

Chapter 15

Toward More Sustainable Infrastructure

Humanity choked amidst its products, and all its energy went in increasing its disorder, like a blind stricken thing that struggles and sinks in a morass.

H.G. Wells, **In the Days of the Comet**, 1906

Carl D. Martland, *Toward More Sustainable Infrastructure*

Evolution of Infrastructure

- Infrastructure last for decades; change may slow, but change is possible
- Over decades, there will be changes in society's perception of infrastructure needs and performance
- It is essential that infrastructure systems evolve toward systems that are more easily maintained, better suited toward serving society's needs and less intrusive upon the environment

Mechanisms of Evolution

- Specific projects and programs
- Better management strategies
- Use of new materials and energy sources
- New regulations concerning use and design

Also, long periods of stability may eventually be disrupted by fundamental changes in technology, institutions, political power, economic conditions or societal norms

Stages in the Evolution of Infrastructure-Based Systems

I	Technological Experimentation and Demonstration
II	Wide-Spread, Uncoordinated Implementation
III	Development of Systems
IV	Consolidation and Rationalization
V	Technological and Institutional Advancement
VI	Responding to Competition
VII	Mitigating Social and Environmental Impacts
VIII	Retrenching and Obsolescence

I. Technological Experimentation and Demonstration

- First, figure out how to make the technology work
- Next, demonstrate how it might be useful to society
- Relevant methodologies:
 - Measuring and modeling system performance
 - Probabilistic risk assessment
 - Performance-based technology assessment

I. Technological Experimentation and Demonstration – Potential Pitfalls

- Excessive investments in technologies without a market
- Introduction of a technology without adequate safeguards
- Inadequate consideration of externalities, leading to intense public opposition
- Failure to consider potential benefits, thereby leading to delays in implementation
- Excessive regulation by governments more concerned with protecting special interests

II. Wide-Spread, Uncoordinated Implementation

- Frenzied efforts to implement; fierce competition; little knowledge of how best to proceed
- Relevant methodologies:
 - Financial analysis
 - Brainstorming
 - Sensitivity analysis
 - Scenarios

II. Wide-Spread, Uncoordinated Implementation – Potential Pitfalls

- Starting too small
- Starting too big
- Starting without adequate financial reserves
- Waiting too long to get started

Primary Motivation for High Rise Construction

- Location, location, location
- Economies of scale in construction
- Economies of density in urban development
- Ability of developers to make greater profits through denser development
- Need to have denser development once property values rise

New Technologies Enable Skyscrapers – Spark Building Boom in Chicago and NYC

Steel frames	1848	Cast-iron posts and beams allow non-load-supporting walls in buildings of 7-8 stories.
	1880	Study indicates that using steel members joined by rivets would allow much higher structures.
	1883	Design for the first skyscraper, the Home Insurance Company Building in Chicago.
Elevator	1853	Graves Otis demonstrates an elevator at the Crystal Palace in London.
	1870	Equitable Building in NYC is first building to install an elevator.
	1889	Otis installs first electric elevator.
Utilities		Water for fire protection and sanitation.
		Electricity for elevators and lighting.

Skycrapers in Manhattan

- 1890s: several buildings constructed with 20-30 stories
- 1929: 188 buildings at least 20 stories tall
- Tallest buildings:
 - 1899: Park Row Building – 29 stories
 - 1913: Woolworth Building – 55 stories, 787'
 - 1920s: Chrysler Building = 77 stories, 1048'
 - 1930s: Empire State Building – 102 stories, 1,250'

The Biggest & the Boldest

Developer's presentation to Met Life stockholders, 1915:

"You and your directors were well advised in the choice of your symbol. For a tower, with its light and its belfry, has always been a source of inspiration. ... Thus your Tower partakes of the character of the ancient towers of refuge and defense ... Your high tower should there be a symbol of God to you and others, standing out boldly and erect as a plea for righteousness and purity in business corporations, and as a monumental protest against the exploitation of the poor."

Response of President of Met Life:

"The tenants will foot the bill."

John Tauranac, **The Empire State Building**, St. Martin's Griffin, NY, 1995, p. 38



Burj Khalifa in **Dubai**, the world's tallest skyscraper
(2717' 160 stories)

Photo: Wikipedia, March 1, 2010

III. Development of Systems

- Suppliers seek economies of scale and density
- Public agencies seek more efficient systems
- Both seek ways to provide better service at a lower cost
- Consolidation of small systems into efficient networks
- Relevant methodologies
 - Analysis of potential network economies
 - Identifying strategic options for expansion

III. Development of Systems – Potential Pitfalls

- Creation of unregulated monopolies lead to excessive prices and poor service
- Difficulties in consolidation caused by lack of interoperability (lack of technological standards)
- Destructive competition that reduces prices to unprofitable levels for all suppliers, leading to inadequate capacity and under-maintained infrastructure

IV. Consolidation and Rationalization

- Deal with problems of the initial, uncoordinated developments
- Consolidate duplicate facilities; eliminate bottlenecks; abandon unnecessary facilities
- Relevant methodologies:
 - Basic modeling of costs, service, competition and financial viability
 - Estimation of public benefits (to gain public support and perhaps funding for complex projects that will perhaps cause severe disruption but that will ultimately provide very substantial benefits)

Example: Results of Uncoordinated Development of Railroad Facilities

How much of this abnormal magnitude [of railroad yard tracks in Buffalo] is the healthy and natural result of peculiar traffic conditions, and how much of it is mere fungous growth from diseases of management whose existence is universally felt, it would be useless to inquire here, because, as things are, it is all necessary, and there is no immediate evidence of any probable change.

Arthur M. Wellington, **The Economic Location of
Railways**, 1911

IV. Consolidation and Rationalization – Potential Pitfalls

- Difficulties in abandoning underutilized portions of a network
- Difficulties in assembling tracts of land suitable for consolidated facilities
- Difficulties of financing investments in a competitive environment where prices will quickly fall to new, lower marginal costs once the project is completed

V. Technological and Institutional Advancement

- Continual efforts to improve the management and technology and regulatory framework for the existing system
- Goals: improve system performance
 - Measuring and modeling performance
 - Performance-based technology scanning
 - Project and program audits

Double Stack Trains Compete with Trucks for General Freight



V. Technological and Institutional Advancement – Potential Pitfalls

- Failure to provide for adequate maintenance and rehabilitation
- Failure to anticipate changes in competition, technology, or society
- Complacent management

VI. Responding to Competition

- Sources of competition
 - Competition from similar systems
 - Competition from systems that use the same technology to provide the same service
 - Competitions from systems based upon different technologies that eliminate the need for the service
- Relevant methodologies
 - Measuring and modeling performance
 - Performance-based technology scanning
 - Brainstorming and scenarios

VI. Responding to Competition

- Sources of competition
 - Competition from similar systems
 - Low-cost airlines like Southwest compete with legacy carriers like United Airlines
 - Competition from systems that use different technologies to provide the same service
 - High speed railways compete with airlines for inter-city passengers
 - Competitions from systems based upon different technologies that eliminate the need for the service
 - Video conferences and the internet eliminate the need to travel to meetings

Widening the Panama Canal to Increase its Capacity



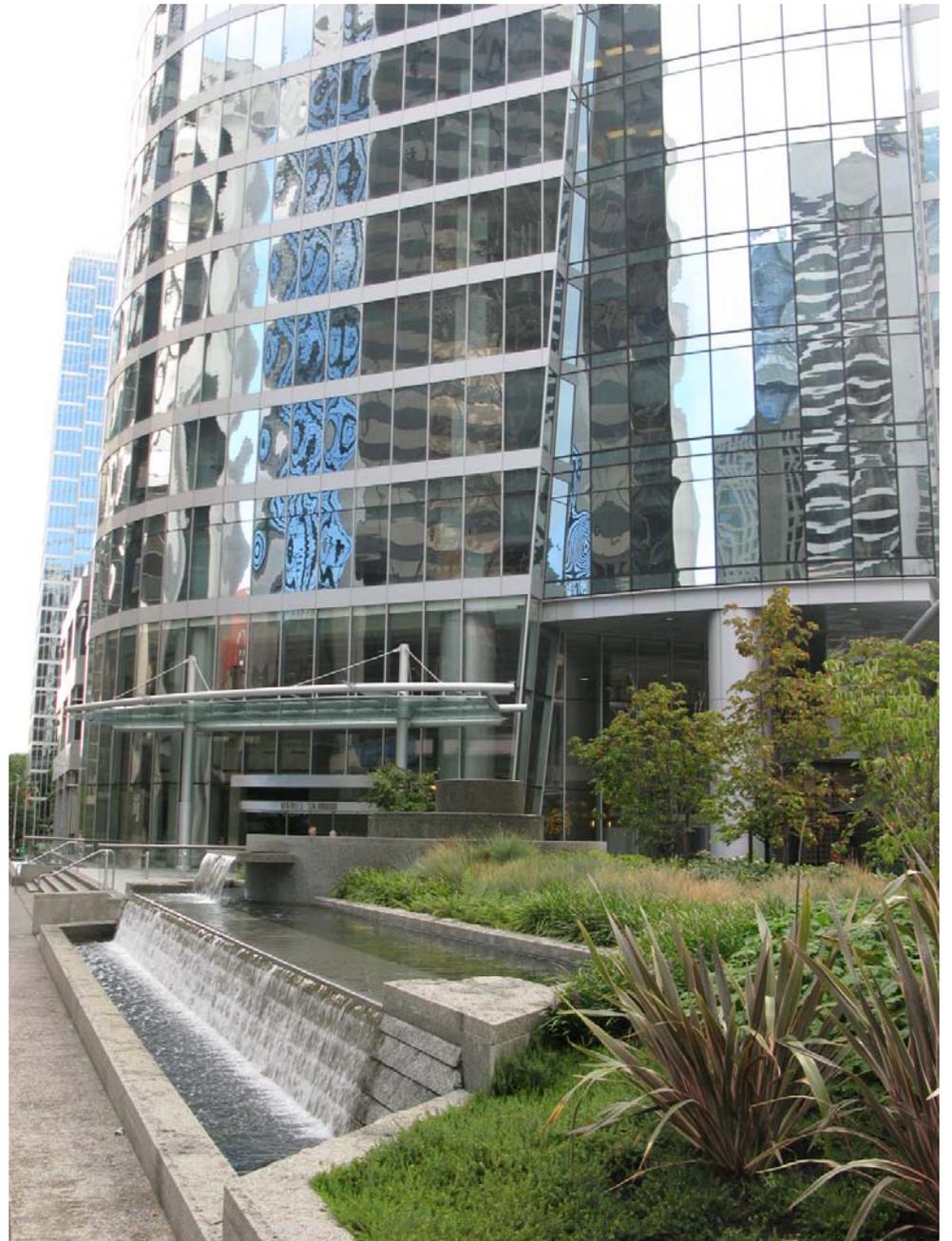
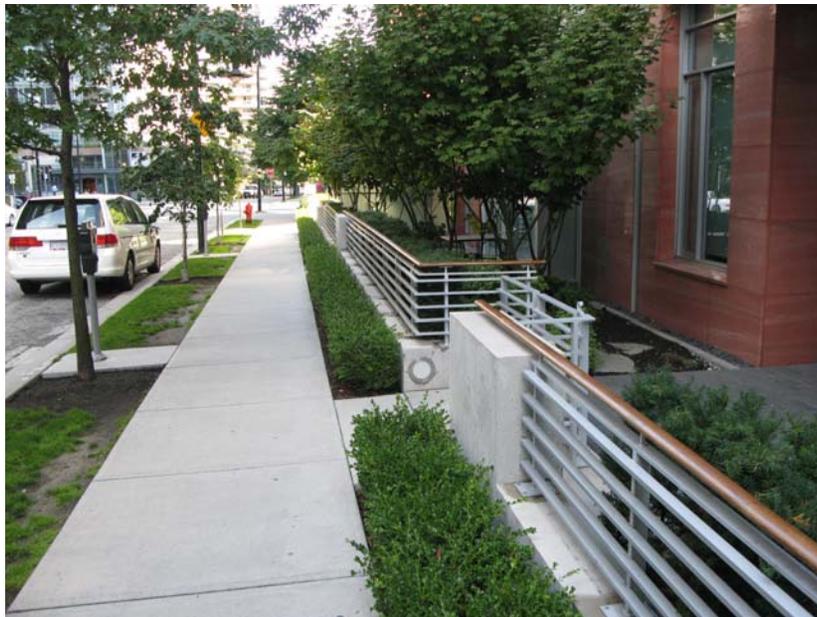
VI. Responding to Competition – Potential Pitfalls

- Failure to consider how current conditions might change
- Overconfidence based upon past profitability
- Regulations relevant only to the old technologies may delay implementation of new technologies

VII. Mitigating Social and Environmental Impacts

- Social and environmental impacts become more important over the life of infrastructure
 - Negative impacts may no longer be acceptable
 - Negative impacts might not have been apparent at first
 - Societal norms change

High rise development in downtown Vancouver has improved the landscape for pedestrians



VII. Mitigating Social and Environmental Impacts

- Examples:
 - Highway safety: continuing efforts to improve cars, roads, drivers, and enforcement to reduce the number and severity of accidents
 - Highway emissions: efforts begun in 1970s to reduce toxic emissions
 - Increasing concern about climate change and the need to reduce CO₂ emissions
 - Asbestos and other carcinogens no longer used in construction
 - Greater concern for clean water
 - Desire to reduce dependence upon fossil fuels
 - Zoning regulations in NYC that limit size and shape of skyscrapers in order to “canyon” effects of high-rise construction





VIII. Retrenching and Obsolescence

- Eventually systems will need to shrink and perhaps disappear
 - This can be well-managed over decades
 - This can be a painfully sudden collapse
- Pitfalls:
 - Short-sighted managers who fail to foresee problems
 - Bull-headed managers who invest vast sums in vain efforts to forestall the inevitable



21st Century Issues

- Over-dependence upon fossil fuels
- Climate change
- Social justice and equity (huge disparities between the rich and the poor and between the developed world and the poorest countries)
- Instability in societies related to disintegrating economies, internal conflict, and lack of opportunity
- Congestion and pollution in large cities
- Cracks in the automobile culture
- Environmental degradation
- Potential battles over water

Responding to 21st Century Challenges

- Managing demands on infrastructure
- Maintaining and rehabilitating existing facilities
- Managing infrastructure more effectively
- Using infrastructure more effectively
- Mitigating the negative social and environmental impacts of existing infrastructure
- Building new, more sustainable infrastructure
- Retiring old, unsustainable infrastructure



Newark's Sewer Rehabilitation Program: Inspection Grades

1. Acceptable
2. Minimal short-term potential for collapse
3. Collapse unlikely near-term, but further deterioration is likely
4. Collapse likely in near future in some locations
5. Collapse has already occurred or is imminent in some locations

Newark's Sewer Rehabilitation Program

- Motivation:
 - The city's brick sewers were very old
 - Collapse of many of these sewers posed risks to the surrounding communities
 - It would be more efficient and effective to rehabilitate the sewers than to wait for them to collapse
- Process:
 - Inspection of brick sewers in order to set priorities for rehabilitation
 - Six-phase, two-decade program for rehabilitation

Newark's Sewer Rehabilitation Program: Three Levels of Risk

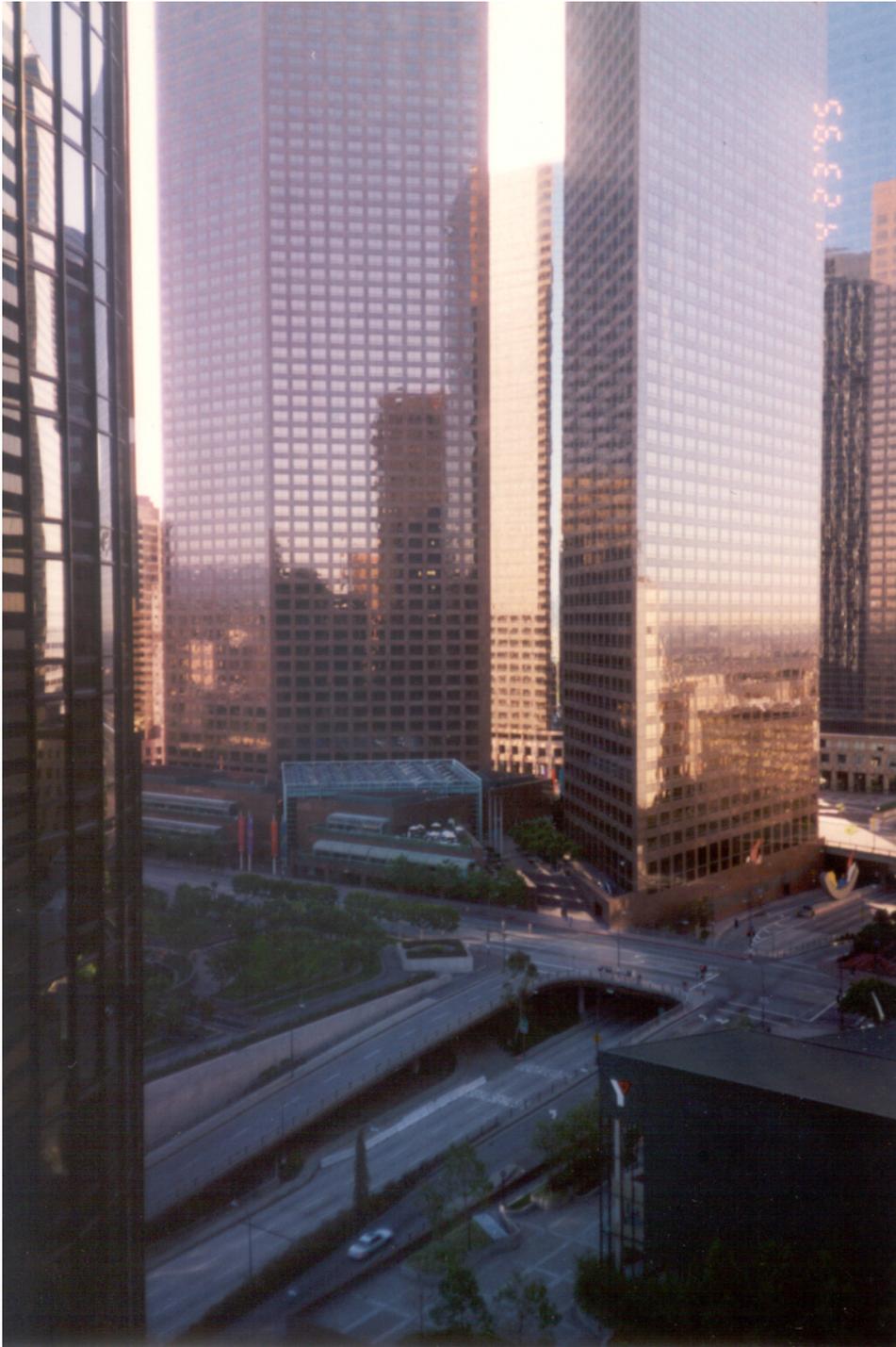
- Critical A Sewers: the cost of failure and impact on surrounding environment would be great
 - All of the brick sewers were located under city streets, they were all placed in this category
- Critical B Sewers: the risk is less, but preventive action would still be cost effective
- Critical C Sewers: failure would have little or no effect unless there were numerous simultaneous failures

Newark's Sewer Rehabilitation Program

Phase	Years	Miles Inspected	Miles Rehabilitated	Cost (\$ mill.)	Major Source of Funds
I	1990-92	13.2	4.2	\$11.1	Low interest loans from NJ
II	1993-96	12.6	5.5	\$12.9	Low interest loans from NJ
III & V	1997-08	21.3	12.1	\$24	Grant from U.S. EPA
V	2008	7.0	5.2	\$19	Loan from NJ Dept of Env. Protection
VI (Plan)	2009-11	23.8	4.5	\$16	Loan from NJ Dept of Env. Protection
Total		68	31.5	\$83	

Newark's Sewer Rehabilitation Program: Lessons

- A reasonable program may take decades to complete
- Inspection can set priorities
- Risks of failure depend upon location
- Priorities are highest for portions in poor condition where risks of failure are high
- It will not be necessary to rehabilitate all of the infrastructure, as some may still be in good condition and other parts may be in locations where failure would not cause any significant problems



Even Los Angeles, with all of its expressways, has skyscrapers and transit.

Vancouver expanded its light rail system to prepare for the Olympics



MIT OpenCourseWare
<http://ocw.mit.edu>

1.011 Project Evaluation
Spring 2011

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.