important US universities such as Massachusetts Institute of Technology, Columbia University, Polytechnic Institute of New York University, and Pace University.

I am very grateful to George for this opportunity and the great gift to appreciate his humanity, generosity, and great friendship.

Chuck Vest and Lance Davis, National Academy of Engineering

George Bugliarello was in all respects a delight to have as a colleague, and his intellectual enthusiasm for discussing all matters of science, engineering, technology, and society was mesmerizing. His dedication and devotion to duty are evidenced by his scholarly engagement on an article for the NAE *Bridge* journal during his last days in the hospital in mid-February 2011.

George was the NAE foreign secretary from July 1, 2003, until his death and the NAE is greatly indebted to him for his outstanding service in international affairs and his wise counsel on all facets of engineering and technology as a member of the NAE Council. His election as foreign secretary was a stroke of insight on the part of the NAE membership, because he brought enormous experience to the post based on many years of participation in both UN and National Research Council international study delegations. He led NAE interactions with the other engineering academies of the world, through the Council of Academies of Engineering and Technical Sciences, and supported and participated in our bilateral Frontiers of Engineering (FOE) symposia with Germany, Japan, India, China, and the European Union.

As one would expect of a person who was a lifelong educator, he was especially drawn to the young engineers invited by NAE to participate in FOE meetings. One of those young engineers, Melissa Knothe Tate, of Case Western Reserve University, was moved to write a remembrance of George:

> The loss of a mentor like George Bugliarello is devastating, but the fruits cultivated through his mentorship will continue to grow, nourish, and disperse new scientific seeds, sowing a bright future for engineering. George was a world citizen who never lost his curiosity to learn anew; perhaps his greatest legacy will be as a role model for mentoring talented young engineers and for helping society to understand the great potential as well as societal implications of the technologies that we, as engineers, develop. At Frontiers meetings, together with other meeting participants, we engaged in discussions as diverse as cell mechanics, alternative energy technologies, engineering human health, and the history of engineering science. These discussions occurred at poster sessions, coffee breaks, bus rides, wherever George could get a discussion going; he was simply insatiable for knowledge!
>
> George had an uncanny way of seeing the "big picture," particularly with respect to engineering, technology, and society. I will never forget how eye opening it was to hear him speak of the technological developments exerting the greatest impact on society; of course he touched on obvious technological developments regarding energy and transportation, but perhaps more remarkably, he talked about the development of television, its impact on human interaction and its

> lasting transformation of society over the past decades. I had never thought of the impact of such ubiquitous entertainment "technology" in that way.

George was revered by NAE members and foreign associates and many have sent notes of condolence to NAE. His legacy extends far, far beyond his service to NAE, and has been captured eloquently by others. Perhaps George's persona was best captured by NAE member Bert Westwood, who described him as a gentleman, a scholar, an outstanding engineer, a dedicated member of our fraternity, a multicultural enthusiast, and an experienced and accomplished diplomat in the cause of international understanding and scientific collaboration.

Richard Wener, NYU-Poly

Of all the faculty members I have met and worked with over my 35 years at Polytech, I am most proud of the time spent with George Bugliarello and the relationship I formed with him, especially over the last 10 years. George had a keen and analytic mind and was a very original thinker—a quick scan of the syllabi for his courses on Sustainable Cities and Biosoma will demonstrate that. But what was most impressive was the way his fascination with new ideas and new projects never waned. Of all the senior faculty I have ever met, he was by far the most open and least resistant to novel proposals or unusual ideas. His intellectual enthusiasm never flagged, even at an age when most scholars suffer "hardening of the acumen." I used to say that I wanted to be George Bugliarello when I grew up. I still do.

CLOSING REMARKS

The legacy and contributions of George Bugliarello are far-reaching and influential in many disciplines such as civil engineering, biomedical engineering, urban development, science policy, water resources, and environmental science. A pioneer in developing ways for universities to advance urban development and sustainability through collaboration and innovative thinking, Dr. Bugliarello is credited with a number of scientific inventions and educational innovations. These include Hydro, a computer language for water resources; pioneering graduate programs in biological and financial engineering; and the journal *Technology in Society*. More specifically, he changed the way we look at urbanization issues and directed us toward creating a more sustainable future. Many activities at NYU-Poly have witnessed this impact, changing the way we engage our curriculum and programs.

Perhaps Dr. Bugliarello's greatest accomplishment was MetroTech. In 1975, during a recession, he foresaw that a university-industry collaboration would revitalize the city, its faltering financial industry, and its economy.

How do we continue George Bugliarello's legacy and culture? The answer to this question begins with this symposium and its contributions to the academic field, along with a scholarship and an endowed chair of urban sustainability in his name.

George Bugliarello was a leader in teaching and research and he successfully tackled some of the 21st century's greatest challenges and opportunities. He was compassionate toward the world, concerned about the conditions in which we live, and adamant in showing how building a better surrounding is a worthy goal for each of us.

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GLOSSARY

Adaptive response: the capacity of an entity (e.g., a city) to sense and respond to a perturbation. An effective adaptive response anticipates a threat and leads to action rather than reaction.

Biosoma: concept created by George Bugliarello to consider the interaction of the natural inanimate inorganic environment with the Earth's biological systems (humans and other species), their social entities, and their machines (artifacts).

DUMBO: acronym for Down Under the Manhattan Bridge Overpass, a neighborhood in the New York City borough of Brooklyn. It encompasses two sections: one located between the Manhattan and Brooklyn Bridges, which connect Brooklyn to Manhattan across the East River, and another that continues east from the Manhattan Bridge to the Vinegar Hill area.

MetroTech: the Metropolitan Technology Center, a university-industry park in Brooklyn, conceived and catalyzed by George Bugliarello and Polytechnic University in 1975.

Urban knowledge parks: dense geographical environments combining industry and research-oriented institutions.

Economic Development Strategy and the Role of Technology and Innovation in Crafting the Economy of New York City's Future

Robert K. Steel
Office of the Mayor of New York City

The Bloomberg administration's economic development strategy is defined by four pillars. The first pillar is a high quality of life characterized by public safety, excellent schools, beautiful parks, clean water, and cultural amenities. The second is a probusiness environment with sensible regulation that ensures safety while encouraging business growth. The third pillar is investment in the future by developing transportation infrastructure, office space, and housing, which are critical for the city's long-term success. The final pillar is innovation and economic transformation.

For much of its history, New York City was the capital of American innovation. As the American economy has shifted from industrial to information-based, places like Boston and Silicon Valley have surpassed New York City, driven by the strength of their academic research programs. Companies started by alumni of MIT have combined revenues equal to the GDP of Brazil.

After the financial crisis began in 2008, Mayor Bloomberg asked the NYC Economic Development Corporation (EDC) to reach out to hundreds of academics, local business leaders, civic leaders, entrepreneurs, and venture capitalists to understand how the city could make a game-changing impact on the economy. New York City has a fantastic higher education system with more postsecondary students than Boston has people. However, we learned that the city has a deficiency in science and engineering, especially relative to the size of the economy. Silicon Valley has four times the concentration of engineers in its workforce as New York City.

In December 2010 EDC issued a request for expressions of interest to determine whether academic institutions would be interested in establishing an applied sciences campus in New York City. We heard from 27 institutions from all over the world and the strength of their responses led us to issue a request for proposals in July 2011 to develop a new campus. We offered up to $100 million to assist with infrastructure, buildout, and/or equipment; three city-controlled sites; and technical assistance in exchange for significantly expanding a current academic facility or building a new applied sciences facility.

In December 2011 Mayor Bloomberg announced the selection of Cornell University and Technion-Israel Institute of Technology to build a $2 billion, 2-million-square-foot applied science and engineering campus on Roosevelt Island. The new Cornell NYC Tech's first class of full-time students, in January 2013 in a temporary campus at Google's Chelsea offices, will begin pursuing a one-year Cornell University master of engineering degree in computer science.

In April and July 2012 the city reached agreements with a consortium led by New York University (NYU) to assist in the creation of an additional applied sciences school, the Center for Urban Science and Progress (CUSP), in the heart of downtown Brooklyn, and with Columbia University to significantly expand its engineering department.

Mayor Bloomberg's applied sciences initiative will generate billions of dollars of economic activity and create thousands of new jobs connected with the campuses' construction, operations, and spinoff companies. Cornell NYC Tech, NYU, and Columbia will more than double the number of engineering faculty and graduate students in NYC over the next decade. Taken together, these three new campuses will dramatically transform the city economy's ability to compete successfully in the 21st century and beyond.

George Bugliarello: Reflections on His Global Impact through the National Academy of Engineering

Ruth David
Analytic Services, Inc.

George made many contributions not only to NYU Polytechnic but also to the National Academies and the nation. Although I am here largely to represent the National Academy of Engineering (NAE), I also got to know George on a more personal level when I joined Analytic Services in 1998.

George was on our board of trustees and I first met him after I had been on the job only about three weeks. I instinctively recognized several very endearing attributes. George was a kind man, he was a colleague, he was a mentor, and he was an intellect without the ego that often goes with it. He had a way of listening and pulling the best from people. I saw him work with analysts of every age: he was an active listener, he would probe for details of the analysis, but he cared more about the impact of the work, and he instilled the sense of passion and commitment in others that he brought to everything he touched. So I treasured his service on my board.

As an aside, we have a corporate bylaw that says when you turn 74 we declare instant senility and you can no longer serve on our board. Over my 14 years with the company I have had a number of trustees hit that age limit and rotate off and I periodically thought maybe we should lower the age. George was the opposite: 74 was far too young to lose him as a member of my board of trustees because he was still actively engaged in the professional community worldwide and was an active contributor. So it was with great sadness that I bid George farewell from my board. I was delighted then to have the opportunity a few years later to reconnect when I joined the NAE Council and found him serving as foreign secretary.

I observed three dimensions of George while working with him for a few years in his capacity as NAE foreign secretary. He understood and valued the connection, the engagement, worldwide. He knew that the National Academies and the nation would benefit from forging a stronger international collaborative network. He was passionate about this. So in addition to being a kind man, mentor, colleague, and educator, George was an activist, never content with the status quo.

The first dimension I want to touch on very briefly was his role with the foreign associates of the National Academy of Engineering. Just as the US membership is elected, these individuals also are elected members of the NAE but they are not US citizens. Some live in the United States and are contributing locally, others live in their home countries. This is a cadre of individuals who are extremely talented and accomplished engineers, and George saw the need to bring their voices to the products of the National Academies. He understood not only that talent existed in lots of parts of the world but that we would benefit from hearing those voices. He not only wanted them elected, he wanted them engaged in the activities of both the NAE and the National Academies.

More broadly, during his tenure George took a number of steps not only to grow the cadre of foreign associates but also to diversify the spectrum of countries represented. Until then many of the foreign associates were from Western Europe and other countries with which we had long-standing collaborative relationships. George recognized immediately the need to reach out and identify rising talent in Asia—China, India, Taiwan, South Korea, and Indonesia, among others. He also reached out to South America, recognizing the growing talent base in countries such as Brazil. So he worked very hard at bringing a more diverse set of voices into the foreign associates cadre of the National Academy of Engineering.

Then he worked tirelessly against some fairly significant institutional impediments, asking how can we better use these voices? How can we engage them in participating in the studies and report activities of the National Academies? This was hard because of the challenges of time and distance, travel money, and language, but he made progress.

The second area I want to describe, again just very briefly, was one of George's passions, the Frontiers of Engineering symposia series, which had a US component as well as an international component, largely started with bilateral symposia. These by-invitation events are opportunities to bring together young researchers to exchange ideas on very important topics. The program started largely with our long-standing partners Germany and Japan, but George worked hard to extend it to other nations.

George had an art of picking topics that were important to the world but also of keen importance to the nations represented in a particular symposium. So he brought together researchers around themes that were high-impact problem areas. He fostered a spirit of exchange of ideas and cooperation in those settings that was very important. It is hard to estimate the lingering value of the networks established because it is very difficult to measure that over time. But George was very passionate about these venues as ways to motivate the exchange of ideas and to build collaborations early in the careers of people who themselves will go on to have huge impact both in their own countries and for the world more broadly.

Finally, George was actively engaged in the International Council of Academies of Engineering and Technological Sciences (CAETS). He helped drive agendas that were meaningful. Many international bodies have a tendency not to implement active agendas, but here again George saw an opportunity to make a difference. So he worked hard to build collaborative agendas on issues like sustainability and others that were of global interest.

He also saw the need to reach out to countries without established academies for engineering and science and to help them understand what science and engineering could do for them. So he worked toward building relationships in Africa and other parts of the developing world where the tech base may not be as well established. He understood well what engineering could do for them as they build their own societies and nations.

George Bugliarello was all of the things I have described. He was a kind man, he was a colleague, he was a mentor, he was an educator, he was a humanist, and he was an activist. With George it was never about personal credit, it was about impact, it was about making a difference, and it was about showing the world a vision of something better and then helping drive action in support of realizing that vision.

George Bugliarello: His Leadership of the Polytechnic Institute and Vision of the Future

Richard S. Thorsen
Polytechnic Institute of NYU

ABSTRACT

George Bugliarello, first president of the Polytechnic Institute of New York University, was an urban visionary, philosopher, and realist. He predicted, decades in advance, the urbanization of the world's population, and foresaw the engineering and other challenges associated with it. With this foresight he expanded civil engineering to include urban engineering at Polytech, and with his vision he laid the groundwork for not only the institute's regeneration but also that of the surrounding community. Urban engineers, NYU-Poly, Brooklyn, and cities around the world are indebted to George Bugliarello for his vision and his ability to act on it very effectively.

UNDERSTANDING GEORGE BUGLIARELLO

George Bugliarello's professional career was forged in urban environments: MIT (Cambridge-Boston), Carnegie Mellon University (Pittsburgh), the University of Illinois at Chicago Circle (Chicago), and Polytechnic (New York). He was the first president of Polytechnic Institute of New York[1] (formed in 1973 by the merger of Polytechnic Institute of Brooklyn and the New York University School of Engineering and Science), and served until 1994.

[1] Now Polytechnic Institute of New York University.

FIGURE 1 Seal of the Polytechnic Institute of New York University

George embraced change and was a leader who went about making change possible. His range of interests and expertise transcended many disciplines—civil engineering, biomedical engineering, urban development, science policy, water resources, and environmental science. He recognized that engineering was not an isolated endeavor but an integral part of the natural world and society. This concept was embraced in the word *biosoma*—which he coined from the contraction of *bio*logy, *so*ciety, and *ma*chines—and eloquently expressed in the Polytechnic Institute seal (Figure 1), which George was instrumental in designing: *Homo et Hominis Opera Partes Naturae.* Man and the works of man belong to the natural world.

LEADER OF THE NEW POLYTECHNIC INSTITUTE

George's 21-year presidency was characterized by change—at Polytechnic, in New York City, and in the world. Through it all he was capable of seeing the big picture, the big trends. One of those trends was the increasing urbanization of humanity.

George recognized the importance of engineering to successful urbanization, but also the need for input from multiple disciplines to determine what constituted success. The engineering of cities needed to be in the context of larger objectives and plans. He persuaded his academic home department, civil engineering, to embrace urban engineering, resulting in the department of civil and urban engineering, which is a sponsor and primary organizer of this symposium. He would also have embraced the newly created Center for Urban Science and Progress (CUSP) and Poly's role in it.

In a conversation with George in 1976, he said, "Within our lifetime more than half of humanity will live in cities." This forecast was realized in

2007 and, in efforts to dramatize the importance of cities, many have cited this reality.

When George joined Polytechnic he became the leader of a financially stressed institution, with a faculty too large for the size of the student body and location in a neighborhood infected with the worst elements of urban decay. After exploring options, which included relocating Poly, George and the board of trustees committed themselves to keeping the institute in Brooklyn and working with the city of New York and corporate leaders to renew its immediate surroundings. A 15-year plan to create the Metropolitan Technology Center, or MetroTech, emerged. MetroTech was part of three big strategies in George's long-term vision for Polytechnic:

1. Rebuilding the local environment—urban decay replaced by MetroTech,
2. Refurbishing and building Polytechnic's own facilities and infrastructure, and
3. Rebuilding the intellectual capital of the institute.

The first strategy took 15 years and resulted in an urban campus for Polytechnic. But MetroTech was more than a project to gentrify the surroundings of Poly and create a campus, both of which were necessary to attract students and faculty. It was the spark that ignited the transformation of downtown Brooklyn from a place to flee from to a major destination for hotels, shopping malls, residential towers, and waterfront development. In addition, an incubator for entrepreneurs creating new companies and the Barclays Center (Figure 2) followed on the heels of MetroTech—an idea brought to reality by George Bugliarello.

After creating a new environment for the institute's surroundings, George recognized that we'd need to improve our educational infrastructure with renovated and new buildings. This would take money—a great deal of money by Polytechnic standards. Although much of the infrastructure transformation occurred after George stepped down from the presidency, his influence in advancing this dream was immeasurable. First, it was during his presidency that the Dibner Building we are now sitting in was built and what became the Wunsch Building was acquired as a landmark.

Perhaps of greater importance were gifts received after George's presidency. He cultivated Donald and Mildred Othmer for 15 years of his presidency and maintained a personal relationship with them until their deaths. Along the way he was often criticized for spending resources on Professor

FIGURE 2 Barclays Center Adjacent to the MetroTech Campus in Brooklyn, New York

Othmer during periods of financial stress for Poly. George viewed this, as any good fundraiser would, as an investment. It was an investment that resulted in a $175 million cash gift from the Othmers, the largest cash gift ever received by an academic institution. It was responsible for two new buildings, the Othmer Residence Hall and, matched with a gift from Joe Jacobs, the Jacobs Academic Building. George had engaged the successful entrepreneur and alumnus Joe Jacobs in the life of Poly since 1976, and Jacobs became a $20 million donor to our successful Fulfilling the American Dream campaign.

Building the intellectual capacity of Polytechnic required urban renewal and infrastructure enhancement and is now proceeding at an accelerating rate as we become part of New York University.

George was a leader who knew that not all of his aspirations for Polytechnic would be realized during his presidency. But his commitment to the institute caused him to start the processes for others to complete toward the renewal and reemergence of Polytechnic as a leader for positive societal change.

URBAN VISIONARY AND PHILOSOPHER

In some sense George Bugliarello's philosophy as it bears on cities or urban life is captured in *biosoma*, the concept that biological systems, social systems, and machines are part of a single organism that grows to maturity in cities. Furthermore, cities will be successful—that is, "livable"—when these are in harmony.

He also believed that such harmony was best achieved by adherence to core values. While these core values may find different expression in different societies and locations they ultimately come down to the values embraced in the US Declaration of Independence: all people are created as equals and entitled to life, liberty, and the pursuit of happiness.

City life is characterized by a collective approach to collectively important issues while preserving core values for all. Life has been extended through enhanced health care. Could a robust healthcare system exist in a totally nonurban distributed population? Could energy be delivered effectively to a totally dispersed population? What would education systems look like in such a society? Clearly urbanization has made some things better than they would be in a society without cities.

George believed in the merits of urbanization as the best path for society, but he also recognized threatening issues. We can present a utopian view of future cities, but realities must be faced to achieve that utopia. These concerns were perhaps overstated in another time by a great American statesman:

> When we get piled upon one another in large cities, as in Europe, we shall become as corrupt as Europe.

Thomas Jefferson may be forgiven for this overly pessimistic view of cities. He could not have foreseen the rise of skyscrapers made possible by steel cables—cables that were invented by Poly alumni for the Brooklyn Bridge and that in turn made elevators possible—or telecommunications technology or centralized power generation.

But as George knew there are some residual assumptions from our rural and agrarian beginnings that may have to be addressed if a utopian vision of the future is to be achieved. What are the best power generation and delivery systems to ensure the healthiest urban environments? Can individual rights to bear arms in densely populated urban environments continue to be justified? Perhaps the greatest challenge will be in the area of individual liberties, which can easily come in conflict with the collective need or collective good in an urbanized society.

For example, privacy becomes a major concern when millions of people are "piled upon one another." But Jefferson and the founders were not particularly concerned about privacy. They foresaw a minimalist government, electronic databases didn't exist, and society was relatively dispersed. In fact, for all of its wonderful provisions intended to preserve individual liberties, the US Constitution has no explicit guarantee of individual privacy—it was essentially a nonissue in the United States in 1787. But it is a burning issue today and going forward. George recognized this.

The population and resource density of cities make them target-rich environments for those who would seek to inflict harm on others. The consequences of modern warfare for cities become incomprehensible whether we're talking about nuclear weapons or cyber attacks. One of the reasons George embraced his role as international secretary for the National Academy of Engineering was his belief that individuals coming together shed their differences when working for a common goal.

Although George the realist was aware of these and other potential threats, he never lost his optimism. He was confident of this country's ability to confront and resolve conflicts arising from competition between individual liberties and collective needs in an urban environment on the one hand, and the vulnerability of cities to hostile threats of many varieties on the other. He remained a believer in the utopian view of cities of the future, and it is our honor to dedicate this symposium and its proceedings to his memory.

Infrastructure Renewal: Water, Energy, and Transportation— Opening Comments, Session Summary, and Concluding Remarks

Ilan Juran
Polytechnic Institute of NYU

OPENING COMMENTS

As the head of the Civil and Environmental Engineering (CEE) Department during Prof. George Bugliarello's tenure as president of Polytechnic University, I had the distinct pleasure and honor of working closely with him on shaping a vision for the development of the department and its urban-focused, nationally recognized research program. It was a most inspiring endeavor and a very stimulating learning experience.

George's vision of the university's core mission was anchored in the belief that, as the prime urban engineering and science university of New York, Poly should establish dynamic partnerships with metropolitan stakeholders, government agencies, and utilities to accelerate the development and application of state-of-the-art technologies and solutions to metropolitan renovation and sustainable development challenges. This universitywide initiative involved a great diversity of interconnected disciplines and supported the development of several academic centers, including the New York State–sponsored Center for Advanced Technology in Telecommunication (CATT, in 1982), Poly's fast-expanding graduate program in financial engineering, and the research program of the CEE department, which was initiated with George's personal commitment and support.

With George's leadership and support, the CEE faculty have explored partnerships with government agencies and utilities involved in various metropolitan service sectors to launch several multidisciplinary research centers, including NSF-funded Civil Infrastructure Systems as well as Intelligent Transportation Systems, Urban Construction Management Technology, and Urban Energy and Water Utilities.

Simultaneously, with the support of the metropolitan agencies and utilities, faculty have pursued the development of new professional graduate education programs in construction management and urban systems engineering and management. On behalf of the CEE department I would like to thank the New York City infrastructure agencies and utilities for their support and cooperation. During the past 20 years, these industry-university collaborative efforts have continuously stimulated our research and greatly contributed to the development of nationally and locally sponsored research programs on cutting-edge technology solutions and smart infrastructure monitoring systems. In addition, since 2005, with the leadership of NYU-Poly President Jerry Hultin, George's vision has inspired a universitywide initiative to establish the Center for Urban Science and Progress (CUSP) as a city government-industry-university partnership for innovation in urban research and education.

George's scientific legacy and academic vision will surely continue to greatly impact the education of the next generation of urban engineers and metropolitan systems managers, nurturing a professional culture that will recognize the integration of environmental risks, societal inspirations, economic viability, and technological innovation as key elements for sustainable urban development.

SESSION OVERVIEW

The purpose of this session was to provide a metropolitan infrastructure leadership forum for exploring the way forward in reinforcing the government-industry-university partnership for innovative solutions to infrastructure renewal challenges. The following four distinguished speakers—infrastructure experts and executives of the metropolitan agencies and utilities—accepted the invitation to share their vision of current infrastructure challenges, critical needs for infrastructure financing, strategies, and the role of technology innovation in their implementation. They also discussed anticipated impacts of the envisioned strategies on New York City's sustainable development, the performance and resiliency of the city's infrastructure, and the economic growth of the metropolitan region.

- Patrick J. Foye, executive director of the Port Authority of New York/New Jersey, represented by John Ma, chief of staff, talked about the Critical Role of Transportation in the Livable Cities of the Future, describing current Port Authority projects and their anticipated impacts on the economic development of the metropolitan region.
- Andrew W. Herrmann, president, American Society of Civil Engineers, addressed Sustainable Urban Renewal Challenges and Engineers' Role in Changing the Built Environment. He emphasized infrastructure financing challenges and the critical economic impacts of failure to make the case for resources to rebuild the national infrastructure for water, energy, and transportation.
- Craig S. Ivey, president of Consolidated Edison Company of New York, presented his vision of Energy as the Core of New York City. He discussed the impact of introducing the oil-to-gas transition on the future of environmentally sustainable clean energy. He also spoke about the role of innovation and integration of electrical power smart grid technology in upgrading the reliability, efficiency, contingency capacity, and flexibility of including other energy sources and customers' assets in cost-effectively responding to the growing energy demand of urban society.
- Daniel P. Loucks, professor of civil and environmental engineering at Cornell University, described the Challenges of Water and Wastewater Management for Urban Renewal, emphasizing the benefits of green initiatives and the potential of decentralization strategies for wastewater treatment and reuse.

CONCLUDING REMARKS

With the ever growing demand for more secure, affordable, safe, and sustainable metropolitan water and energy resources and supply systems, national and local governments and metropolitan utilities face the challenge of upgrading their infrastructure monitoring and system management capacity. Growing ecorisks of climate change impacts and accompanying uncertainties pose economic, financial, environmental, operational, and societal challenges to metropolitan governments and urban utilities for the strategic and operational deployment of their natural resources and the management of their interdependent urban distribution systems.

Sustainable urban economic growth and development over the coming decades will depend on cities' capacity to respond to these challenges, which in turn will require reinventing regional planning practices, adapting sustainable development strategies, and implementing smart control systems and proactive incident detection and mitigation measures. In addition, creative public-private partnership models are needed for critical infrastructure financing. Transportation infrastructure agencies as well as energy and water utilities need innovative solutions and "intelligent" quality control, infrastructure monitoring, and supply management systems for real-time system performance assessment, asset management, capital improvement optimization, incident control and command, disaster response and recovery, and contingency management.

Furthermore, as energy and water utilities face growing uncertainties of ecorisks and greater frequency of extreme events, they have a critical need for smart control capabilities for integrated and real-time system management, early incident detection, and preemptive mitigation. Expansion of distributed renewable power generation (e.g., through the use of solar, wind power) and renewable water resources (e.g., through the use of desalination, recycled wastewater) will introduce another set of multivariable management objectives for urban supply systems, raising risks of cascading systemic failure modes. The reliable management of urban systems requires the development and deployment of innovative solutions for integrating smart monitoring and "intelligent" management systems for ensuring environmentally sustainable and economically viable development.

We look forward to working with the metropolitan infrastructure and utilities agencies to turn New York City into a living laboratory for innovative solutions to infrastructure renewal challenges to energy, transportation, water, and wastewater infrastructure. The purpose is to strengthen the city's creative resources, contribute to improved reliability and quality of urban services, and, ultimately, increase the city's competitiveness in attracting high-tech businesses and dynamic global corporations.

The Critical Role of Transportation in Livable Cities of the Future

Patrick J. Foye[1]
Port Authority of New York and New Jersey

ABSTRACT

The Port Authority of New York and New Jersey is a bistate agency that operates and maintains the following transportation infrastructure assets:

- six bridges and tunnels connecting the two states;
- five airports that constitute the busiest commercial aviation system in the United States;
- two bus terminals, including the Port Authority Bus Terminal, the oldest and busiest bus facility in the world;
- the Port Authority Trans-Hudson (PATH) rail system, used by more than a quarter of a million commuters every weekday;
- marine facilities on both sides of the Hudson River that are the largest destination for cargo on the East Coast and third largest port in the country; and
- the 16-acre World Trade Center site.

This paper presents an overview of Port Authority plans to meet the transportation challenges of the future to ensure that the region, which

[1] This paper was presented at the symposium by John Ma, chief of staff to the executive director, on behalf of Patrick Foye.

encompasses 1,500 square miles in both states, remains livable and economically viable.

INTRODUCTION

It is fitting that this symposium is taking place at the New York University (NYU) Polytechnic Institute because one of the founders of NYU was Albert Gallatin. Aside from his many accomplishments during a distinguished career in public service—as treasury secretary, congressman, and foreign minister to France—Gallatin is also known as the "father of the American road."

In 1808 he reported to President Thomas Jefferson and the Congress on the state of the nation's transportation infrastructure—its roads, canals, harbors, and rivers. One of the results of his report was the construction of the Cumberland Road, also known as the National Highway, from Western Maryland to Illinois—the first-ever federal highway project. Gallatin knew that modern, reliable transportation infrastructure was vital to the country's survival and its economic well-being. At the same time, in his role as treasury secretary, he was a strong advocate of fiscal discipline for our newly formed nation.

The Port Authority shares Gallatin's views on the need for both modern, reliable transportation infrastructure as a way to promote economic growth and development and fiscal discipline in building and operating that infrastructure. Billions of dollars are required to maintain the Port Authority's airports, bridges, tunnels, mass transit facilities, and ports—some of which predate the Great Depression—in a state of good repair.

The Port Authority's facilities enable commerce, create and sustain jobs, and drive economic development throughout the New York–New Jersey region and beyond (Figure 1). Partnerships with the private sector are but one way to maximize the Port Authority's investment dollars and deliver the greatest benefit to the public that relies on the agency's critical transportation infrastructure.

This paper addresses

- transportation challenges facing cities today,
- what the Port Authority of New York and New Jersey is doing to meet those challenges as they relate to the bistate region, and
- the role of public-private partnerships in helping the Port Authority address the region's infrastructure needs to create livable cities.

FIGURE 1 The Port Authority of New York and New Jersey

THE WAY FORWARD

Port Authority transportation infrastructure assets support more than 550,000 regional jobs and generate tens of billions of dollars in annual economic activity. But that infrastructure is aging: many bridges and tunnels are more than 80 years old, and many airport terminal facilities are 45 years old or more. The agency has done its job of maintaining them but is facing a cycle of major replacement and renewal. To ensure that the city and entire port region remain livable and competitive—and that people can travel to and from work reliably, fly in and out of the region whether on business or for vacations, and connect with their families in the region and around the country and the world—the Port Authority must renew its transportation infrastructure. To that end, it is updating its $25 billion, 10-year capital plan, the economic impact of which will be the creation of 125,000 direct and indirect jobs, $7.5 billion in wages, and more than $29 billion of economic activity.

But the leap from planning for the future to delivering completed projects requires more than vision and good intentions. If the Port Authority is to meet its obligation to build and maintain key assets in the region's transportation infrastructure and ensure a sustainable, livable region for the future, it must follow Gallatin's lead and manage the capital program in a disciplined, responsible manner. One of the ways to stretch resources is by engaging in partnerships with the private sector wherever feasible. Public-private partnerships will allow the Port Authority to

- reduce the capital burden on its balance sheet,
- lower construction and maintenance costs and risk,
- complete projects faster in some cases, and
- deliver greater value for the public.

The Port Authority is involved in several public-private partnerships that will help improve its transportation infrastructure for the region.

EXAMPLES OF PORT AUTHORITY PUBLIC-PRIVATE PARTNERSHIPS

Goethals Bridge

One public-private partnership supports the Port Authority's plan to replace the Goethals Bridge (Figure 2). Connecting Staten Island and New Jersey, the Goethals Bridge, opened in 1928, was one of the first bistate projects completed by the Port Authority. It sits at the center of one of the most strategic cargo transportation corridors in the nation—last year $33 billion of goods and more than 28 million vehicles crossed in both directions.

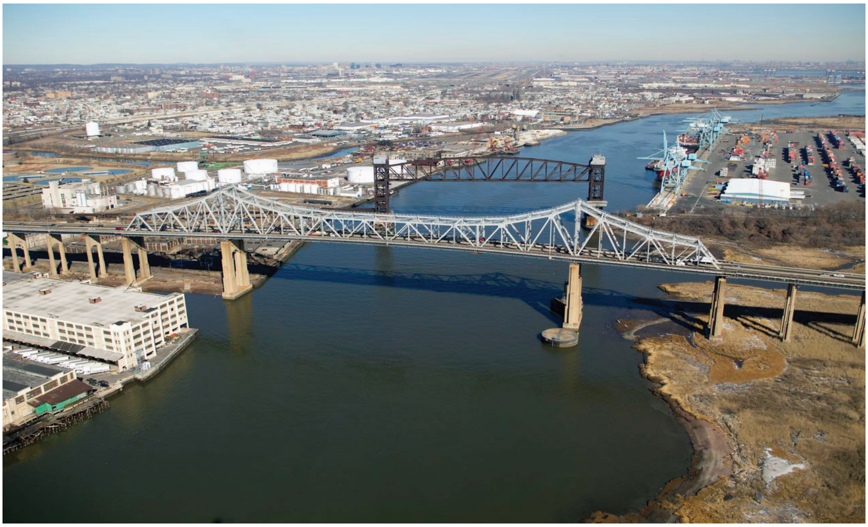


FIGURE 2 Existing Goethals Bridge (Foreground)

FIGURE 3 Proposed Goethals Bridge Replacement

But the bridge is now physically and functionally obsolete and does not meet modern highway standards. The roadway has no median, no shoulders, and 10-foot-wide lanes instead of the 12-foot-wide lanes that are standard today. In inclement weather, motorists must cross at significantly reduced speeds.

A modern replacement Goethals Bridge is critical to the future of the city and the region. The Port Authority is pursuing a public-private partnership for a replacement bridge. Private developer teams are competing to design and build the bridge and then assume responsibility for its maintenance over a 35-year period. The Port Authority will continue to set and collect tolls on the bridge. In terms of economic development, this roughly $1.5 billion project is estimated to create 2,500 direct construction jobs (Figure 3).

The partnership structure requires that the developer secure its own financing, reducing the burden on the Port Authority's balance sheet. While private financing is often more expensive than Port Authority debt, the project has been designated for a $500 million loan through the US Department of Transportation's Transportation Infrastructure Finance and Innovation Act (TIFIA). This will allow the developer to borrow money long-term at rates roughly equal to those of US Treasury bonds.

The project has also qualified for private activity bonds, which will allow the private developers to issue tax-exempt bonds to finance the project. The Port Authority will collect toll revenues and repay the developer a fixed annual amount over time once it has finished construction of the replacement bridge. This arrangement lowers the risk for the Port Authority and gives the private entity a huge incentive to stay on schedule and on budget—if the developer fails to meet established metrics or cuts corners, payment will be reduced.

LaGuardia Airport

The Port Authority is considering a public-private partnership to rebuild LaGuardia Airport's Central Terminal Building (CTB; Figure 4). Here again is a facility that is old, obsolete, and unable to meet the demands of travelers today, let alone in the future. It is crowded and lacks amenities and retail offerings for travelers, especially after security screening. It consistently ranks among the worst airport terminals in the United States in customer surveys.

The CTB opened in 1964 at the dawn of what was then called the "jet age." DC-9s were the most modern aircraft and the terminal was designed to accommodate 8 million passengers annually. Last year, about 12 million passengers passed through it, and the number is expected to reach 15 million by 2020.

Beyond capacity issues, the gates are not configured to handle today's larger, wider aircraft, resulting in costly delays. How costly? A study by the Partnership for New York City found that delays at the Port Authority's three

FIGURE 4 Current LaGuardia Central Terminal Building

FIGURE 5 Rendering of Proposed Update of the LaGuardia Central Terminal Building

main airports—JFK, LaGuardia, and Newark-Liberty—cost the regional economy $2.6 billion annually.

In December 2011 the Port Authority issued a request for information from developers and received proposals from several teams. The CTB upgrade is estimated as a $3.6 billion project that will create roughly 6,300 direct jobs and generate hundreds of millions of dollars in wages over the six to eight years it will take to complete (Figure 5).

World Trade Center

The Port Authority is partnering with the Durst Organization to bring tenants and jobs to a new World Trade Center, transforming the 16-acre site in lower Manhattan into an urban beacon of hope, freedom, and sustainability for the future (Figure 6). The building is more than 55 percent leased more than a year before completion. The restored 16-acre site will feature almost half a million square feet of retail space, the 9/11 Memorial and Museum, and a state-of-the-art transportation hub that will link PATH trains, 13 subway lines, and the Battery Park City Ferry Terminal. Unlike the original World Trade Center site, which was a "superblock" without streets across the site, the rebuilt site will feature a semi-open street grid, facilitating improved access to the buildings and integration of the site into the surrounding neighborhoods.

FIGURE 6 One World Trade Center

Understanding that livable cities of the future must be sustainable, the Port Authority is making One World Trade Center one of the most environmentally friendly buildings of its size anywhere. It is seeking LEED Gold Certification, and the building will feature state-of-the-art technologies to reduce carbon emissions, energy use, and environmental impact; in fact, it has been designed to reduce whole building energy consumption to 20 percent below New York State Energy Code requirements.

MEASURES IN SUPPORT OF SUSTAINABILITY

The Port Authority is committed to sustainable infrastructure investment and responsible environmental stewardship in all its facilities. For example, in August 2012 the Port Authority Board approved a $4.9 million Clean Vessel Incentive Program that encourages ship operators to improve engines, use cleaner fuels, and upgrade technology to reduce emissions. The program is expected to eliminate almost 500 tons of air pollutants annually.

In Brooklyn, the Port Authority is funding the first onshore port power facility serving ships at the cruise terminal: ships can turn off their engines while docked and use a land-based electrical grid to run their systems. This project will remove 1,500 tons of carbon dioxide, 95 tons of nitrous oxide, and 6.5 tons of particulate matter from the air annually.

The Port Authority's $60 million Hudson-Raritan Estuary Resource Program has protected more than 340 acres for public use. The program preserves open space habitat and wetlands on both sides of the Hudson.

CLOSING REMARKS

The Port Authority is responsible for the transportation infrastructure that drives economic development and prosperity in our region. It is committed to accomplishing the dual mission of sustainably meeting the transportation needs of the region, now and in the future, while serving as a catalyst for jobs and economic development. Without sustainable transportation systems, there won't be livable cities.

Sustainable Urban Renewal: Engineers' Role in Changing the Built Environment

Andrew W. Herrmann
American Society of Civil Engineers

ABSTRACT

Urban infrastructure for water, energy transmission, and transportation requires significant investment to effectively manage its economic and environmental impacts. Investment in *water infrastructure* must be increased to prevent higher costs to businesses and households and to protect almost 700,000 jobs, personal incomes, gross domestic product (GDP), and US exports. Investment in *energy transmission infrastructure* can prevent or minimize the impact of future blackouts and brownouts, yielding further protection for 529,000 jobs, personal incomes, GDP, and US exports. Finally, investment in *surface transportation infrastructure* can both create millions of jobs and protect existing positions, save nearly 2 billion hours in travel time, save each family $1,060 per year, and add $2,600 in GDP for every person in the United States. These investments can also help improve the overall standard of living. In all these different fields, engineers play a critical role in shaping the world and making the environment sustainable.

INTRODUCTION

Urban infrastructure is failing to keep up with modern life. Additionally, the emergence of new "megaregions," as more people move to urban centers, requires sustainable and resilient renewal for three basic aspects of life: water, energy, and transportation. In the words of Dr. Bugliarello,[1]

> The infrastructure problem is enormous in its dimensions; its causes and remedies are complex; and the need to address them is urgent. The nation is at a crossroads—should we continue to make expedient fixes, hoping they will suffice in the short term, or should we rethink fundamentally the role of infrastructure in our future, reconsider our choices and opportunities, and reassess the road blocks facing us.…
>
> Today, [the] foundation is inadequate in capacity and performance and in need of maintenance and repair, close surveillance, and assessment. In addition, substantial portions of our infrastructure are vulnerable to environmental disasters, such as earthquakes, floods, hurricanes, and rising sea level, as well as to hostile attacks.

The question is, How can we as engineers and thinkers change how we think about and build the urban environment?

FACTS AND FIGURES

Infrastructure has a lifespan. Proper maintenance extends that lifespan, poor maintenance shortens it. Far too many infrastructure systems lack the funding needed for proper maintenance. The American Society of Civil Engineers (ASCE) has for several decades issued a report card for America's infrastructure; the last one came out in 2009—and for 15 categories of infrastructure assigned an average grade of D.[2]

Consider these facts:

- Leaking pipes lose 7 billion gallons of clean treated drinking water each day.
- 10 billion gallons of untreated wastewater reach the nation's waterways each year.
- The United States produces 254 million tons of solid waste per year.
- Motorists spend more than 4 billion hours each year stuck in traffic, wasting time and fuel.

[1] Bugliarello G. 2008. Infrstructure and transportation: Our nation at a crossroads. The Bridge 38(2):3–4.

[2] The ASCE Report Card for America's Infrastructure is available online at www.infrastructurereportcard.org/.

- One in four bridges is either structurally deficient or functionally obsolete.
- Electricity demand has grown by 25 percent since 1990, taxing transmission and distribution systems.

The goal is to rethink how to build, maintain, and repair America's infrastructure with an eye toward the future.

The urban environment is of increasing importance, as US city centers become more condensed and new megaregions start appearing, as seen in Figure 1. Today, US cities with populations of at least 150,000 are home to 80 percent of Americans and generate almost 85 percent of the nation's GDP. By 2050, the US population is expected to grow to about 439 million, compared to 310 million in 2010, a 42 percent increase in 40 years. Worldwide there will be 9 billion people compared to 6.9 billion today.

Population growth has been a major source of GDP increases in US cities. Infrastructure has to be ready to handle the new burden of the megaregions in new, sustainable, and resilient ways.

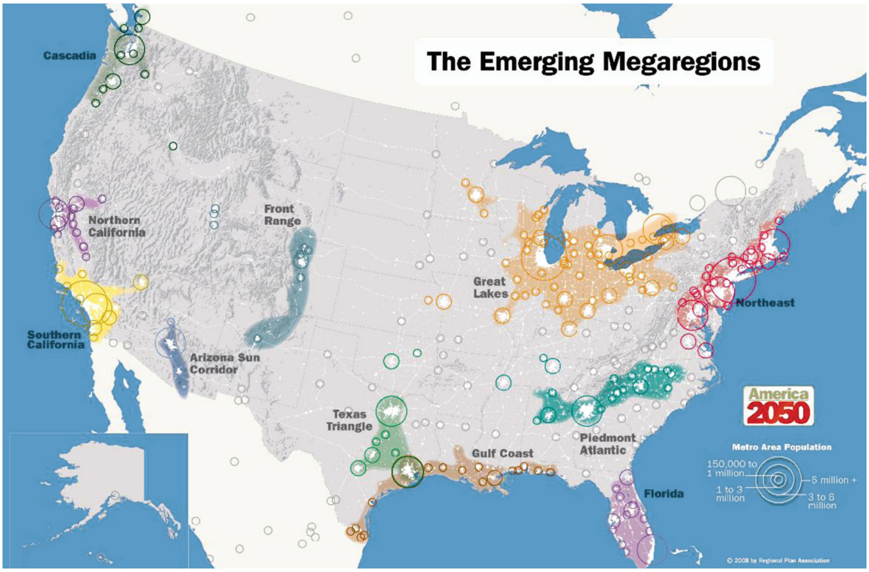


FIGURE 1 Emerging Megaregions of the United States

SUSTAINABILITY AND RESILIENCE

The term *sustainability* seems to crop up everywhere these days, in conversations on topics ranging from compostable paper products to LEED-certified buildings to national energy policy. Sustainable civil infrastructure concerns environmental, economic, and social (the triple bottom line) well-being now and for the future.

Another buzzword is *resilience*, which has a more complex definition. It can be described as the capability to militate against significant all-hazards risks and incidents, and to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security. Long-term resilience takes into consideration the stability of the system and how it functions and adapts. Resilience can be on the pathway to a sustainable approach. With resilience, one anticipates irreversible change and assigns a risk value to it, and then acts to mitigate consequences for the next event.

In urban renewal, both sustainability and resilience are critical to infrastructure that works in a world with more people and more significant infrastructure needs.

Let's link these ideas to three key areas of infrastructure—water, energy, and transportation—and consider how engineers can incorporate sustainability and resilience in each.

Water

Many regions in the United States are juggling competing needs for water between municipal and domestic users, agricultural and industrial users, and the environment. Population growth, urbanization, and climate change will continue to stress water resources and accelerate the need for new solutions to conserve, supply, treat, store, and distribute water. Worldwide, nearly 800 million people lack access to clean water and 2.5 billion lack access to sanitation.

What should engineers be doing? I suggest the following:

- Find new methods for making upgrades and repairs to aging infrastructure to fix leaks that waste billions of gallons of water every day.
- When designing and building new water infrastructure, or repairing or replacing existing infrastructure, ensure that the owner considers investments that are cost effective over their life cycle, are resource efficient, and are consistent with community sustainability goals.

- Follow resilience management practices for water and waste that make it possible to calculate risks and prepare responses specific to natural and human-caused hazards.
- Establish collaborative response networks with other utilities to support response to and recovery from emergencies.
- Reclaim and/or restore surface water bodies in wetlands to naturally filter out and remove contaminants. If designed properly, restored creeks and wetlands can offer greater flood protection and enhance city cooling.
- Develop new sources of water, such as desalination plants, tertiary water treatment for recycled water use, or rainwater collection treatment and redistribution systems.

Energy

The main sectors of energy consumption in the United States are electric power generation, which is the largest at 40 percent of the total, followed by transportation at 28 percent, industry at 20 percent, and residential at 11 percent. The primary sources of fuel used to create this energy are petroleum, natural gas, and coal. By 2050, the national global demand for energy will dramatically increase, but the capacity of the US grid is already being challenged.

What should engineers be doing?

- Focus on substituting low-carbon renewable energy for the current mix of carbon-based energy. If this shift is successful, emissions from the energy and power sectors will be lower and the energy sector's environmental footprint will be smaller.
- Prepare to add to the network by building and permitting new energy generation facilities, considering that new transmission lines will be needed to move energy from new sources to where it's needed.
- Strengthen the grid by addressing the resilience of the operation and planning of the bulk power system, such as real-time transmission operations, balancing load and generation, emergency operation, systems restoration, voltage control, and cyber security.
- Determine whether the system should be expanded or changed, and if so, how to meet resiliency standards across the grid.
- Consider new approaches to permitting and building transmission lines in the context of sustainability.

Transportation

With projected population growth comes a huge increase in demand for transportation, for both passengers and goods. A vision for the future is that all people have access to affordable and safe transportation, as greater access to mobility will improve social and economic activities.

What should engineers be doing?

- Develop transportation infrastructure concepts with a mix of travel options, such as vehicle, air, and rail transit; pedestrian and bicycle thoroughfares; and efficient traffic flow.
- Actively contribute to planning, designing, and building new infrastructure as well as improving existing infrastructure. Focus on eliminating bottlenecks, providing convenient interfaces (e.g., intermodal transfer stations), upgrading traffic control technology (e.g., smart traffic lights) and detection technology, and supporting new systems (e.g., high-speed rail) that allow large passenger volumes on interregional routes.
- Design intelligent transportation systems (ITS) to enhance the efficiency, speed, and reliability of public and private transport. ITS will enable people to minimize waiting times by combining different modes of transport, thereby improving social capital.

Sustainable transportation systems help lower the number of transportation-related deaths and injuries and significantly reduce negative environmental impacts by, for example, decreasing greenhouse gases and other harmful air emissions.

INVESTMENT

Engineers play a unique role in the built world—planning, analyzing, designing, building, and rebuilding things that touch the planet—and therefore have an optimal and natural role in changing the built environment to meet new needs.

Infrastructure is the cornerstone of the US economy, and repairing and modernizing it has positive impacts on GDP and jobs, in both the short and long term. ASCE commissioned a series of economic studies, called "Failure to Act," to show the consequences—for families, businesses, jobs, and the economy as a whole—of failure to invest in US infrastructure.[3] ASCE found

[3] The studies are available online at www.asce.org/failuretoact/.

that there is a rough road ahead, and that there is definitely a link between investment in infrastructure and economic performance.

In the case of water and wastewater treatment infrastructure, a strong system is essential to protect and support US businesses, families, and the entire economy. Figure 2 shows that failure to invest in the maintenance of this system causes business costs to rise by $147 billion and household costs by $59 billion. Families are squeezed by another $900 per year as water rates go up and personal income falls. However, an additional $84 billion invested between now and 2020 could help prevent those increased costs to businesses and households, and protect 700,000 jobs, $541 billion in personal income, $460 billion in GDP, and $6 billion in exports.

In terms of electrical transmission, an additional $11 billion per year between now and 2020 could prevent blackouts and brownouts that cost businesses $126 billion and households $71 billion (Figure 3). In addition, 529,000 jobs would be protected, as would $656 billion in personal income and half a trillion dollars in GDP.

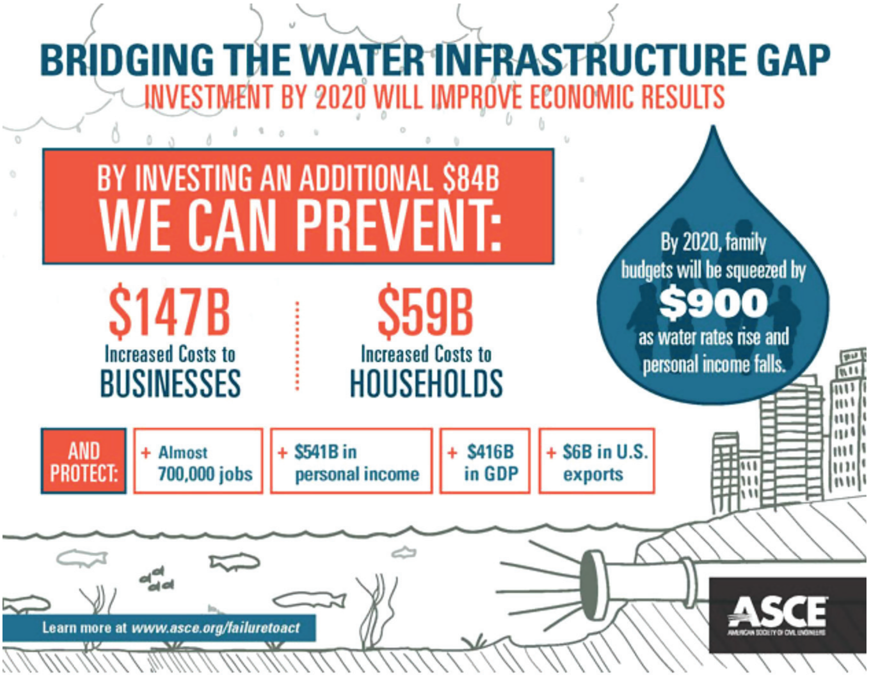


FIGURE 2 Water Infrastructure Investment

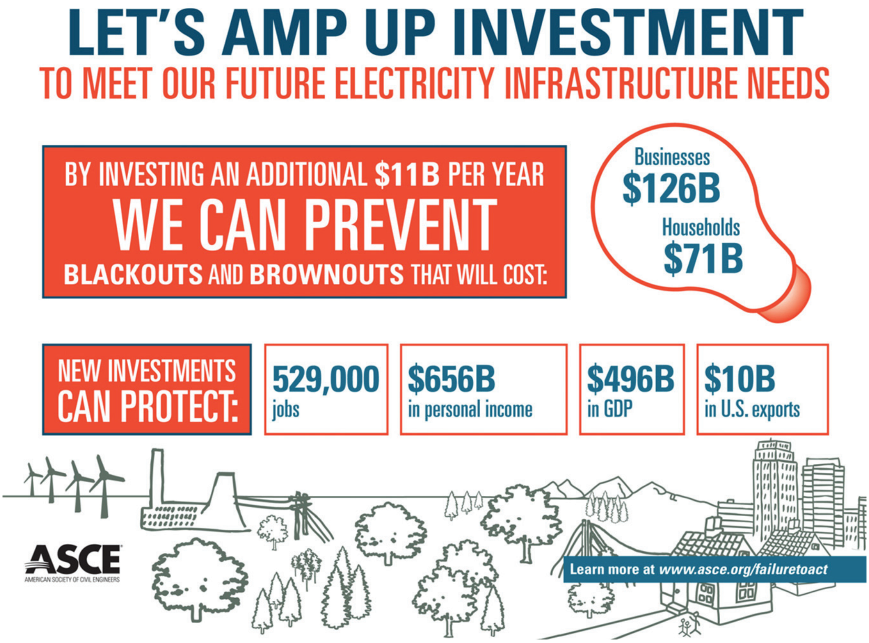


FIGURE 3 Energy Infrastructure Investment

In the case of surface transportation, an equally rough road lies ahead in the absence of investment in infrastructure (Figure 4). By 2020 overall transportation costs will increase by $430 billion. Families will have a lower standard of living, earning $700 less per year but spending an additional $360 per year for transportation. Businesses and workers will pay a heavy price with the net loss of 877,000 jobs. America will lose ground in the global economy as the GDP underperforms by almost $1 trillion.

The investment needed for transportation is $94 billion per year between now and 2020. This investment would create millions of new jobs, protect a million existing jobs, save nearly 2 billion hours in traffic time, save families over $1,000 a year, and add $2,600 in GDP for every person in the United States.

Figure 5 summarizes some of the key results of the "Failure to Act" reports. A tenfold return on investment in infrastructure is expected, easily justifying such investment. The link between a nation's infrastructure and its economic competitiveness has always been understood, but now the costs to the United States of stalled or insufficient investment are clear.

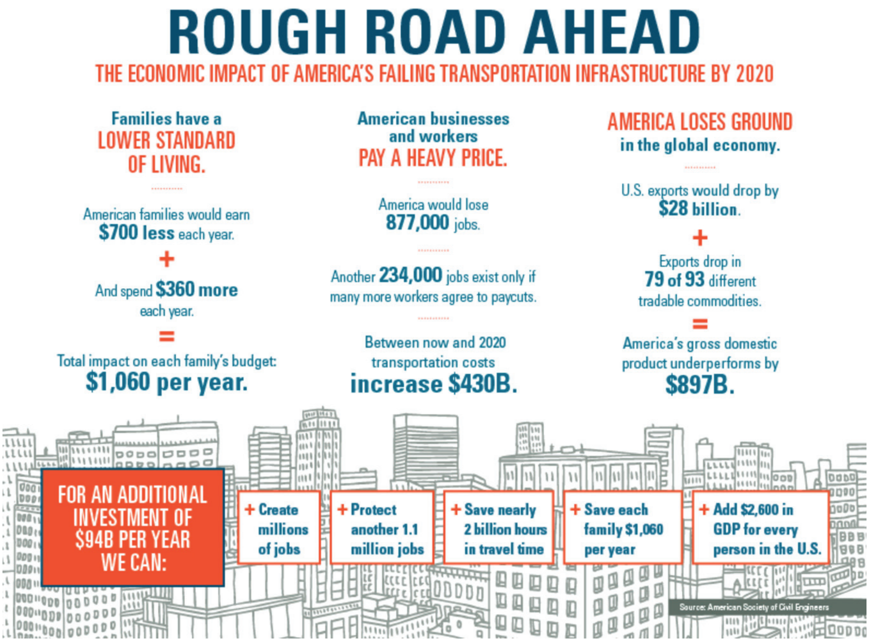


FIGURE 4 Transportation Infrastructure Investment

Study	Additional Investment Needed	GDP	Jobs and Cost to Businesses	Cost to Families	Value of Exports
	In billions	In billions	In the year 2020		In billions
Surface Transportation	$846, or $94 billion a year	$897	877,000 jobs and $430B cost to business	$1,060 per household annual	$28 (2020 only)
Airports	$19 billion + $20 billion for NextGen, or $4 billion a year	$313	350,000 jobs and $87B cost to business	$361 billion, or $320 per household annual	$54
Marine Ports and Inland Waterways	$16 billion, or $2 billion a year	$697	738,000 jobs and $183B cost to business	$872 billion, or $770 per household annual	$270
Water & Wastewater	$84 billion, or $9 billion a year	$416	669,000 jobs and $147B cost to business	$600 billion, or $530 per household annual	$20
Electricity	$107, or $12 billion a year	$496	529,000 jobs and $126B cost to business	$727 billion, or $640 per household annual	$51

FIGURE 5 Summary of "Failures to Act" (from the ASCE website; www.asce.org/failuretoact/)

CONCLUSION

Engineers are at the forefront of the nation's infrastructure upgrades, with a critical opportunity to approach infrastructure repair, enhancement, and construction in new ways that incorporate sustainability and resiliency to make existing and emerging cities and megaregions smarter and greener.

Energy As the Core of New York City

Craig S. Ivey
Consolidated Edison Company of New York (CECONY)

ABSTRACT

There are five critical components to the livable cities of the future: public safety, reliability, affordability, reduced environmental impact, and smarter and more secure facilities. Cities must also prepare for both a growing demand for power and the effects of increasingly severe weather patterns that threaten the grid. This became dramatically clear with Superstorm Sandy, which hit the New York City region three days after this symposium, on October 29, 2012.[1] Utilities, urban planners, climate experts, government leaders, and regulators must all collaborate to determine the best approaches to fortify the city's infrastructure and protect residents and businesses from future threats. New York City's largest energy provider is taking steps to address challenges and meet needs in order to ensure delivery of these critical components.

FACTS AND FIGURES

Con Edison (Con Ed) and its 14,000 employees support one of the most active and densely populated areas in the country. New York City and Westchester County are home to 9 million people, and more than 50 million

[1]This paper was adapted for this publication to reflect the storm's impact and Con Edison's response.

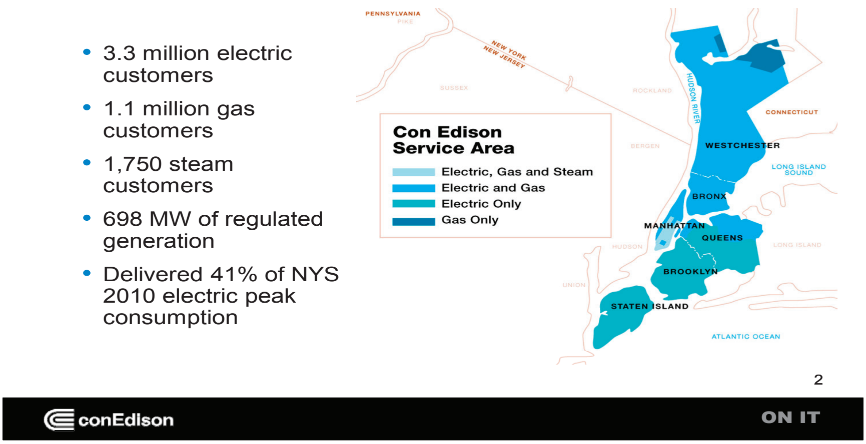


FIGURE 1 Energy Provision in New York City and Environs

visitors come to the city each year, based on 2011 data. The company serves 3.3 million electric customers and 1.1 million gas customers (Figure 1). The intense energy demand of the area requires a reliable energy infrastructure, and Con Ed substations are designed to safely meet the community's energy needs.

Sandy's relentless winds and unprecedented storm surge caused damage across the region unlike anything we've ever seen. Catastrophic flooding and corrosive salt water destroyed electrical equipment and downed trees ravaged our overhead system, making repairs difficult and time consuming. Now and in the future, thoughtful, forward-thinking construction will help keep our systems reliable for the "new normal" that we must design and prepare for in the wake of Sandy.

Our investment in smart grid technologies and other innovations allow greater flexibility and reliability during extreme weather. For example, for the past seven years Con Ed has implemented a policy requiring any new business in a flood zone to either install submersible electrical equipment or locate its electrical equipment at higher elevations.

CHALLENGES

Efforts to minimize construction in the streets are challenging and costly because of numerous underground structures that compete for limited space

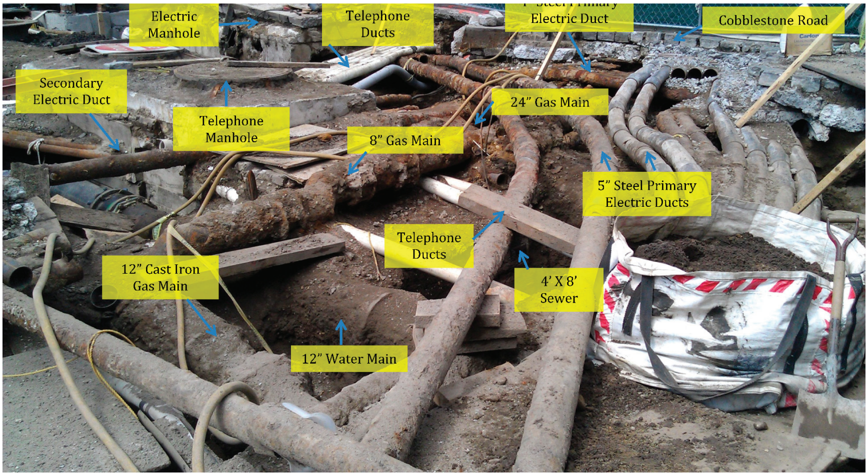


FIGURE 2 Construction in NYC is expensive and challenging.

to accommodate growing demands not only for electricity but also for the distribution of communications, water, and natural gas (Figure 2).

In addition, demand is at peak—above 12,000 megawatts (MW)—for only 36 hours *per year* (Figure 3). Peak demand occurs when many users across an energy system simultaneously increase their energy use—for example, in the afternoon or evening of a day of extreme or record-breaking heat, when both homes and offices turn up the air conditioning and households also turn on televisions, computers, washers and dryers, and other appliances. In the absence of storage mechanisms energy must be produced when it is demanded, so the infrastructure as a whole must be ready to meet peak demand even if it is idle for the balance of the year.

SOLUTIONS

Smart grids enable two-way communication between our facilities and our customers' equipment (e.g., smart meters, distributed generators, plug-in vehicles), and switches enhance flexibility in the network, thus increasing reliability (Figure 4). Smart grid technology, which relies on underground auto-loop and wireless-controlled switches, reduces the likelihood and severity of service disruption caused by a network event.

During Sandy, Con Ed was able to use remote sensors on the distribution system and remotely operated switches to reduce the damage to the system and speed up repairs. New sensors allowed control room operators to see

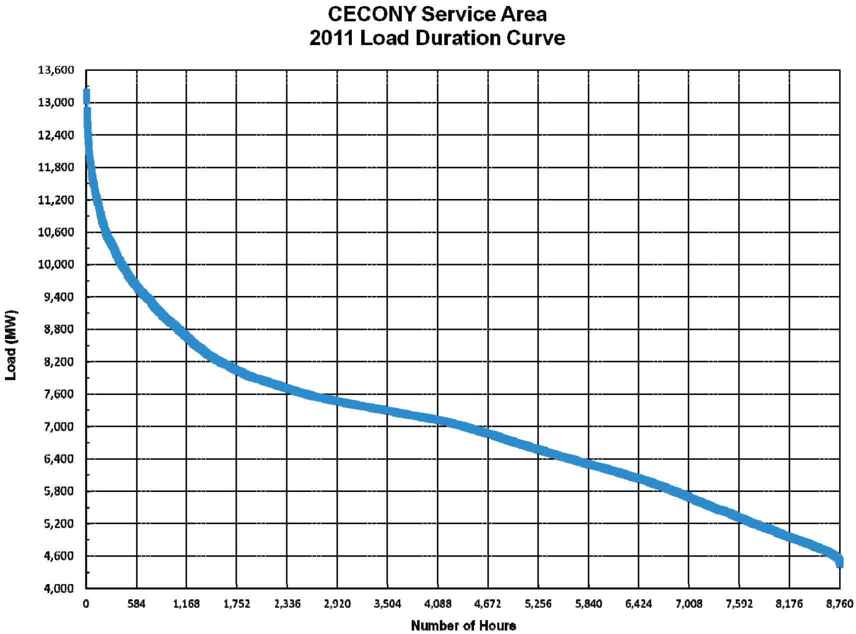


FIGURE 3 Utilities must invest to support a very short peak period. CECONY = Consolidated Edison Company of New York.

real-time power flows on feeders and, in conjunction with remotely operated switches, made it possible to reinstate service more quickly.

Con Ed was also able to sectionalize overhead lines ahead of the storm to improve both outage restoration times and public safety. New underground switches designed by company engineers have been installed, allowing greater flexibility and reliability during weather events and enhancing the ability both to monitor underground transformers, network protectors, and other equipment and to isolate problems. In addition, recently installed flood detectors in low-lying substations alert operators when flood waters reach critical levels.

There has also been a shift in sources of energy generation. With development of the Marcellus Shale formation, some coal plants have been retired and new gas plants have been established. Natural gas is a much cleaner source of energy than coal and oil. Furthermore, in 2010 renewable sources of energy such as solar and wind power exceeded the amount of oil-based energy in the region.

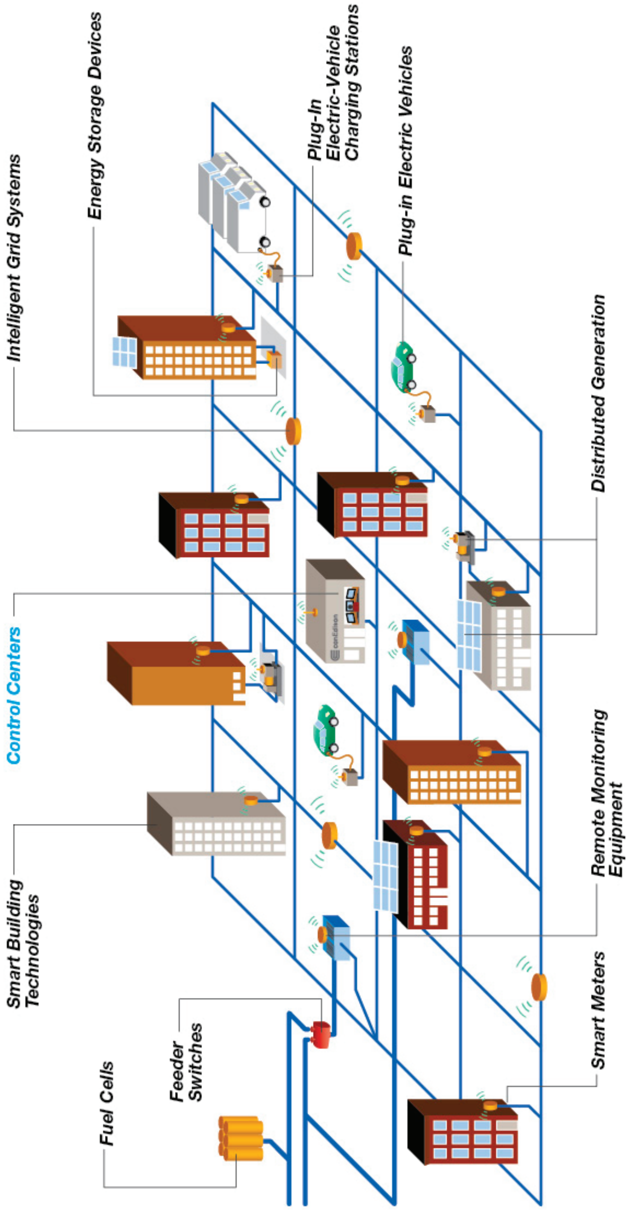


FIGURE 4 Schematic of Smart Grid Components and Layout

CLOSING REMARKS

For a city to be livable, safety is critically important, as are reliability, risk reduction, and affordability. As urban sites continue to grow, reduced environmental impacts, smarter systems, and more secure infrastructure are also paramount to the future of the cities and their inhabitants all over the world.

Con Ed is committed to working with other stakeholders to determine the most cost-effective ways to protect our systems and the public from future natural disasters and to prepare for the demands of future growth without sacrificing reliability.

Using Water for Urban Renewal

Daniel P. Loucks
Cornell University

ABSTRACT

The needs for clean water in all aspects of urban development and maintenance can be met through the integration of multiple decentralized schemes for capturing and collecting precipitation, wastewater sanitation management, and modernization of infrastructure maintenance technologies. New York City has had success in using natural systems to provide clean drinking water and manage storm runoff. The city has saved billions of dollars through integration of diverse methods for controlling water quality, distribution, use, and reuse.

URBAN WATER IN THE LARGER WATER NEXUS

Humans depend on water for life, which is obvious, but also for almost everything we see or make. Everything you see while reading this document required water to create, including the electricity and bulbs that provide the light you may be seeing it with. Humans are completely dependent not only on water but also on the fact that there are no substitutes. (Even if we drank only beer, it is mostly water and takes a lot more water to make whatever amount of beer we drink.)

Water is a critical input to all sectors of our economy and environment (Figure 1). All the components shown in Figure 1 are impacted by each other,

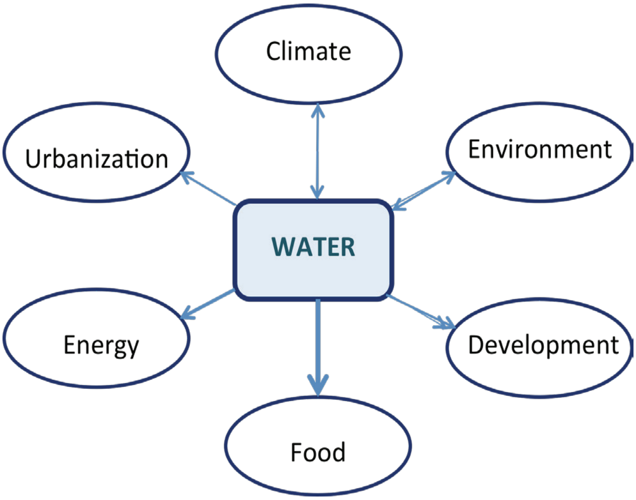


FIGURE 1 Water is a critical input to all sectors of our economy and to our built and natural environments.

in part by how water is allocated to them and how climate, which seems to be changing, plays a role in determining the available supplies of water.

But what is amazing, at least to me, is that everyone living on this planet could not only survive but thrive on the small percentage of the total freshwater supply that is actually available to use globally. How much is that? If a half-liter (one pint) water bottle represents all the water on this planet, only a teaspoon of that water is available for human use. That is less than what you can put in the cap of that bottle. The trouble is that this water is not always where and when and of the quantity and quality needed. And then sometimes there is too much of it. Cities have to consider both the reliability and quality of their freshwater supplies as well as protection against too much of it in any given time period. Urban areas need stormwater management.

A region's demands for fresh water are a function of the need to provide clean drinking water and sanitation, to ensure public health in growing urban centers, to create electric and liquid fuel energy, to maintain a healthy environment and well-functioning ecosystems, to grow and process food, and to support the industries and economic development that provide jobs and welfare.

In developing regions meeting these needs is even more urgent, and often more difficult, especially in urban slum environments. But even in such

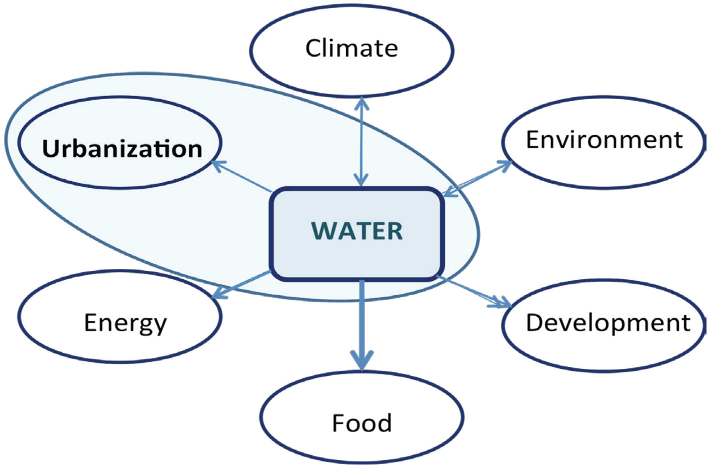


FIGURE 2 The Water-Urbanization Nexus

cities, the options or opportunities can be improved given sufficient funding, effective governance, and appropriate technical expertise.

Let's focus on the water-urbanization link, highlighted in Figure 2. How do we provide the right amount of water at the right places, times, pressures, qualities, and costs? And how can water be used to enhance the urban environment and aesthetics? After all, according to the *New York Times* (Oct. 7, 2012), 80 percent of all Americans now live in urban areas. So this issue is important to most of us.

URBAN RENEWAL: "GREY" VERSUS "GREEN" INFRASTRUCTURE

Urban renewal is a primary approach to building new infrastructure, attracting job-producing industry, stabilizing communities, and improving residents' quality of life. It almost always involves investments in infrastructure.

Grey Infrastructure

In the past public works engineers had a major role, if not the only role, in the planning, design, development, installation, and operation of water supply and stormwater management infrastructures. These engineers are trained to use concrete and steel, so they do, and the concrete and steel infrastructure they build is called "hard" or "grey" (because of its color) construction.

Water supply systems typically pump natural water through pipes or canals to water treatment plants and then through storage and distribution systems to the tap. Wastewater systems typically pump wastewater through collection sewers to wastewater treatment plants, and the resulting effluent may be reused or released into natural water bodies. Many creeks, streams, and rivers now flow through cities underground in pipes and tunnels. Rainfall that used to soak into the ground now becomes runoff from paved (impervious) areas and flows into cement ditches and stormwater drains, again becoming an underground waterway in either pipes or tunnels. All of this water is out of sight, out of mind, and benefiting no one.

Reliable and safe water supply and sanitation systems are basic necessities of urban areas. In developing regions, however, they are not always available (Figure 3). Clean drinking water is still not available to about a billion people—one out of seven. These people cannot be fully productive members of their communities or cities. Even more people—2.4 billion, most of them in cities—lack adequate sanitation. The World Health Organization (WHO) reports that 3.4 million of these people die each year, about the population of the city of Los Angeles.[1]

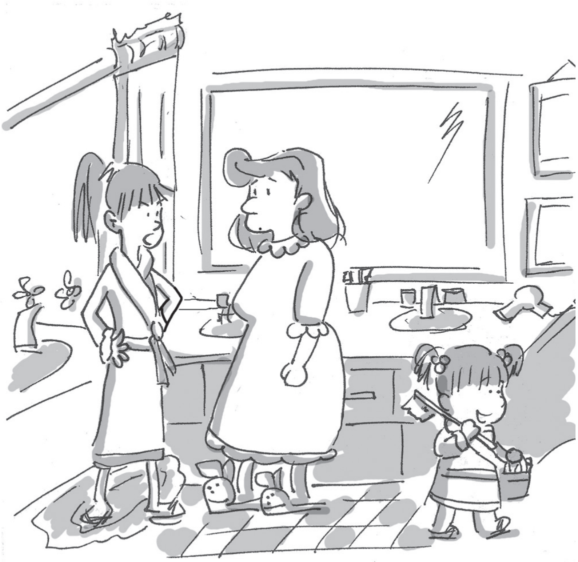
New York City certainly does not have the water supply and sanitation issues that developing regions have. But it does have an infrastructure that requires attention. The 15- to 35-million-gallon daily leak in the Delaware Aqueduct may be among the most visible evidence of this, except for the street where a water main breaks and half the street instantly disappears.

Here and in cities around the country and the world, there is an opportunity to manage stormwater runoff in more energy- and cost-efficient ways that will also enhance the environment of those who live and work in the city.

Green Infrastructure

The NYC Department of Environmental Protection (DEP) is widely recognized for successfully using natural systems to provide clean drinking water and manage stormwater. DEP estimates that such efforts have saved ratepayers billions of dollars—by eliminating the need for construction of hard infrastructure such as storm sewers and filtration plants—while preserving large tracts of natural areas. The department's *Green Infrastructure Plan* lays

[1] The WHO data are available online at www.who.int/water_sanitation_health/hygiene/en/.



"It's not fair that I have to share a bathroom with my sister!"

"It's so wonderful that our village now has a clean sanitation facility."

FIGURE 3 There are stark differences in the availability of sanitary facilities between developed and developing countries. Reprinted from Grayman et al. (2012) with permission from ASCE.

"And they said green roofs would never catch on."

FIGURE 4 Green roofs are an increasingly widespread and effective way to reduce stormwater runoff. Reprinted from Grayman et al. (2012) with permission from ASCE.

out how the city will improve the water quality in New York Harbor, for example, by capturing and retaining stormwater runoff before it enters the sewer system, and from there the harbor, through the use of streetside swales, tree pits, and blue and green rooftop detention techniques to absorb and retain stormwater (Figure 4). This hybrid approach will reduce combined sewer overflows by 12 billion gallons a year—over 2 billion gallons a year more than the current all-grey strategy—while saving New Yorkers $2.4 billion (NYCDEP 2012).

New York City, like other older urban centers, is largely serviced by a combined sewer system in which stormwater and wastewater are transported together through a single pipe. Treatment plants are designed to treat and disinfect twice the dry-weather flow, but during heavy storms the system can exceed its capacity. When this happens a mix of stormwater and wastewater—called combined sewer overflow (CSO)—is discharged into New York Harbor. DEP has committed to reducing the annual volume of CSOs by more than 8 billion gallons over the next 20 years—10 percent of the runoff from the city's impervious surfaces.

Rather than build additional large storage tanks or tunnels to temporarily store stormwater at the end of the sewer system, DEP determined that it was more cost effective to first construct source controls and "soft" infrastructure (e.g., bioswales, blue and green roofs, and subsurface detention systems) to control and reduce stormwater runoff from impervious spaces such as roofs, sidewalks, and parking lots. Together with conservation measures and operational improvements, the widespread adoption of such soft infrastructure can reduce CSOs at less cost than second-tier hard or grey infrastructure. Moreover, green infrastructure provides many quality of life benefits, by improving air quality, increasing shading, contributing to higher property values, and enhancing streetscapes.

The department is also implementing lots of other innovative measures such as giving people rain barrels, installing automated meter-reading devices, and developing an energy strategy that will (1) reduce the carbon footprint, including emissions of greenhouse gases; (2) reduce electricity demand, the cost of which is expected to almost double every 5 years in the absence of aggressive energy efficiency investments; and (3) explore clean energy options.

WHAT HAVE WE LEARNED?

Experience indicates that green buildings can reduce energy costs, water use, and carbon emissions by 30–50 percent. In addition, going green can create environments that attract people rather than motivate them to leave. Living and working in a greener, more natural environment can quite literally make people feel better.

But in the developing world, providing adequate water supplies and sanitation in expanding urban areas is tough. It would be a challenge even if water supplies were adequate and funding were available, because the technical capacity to do it and maintain it is often lacking. And the need is enormous. As mentioned above, the equivalent of Los Angeles' population dies every day from diseases associated with dirty water, and the risks are greatest for children. It's an economic issue in the affected regions, and a moral issue for all of us more fortunate thanks simply to the luck of the draw. It's a major issue on the agenda of many UN and relief agencies today.

Here in New York City the issues are how to revitalize urban areas and manage stormwater runoff in ways that contribute to the revitalization of neighborhoods and at the same time save money. We are learning that we can do it through the construction and adoption of blue and green roofs, streetside bioswales, tree pits, and other green infrastructure that absorbs or delays runoff from storms, keeps it out of combined sewer systems, and reduces CSOs, which are the primary source of pathogens in New York Harbor. We have learned that we can save billions of dollars by not having to build as much hard infrastructure for stormwater runoff, and at the same time we can beautify neighborhoods, increase property values, and improve air quality.

GOVERNANCE CHALLENGES

But there are challenges relevant to implementing effective water–urban renewal projects. Experiences in New York City and elsewhere in the United States and abroad suggest that work is still needed to address:

1. the often fragmented nature of water systems management and the lack of a clear central government "home" for the necessary policy and legislation that underpin this essential resource and its infrastructure;
2. the lack of sufficient stakeholder awareness and understanding of urban water systems and involvement in their management—reaching a consensus among the various stakeholders on the environmental, social, and economic goals of urban water systems takes time, and time is money;
3. the need for a better understanding of the issues among all stakeholders;
4. community and political tensions surrounding water businesses: who owns water, who manages it, and how it is valued and priced;
5. concerns about equitable access to water and privatization of water systems;
6. the lack of appreciation of the need to manage water in an integrated way according to ecosystem principles;
7. the disaggregated view of urban water management needs, which is shaped by current infrastructure models and is a major barrier to developing more sustainable, fully integrated, and cost-effective systems—a more integrated, lifecycle approach is required, treating the various components of water catchment, supply, wastewater, and stormwater as one system or life cycle, and in turn supporting the renewal of other urban service systems; and
8. the lack of recognition and understanding of the role of ecosystem services, and a resultant undervaluing of the associated benefits of these services.

The value of these ecosystem services—such as pure water supply, and waste treatment and assimilation—needs to be factored into decision making and incorporated into asset management planning.

No doubt there are other needs and challenges in specific cities, but in each case it is fair to say that enhancing water management along with urban renewal is primarily a sociopolitical challenge rather than an economic or technical one. Certainly capital constraints and some technical issues can restrict opportunities. But it is the way institutions are organized and function—the legislation, policies, infrastructure, and community expectations—that is the greatest challenge, in my opinion.

While the water–urban renewal nexus challenges mentioned above generally apply globally, decisions about water management and urban renewal are made at the regional or local level. Water is linked to local politics and without adequate governance—a decision-making process often requiring reforms in many political and social systems—progress in integrating water in urban renewal will be limited.

Governance is not made any easier when those who benefit from the allocation and use of water cannot know of the tradeoffs made elsewhere to provide that water and the costs or damages to others as a consequence of allocation decisions. This has to do with economic globalization that decouples the risks and costs to some and the rewards and benefits to others at a distant location. The inability to observe or even be aware of the consequences of our decisions has implications for progress toward achieving a more sustainable environment and socioeconomic development.

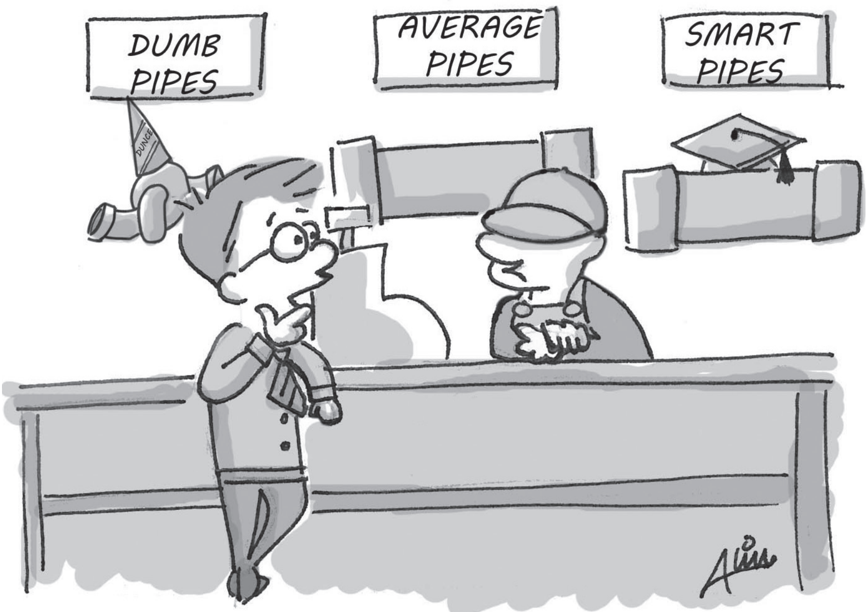
All this argues for a more decentralized approach.

VALUING, PRICING, AND CHARGING FOR WATER SERVICES

Although New York City has some of the best-tasting and safest water in the world, many New Yorkers studiously avoid drinking it. Instead of giving the public water supply the respect it deserves, they purchase 1.25 billion plastic water bottles every year, requiring 60 million gallons of oil to produce and costing the city approximately $8 million annually to dispose of them. The average recycling rate of these plastic bottles is only 25 percent, which means that 75 percent end up either in a landfill or in the ocean.

What is also interesting, at least to me, is the fact that the public still expects water to be, if not free, a low-cost good. Surveys show that the public does not want to pay higher taxes that would enable the maintenance of water supply and wastewater collection and treatment infrastructure. As it is they end up paying higher water utility bills, or higher taxes that are not identified or related to water services. But without adequate funding for maintenance the likely result is periodic emergency repair of broken water pipes or sewers. This in turn has motivated the development of "smart pipes" that can repair themselves without having to be dug up (Figure 5).

A *USA Today* (Sept. 28, 2012) article on the nation's water costs highlighted the fact that some cities have experienced a doubling or tripling of costs over the past 12 years; for example, Atlanta, 223 percent; San Francisco, 211 percent; Wilmington, Del., 200 percent; Philadelphia, 164 percent; Portland, Ore., 161 percent; and New York City, 151 percent. The trend toward higher water bills is being driven by the cost of paying off the debt on bonds issued to fund expensive repairs or upgrades on aging water systems, increases in the costs of electricity, chemicals, and fuel used to supply



"We're upgrading our water system.
I'll take 200 miles of those smart pipes."

FIGURE 5 Smart pipes that can repair themselves reduce leaks without having to be dug up. Reprinted from Grayman et al. (2012) with permission from ASCE.

and treat water, compliance with federal government clean water mandates, rising pension and healthcare costs for water agency workers, increased security safeguards for water systems since the 9/11 terror attacks, and a general decline in public water consumption.

CHALLENGES OF THE FUTURE

Urban populations are projected to rise, nearly doubling from the current 3.4 billion to 6.4 billion by 2050, with the number of people living in slums rising even faster, from 1.0 to 1.4 billion in just a decade. Already, half of the world's population lives in cities, and 80 percent of Americans do.

Providing adequate water supply and sanitation, particularly in urban areas, is a challenging task for governments throughout the world. Many, especially in Africa and Asia, have virtually no or only inadequate infrastructure and limited resources to address water and wastewater management in an efficient and sustainable way. Because of inadequate infrastructure almost 85 percent of all wastewater is discharged to water bodies without treatment, resulting in one of the greatest health challenges, restricting development, and increasing poverty through costs to health care and lost labor productivity (UN 2012).

This task is made even more difficult by predicted climate changes, which are associated with significant alterations in precipitation patterns, both spatially and temporally, affecting the availability and variability of water supplies.

In addition, technological and financial constraints are challenges in maintaining and upgrading infrastructure assets to deliver water to all sectors while maintaining the quality of water distributed to various users. Furthermore, population growth, urbanization, and industrial activities are leading to a dramatic increase in water use and wastewater discharge.

Cities are facing difficult strategic decisions. Do they continue business as usual, following a conventional technical, institutional, and economic approach to water and sanitation? Do they tinker, following the conventional approaches while trying to optimize and fine-tune them? Or do they look for a new paradigm that considers interventions over the entire urban water cycle to provide security through diversification of water sources, reconsideration of the ways water is used (and reused), wastewater as a valuable resource, governance structures covering the entire urban water cycle, and the resiliency of water and sanitation to global change pressures?

CLOSING REMARKS

To meet future urban water and sanitation challenges we have to rethink the way we manage urban water systems. We need a paradigm shift. A more integrated approach may transform threats into opportunities and address the challenges of urban water management in both developed and developing countries. Do we continue to spend money to treat water to drinking water quality only to use it to fight fires or carry wastes to a wastewater treatment plant? Do we continue to spend money on the traditional (grey) infrastructure?

In addition to the integrated approach, do we consider more decentralized approaches where beneficial? Water reuse, energy recovery, the use of local water sources, and waterless toilets all foster decentralization. I predict that we will see many more integrated decentralized approaches to urban renewal efforts in the future, in the cities of both developing and developed countries.

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We Can Fight Climate Change and Create Jobs—Here's How

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ABSTRACT

Cities around the world are acting to both fight climate change and adapt to it. They have strategic plans, like Toronto's Clean Air and Climate Change Action Plan, and in executing those plans are lowering carbon emissions and building new resilient infrastructures. The role of cities is critical, because as of 2008 most residents of the world lived in cities, which is where most jobs are and most carbon emissions occur. By addressing carbon emissions in three sectors—heating and cooling buildings, energy generation, and transportation—emissions can be dramatically reduced, the livability and resilience of cities improved, and new jobs created.

INTRODUCTION

Cities around the world are facing economic challenges. One of the simplest ways to put people back to work is by rebuilding the infrastructure of cities—including infrastructure that helps mitigate and adapt to climate change. Large cities are seeing the impact of climate change through increased frequency and severity of storms, sea level rise, and other natural disasters (Figure 1), and they are responding to those challenges in ways that not only address environmental challenges but also create jobs.

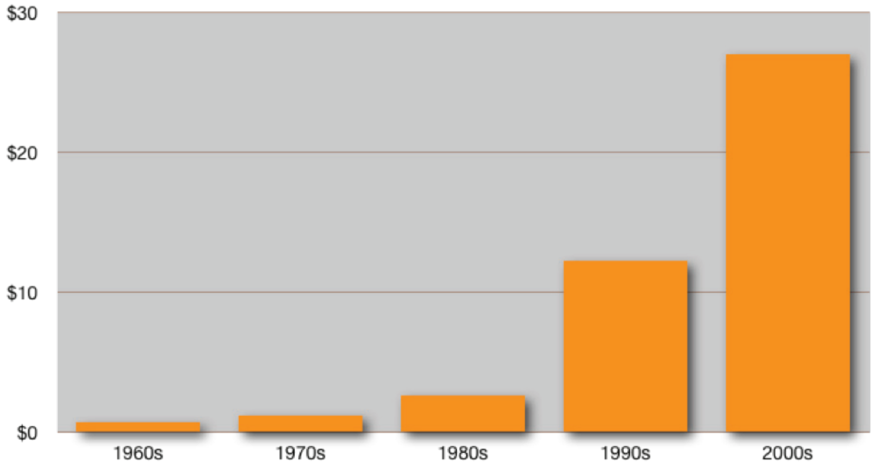

FIGURE 1 Rise in Global Disaster Damage, Based on Annual Insurance Disaster Claims, in Billions of US Dollars, Adjusted for Inflation, 1960s–2000s

CITIES AROUND THE WORLD LEAD THE WAY

The C40 group of cities (Figure 2)[1] are leading the fight against climate change, partnered with the Clinton Climate Initiative.

About 80 percent of greenhouse gas (GHG) emissions come from activities that take place in or are needed to support cities. Most of these emissions are from three sources: generation of energy, use of energy to heat and cool buildings, and transportation. In each of those sectors, C40 cities are taking specific actions that measurably and significantly reduce GHG emissions *and* create jobs. Many cities are also using the job creation from positive environmental strategies to address poverty by targeting the employment to those most in need, thus creating a green economy that is socially, economically, and environmentally sustainable.

Cities can learn from each other and act on new ideas. For example, upon learning of Sao Paulo's success in generating energy through methane gas capture at a large landfill (Sao Paulo generates about 8 percent of its electricity from this project, reducing GHG emissions by 11 million metric tons), Toronto implemented a new methane gas capture project of its own. The city now pipes the methane to a nearby farm facility where it is used to generate

[1] The C40 cities are an international network of megacities taking action to reduce greenhouse gas emissions; www.c40cities.org.

FIGURE 2 C40 Partner Cities and 18 Affiliate Cities. CCI = Clinton Climate Initiative.

electricity, which in turn is sold into the electricity grid, generating income for the city and creating good technically skilled jobs. The waste heat is used on the farm to heat industrial-scale greenhouses, which grow food. Thus Toronto's garbage is producing energy, lowering greenhouse gases, creating jobs where they are needed, and growing food!

There are other important examples. Los Angeles is retrofitting its 140,000 streetlights with LED bulbs to lower energy consumption and within 7 years will save $10 million annually. In the city of Calgary (home of the head offices of all of Canada's major oil companies) all municipal power, including for the city's light rail transit, comes from wind energy. And in Copenhagen, with the help of 80 turbines, 160 megawatts of electricity was generated from offshore wind, supplying energy to 150,000 homes.

A CLOSER LOOK AT TORONTO'S STRATEGIES FOR SUSTAINABILITY

Toronto has adopted a variety of strategies to enhance energy generation, buildings, and transportation, dramatically lower greenhouse gases, and create an economically and socially sustainable community (Figure 3).

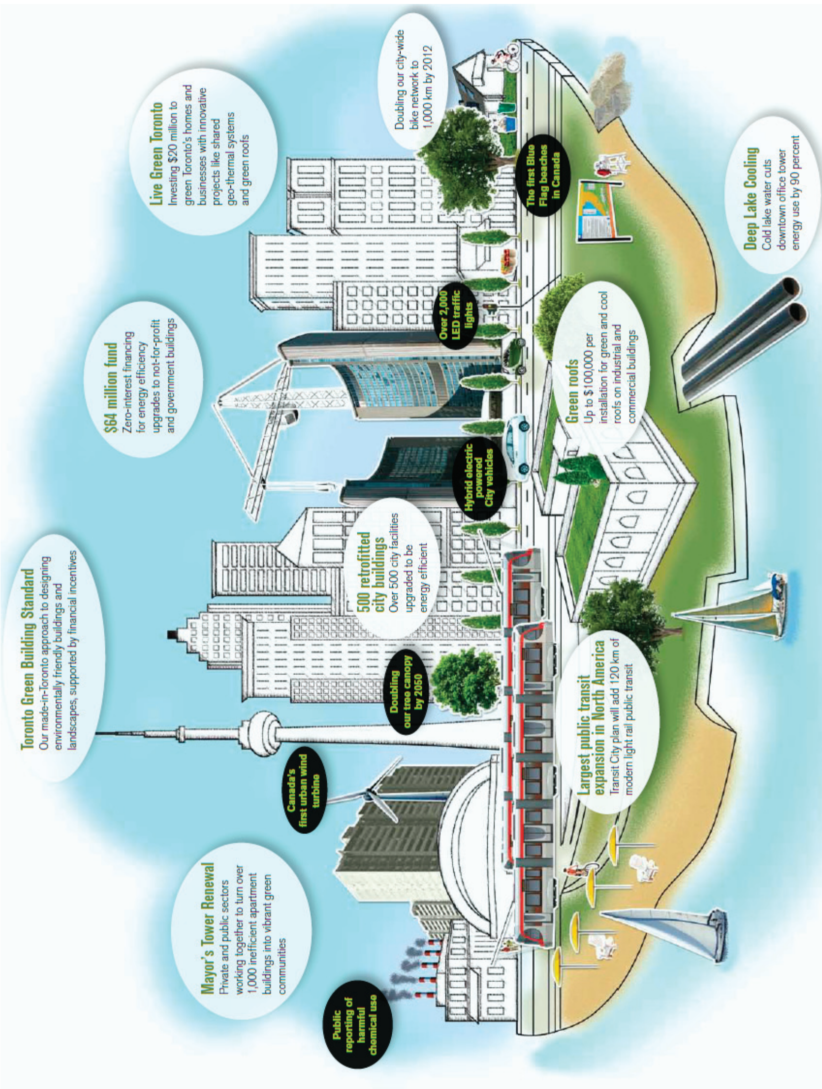

FIGURE 3 Toronto Strategies for Sustainability

The first step is a plan with specific targets and timetables. The city's 2007 Climate Change Action Plan, "Change Is in the Air" (updated in 2008 and 2009), requires it to meet the Kyoto targets for GHG emission reductions.

A Smart Grid

The city owns the local electricity utility (Toronto Hydro) and is working to develop a strategy to determine how to meet the city's GHG reduction targets. The strategy is very simple in concept but will require sophisticated technical expertise to execute. It centers on demand management, conservation, and distributed energy using green sources and based on a smart grid.

The grid in Toronto needs to be rebuilt because it is aging, and this construction will be a very expensive undertaking to be paid for by the rate base. The compelling benefit is that it provides a once-in-a-lifetime opportunity to transition to a smart grid. Additionally, the private sector is displaying a remarkable entrepreneurial spirit in developing technologies to support this development. One Canadian company developed a smart grid device that helps remotely lower the amount of electricity a house uses. The device is manufactured in Toronto, sent to China to be upgraded, and then sold in Texas.

Net Zero Electricity Consumption

To demonstrate the feasibility of this kind of project, the city of Toronto developed Exhibition Place—a large, historic industrial and consumer fairground—to produce as much electricity as it consumes. To that end, Canada's first urban wind turbine was installed as well as the largest urban rooftop solar installation, a trigenerator (which provides combined cooling, heat, and power), and a ground source geothermal heat pump. These energy generators, together with several energy efficiency measures, have enabled Exhibition Place to accomplish its goal of net zero electricity consumption.

Natural Heat Exchange

Toronto uses lake water to cool most of its downtown office buildings in the summer. The temperature of the deepest waters of Lake Ontario is the same all year round, so a heat exchange system was installed. Energy demand peaks in the summer, as is the case in many cities, when on hot days everybody is using air conditioning. Anything that can be done to lower the peak demand translates into large financial savings for the electricity system, as the cost of building new plants to accommodate the peak demands can be eliminated.

Energy Retrofits

Toronto has aggressively invested in energy retrofits for buildings. Its Better Buildings Partnership with the private sector and the (private) gas company has resulted in energy retrofits for millions of square feet of public, private, and institutional buildings. These activities are critical because the energy used to heat and cool buildings in Toronto creates 60 percent of the city's GHG emissions. In New York City it is 80 percent, hence the importance of measures like Mayor Bloomberg's requirement for commercial buildings to post their energy consumption, which helps to create private market demand for energy efficiency initiatives.

Toronto has the second highest concentration of concrete slab apartment buildings in North America after New York City. These buildings offer important benefits because they often were built with larger units. Furthermore, because they are concrete, their lifespan is least 100 years and proper maintenance can add to their durability. However, concrete has no insulating power, which translates into significant energy inefficiency. Engineers from the University of Toronto developed a strategy to reskin the buildings with aluminum and insulation, dramatically reducing energy consumption at a low cost (payback over just 7–10 years). Studies show that, if all of its buildings were insulated, Toronto would reduce its GHG emissions by 5–6 percent—the first Kyoto target.

Transportation

In most cities transportation sector emissions as a percentage of total emissions are a significant concern. Toronto has responded by developing, securing funding for, and starting construction of the Transit City Light Rail (Figure 4). The plan is effective because it creates a network of rapid transit to all neighborhoods of the city, meets transportation demands now and for the future, creates opportunity for inner city development (rather than sprawl), and is cost effective, allowing for rapid construction.

Toronto is also adding capacity to its subway lines not by building new lines but by changing the cars, making it possible for them to run at shorter intervals because of technical advances in smart communication between

FIGURE 4 Toronto's Transit City Light Rail Plan

signal systems and the subway cars—a cost-effective and simple way to add significant potential to already busy lines.

CLOSING REMARKS

Future strategies should not focus only on economic or environmental sustainability. Social sustainability must also be at the forefront of a city's planning strategies. The city of Toronto calls it prosperity, livability, and opportunity.

Environmental strategies can provide many skilled-job opportunities. Together with trade unions, Toronto has developed strategies to help train young people in low-income neighborhoods with the skills needed to obtain jobs. Combining all these effects, the strategy will help meet important environmental goals, create jobs, and support social sustainability.

Toronto isn't alone—city strategies from around the world, with the support of innovative engineers, can achieve the same thing on a large international scale.

Sustainability, Information Technology, and Environment

John C. Falcocchio
Polytechnic Institute of NYU

Sustainability is based on a simple principle:

> Everything that humans need for survival and well-being depends directly or indirectly on our natural and built environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony to permit fulfillment of the social, economic, and other requirements of present and future generations.

The focus of this session was to illustrate a variety of applications of the above principle by addressing four sectors: information technology, transportation, urban water, and environmental sustainability.

Joan McDonald described the role of the New York State Department of Transportation and its linkages with communities, economic competitiveness, and environmental quality. She emphasized the importance of incorporating sustainability into transportation decisions and illustrated the application of this principle by describing a number of projects throughout the state.

Ruthie D. Lyle discussed the importance of innovative information technology (IT) in creating sustainable cities. She explained why the digital and physical worlds are converging and how this convergence is creating smarter approaches to infrastructure management leading to greater sustainability. She illustrated IT applications in various urban sectors, such as water consumption, security, flood and landslide forecasting, and traffic congestion mitigation.

Upmanu Lall addressed the effects of climate change on urban water in coastal zones, and discussed various issues involved in the development of adaptive approaches to risk mitigation.[1] He pointed out that reducing urban water vulnerability to climate variations and change requires the adoption of management, planning, and operational practices based on adaptive rules informed by climate observations and predictions. One immediate opportunity for effecting gains lies in addressing seasonal to interannual climate risk, especially for multiyear droughts.

Carter H. Strickland's remarks, presented on his behalf by Christopher M. Hawkins, concerned the crucial role of waterways, water supply, energy, and air quality, as set forth in New York City's "PlaNYC 2030" for environmental sustainability. He cited examples illustrating (1) improvements of waterways to increase opportunities for recreation and restoration of coastal ecosystems, (2) the expansion of capacity for wastewater treatment, (3) green strategies to improve water quality, and (4) the use of various efficiency measures to reduce energy and emissions from existing buildings, wastewater treatment plants, solid waste management facilities, and vehicles.

[1] Dr. Lall's remarks are not included in this volume.

New York State Department of Transportation Sustainability Initiatives

Joan McDonald
New York State Department of Transportation

ABSTRACT

The New York State Department of Transportation broadly assesses the state's transportation systems to identify the needs of these systems and determine how decisions can best support the needs of a sustainable society. The department has adopted four guiding principles for maintaining and improving transportation resources: preserving current enterprises, taking a systems approach to projects, maximizing the effectiveness of investments, and making the system sustainable.

INTRODUCTION

The New York State Department of Transportation (NYSDOT) is divided into 11 regions, from Long Island to Buffalo and up to the Adirondacks. It is responsible for 113,000 highway miles, 17,400 bridges, a 3,500-mile rail network, 130 public transit operators, 485 public and private aviation facilities, and 12 major public and private ports. To manage this geographic breadth and scope of projects, department leaders need to address issues creatively and to work not only with the federal government—the Federal Highway Administration, our traditional partner—but also with partners in local government.

At NYSDOT we are investing in the future. As always safety is our top priority. We also look at demand-response, preservation, renewal of the system, and what needs to be modernized.

GUIDING PRINCIPLES FOR INVESTMENT IN SUSTAINABILITY

To fulfill its vision for sustainability, NYSDOT must integrate sustainability into all its decisions, use a multimodal and corridor approach, take care of present infrastructure for future generations, and enhance quality of life for all users.

Actions in support of sustainability follow a three-step decision-making process that considers *why*, *what*, and *how* to determine strategic plans, tactical moves, and operational practices, respectively (Figure 1).

Complementing the three-step process are four guiding principles for making sound investments: preservation first, a focus on the system not on discrete projects, maximized return on investment, and sustainability (Figure 2).

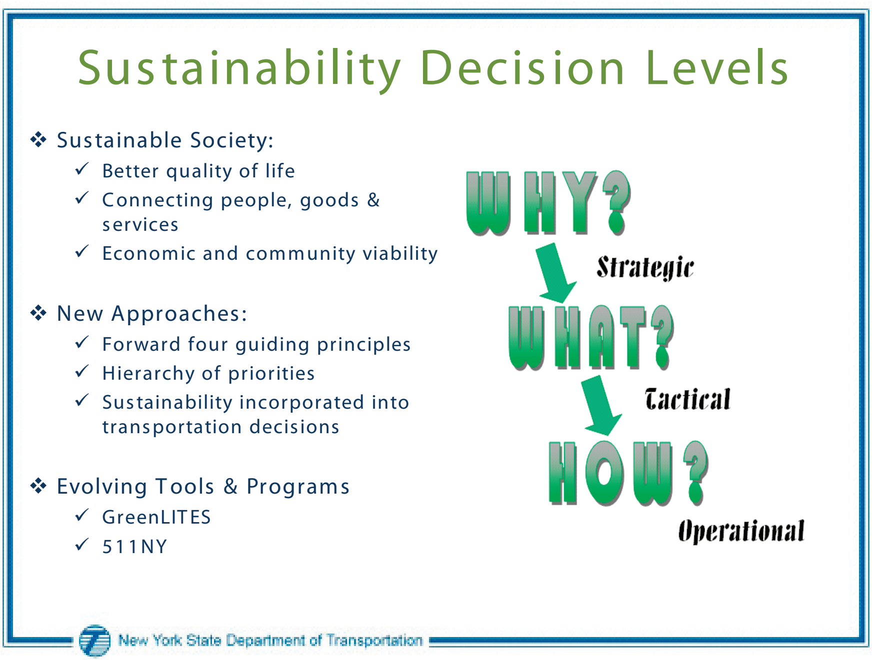

FIGURE 1 Sustainability Decision Levels

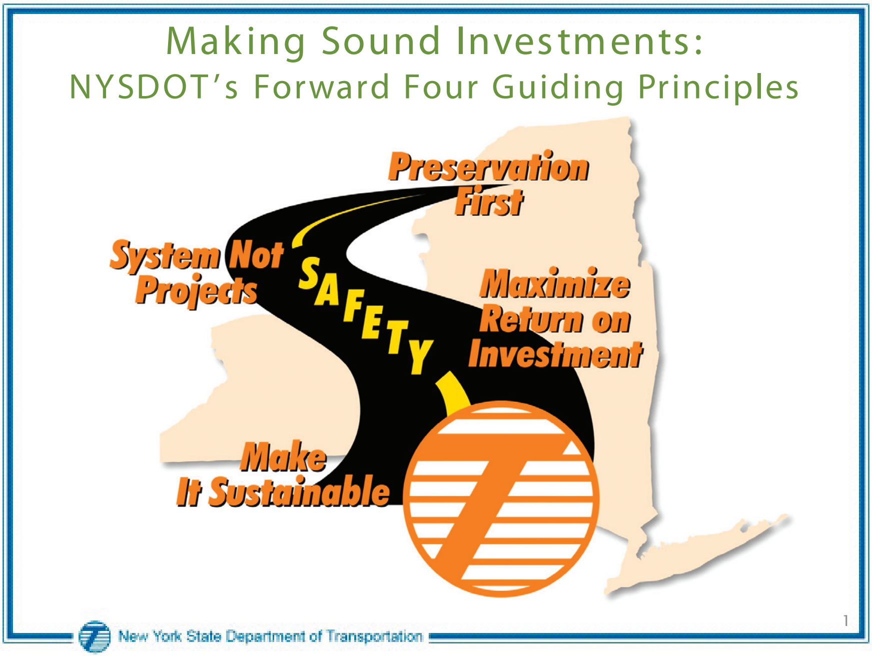

FIGURE 2 Making Sound Investments: NYSDOT's Forward Four Guiding Principles

For example, because of the aging transportation systems, one of the state's strategies is to shift investments from new construction to the *preservation* of existing infrastructure. This strategy will both maximize public benefits and be affordable over the long term. And whereas NYSDOT used to consider a project only in the context of what it meant for a very small defined area, each project is now understood as part of an overall *system*. This understanding can change the dynamics of decision making, maximizing return on investment and ensuring sustainability.

In these and other ways NYSDOT is incorporating sustainability into all its decisions and practices, using the triple bottom line approach in making investment decisions that affect the environment, the economy, and social concerns (Figure 3).

THE IMPORTANCE OF POLITICAL WILL

It is impossible to take politics out of transportation decision making—politicians love groundbreakings and ribbon cuttings—so it's important to

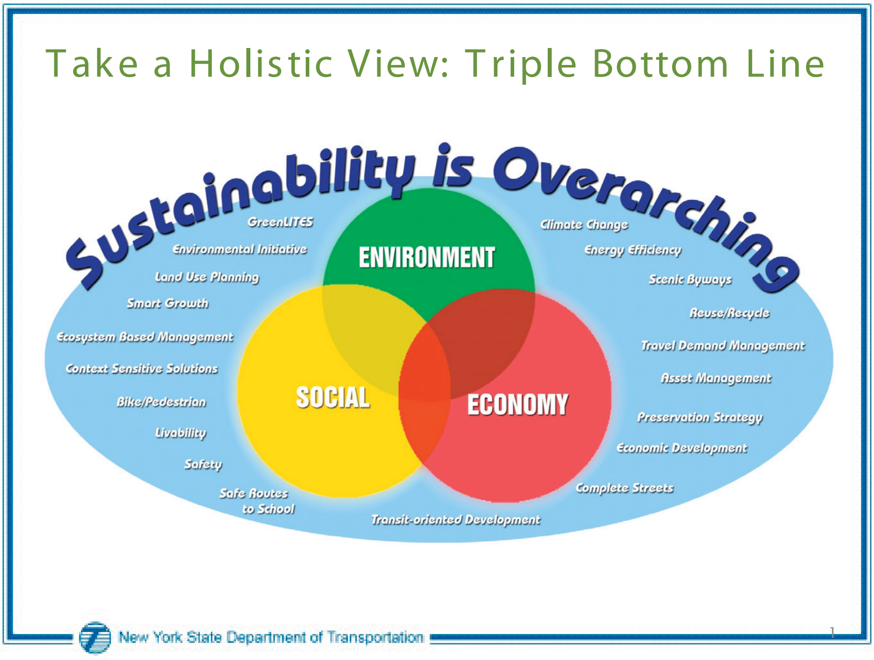

FIGURE 3 The Triple Bottom Line Approach to Sustainability

balance the preservation-first strategy with linking big infrastructure projects to economic development.

Because each of the state's 11 regions has a different way of making capital planning investment decisions, working across so many regions requires political will. People typically think of politics with a capital P—the president, the governor, the mayor,… But managers have to challenge staff and that takes political will. Bucking long-held systems and processes requires political will. This political will in changing how we do business is equally important for achieving a sustainable society.

PRACTICAL STEPS IN SUPPORT OF SUSTAINABILITY

One department program that fosters sustainability is GreenLITES, which recognizes Green *L*eadership *i*n *T*ransportation *E*nvironmental *S*ustainability in NYSDOT projects and offices that encourage the use of green processes and green design.

Traditionally, when people think of a green program and sustainability they think of design and construction: How are transportation engineers adding bike paths? How are they using landscaping to make a road or bridge improvement project more pedestrian friendly and community friendly? With the GreenLITES program the department rewards the efforts of not only the design and construction side but also operations and maintenance, where staff adapt and use green technology by, for example, using less salt to keep highways free of snow, or using sustainable detergents and cleaning fluids at department facilities.

Sustainability must also address the needs of the community. To that end NYSDOT is working with local administrators around the state on a number of projects—the Hempstead Turnpike Pedestrian Safety Corridor, the Economic Development Corridor in Fuller Road (Albany), an Urban Waterfront Revitalization Project for Buffalo Outer Harbor, a Bus Rapid Transit Corridor along Central Avenue (Albany-Schenectady), and the Bronx River Greenway (Figure 4). For the latter, NYSDOT collaborated with New York City Parks, the US Department of the Interior, and Amtrak using federal CMAQ (Congestion Mitigation and Air Quality) funds to make some wonderful investments in the community.

All of the projects show that a lot can be done to improve safety for pedestrians and bicyclists with very small amounts of dollars, for example by raising medians, changing bus stops to be more pedestrian friendly, integrating landscaping, improving drainage, and maintaining bike and pedestrian paths.

The digital age also affords opportunities, and NYSDOT has made it a priority to use 511, the National Transportation Information System that DOTs use across the country. It provides travel information and updates on capital construction projects so that by accessing 511—whether on a computer or cellphone or mobile device—people can find out where the construction projects are, what the alternate routes are to get to their destination, and upcoming transit options.

CLOSING REMARKS

It is the responsibility of leaders to address challenges creatively and to build a legacy of safety, mobility, and economic development in order to ensure quality of life and sustainability for our children and future generations. I have found that all entities want to be part of the solution. If you engage people in dialogue at the beginning, present ways to achieve shared goals, and discuss options, the outcome is a great design. Great ideas come from great conversations, a great dialogue. NYSDOT can come up with creative

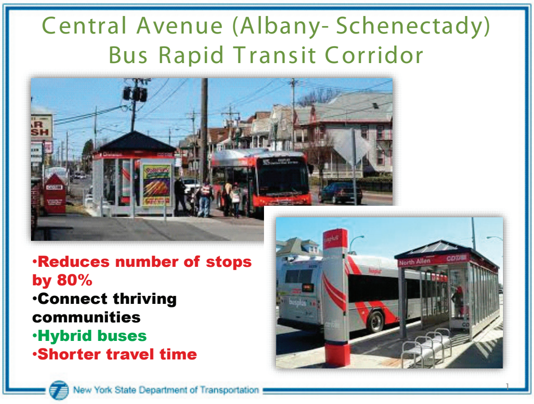

FIGURE 4 Central Avenue Bus Rapid Transit Corridor (top), Bronx River Greenway (center), and Green Route 347 in Suffolk County (bottom)

solutions by working with our partners in local government, academia, not-for-profits, and the private sector.

Through balanced, multimodal planning and actions, NYSDOT supports economic development and a transportation system that is safe, efficient, balanced, environmentally sound, and sustainable for the future. It takes vision, passion, and political will to plan and take action toward a sustainable future.

IBM Intelligent Operations Center: A Breakthrough in Information Technology for Smarter Cities

Ruthie D. Lyle
IBM Corporation
and
Colin Harrison
Smarter Cities Technical Strategy

ABSTRACT

A *smarter city* is one that makes optimal use of all the interconnected information available to better understand and control operations and to optimize the use of limited resources. In support of this vision IBM has established an Intelligent Operations Center that enables the optimization of critical information stored in disparate systems across multiple departments for the benefit of the city's population, economy, and greater ecosystem. This paper provides an overview of the IBM Intelligent Operations Center and briefly presents examples of its real-world application.

THE PRINCIPLE OF "SMART"

Smarter Planet

IBM's Smarter Planet Strategy can be described as an articulation of capabilities that are realized by leveraging technological advances and insights. Intelligence is infused into the systems, processes, and infrastructure that make up our world, making it "smarter." As a result it is possible to make decisions based on evidence instead of habit or opinion, and to anticipate and respond to events rather than simply reacting to them after they have occurred.

The digital and physical worlds are converging such that systems, processes, and infrastructure are becoming intelligent, interconnected, and instrumented. Embedded instrumentation such as actuators, programmable logic controllers, and distributed intelligent sensors are in everything from traditional infrastructure such as bridges and pipelines to personal devices such as smart phones, appliances, and even living organisms such as agriculture, livestock, and human beings.[1]

Smarter Cities

A city can be thought of as a complex system of systems with dynamic interconnections and interdependencies across individual systems or domains. Interdependency is inherent in complex systems. Health care, for example, can be dependent on domains such as transportation, environment, and agriculture; green transportation options for walking and biking in a city can enhance citizens' health, as can decreased emissions, better air quality, and improvements in the quality of drinking water and food.

Cities all over the world are in a state of unprecedented growth, especially in emerging nations, placing a huge strain on the underlying processes and systems that support them. Unbridled consumption of energy, increases in emissions of greenhouse gases, and the unavailability of drinking water are examples of the challenges that impair quality of life. There is thus a tremendous mandate for positive change.

What if cities could achieve effective and efficient operations by using information that is, in some cases, already available and applying insights based on this information?

CITY OPERATIONS AND MANAGEMENT SOLUTIONS

Critical information in a city is typically stored in multiple disparate systems across multiple disconnected departments. A fundamental change is needed for a city to become effective and efficient by using available critical information to become "smarter." The IBM Intelligent Operations Center (IOC) for Smart Cities is designed to enable this fundamental change.

IOC enables city leaders, managers, and planners to leverage information across all city agencies and departments, anticipate problems and mini-

[1] "IBM Offers Smarter City Assessment Tool to Help Cities Prepare for Challenges and Opportunities of Unprecedented Urbanization," June 24, 2009, available at www.ibm.com/press/us/en/pressureless/27791.wss.

mize the impact of disruption to services and operations, and coordinate cross-agency resources to respond to both real-time and anticipated issues. This approach for managing the city creates a fully integrated and interconnected holistic perspective as shown in Figure 1. Among the features of this system are gateways connecting IOC to various sources of data in the city (e.g., traffic and public safety), a visual interface between IOC and its operators, and bidirectional communication and interaction with citizens. Finally, analytic computational capabilities enable customization of solutions.

In terms of usability, the IOC provides an enhanced visual user interface that can be customized based on operator role. The interface makes it possible to

- bring together different data sources to provide a comprehensive perspective,
- present easily consumable critical information,
- display summarized data that can be analyzed to give insight, and
- support real-time workflow and alerts.

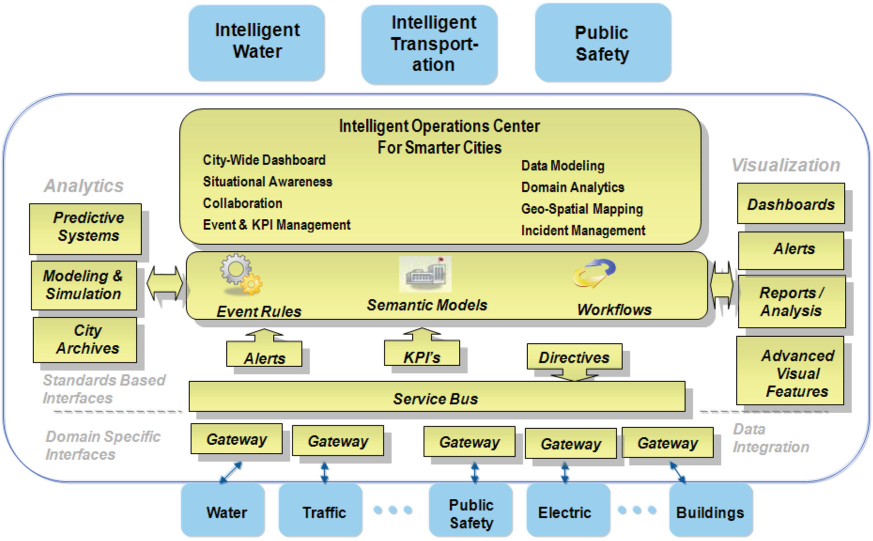

FIGURE 1 IBM Smarter Cities Cross-Domain Operations Center. KPI = key performance indicator.

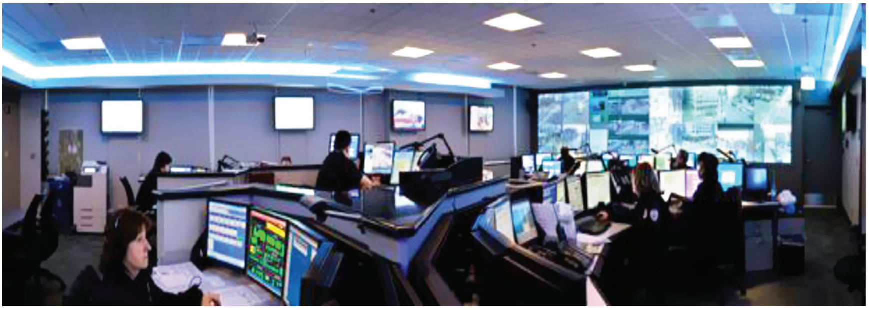

FIGURE 2 IBM Intelligent Operations Center User Interface

Figure 2 shows IOC being engaged by various operators. Wall monitors show multiple sources and types of information such as weather forecast data and traffic flow data. The interface can be thought of as a visual control center with multiple dashboard views available depending on the role of the user.

USING IOC TO ADDRESS REAL-WORLD ISSUES

IOC-based solutions are amenable to private- as well as public-sector application (Figure 3). Of particular interest and relevance are large sports stadiums, which have many of the same issues as a typical city. Following is a summary of two examples, Smarter Cities and Smarter Stadiums.

Smarter City Implementation

Rio de Janeiro is the second largest city in Brazil and the third largest metropolitan area in South America. In April 2010, faced with what is believed to be the worst flood in its history, the city leaders scrambled to leverage available resources in response. At their request, IBM helped to implement IOC together with IBM's Deep Thunder weather monitoring, creating a much smarter city with diverse "smart" capabilities. Initially the focus was on preventing death from annual flooding, but with positive political will the solution expanded to enable monitoring of multiple emergency situations.

Smarter Stadium Implementation

At the request of the Miami Dolphins football team, IBM, using the IOC, helped to transform the Sun Life Stadium into an entertainment destination

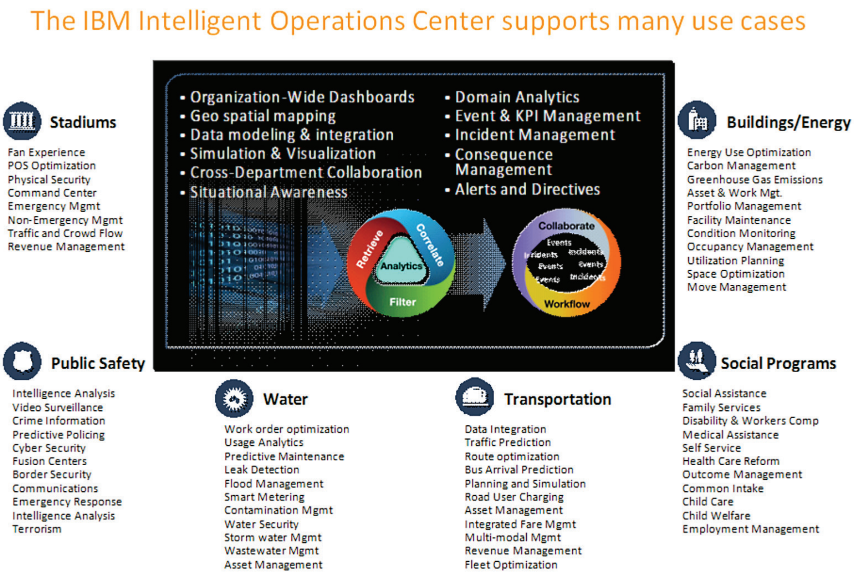

FIGURE 3 Types of IBM Intelligent Operations Center Uses

for fans. The stadium's mission is to become nationally and internationally recognized as the premier sports and entertainment center in the Americas. During games and other live events the stadium becomes a vibrant "mini city." The customized IOC solution enables information to be managed across all stadium assets and departments to facilitate data-driven decision making, anticipate problems to minimize the impact of disruption to stadium operations, and coordinate resources to respond to issues rapidly and efficiently, all of which helps to ensure the best fan experience possible.

SUMMARY

The principle of "smart" is fundamentally about recognizing the interconnectivity and interdependency of a complex system and applying technology to gain insight and formulate decisions. Smarter Cities efforts are about using information more intelligently to make better predictions and decisions that can improve both safety and quality of life. IBM's Intelligent Operations Center provides the tools to analyze and act on that information.

PlaNYC and the New York City Department of Environmental Protection's Role in a Greener, Greater New York

Carter H. Strickland, Jr.[1]
and
Christopher M. Hawkins
New York City Department of Environmental Protection

ABSTRACT

Viable solutions for more livable cities of the future must consider three pillars of sustainability: the public's quality of life, the environment, and the economy. On Earth Day, April 22, 2007, New York City released PlaNYC, its far-reaching sustainability plan to prepare the city for significant population growth, strengthen its economy, address climate change, and enhance quality of life for the city's residents. Updated in 2011, PlaNYC has 132 initiatives and more than 400 specific milestones that bring together more than 25 city agencies to work toward a greener, greater New York. This comprehensive plan has provided compelling justification for investing in infrastructure at a time when many government entities have cut back on spending to meet short-term needs.

The New York City Department of Environmental Protection plays a key role in more than a quarter of the plan's initiatives, creating innovative and sustainable source water protection techniques to maintain high-quality drinking water; using green infrastructure, such as artificial wetlands, blue

[1] This paper was presented at the symposium by Christopher M. Hawkins, chief of staff, NYC Department of Environmental Protection, on behalf of Carter H. Strickland, Jr. The symposium preceded Hurricane Sandy and therefore did not cover that important event or the city's response, including the June 2012 plan titled *A Stronger, More Resilient New York* for addressing the impacts of climate change.

roofs, and bioswales, to manage stormwater and provide other sustainability benefits to the city; developing alternative and distributed generation technologies at wastewater treatment plants; and improving the city's air quality by supporting the transition to cleaner heating oil and updating the Air Code.

INTRODUCTION

In 2006 there were approximately 8 million people in New York City and the population was expected to grow to approximately 9 million by 2030 (Figure 1), raising questions of how to meet the complex challenges to accommodate an additional 1 million people while continuing to improve the quality of life for New Yorkers.

To address these and other emerging challenges associated with the city's growth, Dan Doctoroff, then deputy mayor for economic development and rebuilding, formed the Office of Long-Term Planning and Sustainability (OLTPS), which brought together multiple city agencies and stakeholders to create the long-term vision for the city. In 2006 the city formed a Sustainability Advisory Board of local elected officials and local and national experts with backgrounds in environmental justice, green buildings, environmental policy, real estate, business, labor, energy, and urban planning. The board

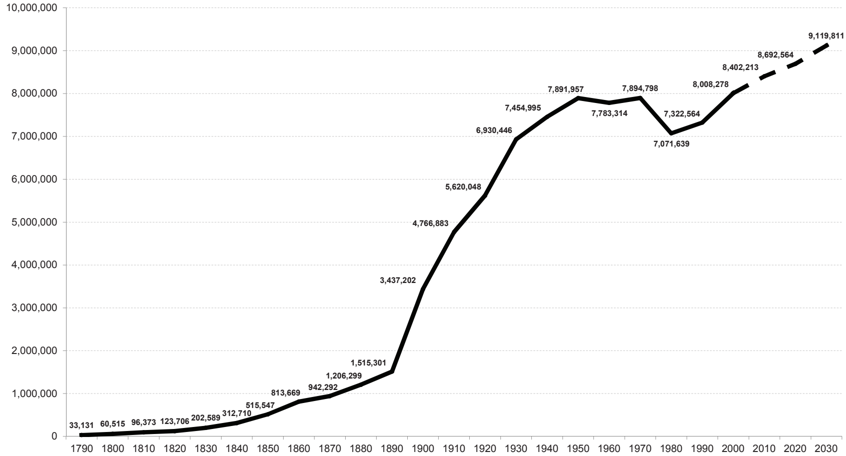

FIGURE 1 Historic and Projected Population of New York City, 1790–2030. Source: NYC Department of City Planning.

and subsequent outreach generated more than 5,000 comments that helped shape PlaNYC and served to facilitate and synthesize public engagement.

To determine the impact of climate change on New York City, the mayor's office also created the New York City Panel on Climate Change (PCC), composed of leading climate change scientists and legal, insurance, and risk management experts, which came out with findings in 2009. In a similar fashion, initiatives to address energy efficiency in buildings, local air pollution, traffic congestion, and other topics were developed through careful factual analysis, followed by extensive economic cost-benefit analysis and stakeholder consultation to arrive at policy proposals that prioritized practical results. Annual progress reports, supplementing existing accountability mechanisms, support accountability for achieving the goals of the plan and advancing each of the 132 initiatives.

First published in 2007, PlaNYC is required by law to be updated every four years. The latest iteration, released in 2011, is divided into ten subject areas.[2] More than a quarter of the initiatives in the plan are led by the city's Department of Environmental Protection (DEP), including those related to water supply, harbor water quality, and air quality. The remainder of this paper provides a summary of the subject areas and initiatives relevant to DEP and the department's progress since the release of the 2007 version of PlaNYC.

DRINKING WATER

Ensuring a livable city requires a high-quality, reliable water supply. Since the 17th century when the first Dutch settlers began to colonize the islands, New York City has prioritized the search for ever more plentiful and reliable sources of water to fight fires, improve sanitation and public health, and accommodate a growing population. Today, the city's 2,000-square-mile watershed contains 19 reservoirs and three controlled lakes, and water is delivered from more than 125 miles away. The city also performs more than 500,000 water quality tests each year to ensure that our drinking water is safe and meets federal standards.

[2] One significant topic added was solid waste management and recycling, which had been left out of the 2007 plan because the city had published a standalone Solid Waste Management Plan in 2006 after a decade of discussion and dispute following the closure of Fresh Kills Landfill in 1996.

Watershed Protection

To maintain high-quality drinking water, the city has continued to invest in a robust watershed protection program. Since 1993, the federal government has deemed that New York City's watershed and drinking water are of high enough quality that it has permitted the city to supply unfiltered drinking water, making it just one of five major cities in the country with this privilege.

Much of the land in the watershed is rural and composed of family farms and forestlands. Since 1997, the city has acquired more than 130,000 acres of land in high-priority areas that are most likely to benefit the city's water supply. To balance watershed protection with the interests and economic vitality of watershed communities, the city has avoided acquisitions in and around towns that have designated such properties as important for their future growth while maintaining watershed protection rules that reduce or eliminate sources of pollution. The city has also worked with the Watershed Agriculture Council to help more than 350 farms develop and implement Whole Farm Plans that protect water quality from agricultural pollutants and benefit farmers as well.

These investments have helped New York City maintain its ability to provide unfiltered drinking water and eliminated the need to build a multi-billion-dollar water filtration plant, while keeping the city's drinking water clean, reliable, and affordable.

Water Delivery and Treatment

The city continues to invest in the critical infrastructure that delivers more than 1 billion gallons of water per day to more than 9 million New Yorkers.[3] The Delaware and Catskill Aqueducts currently deliver all of the city's drinking water to the in-city distribution system. Since the 1990s, DEP has been monitoring significant leaks in a portion of the Delaware Aqueduct that connects the Rondout Reservoir in Ulster County to the West Branch Reservoir in Putnam County. To overcome the great challenge of these leaks, DEP will build a $1.4 billion 3-mile bypass tunnel around a portion of the aqueduct (Figure 2), running east from the town of Newburgh in Orange County, under the Hudson River to the town of Wappinger in Dutchess County, on the east side of the Hudson. Under the plan, DEP will break ground on the

[3] This number includes upstate residents in addition to New York City's population of 8.3 million.

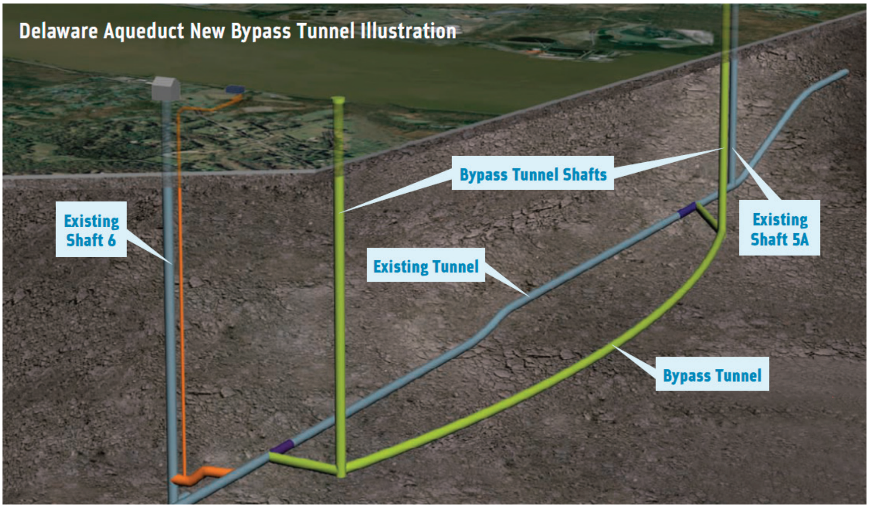

FIGURE 2 Illustration of the Delaware Aqueduct Bypass Tunnel

bypass tunnel in 2013 and complete the connection to the Delaware Aqueduct in 2019.

Despite the city's extensive history of protecting public health, under the Safe Water Drinking Act the federal government has mandated that the city complete two major water treatment facilities, the Catskill/Delaware Ultraviolet Disinfection Facility and the Croton Water Filtration Plant. In 2008, the city began construction on the $1.6 billion Catskill/Delaware Facility to comply with a federal mandate that requires treatment of surface-level drinking water supplies with two sources of disinfection—in our case, chlorine and ultraviolet light. In October 2012, the city began treating all tap water at the plant and will complete construction in 2013.

The Croton Watershed was first tapped to supply drinking water in 1840. Today this watershed is highly developed and, although the water supply meets all health-based water quality standards, there have been seasonal complaints about color, odor, and taste. In 2007, the city began construction on the $3.2 billion Croton Water Filtration Plant in the Bronx. The city completed two water tunnels linking the plant to the New Croton Aqueduct in February 2011 and expects to begin operating the plant by the end of 2013.

WATERWAYS

New York City's five boroughs are situated on an archipelago and together account for more than 520 miles of coastline. The city's harbor is a national treasure and is cleaner now than it has been in more than 100 years, thanks to achievements in wastewater collection and treatment as well as a shift away from a heavily industrial economy. This rejuvenated waterfront provides economic, recreational, and environmental benefits to the city's residents.

To continue to improve the quality of our waterways, increase opportunities for recreation, and restore coastal ecosystems, the 2011 version of PlaNYC sets forth a plan for the city's waterways with 15 initiatives and more than 50 milestones.

Harbor Water

Over the past decade New York City has invested more than $10 billion to successfully improve water quality in the harbor. A $5 billion upgrade at the Newtown Creek Wastewater Treatment Plant will increase both the amount of pollution removed from the wastewater and the plant's treatment capacity from 620 to 700 million gallons per day in wet weather. The plant went into operation in 1967, before Congress passed the landmark Clean Water Act, requiring municipalities to remove at least 85 percent of certain pollutants from wastewater before discharging it into surrounding waterways. An upgrade begun in 2000 brought the plant into compliance with Clean Water Act standards in 2011, two years ahead of schedule. Now all 14 wastewater treatment plants in New York City meet secondary treatment and removal requirements.

In addition, the city has made investments to upgrade and improve a number of other plants over the last ten years. At the Hunts Point Wastewater Treatment Plant, the city invested $595 million to increase wet weather capacity, build a new nitrogen removal system, and construct a central residuals facility to reduce odors from the plant. The city has also undertaken major upgrades to the 26th Ward, Coney Island, North River, and Owls Head wastewater treatment plants. Over the next ten years, the city will invest $3.3 billion to keep wastewater treatment facilities in a state of good repair.

Stormwater is a challenge for urban areas, such as New York City, that have combined sewers, which carry both sanitary waste and stormwater in the same pipe. When there is more rain than the system is designed to carry, the combined sewer is built to overflow into local waterways to mitigate damage to the wastewater treatment plants. Traditional solutions to many

FIGURE 3 Paerdegat Basin Combined Sewer Overflow Detention Facility

water quality challenges employ "grey infrastructure" (so called because it is often built with steel and concrete), such as the Paerdegat Basin Combined Sewer Overflow (CSO) Facility, that can detain wastewater until the treatment plants have the capacity to treat it (Figure 3). These facilities serve only one purpose and often are expensive to build; the Paerdegat Basin Facility, for example, cost approximately $404 million, but it is quite effective, eliminating 70 percent of CSO into Paerdegat Basin.

Artificial Wetlands (the Bluebelt System) and Green Infrastructure

First developed on Staten Island and now used in Queens and the Bronx, the bluebelt system provides ecologically sound, cost-effective stormwater management by preserving streams, ponds, and other wetland areas that collect stormwater runoff from the streets and temporarily detain or permanently retain it. In addition, the people that live nearby gain from the aesthetic and environmental benefits of the wetlands and have seen their property values increase because of the amenities.

Bluebelts have proven to be effective at managing stormwater where the city has enough space for large artificial wetlands. However, in ultra-urban areas of the city, where approximately 72 percent of land is impervious (e.g., parking lots, roads, sidewalks), it is difficult to manage stormwater using the bluebelt model.

In 2008, the Mayor's Office of Long-Term Planning and Sustainability published the *Sustainable Stormwater Management Plan*, which concluded not only that green infrastructure was feasible in many areas of the city but that it could be more cost effective than certain large, grey infrastructure projects like the Paerdegat Basin CSO Facility. Two years later the city published the *NYC Green Infrastructure Plan*[4] and subsequently entered into a revised consent order with the New York State Department of Environmental Conservation based on the plan that will eliminate or defer $3.4 billion in traditional investments and achieve greater water quality improvements.

This approach provides the city with an adaptive and scalable toolkit of green infrastructure systems that can manage stormwater under, alongside, and on top of all varieties of urban structures. Green roofs and blue roofs are an ideal strategy for highly urbanized areas where buildings occupy a significant portion of urban land area (up to 45.5 percent in New York City). Porous pavement and pavers could be used in the city's streets, sidewalks, and parking lots—which account for 26.6 percent of the city's ground surfaces—if underlying soil and infrastructure can support the infiltration of water.[5] And bioswales and stormwater greenstreets capture stormwater along the curb and prevent it from entering the sewer system. All of these systems provide additional benefits to the community such as higher property value, greater ecosystem diversity, and reduced urban heat island effect, among others.

Based on the performance of prototypes, DEP recently published standard designs for bioswales so that, just like traffic lights or fire hydrants, they are now part of the city's palette of infrastructure. Each bioswale has a curb cut to divert runoff from the curb into the system. Next, a permeable gravel strip lets water seep into the water table, effectively removing this water from

[4] New York City Department of Environmental Protection. 2010. Available at www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_plan.shtml.

[5] *Sustainable Stormwater Management Plan*, New York City Mayor's Office of Long-Term Planning and Sustainability, 2008.

FIGURE 4 Examples of Green Infrastructure: (A) Green Roof, (B) Blue Roof, (C) Porous Pavement, (D) Bioswale

C

D

the sewer system, increasing the system's capacity, and reducing combined sewer overflows.

By 2015 DEP will have built or funded 6,000 bioswales and committed over $187 million to green infrastructure, creating a solid foundation for this program and adding to the distributed infrastructure that it will maintain.[6]

Stormwater Performance Standards and Other Initiatives

To address stormwater from new buildings, DEP published stormwater performance standards that require all new and redeveloped buildings to limit their stormwater outflow to approximately 10 percent of the current permitted flow into the combined sewer system. Some cost-effective methods to achieve this are detention (e.g., rain barrels and tanks), infiltration (e.g., permeable pavements and rain gardens), and reuse (e.g., grey water systems).

To address stormwater from existing buildings, the city has adopted a green roof tax credit, changed zoning rules to permit green roofs and other stormwater installations, and created a Green Infrastructure grant program that has funded 29 projects with $11 million in public funds that were matched by $5 million in private funds.

ENERGY

New York City's energy and emissions goals include a more than 25 percent reduction in energy consumption by 2017 and a 30 percent reduction by 2030. To that end, DEP is helping to develop alternative and renewable energy supply projects (e.g., the city's largest array of solar panels on the Port Richmond Wastewater Treatment Plant) and developing cogeneration at the North River Wastewater Treatment Plant. When complete in late 2017, the North River plant will be a prime example of highly efficient, clean distributed generation integrated in a dense urban environment. The plant will use its anaerobic digester gas to generate 15 megawatts of electricity while capturing and reusing waste heat, thus reducing greenhouse gas emissions by more than 40 percent from 2006 levels (Figure 5).

DEP is also working with National Grid to convert anaerobic digester gas from the Newtown Creek Wastewater Treatment Plant to pipeline-ready natural gas. This project is the first example in the United States of injecting purified digester gas directly into a local natural gas distribution system.

[6] DEP maintains 148,000 catch basins and 109,500 fire hydrants.

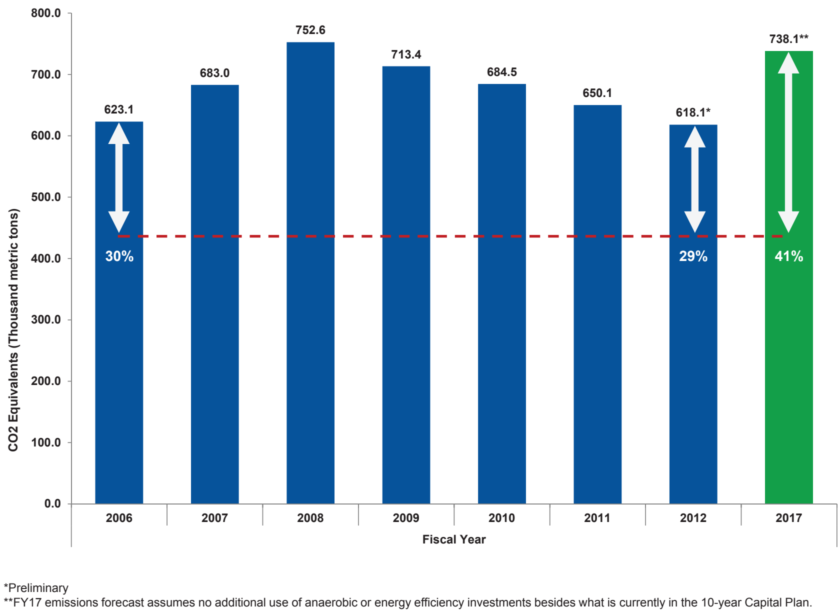

FIGURE 5 Current and Projected Greenhouse Gas (GHG) Emissions, New York City. Dashed line = 30% reduction goal by 2017; white arrows with accompanying white text show the projected remaining GHG reduction. GHG emissions increase through 2017 because of new infrastructure including an ultraviolet disinfection facility and a water filtration plant. Source: New York City Department of Environmental Protection.

The gas, which normally would be flared, could heat up to 2,500 homes and would account for the removal of approximately 15,000 metric tons of greenhouse gases per year. After finalizing a contract with National Grid, DEP expects to begin construction in 2013 and put the system into operation by 2014.

AIR QUALITY

As the agency responsible for regulating air quality, DEP has launched a number of initiatives, such as a comprehensive revision to the New York City Air Code, which has been updated in a piecemeal fashion since its promulgation in 1975. The revision will streamline the code, increase ease of compliance, and regulate previously unregulated sources. The agency expects to present the updated code to the city council at the end of the year.

In April 2011 DEP established a new rule to phase out the use of No. 4 and No. 6 heating oils over the next 20 years. These regulations are expected to save more than 300 lives and avoid 600 emergency room visits and 200 hospitalizations each year by 2030. In July DEP and the New York City Department of Buildings streamlined the fuel change filing process, making the transition to cleaner No. 2 oil or natural gas faster and easier and saving building owners approximately $3,000 for each boiler conversion. In 2011 the city also announced the Clean Heat campaign, to assist property owners in complying with these regulations through education, outreach, and technical assistance.

CONCLUSION

The 2012 PlaNYC Progress Report showed that New York City has completed or made substantial progress on more than three-quarters of the milestones set forth in the 2011 version of PlaNYC. With responsibility for more than a quarter of the city's initiatives, DEP is proud to be making significant contributions to protect the city's public health and the environment by providing high-quality drinking water and collecting and treating wastewater. Over the past decade, DEP has invested more than $20 billion to protect our drinking water supply and improve the health of our waterways—more than any other city in the United States. And over the next decade, DEP will continue to invest more than $14 billion to further improve our infrastructure and continue to lead the nation in finding the most cost-effective, sustainable, and efficient ways to deliver high-quality drinking water and protect our waterways.

Challenges: The Way Forward

Paul Horn
New York University

The challenges of creating and maintaining a sustainable and renewable urban environment are many:

- How do we create and fund the major current and future infrastructure needs of cities? Can a city be designed and/or refined for retrofitting infrastructure?
- As population densities soar, how do we deal with growing issues of safety, security, and cybersecurity for cities?
- How do we resolve conflicts between the energy supply and the environment?
- How can we take advantage of the potential of vast information and smart technologies while at the same time respecting the privacy and liberty of citizens?
- How can we deal with the debilitating effects of noise pollution?
- How do we build economic regions so that cities of the future have a sustainable engine for economic growth?

These questions and more were discussed in the final session with the following panelists:

- Steven E. Koonin, director of the NYU Center for Urban Science and Progress (CUSP)

- Gerard M. Mooney, vice president of IBM Global Smarter Cities
- Thomas D. O'Rourke, Thomas R. Briggs Professor of Engineering at Cornell University
- Theodore S. Rappaport, David Lee/Ernst Weber Professor of Electrical Engineering at NYU-Poly

It became clear in the session that an important component of the answer to these questions lies in the systematic gathering and use of data about cities. The data can come in a variety of modalities: visual, infrared, cellular/GPS signals, water monitor outputs, and so on. Analysis of the data can be used for optimization and to generate efficiencies of all kinds, such as shorter commuting time, less wasteful water and energy management, improved disaster response, and more efficient product distribution.

A second component of any solution is modeling and simulation. Cities are highly complex both structurally and organizationally. Changing any one variable even slightly can have unanticipated catastrophic effects in unexpected places. The better we use data to model and understand cities, the better we can optimize outcomes and minimize negative repercussions.

Finally, key to success will be partnerships between city agencies and the academic and private sectors. The city needs to open its data to careful analysis, which can stimulate novel "smart" solutions from the general public and the private sector. The academic and private sectors are motivated to help; what they need is direction and encouragement from city and state agencies, augmented by small amounts of seed funding.

As with many things, George Bugliarello understood these issues well before most of the scientific community. Perhaps more slowly than optimum, we are finally following his lead.

Center for Urban Science and Progress: Opportunities in Urban Data

Steven E. Koonin
Center for Urban Science and Progress

ABSTRACT

New York City's Center for Urban Science and Progress is a new research and education center for urban informatics that is engaging public and private partners to gather urban data and at the same time contribute to urban renewal. Its goal is to enhance understanding and optimize methods for sustaining and improving cities around the world through the collection and analysis of data on citizens' behavior and health, economics, transportation, communication systems, food and water, power consumption, and risks to public safety.

INTRODUCTION

The New York City Center for Urban Science and Progress (CUSP) was established in April 2012, as part of the city's Applied Sciences Initiative, to create a system of innovation that links education and research programs to local and international knowledge networks and markets. Its goal is to contribute to the development of local knowledge networks, local innovation enterprises, and regional technology clusters while linking New York City commerce to global research networks, production activities, and markets.

CUSP is both multi- and transdisciplinary, it engages citizens and users, it integrates physical and tabular data, and it welcomes open innovation, commercialization, and entrepreneurship, including education of the next generation of innovators in making cities sustainable. It will be a major center for research and education in urban informatics, with 50 full-time senior researchers, 30 postdocs, 430 master's degree students, and 100 PhD candidates located in downtown Brooklyn and funded by government, corporate, philanthropic, and academic capital. The living labs and innovation district provide facilities, processes, real-life context, and management support for research projects at CUSP.

CUSP is a creative district comprising NYU-Poly, MetroTech, the neighborhood "Down Under the Manhattan Bridge Overpass" (DUMBO), the Brooklyn Navy Yard, the Pratt Institute, and the Brooklyn Academy of Music, as seen in Figure 1. Brooklyn now has the potential to become an innovation district and technology cluster.

Together with NYU and NYU-Poly, CUSP is helping in the development of the Brooklyn Tech Triangle Strategic Plan, shown in Figure 2. The Triangle is addressing challenges such as needs for space, infrastructure and facilities, new construction and the retrofitting of existing facilities, and alignment of clear roles and responsibilities. A recent economic impact study found 523 innovation firms, 9,628 direct new jobs, 23,000 additional jobs supported,

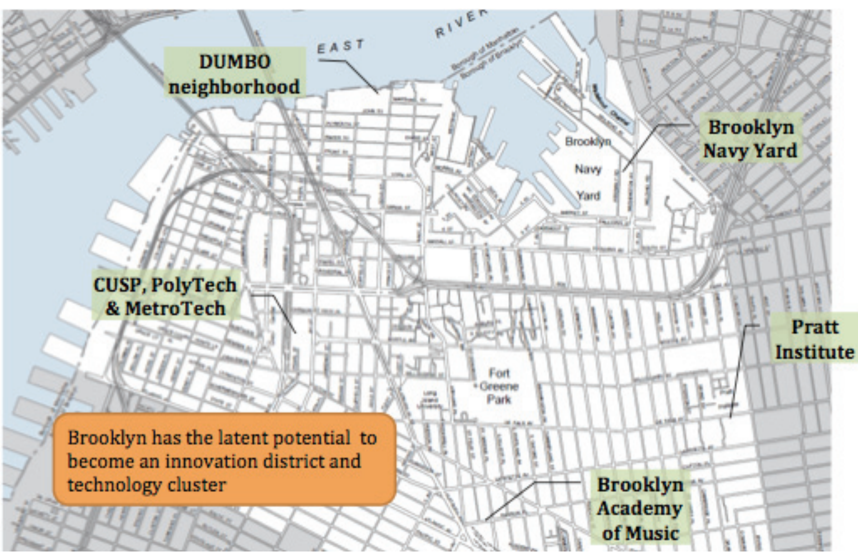

FIGURE 1 Downtown Brooklyn

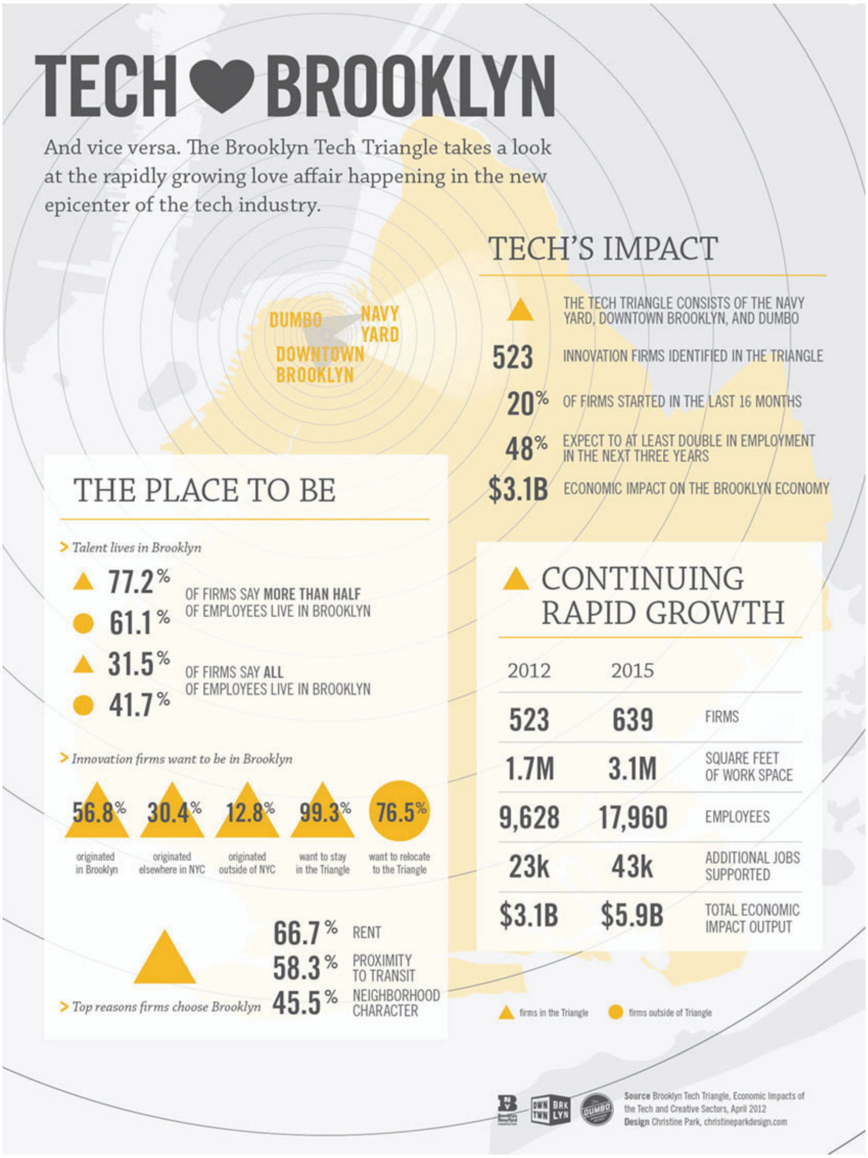

FIGURE 2 Brooklyn Tech Triangle Strategic Plan. DUMBO = down under the Manhattan Bridge overpass.

1.7 million square feet of office space, and a $3.1 billion local economic impact.[1]

OPPORTUNITIES

New York's data ecosystem presents CUSP with a number of opportunities for the acquisition and mining of data on the behavior of city inhabitants (e.g., their preferences, the effectiveness of inducements for change), current and projected health needs, projected living needs (e.g., power, heat, light, transportation, water, communications), and potential natural and human-generated threats to public safety.

Data are the new "plastics" and data startups are becoming the next layer of the NYC tech scene. Companies such as Google and Microsoft Research New York City, investors such as IA Ventures and Union Square Ventures, major events such as the O'Reilly Strata Conference, meet-ups such as NYC Data Business, hubs such as General Assembly, and open-source projects and nongovernmental organizations are taking advantage of the opportunity to interact in this mix of academic, corporate, and government partners, and various other organizations have expressed interest.

CUSP is a unique public-private research center that will use New York City as its laboratory and classroom to help cities around the world become more productive, livable, equitable, and resilient. CUSP participants can observe, analyze, and model cities to optimize outcomes, prototype solutions, formalize new tools and processes, and develop new expertise and experts. These activities will make CUSP the world's leading authority in the emerging field of "urban informatics," supporting user-driven innovation in real-life urban settings.

THE NEED FOR DATA

Cities are in competition for talent and capital in order to achieve sustainability. A city's informatics overlay can help it be more efficient, more resilient, and more sustainable while improving quality of life, citizen engagement, and equitability.

Cities deliver services through infrastructure and processes. How do these systems operate and how do they interact? How can they be opti-

[1] Economic Impacts of the Tech and Creative Sectors: Brooklyn Tech Triangle. April 2012. Available at http://brooklyntechtriangle.com/assets/Brooklyn-Tech-Triangle-Economic-Impact.pdf.

mized? The city's infrastructure (its condition and operations) needs to be instrumented.

Cities are built by and for people, whose behavior needs to be understood and therefore included with other essential data in the information base. Privacy protection limits access to data such as people's location, their economic and communication activities, and their health; but government agencies, organizations, and industry need this information and so depend on information-gathering instruments.

Other sectors too are interested in such data: citizens are interested in what is going on in their city, the private retail sector wants to target advertising, insurance companies need to stratify risk, and campaigning politicians want to know what the population is thinking. Also interested are security organizations—local law enforcement, the FBI, the National Security Agency, Homeland Security, and the US intelligence community.

New data-driven technologies can get beyond current limited-quantity and low-quality surveys and aggregated dynamic data banks and enhance the way social scientists work by providing data with far greater resolution, quality, quantity, and fidelity.

CLOSING REMARKS

CUSP concentrates on urban data and access to societal and physical data sources, among others, focusing on three dimensions of concern: proprietary datasets or algorithms, privacy, and protection of critical infrastructure data. CUSP participants use the data to try to solve urban problems such as operational optimization, infrastructure condition monitoring, infrastructure planning, travel and intersection patterns, emergency management, hazard detection, urban meteorology, emissions monitoring, validity and calibration of proxies, variation among cities, and so on.

Urban Challenges: The Way Forward

Gerard M. Mooney
IBM Corporation

ABSTRACT

Cities are often the largest contributor to a country's GNP. Current high unemployment, languid economic growth, and growing urbanization make cities' role in driving growth more important than ever. Governments need to accelerate the development of common standards for new solutions and open data, industries need to collaborate across industry boundaries, and cities need to continue to build smarter. "Smarter cities" use instrumentation, interconnection, and intelligence to provide awareness of and coordinated responsiveness to activities and events. Interconnected technologies are changing the way the world literally works, and cities are the brightest opportunity to begin working toward a smarter planet.

INTRODUCTION

A city can be viewed as a complex system of systems, and the integration of these systems is essential for growth and job creation. Good urban planning strategies—manifested in neighborhoods that promote walking and bicycling and quality transit—are the foundation for livable cities. But cities also need to be infused with new capacities such as information technology (IT) and analytics to help make them smarter.

At the October 2012 EUROCITIES Knowledge Society Forum in Vienna, however, an astounding point was made. According to a member of the European Commission Intelligent Transport Systems Department of the Directorate-General for Mobility and Transport, although the commission developed many pilot projects across Europe over the last two or three years, not one was scaled or replicated. It is extremely important to know what works in order to understand what to scale. Tools are needed to measure impact and determine what needs to be developed to make cities and systems more efficient and effective.

CHALLENGES

In the globally interconnected business and IT world, natural disasters, failures of large-scale systems, and malicious threats highlight the complexity and fragility of systems, whether natural or developed for global business and government operations. Moreover, as vividly illustrated in Figure 1, reported disasters/incidents have been increasing in recent years in both number and intensity.

FIGURE 1 Acute Threats, Natural and Man-made

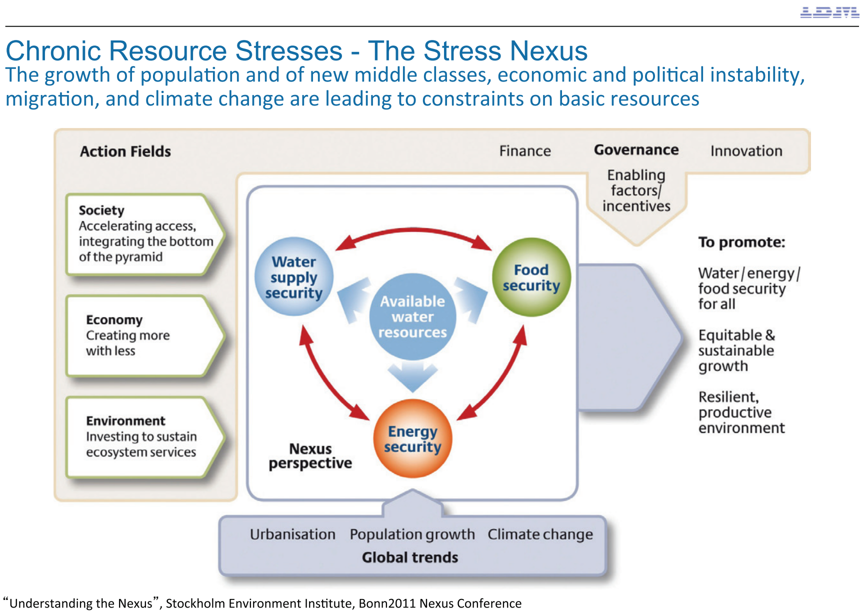

FIGURE 2 Chronic Resource Stresses: The Stress Nexus

In addition, the growth of populations, shifts in the balance in economic status of individuals and nations, political instability, migration, and environmental changes are leading to constraints on basic resources such as water, food, and energy. This "stress nexus," as shown in Figure 2, is limiting economic development in many places around the world.

All of these threats, both natural and human-generated, make the challenges of sustaining cities that much more difficult. To avoid succumbing to these threats and challenges it is essential to deploy smarter infrastructure and invest in resiliency and sustainability.

THE LEADERSHIP ROLE OF CITIES

Cities are often the largest contributor to a country's GNP and, because of their importance, must determine what investments to make in order to become world-class and compete globally.

A city's economic engine (Figure 3) can be identified by the types and quality of infrastructure. City leaders also need to decide what their city

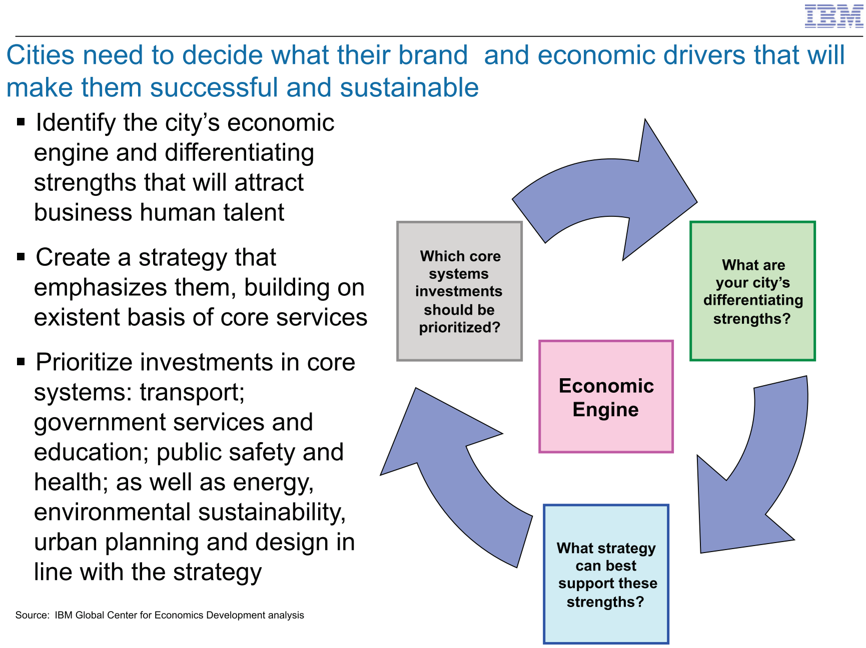

FIGURE 3 A City's Economic Engine

should be—determine its "brand." The first step in this process is to articulate the city's high-level objective, in terms of economic and social competitiveness, by

- identifying the city's differentiating strengths that will attract skills, knowledge, and creativity;
- creating a strategy that emphasizes these strengths while building on potential capacity; and
- prioritizing investments in core systems such as transport, government services and education, public safety and health, energy, environmental sustainability, urban planning, and design aligned with the strategy.

A city's policies should be conducive to skills, creativity, and knowledge-driven growth, as shown in Figure 4. With the growing importance of these attributes in the global economy, it is critical that cities create an environment that supports and promotes them. Such an environment

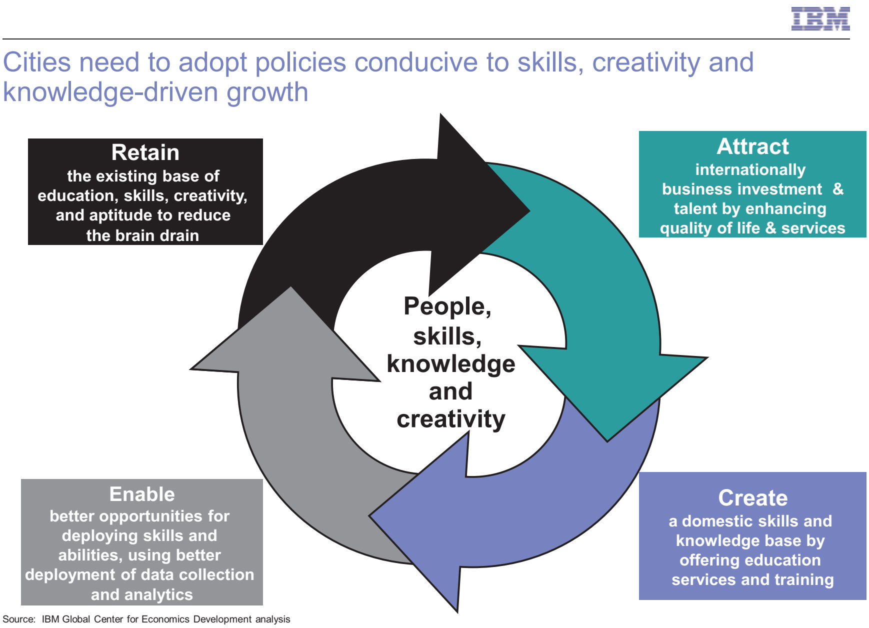

FIGURE 4 Components of Policies That Support Skills, Creativity, and Knowledge-Driven Growth

- Attracts internationally mobile talent by enhancing quality of life services in line with changes in demand.
- Creates a domestic talent base by offering education services and training and by investing in education infrastructure. Cities that invest in people through education and training have a higher-quality stock of skills, talent, and knowledge, thus improving their chances for greater prosperity. There is, for example, a strong positive relationship between investment and enrollment in higher/tertiary education and level of prosperity and economic performance, even at the national level: estimates of the gain in income from an additional year of education range from 5 percent to 15 percent.[1] In addition, empirical evidence suggests a link between education, R&D, technology adoption, and growth.[2]

[1] Deutsche Bank Research. Available at www.dbresearch.com/prod/dbr_internet_en-prod/prod0000000000190080.pdf.

[2] Benhabib J, Spiegel MM. 1994. The role of human capital in economic development: Evidence from aggregate cross-country data. Journal of Monetary Economics 34:143–173.

- Enables better job and growth opportunities for citizens by using data collection and analytics to identify changes in the labor force and skills supply and demand.
- Promotes business and entrepreneurial investment to increase economic capacity to generate, absorb, and commercialize innovation and creativity.
- Retains the existing base of talent to minimize "brain drain." In international competition for skills, knowledge, and innovation, successful cities experience net inmigration—and less successful cities outward migration—of skilled people. For example, in the United Kingdom there are large inflows of graduates in London and the southeast whereas some cities in the north find it difficult to retain their graduates. Similarly, in former industrial cities of the US Rust Belt the decline associated with a deindustrializing economy has resulted in people leaving.

BUILDING ON COLLABORATION: A SUCCESS STORY

Industries, universities, and governments can work together to bring real economic development to cities and regions. For example, just a few hours north of New York City, IBM was involved in creating a world-class center for nanotechnology and microelectronics, Albany Nanotech. Figure 5 shows the basic strengths and needs of the project in each of the three sectors.

The project brought together the local university, industry, and government to create benefits to the region's economy and employment. The government invested in the project, helping to underwrite not only the facility, which a number of microelectronics companies share, but also all of the infrastructure needed to support future research for that industry in the region.

Before long this initiative attracted every major player in the industry to locate a research team at the facility in Albany. The expected—and achieved—results from the project are shown in Figure 6. Thousands of high-skilled jobs were created and people who had been doing research alone started working together. It was a solid success that required the collaboration of industry, university, and government.

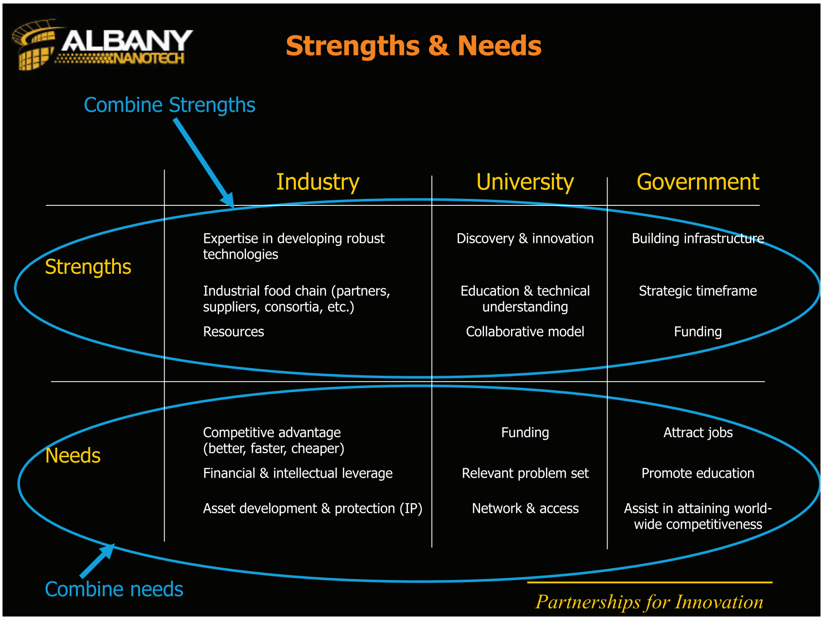

FIGURE 5 Strengths and Needs of a Cross-Sectoral Collaboration: Albany Nanotech

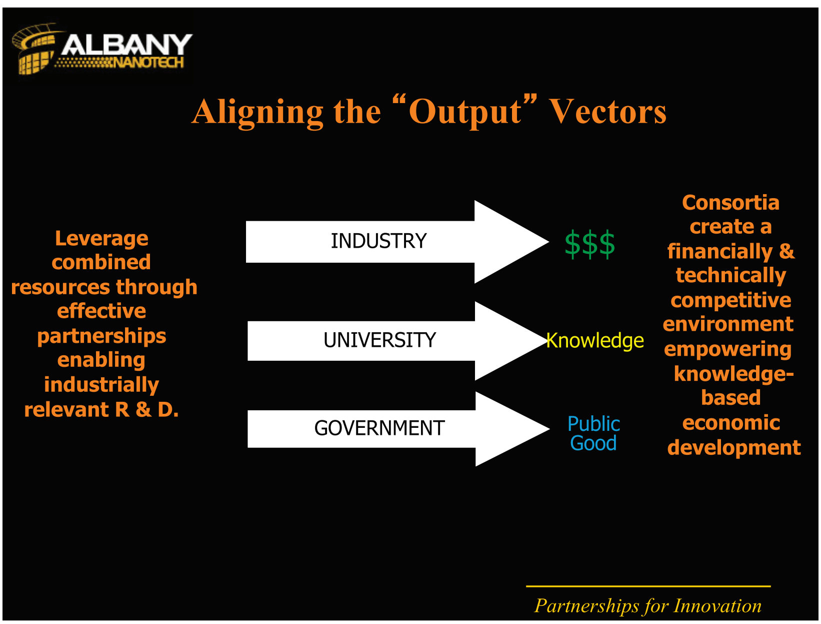

FIGURE 6 Aligning the "Output" Vectors

CLOSING REMARKS

Today's cities face a range of challenges and threats to their sustainability. Modernized capabilities, supportive policies, and cross-sector collaboration are the fundamental ingredients that build and enable economically viable smarter cities, enabling both residents and local industry to benefit from a great place to live, work, and run a business in a city that is adaptive, collaborative, efficient, secure, supportive, and sustainable.

Prospects for Critical Infrastructure

Thomas D. O'Rourke
Cornell University

ABSTRACT

Critical infrastructure needs have changed significantly both in the wake of disasters such as the terrorist attacks of 9/11 and Hurricane Katrina and as a result of emerging technologies. It is important to understand critical infrastructure's interdependencies, high-tech opportunities, and the need for long-term investments. Other key aspects are interoperability, real-time monitoring, intelligent networks, and effective modeling and simulation. Underlying all of these is the necessity of communication and education among the various stakeholders—utilities, federal and local governments, businesses, communities, and, of course, engineers!

INTRODUCTION

The concept of critical infrastructure is evolving. In the 1980s, the National Council on Public Works Improvement (1988) concentrated on public sector infrastructure, such as highways, roads, bridges, airports, public transit, water and wastewater facilities, and municipal/hazardous waste services. In the 1990s, the core concept of infrastructure was redefined in terms of national security. After 9/11, the number of "critical" infrastructure sectors and key assets listed in the National Infrastructure Protection Plan[1] was expanded

[1] The Department of Homeland Security's 2009 National Infrastructure Protection Plan is available at www.dhs.gov/xlibrary/assets/NIPP_Plan.pdf.

and now includes 16 sectors: chemical; commercial facilities; communications; critical manufacturing; dams (including locks and levees); defense industrial base; emergency services; energy; financial services; food and agriculture; government facilities; health care and public health; information technology; nuclear reactors, materials, and waste; transportation systems; and water and wastewater systems (Federal Register 2013).

The national protection plan defines a broad spectrum of assets in need of security, which is complex and unwieldy with respect to unifying concepts and modeling for engineering purposes. In contrast, the concept of a "lifeline," developed by the Technical Council on Lifeline Earthquake Engineering to evaluate the performance of large, geographically distributed networks during earthquakes (O'Rourke 2007), involves a smaller number of critical systems—electric power, gas and liquid fuels, telecommunications, transportation, waste disposal, and water supply. If flood and hurricane protection systems are added, one can identify a subset of seven geographically distributed networks that are intimately linked with the economic well-being, security, and social fabric of the communities they serve. Thinking about critical infrastructure through this subset of lifelines helps clarify common features and provides an effective framework for understanding interdependencies among the different systems.

Hurricane Katrina in 2005 challenged the 9/11 paradigm of protection of critical infrastructure. The hurricane protection system (HPS) of New Orleans was authorized by the US Congress under the 1965 Flood Control Act, and its design and construction were supervised by the US Army Corps of Engineers. But when Hurricane Katrina struck, the HPS was incomplete and no parish had the full level of protection authorized in 1965. As the Interagency Performance Evaluation Task Force concluded, the HPS "did not perform as a system"; it had been constructed in a piecemeal fashion over many years that represented a history of "continuous incompleteness" (IPET 2008).

A new paradigm emerged after Hurricane Katrina, centered on the concept of resilience, and much has been written and discussed about this concept. In current parlance, the resilience of an organization or community is an overarching attribute that reflects its degree of preparedness and ability to respond to and recover from shocks. The term has become the scaffolding on which to build a community or organization that is well prepared and responsive to a wide range of demands, including natural hazards and human threats. Current US policy for critical infrastructure is an amalgam of concepts and activities based on the development of community resilience and the protection of critical infrastructure.

CRITICAL INFRASTRUCTURE IN THE 21ST CENTURY

Critical infrastructure is shaped and characterized by three specific features. First, much of it, especially in cities, is located underground, where it is removed from direct observation unless uncovered, and its state of repair and proximity to other structures is often unknown. Urban congestion increases risk due to the close proximity of many pipelines, cables, and supporting facilities. Damage to one facility, such as a cast iron water main, can cascade rapidly into damage in surrounding facilities, such as electric and telecommunication cables and gas mains, with systemwide consequences.

Interoperability is another key feature of modern infrastructure. Electric power, natural gas, water, oil, telecommunications, and transportation are all interdependent, as illustrated in Figure 1. Electric power is essential for the reliable operation of virtually all other infrastructure systems. During extreme events electric power is, in effect, the gateway for local damage to escalate or cascade into other systems. Telecommunications are used for surveillance and control of virtually all lifeline networks, and will become increasingly important as information technologies are improved for

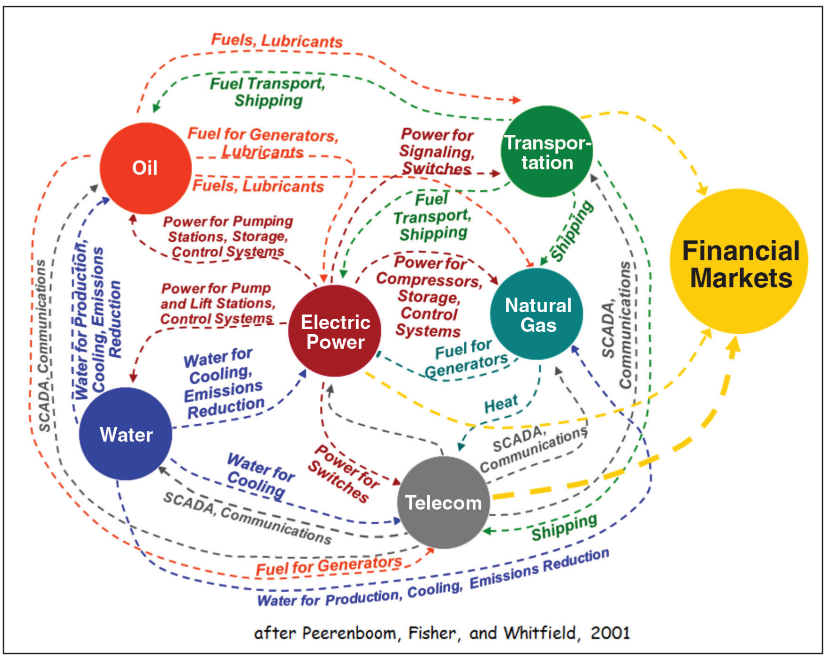

FIGURE 1 Infrastructure Interoperability (after Peerenboom, Fisher, and Whitfield 2001). SCADA = supervisory control and data acquisition.

network monitoring and operations. Transportation is necessary for moving people and resources and, after extreme events, crucial for emergency response and recovery. Many communities have come to recognize that critical infrastructure also supports economic well-being and therefore must be part of policy and planning for business continuity.

The third key feature is institutional fragmentation. Much infrastructure is not only institutionally balkanized—independent organizations are responsible for electric power, telecommunications, water supplies, transportation, waste conveyance and treatment, and gas and liquid fuel delivery—but also divided between public and private ownership. This compartmentalization makes it all but impossible to develop a unified approach.

Proper management of infrastructure requires an understanding of the different institutional and corporate cultures that are the basis for working relationships, competition, employee incentives, and levels of service.

Modern Tools and Needs

Critical infrastructure in the 21st century will involve radical improvements in real-time monitoring, intelligent networks, remote sensing capacities, and complex system modeling and simulation.

One example of emerging technology for intelligent infrastructure involves fiber optics technology. Brillouin optical time domain reflectometry (BOTDR; Figure 2) for infrastructure monitoring has been applied successfully to monitor construction effects on tunnels, pipelines, and buildings (Klar and Linker 2010; Mair 2008). The BOTDR technology involves the precise measurement of phase shifts in light frequency (a single optical fiber 30 km long can resolve strains to 10 microstrain). BOTDR can monitor changes in temperature and pressure over very large distances, and is thus akin to a "smart" skin for geographically distributed infrastructure such as highways, bridges, pipelines, and tunnels.

System performance is important for at least three main reasons (O'Rourke 2010). First, it provides the basis for planning and engineering at a scale commensurate with large, geographically distributed effects. Second, it is the logical extension of integrated component behavior, and for a network represents the ultimate expression of performance in terms of diverse environmental effects. Third, it provides the only way by which managers and engineers can gauge the scale and regional impact of network behavior. System performance sets the stage for quantifying the regional economic

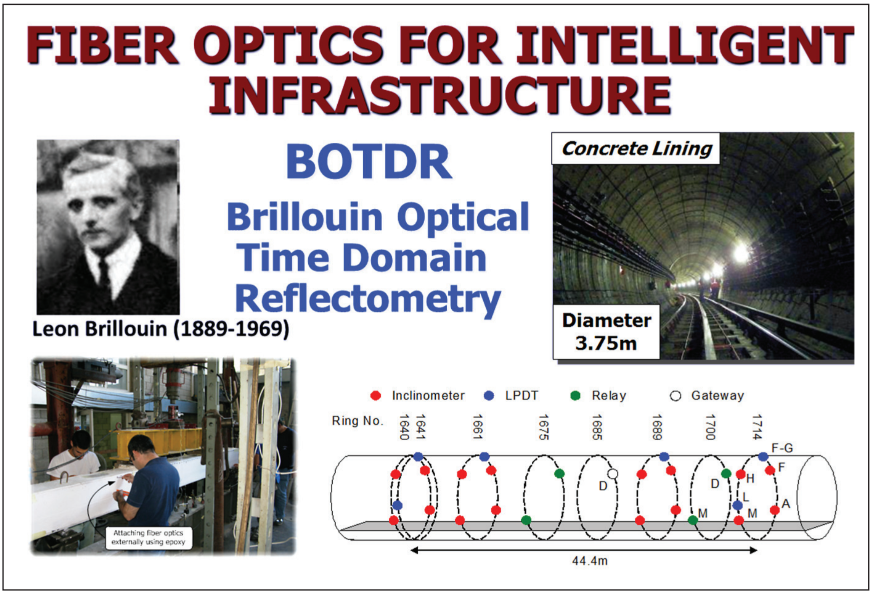

FIGURE 2 Fiber Optics for Intelligent Infrastructure (after Klar 2012)

consequences and community impact of an earthquake as well as planning for emergency response and system restoration.

The current generation of hydraulic network models for large, geographically distributed water supplies has evolved sufficiently that engineers and managers can use them to plan and design for complex performance under the highly variable and uncertain conditions associated with geohazards. For example, the Los Angeles Department of Water and Power has developed a decision support system based on an accurate simulation of its 12,000 km of pipelines and related facilities (O'Rourke 2010). The system comprehensively accounts for seismic and geohazards as well as the interactions among water, electric, social, and economic impacts to produce a multimodal simulation of earthquake effects, ground failures, accidents, and human threats (Figure 3).

Simulations for different scenarios allow system personnel to visualize a wide range of responses for an entire system or a specific part of that system. By running multiple scenarios, with and without modifications of the system, engineers and managers can identify recurrent patterns of response and develop an overview of potential performance, helping them plan for many eventualities and improving their ability to improvise and innovate during an extreme event.

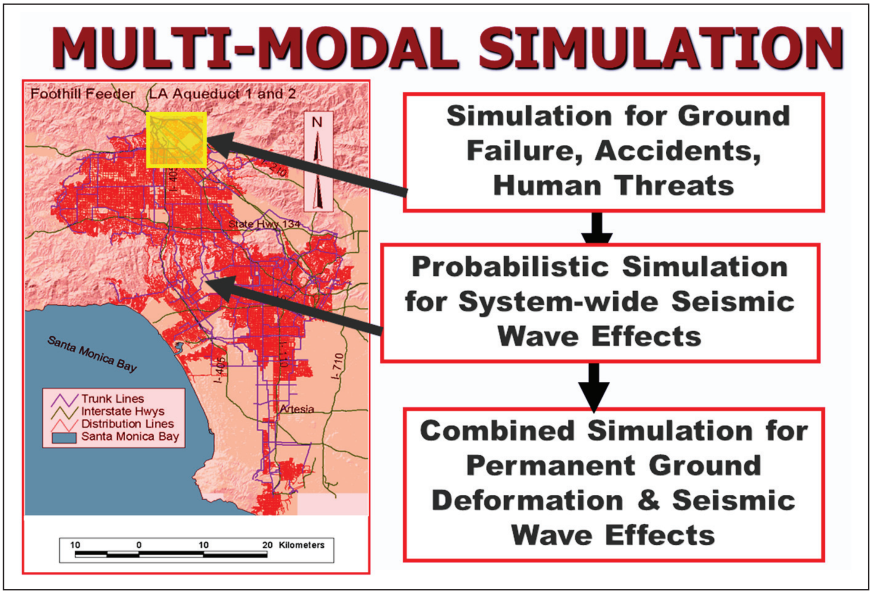

FIGURE 3 Diagram of Los Angeles Department of Water and Power Multimodal Simulation

The plan that emerges from any particular suite of scenarios, however, is not as important as the planning process itself, because as a disaster unfolds, the reality of the event will diverge from the features of the most meticulously designed scenario. With good planning, however, emergency managers and lifeline operators can improvise, and skilled improvisation enables emergency responders to adapt to field conditions.

Investment and Financing

Sustaining critical infrastructure requires adequate financial resources and a long-term commitment to finishing complex projects. Consider, for example, the New York City water supply, which is delivered by City Water Tunnel 1 (commissioned in 1917) and City Water Tunnel 2 (commissioned in 1935). The state of repair of both tunnels can only be inferred from indirect evidence because neither can be dewatered for inspection.

A third water tunnel is crucially important so that each of the first two tunnels can be taken out of service, inspected, and repaired. The construction of City Water Tunnel 3 began in 1970 and is scheduled to open in 2013. The new tunnel will require nearly 100 kilometers of tunneling over a period of five decades at an estimated total cost of more than $6 billion. This project is indicative of the size, financial requirements, and time frame associated with many critical infrastructure projects.

The problems of aging US infrastructure are so severe that the traditional sources of public funding—taxes, bond issues, and tolls—are no longer adequate to meet national and regional needs. Sufficient liquidity is lacking in conventional public works financing to address rehabilitation and new construction. It is therefore crucial to attract private equity by developing alternative financing mechanisms, such as public-private partnerships and infrastructure banks, to expand and reinforce conventional fundraising mechanisms for infrastructure projects.

Information and Information Technology

From an engineering and scientific viewpoint, there has never been a more opportune time for advancing the state of the art and practice for characterizing and modeling complex infrastructure systems. Advanced geographical information systems, remote sensing, condition monitoring, model-based simulation, and systems engineering coupled with the capability of producing precise digital base maps, which can integrate the spatial characteristics of infrastructure, provide unparalleled opportunities.

To benefit from the enormous power of information technology, however, it is necessary to have access to information. Since 9/11 severe restrictions have been imposed on access to information about critical US infrastructure. Although these restrictions are based on legitimate concerns about security, they may become serious barriers to innovation unless we have suitable procedures for information accessibility and dissemination. It is extremely important to develop a consistent policy regarding the need to know vs. the need to secure information and databases about critical infrastructure.

Involvement of Engineers

Solutions to infrastructure require engineering input that is often absent or underrepresented when experts are convened to develop strategic plans and policies for urban centers. A survey of recent conferences provides some interesting statistics. At a 2011 conference in New York City sponsored by the *Economist*, entitled “Intelligent Infrastructure,” less than 10 percent of the invited speakers were engineers. At a conference sponsored by Chatham House, entitled "The Future of Cities 2011," there were no engineers among the 28 speakers. The meetings convened by the Rockefeller Center to produce the influential publication *Century of the City* involved only three engineers among approximately 300 participants.

Solutions for infrastructure are often advanced independently by planners and engineers. Conferences about cities and infrastructure convened by engineers generally do not include planners or significant representation of applied social scientists. Similarly, engineers are frequently underrepresented at conferences of planners and urban policymakers.

Clearly, more interdisciplinary dialogue is needed. The problems of critical infrastructure are suffused by social and technical issues that require close collaboration between engineers and applied social scientists.

CONCLUDING REMARKS

US policy and practice for critical infrastructure have been shaped by 9/11 and Hurricane Katrina to protect critical facilities and support resilient communities. The emphasis on resilience has been growing, and in the wake of Superstorm Sandy has concentrated on coastal communities and the consequences of global climate change. It is likely that the concept of community resilience will evolve over time, similar to the way our awareness and policy formulations have changed with respect to critical infrastructure.

We are challenged to redefine infrastructure in terms of resilience, focusing on engineering and social science collaboration. The most promising prospects for improved infrastructure include understanding and managing interdependencies, reducing the constraints of institutional fragmentation, harnessing sensor and monitoring technologies to create "smart" systems, modeling complex networks, developing long-term financing mechanisms that attract private equity, and leveraging the power of information technology with improvements in access to and use of information about critical infrastructure.

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Impacts of Evolving Wireless Communications

Theodore S. Rappaport
Polytechnic Institute of NYU

ABSTRACT

This paper reviews the key technological drivers for the future of wireless communications and what wireless will bring to cities of the future. Trends and challenges in licensed, unlicensed, and public safety technologies are discussed, as are applications and explorations at a new research center at NYU-Poly called NYU WIRELESS.

INTRODUCTION

Wireless communication services may be viewed in three ways. First is cellular, which uses licensed spectrum bands for which companies pay billions of dollars. Cellular spectrum is owned and controlled by federal governments and tightly regulated to ensure a lack of interference from unauthorized users; cellular carriers invest billions of dollars in infrastructure to make the service work in "protected" bands while collecting revenues from a large subscriber base. Second, there is the unlicensed spectrum, which is used for Wi-Fi and Bluetooth and provides short-range free access (e.g., in public places such as hotels and Starbucks). Third is public safety and government wireless communications, a big part of the telecommunication services used by cities for government activities and public safety (e.g., mass transit, fire departments, police). Although these public service organizations must use public safety radio frequencies, this kind of spectrum is in short supply and often does not receive the benefit of the technology upgrades that occur in the cellular and Wi-Fi world (where markets are much bigger and prices much lower due to market scale).

CELLULAR SYSTEMS

There is a global push to rapidly deploy fourth-generation (4G) cellular systems, including long-term evolution (LTE) technology, which has been in development for about ten years. This technology exploits advances in wireless communications and provides a completely new over-the-air interface for new cellular infrastructure equipment (e.g., base stations and access points) as well as for Internet-ready phones that can handle the massive data transmission rates now available through the fixed telecommunication infrastructure.

The first 4G LTE products came out in the United States in 2010, and to bring these new capabilities to customers cellphone carriers like AT&T and Verizon are spending billions of dollars modernizing the cabinets, antennas, and equipment at hundreds of thousands of base stations around the country, while they simultaneously introduce to customers new 4G LTE smartphones made by numerous vendors.

LTE supports data rates of several tens of megabits per second (Mbps) to cellphone subscribers, and this will scale to over 100 Mbps with LTE Release 12. Older models of cellphones, such as the iPhone 3 and phones that are not "smart," default to pre-LTE technologies, clogging up the cellular network and hampering the speed of 4G, which is built for data efficiency and not the old voice-centric networking.

The analog world is transitioning to the packet data world of the Internet, so carriers are trying to bring older phones off the network and replace them with newer packet-ready 4G phones that support more data-centric applications. Such advances are happening around the world, and the United States and Japan are leading Europe by a few years.

While 4G LTE cellular technologies promise unprecedented cell phone data rates, the expected data demands for consumers are increasing at a much greater rate than the development cycle of technological standards. As discussed further in this article, there is an enormous opportunity for the wireless industry to leapfrog existing capacity limitations by using much greater radio spectrum allocations than have previously been available. Global cellular systems of today operate in the 1 to 2 Gigahertz (GHz) bands (shown on the far left side of Figure 1 by the white bubble in the lower left)

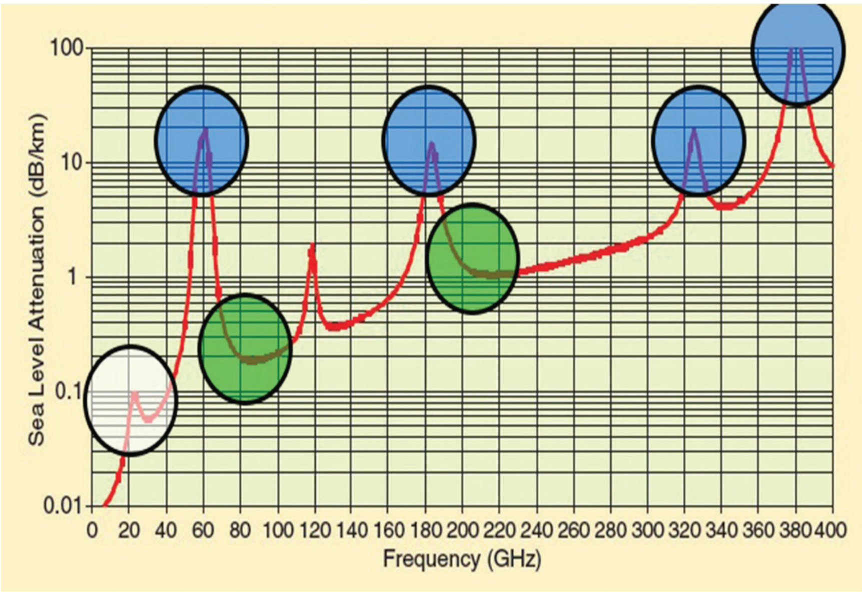

FIGURE 1 Radio Spectrum and Oxygen Attenuation (Above Free-Space Propagation Path Loss) for 1 km Coverage Distance (Reprinted from Rappaport et al. 2013)

and the industry has, until recently, incorrectly believed that higher frequencies would not be viable for mobile communications because of both rain attenuation and atmospheric absorption. However, recent research has shown that there are great opportunities at microwave and millimeter wave frequencies, in the spectrum bands from 3 to 300 GHz, that will expand—by orders of magnitude—the amount of radio spectrum available for wireless communications services, thus expanding the data rates available to users. Figure 1 shows that the millimeter wave spectrum is viable for both outdoor mobile radio (where attenuation due to atmosphere is only about 1 decibel (dB) per km, as shown by the two bubbles at 80–100 and 200–220 GHz), and very short distance local area or personal area networks (with attenuation over 20 dB per km, as shown in the four bubbles along the top of the figure).

UNLICENSED (WI-FI) SPECTRUM

Some very exciting things are happening in Wi-Fi. A relatively recent technology standard for wireless local area network (WLAN), called IEEE

802.11n, allows manufacturers to build multiple-input multiple-output (MIMO) antenna systems (Rappaport et al. 2011; Khan and Pi 2011). The IEEE 802.11n standard is raising the data rates of Wi-Fi connections from 54 Mbps to 500 Mbps. To put this data rate in perspective, a super high resolution movie (say from Netflix) takes about ten gigabytes of data to download (although it could be as small as a few hundred megabytes of data on a smaller, low-resolution screen). Downloading a movie can take several tens or even hundreds of minutes on a very slow Internet connection, or a minute or so on a faster connection, but with Wi-Fi for data rates of 500 Mbps, movies and other huge data files can be downloaded in seconds.

Today there are even more breakthrough technologies that combine MIMO and much higher frequency bands. Technology standards known as IEEE 802.11ac and IEEE 802.11ad, and new industrial consortia and standards called Wi-Gig and wireless HD, are bringing data rates to many gigabits per second (Gbps). These technologies have been developed to operate at an order of magnitude higher frequencies than today's cellular and Wi-Fi networks—about ten times higher than today's 2.4 and 5.2 GHz Wi-Fi networks.

The new spectrum where Wi-Fi is taking hold is at 60 GHz, where radio wavelengths are about the size of a human fingernail and antennas can be tiny, allowing the use of phased arrays and very directional, steerable antennas. Consider the fact that global cellular and Wi-Fi systems now operate at frequency bands of about 1 to 5 GHz, around the frequency range of a microwave oven. Wi-Gig and wireless high definition (HD) operate at a carrier frequency about ten times higher, with a 60 GHz carrier frequency, the millimeter wave frequency band. The commensurate bandwidth that can be carried over a "narrowband" signal increases by a factor of ten as well, meaning that amazing amounts of raw data can be carried by wireless devices as the carrier frequency is increased. Figure 2 illustrates the vast amount of spectrum that carriers and manufacturers are beginning to consider for both unlicensed Wi-Fi and cellular (Khan and Pi 2011; Rappaport 2012). A UC Berkeley spinoff company, SiBeam, helped pioneer 60 GHz broadband wireless devices and was sold in 2011 to Silicon Image, a publicly traded company that makes chips, including wireless HD.

The first applications of this 60 GHz multi-Gbps data connectivity are for gamers, so that they can have mobility with their keyboard in the living room connected to the monitor, and for in-home entertainment buffs who wish to mount flat screen displays without visible connections from the set-top box to the display screen.

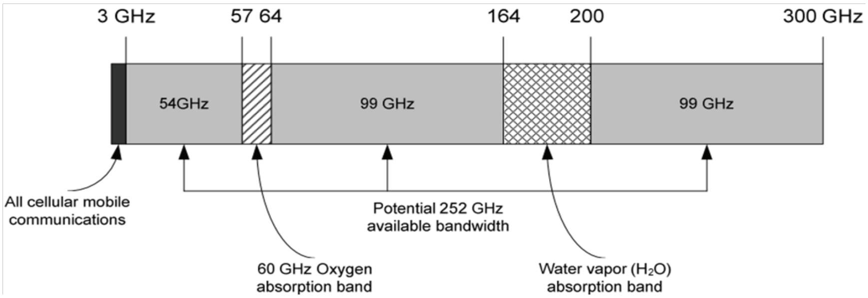

FIGURE 2 Wireless carriers are beginning to realize that semiconductor capabilities can unleash amazing new capabilities at frequencies much higher than current cellular or Wi-Fi bands. Reprinted with permission from Khan and Pi (2011).

Wireless HD is already replacing HDMI cables, and there are other applications, but soon it is going to be available for all Wi-Fi, so everyone will be able to have data rates as great as the fastest wired connection today, deployed wirelessly at very low cost. That is the reality of where wireless is going, in the home and in institutions, government, and industry.

PUBLIC SAFETY RADIO FREQUENCIES

The FCC and the federal government have agreed for the first time to allow a radio spectrum band to be used for all public safety services, enabling first responders to communicate without interference from others in emergency situations.

But there is a huge business problem. No one is sure how the infrastructure is going to be financed and who will pay for the "rebanding" needed to move incumbents off the spectrum. Are states, cities, taxpayers, or the federal government going to pay for the new gear needed to bring together all the systems of various public safety offices? There is debate both in Congress and at the state level, and it will probably take a couple of years to figure out how or whether this type of "unified" public safety network is viable.

For now, the spectrum is allocated and the plan is that fire, police, and other first responders will use a variant of the 4G cellular standard and move some or all of their radio equipment and operations to a new standard with the new public safety spectrum. This is a problem for cities like New York, where some first responders, such as the fire department, know that for many in-building emergency applications, analog FM radio works best—the older

FM technology ensures radio coverage through the large granite walls of skyscrapers.

First responders must have radio service that is very reliable, so there is some concern in cities about a federal mandate for shared spectrum while forcing new digital technology. Any modernization of communication technology for public safety must work flawlessly. Lives are at risk and uninterrupted communication must be guaranteed. This is just a simple, single example of some of the problems for public safety that are on the horizon.

NYU WIRELESS AND FURTHER APPLICATIONS

NYU-Poly has played a role in creating the knowledge and human capital needed to engineer the exciting future of wireless, and continues to play a role in this future. At NYU WIRELESS amazing things are being explored, including applications of wireless to medicine and computing. In summer 2012, students made measurements of radio propagation of future millimeter wave cellular coverage throughout Manhattan and Brooklyn for the first time. In 2011 we conducted similar measurements in Austin, Texas (Rappaport et al. 2011).

The idea is to use the higher millimeter wave frequencies for cellular networks. It should be noted that very few in the industry have been thinking about this. Cellular systems of the future will become truly ultrawideband as the millimeter wave spectrum is considered for future wireless access. The myth in the industry is that if you go up higher in frequency, radio signals will not bounce off building walls or you will not be able to make electrically steerable antennas that can exploit the propagation characteristics at low enough cost. But at NYU WIRELESS we have shown through our measured propagation data that cellular can function effectively at these higher millimeter wave frequencies (close to the spectrum bands used by WiGig and wireless HD). This means that as the technology and engineering expertise becomes mature in the Wi-Fi unlicensed world, it is going to gravitate toward creating new technologies for the cellular world, and in five to ten years cell phones will have a multi-Gbps data rate.

New York subways do not have wireless infrastructure, so it is not possible to place or receive a call in the subway. But with propagation modeling and relatively simple software, we are now able to predict where radio coverage will be and where to put a priority for the location of a base station, and any relay, to provide the coverage needed in urban environments.

There is a peace dividend from the big data movement, the semiconductor movement, the geographic information systems (GIS) movement, and it is coming to the wireless community. With it, wireless will enable us to deploy computing and communication networks much more reliably and much more power efficiently than today.

Finally, on the topic of interoperability, especially for public safety users and future Wi-Fi and cellular users, there is an exciting field called *cognitive radio*, which calls for smart signal processing and being able to make radios work adaptively. Future phones and other devices will be complex and must "think" for themselves. Clearinghouse databases will allow the radio spectrum to be monitored and reported to and between different smartphones and wireless carriers, allowing dynamic spectrum access (e.g., open spectrum usage). Smartphones will actually be able to break up and handle information with the priority needed and will be much better able to handle multiple users. The cost benefit of wireless devices and the improved ability to understand and predict their coverage and their performance, together with new antenna technologies, will result in much better wireless networks when combined with the semiconductor improvements that are coming from the chip industry.

These advances will enable much higher frequencies with the much greater commensurate bandwidths and lower power points. There will be unprecedented abilities for wireless to replace things such as, for example, a laptop hard drive with a wireless radio frequency identification (RFID) card; at any computer the card could make a wireless connection at a multi-Gbps data rate. The RFID card would actually be the personal hard drive and could be carried in a wallet or pocket, thereby reducing the weight of the laptop.

CLOSING REMARKS

This is the future that wireless will bring. Wireless not only will be useful for saving cost, weight, and power while enabling flexibility in all we do, it also will empower completely new sensing and monitoring capabilities. There are so many applications, the future of wireless in cities is quite remarkable. And the "laboratory" of New York City is a rich and wonderful location to experiment and test the capabilities and possibilities of this exciting future. New York City is where cellular telephony was first tested and launched, with the first base station on the Empire State building, and now there is a chance to bring wireless to its renaissance, with the fifth generation of cellular, also in New York.

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Appendix

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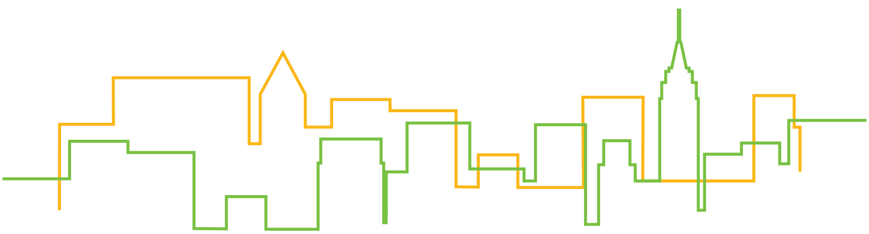

LIVABLE CITIES OF THE FUTURE

A SYMPOSIUM HONORING THE LEGACY OF GEORGE BUGLIARELLO

Friday
October 26, 2012
8 a.m. to 5 p.m.
Pfizer Auditorium
Bern Dibner Library
of Science and Technology
Polytechnic Institute of
New York University
Brooklyn, New York

I got to know and admire Dr. Bugliarello as a member of the board for many years when he headed Brooklyn Poly.

When I wanted to establish a program to support graduate study for new Americans, Dr. Bugliarello was the first person I asked for advice. This evolved into a fellowship program that selects 30 students every year for grants of $90,000. Dr. Bugliarello had been a member of the fellowship board since its inception in 1997. His wisdom and compassion were greatly appreciated.

Dr. Bugliarello was a great educator and wonderful friend.

—PAUL **SOROS**
HONORARY SYMPOSIUM CHAIR

Join in this global metropolitan forum honoring the legacy of George Bugliarello organized by the NYU-Poly Department of Civil and Urban Engineering.

The symposium, *Livable Cities of the Future*, brings together an interdisciplinary group of engineers, civic leaders, and educators in a unique forum that will offer an open discussion of how George Bugliarello's vision manifests itself in innovative urban planning for the cities of tomorrow. Discussions will examine the critical role engineers play in the social and economic development of cities and their ever-increasing importance in the area of policymaking.

THE SYMPOSIUM IS **INTENDED TO**

- cultivate ideas for best practices and innovative strategies for sustainable urban development
- facilitate the evolution of New York City into a real-life laboratory for urban innovation

THE SYMPOSIUM WILL **SPECIFICALLY ADDRESS**

- experiences of private and public service operators, infrastructure agencies, elected officials, the academic community, and other stakeholders in the critical urban sectors
- sectors critical to resilient and sustainable cities including energy, water, infrastructure, transportation, telecommunications, and environment

SYMPOSIUM **PROGRAM**

FRIDAY, OCTOBER 26, 2012

8:00-8:45 a.m. **Registration/Continental Breakfast**

Part I. Opening Session

Moderator: **Mohammad Karamouz**
Symposium Co-Chair
Director
NYU-Poly Environmental Engineering and Science Programs

8:45 a.m. *Welcome Remarks*
Jerry M. Hultin
NYU-Poly President
Symposium Chair

Symposium Objectives/Overview
Mohammad Karamouz
Symposium Co-Chair

9:05 a.m. *Keynote Speech*
Honorable Robert K. Steel
New York City Deputy Mayor for Economic Development
Economic Development Strategy and the Role of Technology and Innovation in Crafting the Economy of New York City's Future

9:25 a.m. *Legacy of George Bugliarello*

Ruth David
President & CEO
Analytic Services, Inc.
on behalf of the National Academy of Engineering
George Bugliarello: Reflections on His Global Impact on the National Academy of Engineering

Richard S. Thorsen
NYU-Poly Vice President Emeritus
George Bugliarello: Leadership of the Polytechnic and His Vision of the Future

10:00 a.m. Coffee Break

Part II. Fundamental Needs and Emerging Challenges in Large Cities

Infrastructure Renewal: Water, Energy & Transportation

Moderator: *Ilan Juran*
Executive Director
NYU-Poly Urban Infrastructure Institute and Urban Utilty Center

10:20 a.m. **Patrick J. Foye**
Executive Director
Port Authority of New York and New Jersey
Transportation and its Critical Role in Economic Development

10:40 a.m. **Andrew W. Herrmann**
President
American Society of Civil Engineers
Resources for Rebuilding the National Infrastructure: Water, Energy and Transportation

11:00 a.m. **Craig S. Ivey**
President
Consolidated Edison Company of New York
Energy as the Core of New York City

11:20 a.m. **Daniel (Pete) Loucks**
Professor of Civil & Environmental Engineering
Cornell University
Water as a Fundamental Need for Urban Renewal

11:40 a.m Q&A Session

12:00 p.m. **Forest City Ratner Companies Working Lunch**
Luncheon Speaker: **Honorable David Miller**
Former Mayor of Toronto
Former Chair of the C40 Climate Leadership Group
NYU-Poly Future of Cities Global Fellow
Cities Act: Leadership Through Sustainability Creates Action on Infrastructure, I.T., and the Environment

(continued on following page)

SYMPOSIUM **PROGRAM**

FRIDAY, OCTOBER 26, 2012

Sustainability, Information Technology & Environment
Moderator: **John C. Falcocchio**
Director
NYU-Poly Urban Intelligent Transportation Systems Center

1:00 p.m.	**Joan McDonald** Commissioner New York State Department of Transportation *Sustainable Transportation Resources: Mobility and Infrastructure Resiliency*
1:20 p.m.	**Ruthie D. Lyle** IBM SmartCloud for Social Business *Breakthroughs in Information Technology for Smart Cities*
1:40 p.m.	**Upmanu Lall** Director, Columbia Water Center Earth Institute Columbia University *Climate, Water and Sustainable Cities*
2:00 p.m.	**Carter H. Strickland, Jr.** Commissioner New York City Department of Environmental Protection *Vision of PlaNYC 2030 for Environmental Sustainability*
2:20 p.m	Q&A Session
2:40 p.m	Break

Part III. Challenges – The Way Forward

Panel Discussion
Moderator: **Paul M. Horn**
New York University Distinguished Scientist in Residence
and Senior Vice Provost for Research

2:55 p.m. **Steven E. Koonin**
Director
Center for Urban Science and Progress (CUSP)

Gerard M. Mooney
Vice President
IBM Global Smarter Cities

Thomas D. O'Rourke
Thomas R. Briggs Professor of Engineering,
Cornell University

Theodore (Ted) S. Rappaport
NYU-Poly David Lee/Ernst Weber Professor of Electrical Engineering

Q&A Session

4:45 p.m. **Closing Remarks**
Katepalli R. Sreenivasan
NYU-Poly Provost
Senior Vice Provost for Science and Technology, NYU

GEORGE **BUGLIARELLO**

1927-2011

George Bugliarello's range of interests and expertise transcended many disciplines, including civil engineering, bio-medical engineering, urban development, science policy, water resources and environmental science. His vision of the role of science, innovation and education, coupled with a passion for turning his vision into reality, is reflected in today's urban communities, forged through academic and industry interactions in ways that spur economic growth and societal well-being, while respecting the quality of human life and the environment.

THE BIOSOMA **PARADIGM**

In emphasizing the urgent need for a clear strategy for urban sustainability, Dr. Bugliarello recommended a new paradigm based on the biosoma—the indissoluble interaction of biology, society and machines, along with the complementary system of systems paradigm. The biosoma-environmental paradigm views the city as a complex, adaptive system where the three biosoma entities interact with the environment. Synergies and trade-offs among these entities and their interaction with sub-components such as materials, energy, information and systems, are at the heart of addressing issues of urban sustainability.

A **BIOGRAPHY**

George Bugliarello, President Emeritus (having served as president from 1973 to 1994), Institute Professor and former Chancellor (1994 - 2003) of Polytechnic Institute of NYU (formerly Polytechnic University), was an engineer and educator with a broad background ranging from fluid mechanics to computer languages, the environment, biomedical engineering and science policy. He held a Doctor of Science degree in engineering from the Massachusetts Institute of Technology, and was awarded honorary degrees from Carnegie Mellon University, the University of Trieste, the Milwaukee School of Engineering, the Illinois Institute of Technology, Pace University, Trinity College, Rensselaer Polytechnic Institute, and the University of Minnesota.

At the time of his death, Dr. Bugliarello was serving his second four-year term as Foreign Secretary of the National Academy of Engineering, of which he had been a member since 1987. He was a lifetime National Associate of The National Academies and served as Chair of the National Academy of Engineering Council's International Affairs Committee.

During his long and fruitful career, he served as Chairman of the Board of Science and Technology for International Development

(BOSTID) of the National Academy of Sciences and as chairman of the National Medal of Technology Nomination Evaluation Committee. He chaired the Advisory Panel for Technology Transfer to the Middle East of the Office of Technology Assessment, and also the Committee on Science, Engineering and Public Policy (COSEPP) of the American Association for the Advancement of Science. He served as chair of the Board on Infrastructure and the Constructed Environment of the National Research Council, and of the National Academies Megacities project for the Habitat II conference. He also served as chair of the National Academies steering committee on the Megacities. Other committee service included the U.S. National Academies-Russian Academy of Sciences Committee on Terrorism Confronting the U.S. and Russia and co-chairmanship of a joint Russian-American Task Force on Urban Security.

Dr. Bugliarello's international experience included consultantships abroad for OECD as reviewer of the science policy of several countries, and for UNESCO, assignments as specialist for the U.S. Department of State in Central Africa, the holding of a NATO Senior Faculty Fellowship at the Technical University of Berlin, membership on the U.S.-Egypt Joint Consultative Committee of the National Academy of Sciences, and membership on the Scientific Committee of the Summer School on Environmental Dynamics in Venice. He had been the U.S. member of the Science for Stability Steering Committee, and of the Science for Peace Steering Committee, of the Scientific Affairs Division of NATO.
He was co-founder and co-editor of *Technology in Society*, An International Journal; Interim Editor-in-Chief of *The Bridge* (the quarterly publication of the National Academy of Engineering), served on several editorial advisory boards, authored over three hundred professional papers, and was the author, co-author or editor of numerous books.

He was a member of the Council on Foreign Relations and a Fellow of the American Society of Civil Engineers, the American Society of Engineering Education, the American Association for the Advancement of Science, the New York Academy of Sciences, and the Biomedical Engineering Society, and a Founding Fellow of the American Institute for Medical and Biological Engineering.

'...[Answers to overarching questions about urban ustainability]...depend on the development of new bio-socio-echnological-environmental paradigms, and of a correspondingly roader conception of engineering and of the interdisciplinarity f knowledge." — GEORGE BUGLIARELLO

LIVABLE CITIES OF THE FUTURE

A SYMPOSIUM HONORING THE LEGACY OF GEORGE BUGLIARELLO

SYMPOSIUM **GUEST SPEAKERS**

RUTH **DAVID**

Dr. Ruth David is President and CEO of Analytic Services Inc., a nonprofit corporation that provides security related studies and analyses to the U.S. government.

Before assuming her current position, Dr. David was Deputy Director for Science and Technology at the Central Intelligence Agency. There she led research, development, and deployment of technologies in support of the intelligence process. Prior to joining the CIA, she served in several leadership positions at Sandia National Laboratories.

Dr. David is a member of the National Academy of Engineering (NAE); she serves on the NAE Council and chairs the National Research Council (NRC) Board on Global Science and Technology. She is a member of the Homeland Security Advisory Council, the Defense Science Board, the Hertz Foundation Board, and advisory boards for Wichita State University and Stevens Institute of Technology.

PATRICK J. **FOYE**

Patrick J. Foye became Executive Director of the Port Authority of New York and New Jersey on November 1, 2011.

Prior to joining the Port Authority, he served as Deputy Secretary for Economic Development for Governor Andrew M. Cuomo. Mr. Foye was a mergers and acquisitions partner at Skadden Arps and managing partner of the firm's Brussels, Budapest and Moscow offices. He was Executive Vice President of AIMCO, a real estate investment trust and a component of the S&P 500, and served as President and CEO of the United Way of Long Island.

ANDREW W. **HERRMANN**

Andrew W. Herrmann P.E., SECB, F.ASCE, principal with Hardesty & Hanover, LLP, serves as President of the American Society of Civil Engineers (ASCE).

During his 38 years at Hardesty & Hanover, LLP, he has held many positions including Structural Detailer, Structural Engineer, Project Engineer, and Associate Engineer before becoming Managing Partner and then a principal. His experience includes design, inspection, rehabilitation, and construction along with managing some of the firm's major fixed and movable bridge projects.

Within ASCE, Mr. Herrmann has served as President of the New York City Metropolitan Section, Chair of the Technical Administrative Committee on Bridges, Director of Region 1, and national Treasurer. He served on the Advisory Council for the 2003 and 2005 Report Cards for America's Infrastructure and chaired the council for the 2009 Report Card. Mr. Herrmann has served as a spokesperson for ASCE in many magazine, newspaper, radio, and television articles and stories. He also appeared in the History Channel documentary, 'The Crumbling of America.' Along with numerous other volunteer efforts, he has served as Director of St. Mary's Rehabilitation Center for Children, a member of AREMA's-Committee 15, Steel Railroad Bridges, and Chairman Emeritus of Heavy Movable Structures.

Mr. Herrmann received his bachelor's degree in civil engineering from Valparaiso University, Indiana, and his master's degree from the Polytechnic Institute of New York, now NYU-Poly. He is a registered professional engineer in 29 states. He is a resident of Pittsburgh, Pennsylvania.

CRAIG S. **IVEY**

Craig S. Ivey is President of Consolidated Edison Company of New York (Con Edison), a regulated utility with 14,000 employees serving New York City and most of Westchester County. The company is a subsidiary of Consolidated Edison, Inc., one of the nation's largest investor-owned electric utilities, with approximately $13 billion in annual revenues and $36 billion in assets.

Mr. Ivey and his team run electric operations across the entire service area; gas operations in Manhattan, the Bronx, and parts of Queens and Westchester; and steam operations in Manhattan. They are responsible for the safety, construction, planning, design, and reliability of an electric system that presently encompasses over 129,000 miles of underground and overhead electric cable, nearly 4,300 miles of gas mains, and 105 miles of steam mains, serving over nine million New Yorkers.

Con Edison is a Dow Jones Sustainability Index company; its continuing emphasis on green initiatives to reduce carbon emissions have been recognized with commendations and awards from government agencies as well as nonprofit and private organizations, including the U.S. Department of Energy, the international Carbon Disclosure Project (CDP), and Innovest Strategic Value Investors.

Mr. Ivey serves on the boards of nonprofit and industry organizations including the Hospital for Special Surgery, the Fresh Air Fund, and the New York State Smart Grid Consortium.

Mr. Ivey joined Con Edison in November 2009 after serving as a senior vice president in two different roles at Dominion Virginia Power since 2006, first as an SVP of Electric Delivery, then as an SVP of Transmission and Distribution. He had risen through a succession of increasingly responsible positions at Dominion, where he developed a reputation for emphasizing safety, operational excellence and leadership.

A native of Roanoke Rapids, N.C., Mr. Ivey originally joined Dominion in May 1985 after spending several summers during college working in the company's Engineering and Planning Group. In 2003, three years after becoming vice president of Electric Operations, he played a key role in expeditiously managing service restoration of 1.8 million customers after the devastating Hurricane Isabel.

Mr. Ivey earned his bachelor's degree in Electrical Engineering from North Carolina State University, and has completed executive education programs at the University of Michigan and Harvard University. In 2005, he received the Black Engineer of the Year Award for Career Achievement in Industry.

He is married and the father of three children.

STEVEN E. **KOONIN**

Dr. Steven E. Koonin was appointed as the founding Director of NYU's Center for Urban Science and Progress (CUSP) in April 2012. That consortium of academic, corporate, and government partners will pursue research and education activities to develop and demonstrate informatics technologies for urban problems in the "living laboratory" of New York City. Prior to his NYU appointment, Dr. Koonin served as the second Under Secretary for Science at the U.S. Department of Energy from May 2009 thru November 2011. In that capacity, he oversaw technical activities across the Department's science, energy, and security activities and led the Department's first Quadrennial Technology for energy. Before joining the government, Dr. Koonin spent five years as Chief Scientist for BP, plc., where he played a central role in establishing the Energy Biosciences Institute. Dr. Koonin was a Professor of Theoretical Physics at Caltech from 1975 to 2006 and was the Institute's Provost for almost a decade. He is a member of the U.S. National Academy of Sciences and the JASON advisory group. Dr. Koonin holds a BS in Physics from Caltech and a PhD in Theoretical Physics from MIT (1975) and is an adjunct staff member at the Institute for Defense Analyses.

UPMANU **LALL**

Dr. Upmanu Lall is Director of the Columbia Water Center, Columbia University Earth Institute.

He is a leading expert on hydroclimatology, climate change adaptation, risk analysis and mitigation. His research has emphasized hydrology, water resource systems analysis, operations research, and stochastic processes with applications to flood/drought risk and uncertainty assessment, and the design and operation of water systems.

Recently, he has become concerned with the issue of global and regional water sustainability, and the more general issue of modeling and managing planetary change due to coupled human and natural dynamics. He is developing technical and policy tools for the projection and management of environmental change as part of a quantitative approach to sustainability of earth systems.

DANIEL (PETE) **LOUCKS**

Professor Daniel (Pete) Loucks teaches courses and conducts research at Cornell University in the development and application of optimization and simulation models and decision support systems for predicting economic, environmental, and social impacts of alternative decisions with respect to the management of water and land resources. He has also held appointments at other universities here and abroad, served in UN organizations, the World Bank, and in public agencies and private firms. He is a fellow of the American Geophysical Union, a Distinguished Member of the American Society of Civil Engineers and a member of The National Academy of Engineering.

RUTHIE D. **LYLE**

Dr. Ruthie D. Lyle joined IBM in 1999 soon after being recognized as the first African American woman to earn a doctorate in Electrical Engineering from Polytechnic Institute of New York University (NYU-Poly).

Her career experience with IBM spans assignments in Intellectual Property Monetization, Software Development and Hardware Development. Dr. Lyle is a registered Patent Agent, and the Team Lead Emeritus of IBM's Smarter Planet Invention Review Team. She is an IBM Master Inventor and prolific inventor with 58 issued U.S. patents and over 170 pending patent applications. Most recently, she received the National Women of Color 2010 Technical Innovation Award for her technical contributions.

Dr. Lyle has a passion for supporting, and deep sense of responsibility towards furthering, initiatives targeted at encouraging women and minorities in STEM careers. Personally, she is an avid recreational runner and enjoys spending time with her husband and son.

JOAN **McDONALD**

Joan McDonald was nominated by New York Governor Andrew M. Cuomo on January 14, 2011 to serve as the 11th Commissioner of the New York State Department of Transportation, and was unanimously confirmed by the New York State Senate on March 8, 2011.

An expert on transportation, infrastructure, economic development, policy and planning, Ms. McDonald serves as a key member of Governor Cuomo's cabinet.

Commissioner McDonald's vision for the Department focuses on two core components: (1) operating and maintaining New York's transportation system safely and efficiently; and (2) delivering a world-class capital program on time and on budget. During her first year, Commissioner McDonald launched the Department's new Capital Asset Management-Capital Investment (CAM-CI) program. This innovative program focuses on preservation, looking at New York's transportation system in a sustainable way. Commissioner McDonald has received high marks for bringing transparency to the Department and for her collaboration with the design and construction industry.

Prior to her appointment, Commissioner McDonald served as the Commissioner of the Connecticut Department of Economic and Community Development. Her private sector experience includes five years as the Vice President in charge of New York and New Jersey at Jacobs Engineering. Ms. McDonald began her transportation career as Deputy Commissioner for Planning & Traffic Operations for the New York City Department of Transportation and as the Director of Capital and Long Range Planning for the MTA Metro-North Railroad.

DAVID **MILLER**

David Miller is Counsel, International Business and Sustainability at Aird & Berlis LLP. In that role, he assists the firm in the development of its international clean tech and renewable energy practices.

Mr. Miller is a leading advocate for the creation of sustainable urban economies. In addition to being a strong and forceful champion for the next generation of jobs through sustainability, he advises companies—and governments—on practical measures to make this happen.

He was Mayor of Toronto from 2003 to 2010. Under his leadership, Toronto became widely admired internationally for its environmental leadership, economic strength and social integration.

As Chair of the influential C40 Cities Climate Leadership Group from 2008 to 2010, Mr. Miller was instrumental in demonstrating the practical and real change cities are already making and can continue to make as they fight climate change and create sustainable employment. He continues that work today with the World Bank, OECD, UNEP and other national and international organizations to strengthen the capacity of City governments worldwide to act. He is the Future of Cities Global Fellow at Polytechnic Institute of New York University (NYU-Poly). He is a member of the David Suzuki Foundation Board, an Honorary Director of Canadian Association of Physicians for the Environment (CAPE) and Chair of Cape Farewell North America. Most recently, Mr. Miller was appointed by the Canadian Counsel of Academies to Chair an Expert Panel on "The Potential for New and Innovative Uses of Information and Communications Technologies (ICTs) for Greening Canada."

David Miller is a Harvard trained economist and professionally a lawyer. He and his wife, lawyer Jill Arthur, are the parents of two children.

GERARD M. **MOONEY**

Gerard M. Mooney is currently Vice President, Global Smarter Cities. His team is responsible for delivering the set of initiatives that now form the center of IBM's successful Smarter Planet offerings and that are playing a leading role in the transformation and modernization of governments and cities around the world in core functions like Intelligent Transportation, Public Safety, Advanced Water Management, Smart Grids and Green Buildings, as well as traditional government services.

Since joining IBM in 2000, Mr. Mooney has held a series of increasingly responsible positions in venture capital, strategy, technology, operations, and sales. Most recently, he was General Manager, Global Government and Education and, prior to that, he was IBM's Vice President, Corporate Strategy with worldwide responsibility for IBM's Emerging Business Opportunities program. He has also had responsibility for IBM's Venture Capital organization. He serves as a member of the Board of Directors of the Intelligent Transportation Society of America (ITS America).

He holds an MBA from Yale University, an MS in Accounting from Georgetown University and a BA in Philosophy from Mount Saint Mary's College.

THOMAS D. **O'ROURKE**

Dr. T.D. O'Rourke is the Thomas R. Briggs Professor of Engineering in the School of Civil and Environmental Engineering at Cornell University.

He is a member of the U.S. National Academy of Engineering and a Fellow of American Association for the Advancement of Science. He received several awards for his teaching and from professional societies, including the Collingwood, Huber Research, C. Martin Duke Lifeline Earthquake Engineering, Stephen D. Bechtel Pipeline Engineering, and Ralph B. Peck Awards from ASCE, the Hogentogler Award from ASTM, and Trevithick Prize from the British ICE.

He served as President of Earthquake Engineering Research Institute and as a member of numerous advisory boards and committees for NSF, NIST, and NRC. He authored or co-authored over 350 technical publications.

He served as chair or member of the consulting boards of many projects associated with highway, rapid transit, water supply, and energy distribution systems. His research interests cover geotechnical engineering, earthquake engineering, underground construction technologies, engineering for large, geographically distributed systems, and geographic information technologies and database management.

THEODORE (TED) S. **RAPPAPORT**

Dr. Theodore (Ted) S. Rappaport is the David Lee/Ernst Weber Professor of Electrical Engineering at the Polytechnic Institute of New York University (NYU-Poly) and is a Professor of Computer Science at New York University's Courant Institute of Mathematical Sciences. He is also a Professor of Radiology at the NYU School of Medicine.

Rappaport serves as Director of the National Science Foundation (NSF) Industrial/University Collaborative Research Center for Wireless Internet Communications and Advanced Technology (WICAT), a national research center that involves 5 major universities and is headquartered at NYU-Poly. He is also the founding Director of NYU WIRELESS, the world's first academic research center to combine engineering, computer science, and medicine. Earlier, he founded two of the world's largest academic wireless research centers: The Wireless Networking and Communications Group (WNCG) at the University of Texas at Austin in 2002, and the Mobile and Portable Radio Research Group (MPRG), now known as Wireless@ at Virginia Tech, in 1990.

Dr. Rappaport is a pioneer in radio wave propagation for cellular and personal communications, wireless communication system design, and broadband wireless communications circuits and systems at millimeter wave frequencies. His research has influenced many international wireless-standards bodies, and he and his students invented the technology of site-specific radio frequency (RF) channel modeling and design for wireless network deployment – a technology now used routinely throughout wireless communications.

Dr. Rappaport has served on the Technological Advisory Council of the Federal Communications Commission, assisted the governor and CIO of Virginia in formulating rural broadband initiatives for Internet access, and conducted research for NSF, Department of Defense, and dozens of global telecommunications companies. He has over 100 U.S. or international patents issued or pending and has authored, co-authored, and co-edited 18 books, including the world's best selling books on wireless communications and smart antennas.

In 1989, he founded TSR Technologies, Inc., a cellular radio/PCS software radio manufacturer that he sold in 1993 to what is now CommScope, Inc. (taken private in 2011 by Carlyle Group). In 1995, he founded Wireless Valley Communications, Inc., a pioneering creator of site-specific radio propagation software for wireless network design and management that he sold in 2005 to Motorola.

He received BS, MS, and PhD degrees in electrical engineering from Purdue University, and is an Outstanding Alumni of his alma mater.

KATEPALLI R. **SREENIVASAN**

Katepalli Sreenivasn has been University Professor at New York University since September 2010, where he also serves as Senior Vice Provost in charge of science and technology, and as Provost of the Polytechnic Institute of NYU. Prior to coming to NYU, he served from 2003 to 2009 as the Director of the International Centre for Theoretical Physics in Trieste, Italy, for nearly seven years. Earlier, he taught at the University of Maryland as Distinguished University Professor, Glenn L. Martin Professor of Engineering, and Professor of Physics, and also served for a year and a half as the Director of the Institute for Physical Science and Technology. Previously, Dr. Sreenivasan joined the faculty of the Department of Engineering and Applied Science at Yale University in 1979 and held several posts at Yale until 2002, including the Harold W. Cheel Professor of Mechanical Engineering (1988-2002), joint appointments in the Departments of Physics, Applied Physics and Mathematics; Chair of the Mechanical Engineering Department (1987-1992) and the Acting Chairman of the Council of Engineering (1989). His post-doctoral work included two years of work in Australia and at Johns Hopkins University for a similar period of time. He has been a Visiting Professor at Caltech, Rockefeller University, Cambridge University, and the Institute for Advanced Study at Princeton, among others.

Dr. Sreenivasan's honors include: Guggenheim Fellowship;

Otto Laporte Memorial Award of American Physical Society; TWAS Medal Lecture in Engineering Science; Distinguished Alumnus Award and Centennial Professorship of the Indian Institute of Science; Sir C.V. Raman Visiting Professorship of the Indian Academy of Sciences; the International Prize and Gold Medal in memory of Professors Modesto Panetti and Carlo Ferrari, Academia delle Scienze di Torino, Italy; National Order of Scientific Merit (the highest scientific honor) by the Brazilian Government and the Academy of Sciences; UNESCO Medal for Promoting International Scientific Cooperation and World Peace from the World Heritage Centre, Florence, Italy; President Dr. Zakir Husain Memorial Award from the Duty Society and the Indian Society of Applied and Industrial Mathematics; Honorary Membership, Academia Torre e Tasso, Duino-Aurisina, Trieste, Italy; the Melvin Jones Fellow of the Lions Club (for humanitarian service); the Dwight Nicholson Medal of the American Physical Society for human outreach, and the 2009 Nusselt-Reynolds Prize from the Assembly of World Conference on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics; the 2009 AAAS award for International Scientific Cooperation; and the 2011 Multicultural Leadership Award of the National Diversity Council.

Sreenivasan has been elected to the Indian Academy of Sciences and the Indian National Science Academy, the Academy of Sciences for the Developing World (TWAS), and the African Academy of Sciences, the US National Academy of Sciences, US National Academy of Engineering and the American Academy of Arts and Sciences. Within the National Academies, Dr. Sreenivasan has served on the NAE Committee on Membership and the Mechanical Engineering Section (chair, vice chair, member) and the Mechanical Engineering Peer Committee (chair, vice chair, member); the NAS Class III Membership Committee; the NRC Committee on Human Rights of the NAS, NAE, and IOM; the Committee on Condensed-Matter and Materials Physics; and the Nonlinear Dynamics and Fractals Committee; and on the *Proceedings of the National Academy of Sciences* Editorial Board.

ROBERT K. **STEEL**

Robert K. Steel is New York City

Deputy Mayor for Economic Development. He is responsible for the Bloomberg Administration's five-borough economic development strategy and job-creation efforts, as well as its efforts to expand job training, strengthen small business assistance, promote new industries, diversify the economy, and achieve the goals of the New Housing Marketplace Plan, which is designed to build or preserve enough affordable housing for 500,000 New Yorkers by 2014. He spearheads the Administration's major redevelopment projects, including those in Lower Manhattan, Flushing, Hunters Point South, Coney Island, Stapleton, the South Bronx, and Hudson Yards. Deputy Mayor Steel oversees such agencies as the Department of Housing Preservation and Development, Department of City Planning, Department of Small Business Services, NYC Economic Development Corporation and NYC & Company, and he serves as Chair of Brooklyn Bridge Park board.

Prior to his 2010 appointment as Deputy Mayor, Mr. Steel was the President and CEO of Wachovia. From 2006 to 2008, he was the Under Secretary for Domestic Finance at the U.S. Department of the Treasury. Prior to entering government service, Mr. Steel spent nearly 30 years at Goldman Sachs, ultimately rising to become co-head of the U.S. Equities Division and Vice Chairman of the firm. He is a graduate of Duke University and the University of Chicago's Booth School of Business, and has distinguished himself as Chairman of Duke's Board of Trustees, Chairman of the Aspen Institute's Board of Trustees, Senior Fellow at the Harvard Kennedy School of Government, a member of the FDIC Advisory Committee on Economic Inclusion, Chairman of The After-School Corporation, and Co-Founder of SeaChange Capital Partners, an organization dedicated to helping nonprofits grow.

CARTER H. **STRICKLAND, JR.**

Carter H. Strickland, Jr. is Com-

missioner of the New York City Department of Environmental Protection (DEP), whose 6,000 employees provide more than 1.0 billion gallons of water each day to more than 9 million New Yorkers, treat more than 1.3 billion gallons of water every day, and regulate local air quality. Prior to being

Commissioner, Mr. Strickland was the Deputy Commissioner for Sustainability at DEP where he oversaw the agency's environmental planning, analysis, permitting, and enforcement programs. Before joining DEP, Mr. Strickland was the Senior Policy Advisor for Air and Water with the Mayor's Office of Long Term Planning and Sustainability, where he was responsible for the implementation of New York City's sustainability plan, PlaNYC 2030, across all agencies and departments, with a focus on water, air, and natural resource issues. Commissioner Strickland graduated from Dartmouth College, cum laude, and earned his law degree from the Columbia University School of Law, where he served as Executive Editor of the Columbia Journal of Environmental Law. He lives in Brooklyn Heights with his wife and their two children.

RICHARD S. **THORSEN**

Dr. Richard S. Thorsen is Vice President Emeritus and Senior Advisor to the President and Provost of Polytechnic Institute of New York University.

A Mechanical Engineer with a Ph. D. from New York University, he has been a member of the Mechanical Engineering faculty since 1964. He served as Head of the Department of Mechanical Engineering and then Head of Mechanical and Aerospace Engineering at Polytechnic Institute of New York (now Polytechnic Institute of New York University) from 1974 to 1983. He introduced Polytechnic's first computer-based instructional laboratory.

He has since served as Associate Provost for Computing and Information Systems, Dean of Graduate Studies, Vice President for Research and Advanced Programs, Vice President for Development and University Relations, lead for the $275 million Fulfilling the American Dream Campaign, and Vice President for Academic Affairs.

He is widely published in heat transfer and solar energy literature and has led major government- and industry-sponsored research projects in these areas, and has been Principal Investigator on more than $25 million of sponsored research programs.

Dr. Thorsen was instrumental in the negotiations which led to the 1973 merger of Polytechnic Institute of Brooklyn and the New York University School of Engineering and Science, and its subsequent successful implementation. In 2007-2008 he played a leading role in the negotiations that led to Polytechnic's current affiliate relationship NYU.

SYMPOSIUM **CHAIRS & MODERATORS**

JERRY M. **HULTIN**

Jerry M. Hultin is president of Polytechnic Institute of New York University. In this capacity he heads one of the nation's oldest private science and engineering schools. An innovative resource for science, engineering and technology management, Polytechnic Institute has produced a notable list of corporate, academic, research and engineering leaders—including three Nobel laureates—since it was founded in 1854.

During his first three years as President of Polytechnic, Mr. Hultin led a university-wide initiative of redefining Polytechnic's role for the 21st Century. The resulting strategic plan was approved by Poly's Board of Trustees in May 2007 and focuses the Institute on introducing invention, innovation, and entrepreneurship—known as i^2e—into all of its academic, research, and technology commercialization programs.

For instance, in order to increase entrepreneurial opportunity at Poly and throughout NYC, Polytechnic joined with the NYC Investment Fund and the New York State Technology and Research Authority in funding a new $2 million venture capital fund, NYCSeed, located at Polytechnic and specifically designed to support innovative new ideas for information technology and Web 2.0 products and services.

On July 1, 2008, under Mr. Hultin's leadership and with the support of Poly's Board, faculty, and students, Polytechnic became an affiliate of New York University, one of the leading comprehensive research universities in the nation. This strategic new alliance adds Polytechnic's prowess in technology and engineering to NYU's comprehensive educational and research strengths and provides Polytechnic with substantial resources and opportunities for education, research, and technology commercialization in NYC and around the world.

Before joining Polytechnic University, Mr. Hultin was Dean of the Wesley J. Howe School of Technology Management and Professor of Management at Stevens Institute of Technology in Hoboken, N.J. At Stevens, Mr. Hultin expanded the Howe School's graduate programs in technology management and presided over a major increase in research funding.

From 1997 to 2000 Mr. Hultin served as Under Secretary of the Navy, the Department's number two civilian leader. In this position, he led numerous programs that supported innovation in strategic vision, war fighting and business operations to meet the evolving needs of the Navy and Marine Corps in the 21st Century.

Mr. Hultin's major accomplishments as Under Secretary included taking a leadership role in the Department of the Navy's Revolution in Business Affairs, which brought private-sector business acumen to both the Navy and Marine Corps. He was one of the creators of the Navy-Marine Corps Corporate Intranet and led a major study of the impact of globalization on national security and naval forces conducted by the National Defense University. In 2003 Mr. Hultin served as the on-air military analyst for WNBC in New York City during the Iraq War.

Over the course of his career, Mr. Hultin has helped create and support a number of national, non-profit programs that provide leadership, community development and job skills to young people from all walks of life.

Mr. Hultin is an Honorary Fellow of the Foreign Policy Association, the founding Chairman of the Technology Management Education Association, and an advisor to senior military and defense leaders. He is on the boards of the Advanced Energy Research & Technology Center, Center for an Urban Future, the Downtown Brooklyn Partnership, the National Action Council for Minorities in Engineering (NACME), British American Business, among others. He is a member of the New York Academy of Sciences, International Association of University Presidents, American Council on Education (ACE), the Commission on Independent Colleges and Universities (CICU), and Association of University Research Parks.

Mr. Hultin is married to Jill Foreman Hultin, a management consultant, and they have two grown sons.

MOHAMMAD **KARAMOUZ**

Professor Mohammad Karamouz is Director of Environmental Engineering/Science programs in the Dept. of Civil and Urban Engineering at NYU-Poly since 2008. Prior to that among his academic assignments, he was the Dean of Engineering and a Professor in the School of Architecture (Dept. of City & Regional Planning) at Pratt Institute. He was also a visiting Professor at the University of Arizona. He founded and was president of Arch Construction and Consulting Co. Inc. in Queens, New York for 10 years and worked as a Professional Engineer providing a wide range of civil engineering services as well as promoting entrepreneurship and creating jobs for many civil engineers in NYC metropolitan area. He is a Fellow of American Society of Civil Engineers, and a Diplomat of American Academy of Water Resources Engineers.

Dr. Karamouz received his BS degree in Civil Engineering from Shiraz University, MS in Water and Environmental Engineering from George Washington University, and PhD in Hydraulics and Systems Engineering from Purdue University. He has made significant accomplishments in the field of water resources through research, teaching, graduate student supervision, private consulting, and various scientific publications including 6 books (5 text books) and more than 300 papers. He has over 850 citations according to Google Scholars, and 560 Citations according to the Web of Knowledge/Science. His areas of research include Environmental Systems Management and Environmental Sustainability, Climate Change Studies, Large Scale Signals Rainfall and Flood Forecasting, Urban Water Infrastructures, Flood Resistant Cities, Water Security, Disaster Management, Large Scale Watershed Management, Data Mining, Development of Large scale Water Supply/Demand Decision Support Systems, and Environmental/Climate Management Information Systems.

Dr. Karamouz has served in many leadership positions in a number of national and international societies including ASCE, AGU, AWRA, IWRA and USCOLD (US Committee on Large Dams). He has been the editor of *Iran-Water Resources Research Journal* for 8 years and a member of editorial board of major journals including *ASCE Journal of Water Resource Planning and Management*. He is currently the chairman of ASCE-EWRI International Council. Dr. Karamouz has developed Decision Support Systems and operation models for 9 major watersheds with transboundary water conflict issues in the Middle East. He has had major research grants and contracts from NSF, World Bank, UNESCO, International Water Authority Boards, Utility Companies and other national and international organizations.

JOHN C. **FALCOCCHIO**

Dr. John C. Falcocchio is Professor of Transportation Planning and Engineering in the Department of Civil and Urban Engineering and Director of the Urban Intelligent Transportation Systems Center (UITSC) at Polytechnic Institute of New York University.

As Director of UITSC, he has facilitated and catalyzed the dialogue between the academic community and federal, state, and city agencies related to ITS deployment in New York City.

He has many years of experience both as an educator/researcher and as a practicing professional. His main research interests are in traveler and freight mobility, access to urban activities, and transportation system productivity. He teaches courses in the analysis, planning, and management of urban transportation systems, and has written scholarly and professional papers and one book on these subjects.

Dr. Falcocchio is Chairman of the Board of the University Transportation Research Center, Region 2—a consortium of seventeen universities—and is a registered Professional Engineer in Pennsylvania, New York, and California.

He holds a Bachelor in Civil Engineering and a Ph.D. (Transportation Planning) from the Polytechnic Institute of Brooklyn, and a graduate degree in Traffic Engineering from the Bureau of Highway Traffic, Yale University.

PAUL M. **HORN**

Dr. Paul Horn was named NYU Distinguished Scientist in Residence in September of 2007 and Senior Vice Provost for Research in September 2009. Prior to his NYU position, he was Senior Vice President of the IBM Corporation and Executive Director of Research. In this job, he directed IBM's worldwide Research program with 3200 technical employees in eight sites in five countries around the world, and helped guide IBM's overall technical strategy. Under his leadership, IBM Research produced an unmatched string of technological breakthroughs, including the chess-playing supercomputer Deep Blue, the world's first copper chip, the giant magneto-resistive head (GMR), strained silicon (a discovery that allows chips to run up to 35 percent faster), and BlueGene the world's fastest supercomputer that brought computing leadership back to the United States.

Dr. Horn graduated from Clarkson College of Technology and received his doctoral degree in physics from the University of Rochester in 1973. Prior to joining IBM in 1979, Dr. Horn was a professor of physics in the James Franck Institute and the Physics Department at the University of Chicago. Dr. Horn is a Fellow of the American Physical Society and was a member of the National Academy of Engineering. In addition to NYU-Poly he is a member of numerous professional committees and boards including the GAO (General Accountability Office) board of advisors, the board of trustees of the Committee for Economic Development, NYC Seed, and New Venture Partners.

ILAN **JURAN**

Dr. Ilan Juran is Executive Director of the Urban Infrastructure Institute and Urban Utility Center at Polytechnic Institute of New York University, a Professor of Civil and Environmental Engineering, and former Department Head and Chairman of NYU-Poly's Department of Civil and Urban Engineering. He also serves as Executive Director of W-SMART (Water Security Management Assessment, Research and Technology).

Dr. Juran was a Senior Advisor of Technology and Science and Chair of the United Nations Development Program (UNDP) Task Force ECO-INWARDS on Economic Integration of Neutralized Waste as a Resource Deployment Strategy. He holds a DSc (Doctorat Es Science) in Applied Mechanics and a PhD in Soil Mechanics, both from University of Paris.

POLYTECHNIC INSTITUTE OF NEW YORK UNIVERSITY

Polytechnic Institute of New York University (formerly Polytechnic University), an affiliated institute of New York University, is a comprehensive school of engineering, applied sciences, technology and research, and is rooted in a 158-year tradition of invention, innovation and entrepreneurship: i^{2}e. The institution, founded in 1854, is the nation's second-oldest private engineering school. In addition to its main campus in New York City at MetroTech Center in downtown Brooklyn, it also offers programs at sites throughout the region, around the globe, and remotely through NYUe-Poly. NYU-Poly is an integral part of NYU Abu Dhabi, NYU Shanghai and the Center for Urban Science and Progress (CUSP) in downtown Brooklyn. For more information, visit www.poly.edu.

NYU-POLY DEPARTMENT OF CIVIL AND URBAN ENGINEERING

The ABET-accredited Department of Civil and Urban Engineering at NYU-Poly offers BS, MS, and PhD degrees in civil engineering. With a distinguished history of research in urban infrastructure engineering and planning as well as environmental sustainability, the department is dedicated to advancing the body of knowledge and professional practice of civil and urban engineering to meet the imminent and ever-changing challenges of the future. Offering students the benefits of the most highly regarded faculty, the department continues to utilize the real-world urban laboratory of New York City and produce leaders prepared to meet the needs of an increasingly complex world with breakthrough advances in the field. This symposium is NYU-Poly's Department of Civil and Urban Engineering's tribute to George Bugliarello.

NEW YORK UNIVERSITY

New York University, which was established in 1831, is one of the largest and most prestigious private research universities in the U.S. It has more international students than any other U.S. college or university. Through its numerous schools and colleges, NYU conducts research and provides education in the arts and sciences, law, medicine, dentistry, education, nursing, business, social work, the cinematic and performing arts, public administration and policy, and continuing studies, among other areas.

METROTECH CENTER

George Bugliarello's vision was the creative force behind the development of MetroTech, the 16-acre urban university-industry park in downtown Brooklyn. The creation of MetroTech heralded the gentrification of the area and created over 20,000 jobs. The center attracted employers in major industries such as banking, utilities, securities, the New York City Fire Department, and large hotel chains such as the Marriott and Sheraton. Its success has proven to be a primary case study in university, corporate, government, and private developer cooperation.

CUSP

In April 2012, New York City announced the launch of the Center for Urban Science and Progress (CUSP), an applied science research institute created by NYU and Polytechnic Institute of NYU, with a consortium of world-class universities and the foremost international tech companies to address the needs of cities. Generating an entirely new sector in New York City's economy and placing it at the center of a global stage in this field, CUSP will be located in MetroTech in a city-owned building steps from NYU-Poly.

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Director, Environmental Engineering and Science Programs, NYU-Poly

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Virginia Bugliarello

Lawrence Chiarelli
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Robert D. Dalziel
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