Megaprojects for Megaregions: Global Cases and Takeaways

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16. Abstract

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Abstract

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1. Why, When and Where Do Megaprojects Make Sense?

Megaprojects Pros and Cons

Megaprojects, which are defined as large-scale capital projects costing $1 billion or more and involving multiple public and private stakeholders, are at once fascinating and controversial. They are fascinating because they are ambitious and challenging and require a high degree of expertise and coordination among multiple professional activities including project planning, design, engineering, and management; economic analysis; and project finance and asset management. They are controversial because, despite improvements in planning, construction and delivery techniques, many if not most megaprojects cost far more and take far longer to complete than initially promised. This pattern of underperformance has led funders and academic reviewers to ask whether and how the megaproject planning and review process could be made more robust (Van Marewijk et al. 2008; UCL Omega Centre 2012), and many megaproject practitioners to argue for more rigorous and transparent project management practices (Davies et al. 2017)

In simple terms, the argument in favor of megaprojects is that “bigger is better,” or to put it in economic terms, that there are economies of scale or scope that make it more cost efficient to develop a single large project instead of numerous smaller ones (Stigler 1958, Ansar et al. 2017). These economy of scale-or-scope advantages include:

- <u>Planning advantages</u>: Megaproject planning activities center around determining the balance between project benefits and costs. Costs necessarily rise with project size and scale, although not necessarily in a linear fashion, and by taking a larger and more systematic view, it should be possible to identify standardization and learning practices that keep costs better under control. On the benefit side, larger or more extensive projects are likely to have greater “spillover” benefits in which spatial proximity to the project or interactions between project beneficiaries add up to additional economic or social benefits. *This is the argument for building a metro system instead of a collection of individual subway lines.*
- <u>Design and engineering standardization advantages</u>: Bigger projects, it is thought, offer additional opportunities for sharing specialized design approaches or construction methods among a larger number of applications, or for standardizing expensive construction techniques or project components, thereby reducing their cost. Larger projects also offer the opportunity to ameliorate the effects of capacity or use local bottlenecks. *This is the argument for building highway networks instead of individual roads.*
- <u>Contracting, procurement and construction advantages</u>: By sharing or standardizing information and interaction costs across more transaction, bigger projects, it is thought, have the potential to reduce contracting and procurement costs. Likewise, by sharing and standardizing construction techniques and technologies across multiple facilities, it should

be possible to reduce project construction and delivery costs. *This argument applies to almost every megaproject.*

- Financing and risk-sharing advantages: Bigger projects offer the opportunity to access larger amounts of capital at a lower cost. The promise of magnified benefits also offers the opportunity of higher returns. And by apportioning different types or levels of project revenues to different financing sources, bigger projects also offer greater risk diversification opportunities. *This is the argument for building megaprojects that make use of variable pricing or revenue-generation schemes.*

- Project management advantages: Bigger projects also offer the opportunity to develop and share improved approaches to project management. *This argument applies to almost every megaproject.*

- Benefit capture and equity advantages: To the degree that larger projects create additional benefits across space or larger multiplier effects across beneficiaries, they also offer the opportunity to recapture those benefits in the form of revenues, or to have better-off beneficiary group cross-subsidize less fortunate beneficiaries. *This is an argument for building spatially extensive megaprojects like highways or subway/metro lines.*

- Sustainability, resiliency, and redundancy benefits: To the degree that larger projects can be efficiently designed and engineered to be more resistant to natural disasters or shocks, they may provide greater sustainability or resiliency benefits. *This argument has been used to justify bigger dam, flood control, and power projects.*

- Network effects and operations advantages: The cost of collecting, analyzing, and acting on information is also subject to huge economies of scale. This makes it cheaper to administer and operate larger projects than smaller ones per unit of use, output, or benefit. *This is the argument for building centralized rather than distributed utility systems.*

It should be emphasized that these advantages are all situational and depend on the specifics and context of each project and circumstance. None are inherent or guaranteed.

Balanced against these potential advantages, Flyvbjerg (2014) has identified ten adverse performance traps that many megaprojects all too easily fall into. They include:

1. The long planning and delivery horizons typical of megaprojects exacerbates risks of physical and financial underperformance;
2. Megaprojects are often led by planners and managers lacking "deep domain" experience, adding to the frequency of staff turnover;
3. Public and private megaproject stakeholders may have conflicting interests that are not resolved by contractual documents;
4. Megaproject technologies and designs are often viewed as "one-offs," which impedes learning from the results of other projects;

5. Many megaprojects do not initially undergo a rigorous alternatives analysis, resulting in the wrong technology or scale or scope of project being selected;
6. Because of the large sums of money involved in delivering megaprojects, principal-agent and rent-seeking behavior are common, as is optimism bias;
7. The megaproject scope or ambition may change over time;
8. Megaproject planners and managers systematically underestimate the potential for low likelihood-but-extremely adverse "black swan" events;
9. Megaproject planners, managers, decision-makers and contractors don't include adequate time or budgetary contingency provisions in project contracts; and;
10. As a result, internal and external misinformation becomes the norm throughout the megaproject development and decision-making process.

Avoiding these traps, Flyvbjerg is careful to note, is a matter of humility, awareness, knowledge, foresight, and careful monitoring and evaluation throughout the megaproject planning and delivery process.

Megaprojects and Megacities: The Intersection of Need, Opportunity and Capacity

To the degree that their advantages can be realized and their pitfalls avoided, megaprojects are a natural fit for large and growing urban areas. There are numerous political, economic and physical reasons why this is the case:

- Urban megaprojects have the potential to organize future urban land use and development patterns in a more orderly, productive, easier to serve, and less chaotic manner. *This is especially true for urban transportation and water megaprojects.*
- Big cities are more prone to the occurrence of negative externalities like congestion and pollution which carefully planned megaprojects have the capability to ameliorate. *This is especially true for fast-growing megacities with weak environmental regulations and few public transportation options.*
- There is typically more investment capital available to finance megaprojects in larger or faster-growing cities. *This is especially true in North America and Europe with their more developed investment banking systems.*
- Big and faster-growing cities can more easily retain and transfer the knowledge gained building one megaproject to later applications. *This is especially true in Asia and Latin America, where copying successful practices from other places is more widely accepted.*
- As cities grow outward and upward, inexpensive land becomes more valuable. Anticipating this trend, megaproject planners can acquire land at a lower cost at the beginning of the urban growth cycle, and then recover additional revenues when sites are subsequently developed. This notion of "value capture" was first put forward by economist Henry

George in 1879 as a land value tax. *This is especially true in North America and Europe with their more developed systems of land taxation.*

- Political officials in big cities are often looking to advance to national prominence and overseeing the development of a successful megaproject is one way to do so.
- National (or international) funding is more likely to flow for megaprojects in large and/or fast-growing cities. *This is especially true in developing countries or those with primate cities that serve as migration hubs.*

As Table 1 shows, there is no shortage of global megacities. According to the United Nations Department of Economic and Social Affairs (UN DESA), as of 2018, there were 34 global "urban agglomerations" with more than 10 million residents[1], which is the number commonly used by demographers to identify megacities. Of these 34, twenty-one are in Asia, four are in South America, three are in Africa, three are in Greater Europe[2], and three are in North America. Compared by country, China has the most megacities with six, India follows with five, and Brazil, Japan, Pakistan and the United States follow with two each.

Not all global megacities are currently fast-growing. Of the world's 34 megacities, 10 grew at an average annual rate of three percent or more between 2000 and 2018; 8 grew at an average annual rate of between two and three percent; 6 added population at an average annual rate of between one and two percent; and 10 grew at an average annual rate of less than one percent. Of the 18 megacities currently growing annually be two percent or more, 11 are in China, India and Pakistan. At the opposite extreme, of the 10 megacities currently growing at an average annual rate of less than one percent, 7 are in Japan, North America, or South America.

Need and opportunity are one thing; financial capacity is quite another. Based on their current prosperity levels, many global megacities would find it difficult to finance megaproject construction of any kind. According to World Bank statistics, 14 of the 34 megacities listed in Table 1 have a current per capita gross domestic product (GDP) below $10,000 (as measured in nominal US dollars, and not adjusted for purchasing power parity). These lower-tier megacities are mostly located in India, Pakistan or Africa, and without substantial national government or international assistance, would find it difficult to fund any megaproject effort.

There are another eight megacities, mostly located in Asia or Latin or South America with a per capita GDP between $10,000 and $20,000 ($US). Depending on its cost, its user base, and how it was financed, most of these eight could reasonably afford to take on a major public transportation megaproject, and indeed, some already have. Depending on their current debt levels, the remaining 12 megacities listed in Table 1, each with a per capita GDP level in excess

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[1] Including Seoul, with 9,963,000 residents as of 2018.

[2] Including Russia and Turkey.

of $20,000, should all have the financial capacity to take on one or more large-scale projects as they deem appropriate.

There is of course no rule limiting megaprojects to megacities. Depending on their current levels of prosperity and debt there are countless other cities around the globe that easily have the capability to fund megaproject construction. For them, the issue is not fiscal capacity, but wisdom.

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Table 1: Urban Agglomerations (Megacities) with More Than 10 Million Residents in 2018 : Sorted by Population, Growth Rate, and Prosperity

Megacity	Country	2018 Population (millions)[1]	Megacity	Annualized Population Growth Rate, 2000-2018 [2]	Megacity	GDP per capita (US$) [3]
Tokyo	Japan	37.5	Kinshasa	4.3%	Los Angeles	$67,763
Delhi	India	28.5	Lahore	4.2%	Tokyo	$66,763
Shanghai	China	25.6	Bangalore	4.1%	New York City	$65,240
Sao Paulo	Brazil	21.7	Dhaka	3.6%	Paris	$63,510
Mexico City	Mexico	21.6	Chongqing	3.6%	Osaka	$40,447
Cairo	Egypt	20.1	Tianjin	3.6%	Seoul	$38,352
Mumbai	India	20.0	Lagos	3.5%	Shenzhen	$29,498
Dhaka	Bangladesh	19.6	Shenzhen	3.4%	Beijing	$23,808
Beijing	China	19.6	Shanghai	3.3%	Shanghai	$22,779
Osaka	Japan	19.3	Delhi	3.1%	Guangzhou	$22,676
New York City	USA	18.9	Bogata	2.9%	Moscow	$22,060
Karachi	Pakistan	15.4	Guangzhou	2.7%	Mexico City	$20,000
Buenos Aires	Argentina	15.0	Bangkok	2.6%	Sao Paulo	$16,535
Chongqing	China	14.9	Chennai	2.6%	Bangkok	$15,800
Istanbul	Turkey	14.8	Karachi	2.5%	Tianjin	$13,985
Kolkata	India	14.7	Cairo	2.2%	Lima	$13,397
Lagos	Nigeria	13.5	Beijing	2.1%	Istanbul	$12,714
Metro Manila	Philippines	13.5	Lima	2.0%	Mumbai	$11,890
Rio de Janeiro	Brazil	13.3	Metro Manila	1.7%	Rio de Janeiro	$11,032
Tianjin	China	13.2	Istanbul	1.7%	Chongqing	$10,720
Kinshasa	DR Congo	13.2	Sao Paulo	1.4%	Buenos Aires	$9,122
Guangzhou	China	12.6	Mumbai	1.2%	Jakarta	$8,780
Los Angeles	USA	12.5	Moscow	1.1%	Metro Manila	$8,482
Moscow	Russia	12.4	Buenos Aires	1.0%	Chennai	$8,470
Shenzhen	China	11.9	Rio de Janeiro	0.9%	Kolkata	$8,430
Lahore	Pakistan	11.74	Mexico City	0.9%	Delhi	$7,800
Bangalore	India	11.44	Kolkata	0.6%	Dhaka	$7,712
Paris	France	10.9	Paris	0.6%	Bangalore	$7,110
Bogata	Columbia	10.58	Jakarta	0.5%	Bogata (Columbia)	$6,425
Jakarta	Indonesia	10.52	Tokyo	0.5%	Karachi (Pakistan)	$4,292
Chennai	India	10.46	New York City	0.3%	Lahore	$3,144
Lima	Peru	10.39	Los Angeles	0.3%	Cairo (Egypt)	$3,057
Bangkok	Thailand	10.16	Osaka	0.2%	Kinshasa (Congo)	$2,279
Seoul	Korea	9.96	Seoul	0.0%	Lagos (Nigeria)	$2,200

Sources:

1. United Nations Department of Economic and Social Affairs. (2019)."World Urbanization Prospects, The 2018 Revision"
2. 2000 population estimates downloaded from: https://www.macrotrends.net/cities/20119
3. downloaded from: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

2. Research Questions and Approach

Four Research Questions

The purpose of this book is to answer four sets of questions about the practice of urban megaproject planning across the globe. The four sets of questions include:

1. What is the current state-of-practice with regard to urban megaproject planning, financing, and project management? Why do some megaprojects succeed and others fail?
2. Does the state of megaproject practice differ substantially across megaproject types (e.g., rail transportation vs. bridges and tunnels vs. airports vs. urban redevelopment projects)?
3. Is the state of practice improving? What has been learned in recent years? What remains to be learned?
4. Are some governance and decision-making systems better than others at megaproject planning and delivery?

A Case Study Approach

To answer these questions we will take a deep dive into the planning and delivery histories of a series of megaproject case studies. In each case, we will identify the problem or issue the megaproject was intended to address, how and why it was conceived of in the form it was, how it was planned, which planning hurdles it had to jump over, how it was financed, the project management systems used to deliver it, and the unexpected challenges it encountered along the way.

As with any research project that relies on case studies, the ultimate usefulness of the results will depend on which case studies are chosen and why. We identified eleven criteria to help in this regard. They include:

1. <u>Contemporary relevance</u>: In order to identify practice lessons relevant to today's world, the case studies should be recent. That is, they should have been started or completed after 2010.
2. <u>An urban orientation</u>: With most of the world's projected population growth expected to occur in urban and metropolitan areas, the case studies should have an urban focus.
3. <u>Diverse project types</u>: Identifying generalizable lessons requires including a diversity of megaproject types. Based on a quick survey of recent global megaprojects, we identified six types megaprojects to consider in greater detail: (i) urban rail and bus megaprojects; (ii) bridge and tunnel megaprojects; (iii) airport megaprojects; (iv) urban development megaprojects; (v) urban park megaprojects; and (vi) renewable energy megaprojects.
4. <u>Geographic representation</u>: Urban megaprojects are typically undertaken in places where they generate sizeable economic or public benefits and where the beneficiaries are able to pay for them. Prior to the end of the 20th century, this meant most megaprojects were

undertaken in Europe or North America. More recently, the geographic center of megaproject activity has shifted to Southeast Asia.

5. <u>Iconic case studies</u>: Megaprojects may merit scrutiny because they are they are regarded by experts or popular opinion to be noteworthy.
6. <u>The public sector in the lead</u>: Government-initiated or funded megaprojects are more apt to generate spillover and multiplier benefits than privately-initiated megaprojects. Since they are also likely to involve more and more diverse stakeholders, public sector-initiated megaprojects also apt to be more controversial than privately-initiated megaprojects. Lastly, government-initiated megaprojects are usually able to tap into more diverse forms of financing than privately-initiated megaprojects.
7. <u>Diverse financing forms</u>: Many megaprojects are still paid for the old-fashioned way via government spending and borrowing, but an increasing number are also making use of public-private-partnerships to bring in alternate and private sector sources of financing.
8. <u>Available documentation and information sources</u>: This turned out to be the hardest criteria to meet. Many megaproject selection, financing and contracting details are never made available to the public, making it difficult to connect decisions to outcomes.
9. <u>Good outcomes, bad outcomes, and everything in between</u>: Sponsors whose megaprojects do not live up to expectations are understandably reluctant to share their experiences. Yet these are precisely the projects that offer the most value in terms of useful lessons.
10. <u>Cause-and-effect narratives</u>: Sometimes megaprojects succeed (or fail) because of luck rather than careful planning and delivery. It was important when choosing case studies to be able to trace project success (and/or failure) back to prior decisions or activities taken or not taken and not just to luck.
11. <u>A diversity of takeaways</u>: Case studies should be chosen for their individual lessons as well as because they fit into a larger and more generalizable narrative about why megaprojects succeed and fail.

Based on these criteria, we identified fourteen case studies to profile in greater detail. They include:

<u>Urban Rail and Bus Megaprojects</u>

1. London Crossrail
2. New Metro Systems in Beijing, Shanghai, Guangzhou and Shenzhen
3. China's National High-speed Rail Network
4. Bus Rapid Transit (BRT) Systems in Six Cities in Latin America and Asia

<u>Bridge and Tunnel Megaprojects</u>

5. Seattle's Alaska Way Tunnel
6. The Hong Kong-Zhuhai-Macau Bridge

<u>Airport Megaprojects</u>

7. Singapore's Jewel Changi Airport
8. The Berlin-Brandenburg Airport
9. The New LaGuardia Airport (New York City

<u>Urban Development Megaprojects</u>

10. London's Canary Wharf
11. HafenCity, Hamburg
12. Songdo International Business District

<u>Urban Park Megaprojects</u>

13. Brooklyn Bridge Park (New York City)

<u>Renewable Energy Megaprojects</u>

14. Five renewable energy projects in the United Kingdom, Morocco, India, the United States, and China

As Table 2 indicates, not every case study meets every criteria. Two case studies, the bus rapid transit (BRT) projects and Brooklyn Bridge Park don't meet the conventional $1 billion megaproject cost threshold but are included because of their size, impact, and importance as global models. Except for the BRT projects, all the case studies were started or finished between 2010 and 2020 or are currently underway.

As intended, the case studies are geographically diverse. Three are in China; two each are in the United States, the United Kingdom and Germany; one is in Singapore; and one is in South Korea. The bus rapid transit (BRT) set of projects includes multiple cities in Latin America and Asia, and the renewable energy set of projects includes locations in the United Kingdom, Morocco, India, the United States, and China. Except for the renewable energy projects, all the case study projects are in or connect to very large cities of global import.

Except for London's Canary Wharf, a public sector agency or publicly-chartered company was the lead sponsor for every case study. A majority of the case studies mix public and private financing sources, often times making use a joint venture arrangement or public-private partnership.

In terms of outcomes, except for the Hong Kong-Zhuhai-Macau Bridge and Songdo in South Korea—both of which have fallen far short of their goals—none of the case studies are total successes or failures. A few, notably HafenCity in Germany, the New LaGuardia Airport in New York City, Singapore's Jewel Changi Airport, and China's high-speed rail network system come reasonably close to being unambiguous successes, but even they have experienced unexpected ups and downs. The majority of the case studies have had middling or slightly better-than-middling success in terms of reaching their goals and avoiding significant time or cost over-runs.

Of the two projects that are neither failures nor successes, one, London Crossrail is not yet finished, and the other, the new Berlin-Brandenburg Airport has achieved most of its goals but was grossly over-budget and behind schedule. In the cases of China's high-speed rail network and its four urban metro systems, the projects as a whole have been notably successful even as individual lines or corridors have suffered from lagging performance. The final chapter of this volume goes into much greater detail regarding the determinants of each case study's successes and shortcomings.

Except for the five renewable energy projects—which are presented in summary form—all of the case study projects are characterized by strong cause-effect narratives, meaning that it is possible to trace the effects of initial project planning, financing, or project management decisions on each project's ultimate outcomes. Similarly, all of the case study projects offer useful, timely and generalizable lessons to prospective megaproject sponsors confronting comparable challenges in other locations.

Chapters 3 through 16 summarize each of the case studies in greater detail. Chapter 17 takes a closer look at why particular case studies have performed better or worse and summarizes their many lessons. Table 3, below, presents and compares each case study in brief.

Table 2: Selecting Megaproject Case Studies: Matching Projects with Criteria

Megaproject Type	Megaproject Case Study	Current: Started, Underway or Finished After 2010	Urban Orientation	Geographically Variety (Location)	Iconic or Emblematic Case Study	Public Sector in the Lead	Diverse Financing Forms	Documentation Publicly Available	Diversity of Outcomes	Cause-effect Narrative	Project-specific and Generalizable Takeaways
Rail and Transit Projects	London Crossrail	X	X	United Kingdom	X	X	X	X	X	X	X
	Beijing, Shanghai, Guangzhou & Shenzhen Metro Systems	X	X	China	X	X	X		X	X	X
	China's 35,000-km High Speed Rail Network	X	X	China	X	X			X	X	X
	Bus Rapid Transit (BRT) in 6 Latin America & Asian Cities		X	Latin America & Asia	X	X		X	X	X	X
Bridge & Tunnel Projects	Seattle Alaska Way Tunnel	X	X	USA	X	X		X	X	X	X
	Hong Kong-Macao-Zhuhai Bridge	X	X	China/Hong Kong	X	X			X	X	X
Airport Projects	The Jewel at Singapore Changi Airport	X	X	Singapore	X	X	X	X		X	X
	Berlin Brandenburg Airport	X	X	Germany	X	X		X	X	X	X
	LaGuardia Airport Terminal B Reconstruction	X	X	USA	X	X	X	X		X	X
Urban Development Projects	London Canary Wharf	X	X	UK	X			X	X	X	X
	HafenCity Hamburg	X	X	Germany	X	X	X	X	X	X	X
	Songdo International Business District	X	X	S. Korea	X	X	X		X	X	X
Other	Brooklyn Bridge Park (New York City)	X	X	USA	X	X	X	X	X	X	X
	Diverse Renewable Energy Projects	X		Asia, Africa, UK, USA	X	X	X				X

Table 3: List and Selected Characteristics of Case Study Megaprojects

Megaproject Type	Megaproject	Project Sponsors	Primary Rationale	Year initiated(I)and/or approved (A) or funded (F)	Time to completion from approval or funding	Capital Cost (US$)	Financing Form	Operating or Principal Revenue Sources
Rail and Transit Projects	London Crossrail	UK Department for Transport (Daft) and Transport for London (FL)	Urban congestion relief and enhanced mobility, economic development	2005 (I); 2008 (F)	13 years and counting	$26B and counting	Combination of government funding and value-capture business taxes.	Transit fares and business tax revenues
	Beijing, Shanghai, Guangzhou & Shenzhen Metro Systems	City governments of Beijing, Shanghai, Guangzhou & Shenzhen	Urban congestion relief and enhanced mobility	Beijing 1971; Shanghai 1993; Guangzhou 1997; Shenzhen 2004	3-4 years per metro line	$80M to $200M per kilometer of track	A combination of national and local government funding with a few PPP-financed lines.	Transit fares and value capture revenues (Shenzhen)
	China's 35,000-km High Speed Rail Network	China's Ministry of Railroads, superseded in 2014 by the China National Railways Administration	Improved intercity mobility, regionally balanced economic development	2004	First HSR line opened in 2008	$17M to $21M per kilometer (World Bank 2013)	Joint ventures formed by the China National Railways Administration, provincial governments, and some HSR operators.	Passenger fares and government subsidies
	Bus Rapid Transit (BRT) in 6 Latin America & Asian Cities	City governments and public transport agencies in Curitiba, Quito, Bogotá, Jakarta, Seoul, and Guangzhou	Congestion relief and enhanced mobility	Curitiba 1974; Quito 1995; Bogotá 2001; Jakarta 2004; Seoul 2006; Guangzhou 2010	1-3 years per BRT corridor	$10 to $15M per kilometer	Mixture of financing sources including national and state government grants and loans, and city and public transit agency borrowing.	Passenger fares and government subsidies
Bridge & Tunnel Projects	Seattle Alaska Way Tunnel	Washington State Department of Transportation, City of Seattle. Port Authority of Seattle	Replace an earthquake-vulnerable viaduct with a safer and less intrusive facility	2003 (I); 2011 (A)	8 years	$3.35B	State funding supplemented by tolls to repay Port Authority bonds	State revenues and tolls
	Hong Kong-Macao-Zhuhai Bridge	Governments of Hong Kong and Macao Special Administrative Regions (SARs)and City of Zhuhai	Regional economic development	2009	9 years	$18.8B	Partnership between Hong Kong, Macau, and Guangdong Province, backed by toll revenues	Tolls
Airport Projects	The Jewel at Singapore Changi Airport	Singapore Civil Aviation Authority (CAAS), Changi Airport Group (CAG), CapitaLand	Create a world-class experience that would cement Changi's reputation as the world's finest destination airport	2014	4.5 years	$1.4B	Joint venture between the government-owned Changi Airport Group (CAG) and CapitaLand	Concessionaire rents and payments; passenger service fees
	Berlin Brandenburg Airport	Flughafen Berlin Brandenburg GmbH (a partnership of the state governments of Berlin and Brandenburg (37% each), and the German government (26%).	Expand and modernize airport capacity	2003 (I); 2006 (A)	14 years	$6.5B	Debt and bank loans backed by the states of Berlin and Brandenburg	Gate leases, landing fees, concessionaire rents and payments, cargo revenues
	LaGuardia Airport Terminal B Reconstruction	Port Authority of New York and New Jersey, LaGuardia Gateway Partners (LGP)	Modernize and expand airport capacity	2010 (I); 2015 (A)	7 years (Terminal B remains continuously open)	$4B	PPP between Port Authority (debt financing) and LGP (debt and equity)	Gate leases, landing fees, concessionaire fees, and cargo revenues

Table 3 (continued): List and Selected Characteristics of Case Study Megaprojects

Megaproject Type	Megaproject	Project Sponsors	Primary Rationale	Year initiated(I)and/or approved (A) or funded (F)	Time to completion from approval or funding	Capital Cost (US$)	Financing Form	Operating or Principal Revenue Sources
Urban Development Projects	London Canary Wharf	Olympia and York (1987-1992), The Canary Wharf Group (1995-), The London Docklands Development Corporation (1981-1997)	Create a second & modern London CBD in an abandoned port area	1987	First building opens in 1991, development is ongoing		Commercial buildings are privately financed. Transportation and public realm improvements are publicly funded.	Commercial rents; transit fares for Docklands Light Rail (DLR)
	HafenCity Hamburg	HafenCity Hamburg GmbH (HHG), Hamburg City Government	Create a modern and sustainable mixed-use district in an abandoned port area	1997 (I); 1998 (F)	First building completed in 2002, development is ongoing	$2.8B public funding; $10B private funding	Combination of public funding (public infrastructure), land sales, and city-backed debt.	Property assessments
	Songdo, Korea	City of Incheon, Gale International, POSCO E&C	Develop a high-tech international business district near Incheon Airport	1997 (I); 2001 (A)	First building opens in 2005, development is ongoing	$50B (projected)	PPP between City of Incheon (public revenue), Gale International and POSCO E&C (private equity and debt)	Land and building sales and rental income
Other	Brooklyn Bridge Park (New York City)	Brooklyn Bridge Park Development Corporation (BBPDC), New York City Mayor's Office, Brooklyn Borough President's Office	Convert abandoned docks into a financially self-sustaining park and public amenity	1997(I); 2005 (A);	10 years (Phase I); 15 years (final)	$300M	Public development corporation able to borrow and issue debt	Commercial property rents and fees
	Diverse Renewable Energy Projects	Various national governments and public and private energy companies	Develop a financially-beneficial renewable energy facility	various years	Projects typically take 3-5 years to complete	varies	Typically a PPP between a government entity which provides revenue guarantees and private investors who provide equity and debt.	Rate payers

3. Urban and Intercity Rail & Transit Projects I: London Crossrail

Chapter Author: John Landis

Project Sponsors: UK Department for Transport (DfT), Transport for London (TfL)

Summary Description: Originally scheduled to open in 2018, and featuring 21 km of tunneling under central London, Crossrail, a 117 km (73 mile) rail line connecting Greater London from east to west is the largest public infrastructure project undertaken in the United Kingdom since the Chunnel rail link was completed in 1994. Approved by Parliament in July 2008 at a cost of £15.9 billion after 30 years of on-again-off-again planning, Crossrail was advertised by its government and private sector sponsors as essential to maintaining London's global financial leadership. Once completed, now most likely in 2022, Crossrail trains will run in each direction at speeds up to 140 kph and frequencies up to 24 trains per hour during the morning and evening peak period. This will enable passengers traveling across central London from Paddington Station to Whitechapel to reduce their peak period travel time to 13 minutes (from the current 39 minutes) and those going on to Canary Wharf to cut an additional 7 minutes off their trip time.

Planning and Approval Process: A plan for a single high-speed underground/above-ground train line connecting Central London to its eastern and western suburbs was first proposed in 1974. Two later proposals in 1989 and 1991 were terminated for budgetary reasons. The idea was resurrected in 2001, and after several rounds of financial review, was finally put before Parliament in May 2005. Royal assent (approval) was given in July 2008, and construction began the following May.

Certification and Due Diligence: Early cost-benefit assessments indicated the project as conceived would be unable to cover its construction costs. Later revisions resulted in reducing the number of suburban spurs, slightly reducing construction costs; and better accounting for increases in London area business employment and productivity. The net effect of these changes was to increase the project benefit cost ratio from 1.3:1 to 2.6:1.

Project Financing: 33% of Crossrail's initial £14.8 billion cost was to be provided by the UK government; 28% by a supplemental tax assessment on nearby businesses; 16% from transfers from Network Rail; and 13% from TfL's capital budget. The remaining 10% was to be drawn from a variety of city, business, and developer contributions.

Construction/Delivery Issues: Tunneling operations were completed essentially on schedule in 2015. Problems emerged soon thereafter with the contractor-supplied train and passenger control systems at several central London Crossrail stations. Fixing these problems would add 3.5 years and £4.2 billion to Crossrail's completion schedule and budget. These problems were compounded by turnover among senior project executives and managers.

Key Takeaways: In order to complete Crossrail on time, project leaders hired too many contractors who had little experience coordinating their efforts or implementing new technologies. When persistent problems emerged with the automated train control technology, there was no clear backup or contingency plan. The project management structure was exceedingly complex, and senior project managers were too focused on implementing a new "open innovation" project management model rather than on ensuring timely project delivery.

4. Urban and Intercity Rail & Transit Projects II: Beijing, Shanghai, Guangzhou and Shenzhen Metro Systems

Chapter Authors: Zhong-Ren Peng, Kaifa Lu, Mengyi Jin, Xinghang Zhu and John Landis

Primary Sponsors: Except for a few Beijing and Shenzhen lines developed in partnership with Hong Kong's MTR corporation, all metro lines in China are owned and operated by municipal governments as required by China's ruling State Council.

Summary Description: No country in history has been more active building metro lines in more cities than China. With but six metro lines in service in four cities in 2000, China accounted for just 3.7 percent of the world's metro lines and less than 4.0 percent of its metro system length. Twenty years later, with 214 metro lines operating in 41 cities, China accounts for 30 percent of the world's metro lines and 23.9 percent of its metro system length. Five cities currently stand atop China's metro leader board based on system size and ridership: Shanghai, with 18 lines extending 743 km; Beijing, with 24 lines extending 703 km; Chengdu, with 12 lines extending 518 km; Guangzhou, with 13 lines extending 492 km; and Shenzhen, with 11 metro lines extending 411 km. Shanghai, with 2.8 billion passengers in 2020 is also the world's top-rated metro system in term of total ridership, followed by Guangzhou (ranked fourth with 2.4 billion passengers in 2020), Beijing (ranked fifth with 2.3 billion passengers in 2020), and Shenzhen (ranked tenth, with 1.6 billion passengers in 2020.)

Chinese transportation planners organize China's metro-building activities into three periods. The first was between 1965 and 1999 and involved a handful of high-profile Chinese cities (including Beijing, Tianjin, Shanghai and Guangzhou) each building one or two subway lines to essentially test the market for metro service. A second metro-building period extended from 2000 to 2010 and involved several fast-growing first and second-tier Chinese cities adopting a metro- centric strategy in response to worsening traffic congestion problems. Metro construction activity during this second period was given a further push in 2008 as part of China's infrastructure investment response to the Global Financial Crisis. The third and current phase has seen the construction of new metro systems expand to include most China cities with two million or more residents. This follows from the successes of prior metro investments attracting significant ridership, as well as from national policy imperatives intended to redistribute China's rural-to- urban migration flows away from a few high-flying coastal cities and toward the entire Chinese urban system; to re-orient China's infrastructure investment priorities toward clean energy projects that reduce carbon emissions.

Planning and Approval Process: Every proposal to build or extend a new metro line in China must first be listed in a city's government-approved urban metro transit network plan.

Certification and Due Diligence: Proposed metro projects must first be approved on technical and planning grounds by China's National Development and Reform Commission (NDRC) and then on political and budgetary grounds by China's ruling State Council. Proposed metro projects are not subjected to formal economic feasibility tests.

Project Financing: Beijing and Shanghai rely on government and state-owned banks to finance new metro lines. Guangzhou mostly funds its metro lines out of municipal taxes and land sales. Shenzhen combines government and municipal financing with "R+P" (Rail + Property), and special assessment scheme in which rising nearby property values provide revenues to repay municipal and private investors. that for their financing33% of Crossrail's initial £14.8 billion cost was to be provided by the UK government; 28% by a supplemental tax assessment on nearby businesses; 16% from transfers from Network Rail; and 13% from TfL's capital budget. The remaining 10% was to be drawn from a variety of city, business, and developer contributions.

Construction/Delivery Issues: All four cities (and especially Beijing) have worked to standardize their construction procedures and rolling stock procurement practices across multiple lines. This has sped up completion, delivery and testing times, and helped reduce incremental construction costs.

Operating and Asset Management Issues: Metro fares in China are generally set below (average) per passenger operating costs, so congestion is an ongoing problem on some lines while others (including some lower-ridership lines in Beijing and Shanghai) continue to lose money. This requires higher-ridership metro lines to subsidize lower-ridership lines. Starting in 2014, all four systems converted from flat fare systems to distance-based fares.

Key Takeaways: China's approach of separating the technical evaluation process from political approvals—the former handled by the National Reform and Development Commission and the latter by China's ruling State Council—provides a level of decision-making consistency and continuity not generally present in systems in which a single entity evaluates both technical and political merit. Chinese cities also seem to be accomplished at organizing contractor selection and project management practices as to be able to undertake multiple metro construction projects simultaneously In terms of system design and planning, the overriding lesson is that standardizing route configurations and station placement practices across an entire metro system (as in Beijing) yields economies of scale benefits in terms of reducing planning and construction costs (and construction times as well), but also has significant drawbacks in terms of not being able to match metro service characteristic to the particular land use and economic geography conditions of individual cities.

5. Urban and Intercity Rail & Transit Projects III: China's High-Speed Rail Network

Chapter Authors: Zimring Liu and John Landis

Primary Project Sponsors: China National Railways Administration (owner and regulator), China Railways Corporation (owner), and China Railways Construction Corporation (builder).

Summary Description: Since 2005, China has built 30,000 km of HSR track, more than the rest of the world combined. 2.3 billion passengers traveled by HSR within China in 2019, almost four times as many who traveled by air. Every one of China's 50 largest cities is connected to its HSR network, and more than 3,000 HSR trains depart daily from a Chinese city. Early on, China's HSR system relied on trains designed and engineered in Europe, but in the intervening years, China has developed the world's largest and most advanced HSR train manufacturing capabilities. Today, HSR technologies developed in China are in use around the world, including in Turkey, Russia, and Southeast Asia.

China's HSR network can be categorized by speed, service category, and class. In terms of speed, China's 26 HSR EMUs (or electromotive units) fall into two broad categories: 300-to-350 kph "G-class" EMUs, which are used for long-distance service and where passenger demand requires more frequent departures; and 200-250 kph "D-class" and "C-class" EMUs, which are used on shorter and lower demand routes.

In terms of service category, China's HSR system is organized into *main line* routes, such as the Beijing-to-Shanghai line, which connect large cities between provinces; *regional* routes, such as the 100-km Quizhou-to-Behai line, which connect medium-sized cities; and *Inter-city* routes, such as the 115-km Beijing-Tianjin line, which connect nearby large cities to each other. Because of their longer distances, mainline routes mostly rely on 350 kph "G-class" EMUs, while the shorter distance regional and intercity routes make greater use of "C" and "D-class" trains.

China's original eight HSR routes were organized into four north-south or "vertical" corridors, and four east-west or "horizontal" corridors. Three of the original vertical corridors had their northern terminus in Beijing, and two of the original horizontal routes terminated in Shanghai. In 2016, China's National Development and Reform Commission (NDRC) announced plans to expand the original "4 + 4" mainline HSR network into a new "8 + 8" network comprised of eight north-south and eight east-west corridors. The updated system also introduced the idea of HSR "passageways," consisting of two or more HSR lines connecting the same set of cities.

China's strategy of linking every major city by HSR has paid off in terms of ridership. Between the launch of HSR service in 2008 and 2019, its share of domestic passenger travel in China (measured in terms of passenger-kilometers to account for different trip lengths) has grown from 0.1% to 24%. Much of this increase has come at the expense of long distance highway travel, which has seen its inter-city passenger-kilometers volumes decline from 1,114 billion in 2011 to 886 billion in 2019, and its passenger-kilometer mode share fall from 43% to 28%.

Planning and Approval Process: China's original "4 + 4" HSR network plan, as proposed by the Ministry of Railways (now the National Railways Administration) in consultation with the National Development Reform Commission (NDRC) was approved by the ruling State Council in 2004. An accelerated version of the plan was approved in 2008 to respond to the Global Financial Crisis, and the current "8 + 8" plan was approved in 2016. HSR rail alignments and station locations are determined by the NRA in consultation with provincial and city governments.

Certification and Due Diligence: All HSR design and engineering features must conform to preset standards and specifications established by the National Railway Administration. Construction of individual HSR projects is coordinated nationally so that specialized construction equipment and labor can move from project to project as needed. The design and manufacturing specifications for all HSR trainsets and signaling equipment are also standardized. The individual railway authorities that operate China's HSR lines are limited in their choice of trainset designs to those approved by China Railway Rolling Stock Corporation (CRRC), which also oversees all trainset manufacturing activities. Individual HSR lines are not subjected to formal economic feasibility tests.

Project Financing: HSR projects in China are financed using a joint venture (JV) structure that brings together the CRC, one or more of the CRC's subsidiary regional administrations (RA), various provincial or city governments, and the occasional private or social capital investor. Once legally established, the JV supervises design and construction activities, negotiates with one or more railway operating companies to provide service, arranges for additional financing as needed, and serves as the legal owner of record of all facilities and equipment. Exactly how each JV is structured is determined on a case by case depending on the type of HSR line and on how much financing each JV partner is willing to bring to the deal. The CRC and its regional subsidiaries typically have larger roles in main line JVs, while provincial and local governments usually dominate regional and inter-city JVs.

Construction/Delivery Issues: The Ministry of Railroads (MOR) realized early on that the only way to meet its ambitious HSR construction budget and schedule would be to standardize every aspect of the HSR design, construction, and procurement process, starting with right-of-way and track specifications, and including bridge and tunnel designs, power supply systems, signaling and communications equipment; as well as the trainsets themselves. Rather than contract out EMU manufacturing, the MOR established five EMU manufacturing plants at Qingdao, Tangshan, Changchun, Jiangmen, and Nanjing, each to be administered by the China Railway Rolling Stock Corporation(CRRC). To manage the construction process, each financing joint venture (JV) typically hires a Railway Design Institute, to finalize the project design; contractors, who do the actual construction work; and an engineering supervisor, who manages the day-to-day work of the contractors, and ensures that the project meets all quality and safety requirements. JV's are also required by law to use a competitive tendering process to select all contractors, suppliers, and supervising managers from a list of pre-certified contractors. These many standardization efforts have resulted in significant cost savings. According to a 2018 cost comparison study by the European Court of Auditors, the cost of building a 350 kph HSR line averaged out to about 139 million yuan (or US$ 20.6 million) per kilometer. Costs declined with line speed, falling to 114 million yuan ($16.9 million) per kilometer for 250 kph lines, and to 104 million yuan ($15.4 million) for 200 kph lines. Correcting for inflation and purchasing power parity, China's HSR construction costs were about forty percent lower than in Europe

Operating and Asset Management Issues: Drawing on available revenue and operating cost data, World Bank analysts modeled the aggregate financial performance of China's HSR system in 2019 using the prevailing access charge model, 2015 passenger volumes and fares as inputs, a JV debt-to-equity ratio of 1.0, and a debt repayment interest rate of five percent with a maturity of 20 years. All of China's 300-350 kph lines met the World Bank's minimal operating and maintenance cost passenger threshold as of 2019, but only eight met the additional interest cost threshold, and just five could cover their principal repayments. Only five of the 16 200-250 kph lines were able to cover their operating and maintenance costs as of 2019, and none were able to fully cover their interest payment costs. All told, World Bank analysts estimated the 30-year internal rate of return to be 5.5%.

Key Takeaways: China's experiences building and operating what is by far the world's biggest HSR system offer numerous takeaways to other countries about the benefits of investing in HSR, and more broadly, about how best to undertake transportation megaprojects. Among the key lessons: (i) Being a pioneer isn't important if you can take advantage of others' experiences; (ii) There is no substitute for a long-term commitment from the top; (iii) Standardization has its benefits; (iv) Government-sponsored joint ventures are a useful alternative to the usual public-private-partnership financing model; (v) When properly located, connected and priced, HSR service can quickly attract a large ridership base; and (vi) Not all HSR services must operate at very high speeds.

6. Urban and Intercity Rail & Transit Projects IV: Bus Rapid Transit (BRT) Projects in Six South American and Asian Cities

Chapter Authors: Erik Vergel-Tovar and John Landis

Summary Description: First implemented in its modern form in 1974 in Curitiba (Brazil), Bus Rapid Transit (BRT) combines the separated right-of-way, fixed stations and higher speeds of urban rail systems with the lower capital and operating costs and routing flexibility of urban buses. As of this writing, some 180 cities, primarily in Latin America and Asia, have initiated BRT service in more than 300 BRT corridors; with most having done so since 2000.

BRT's chief advantage lies in its lower capital costs, especially compared to light-rail. Based on a sample of 42 BRT projects, 19 light rail projects, and 26 subway/metro projects, the non-profit Institute for Transportation Development and Policy (ITDP) estimated the per kilometer capital cost of building a BRT line at $10.1 to $11.5 million (in 2013 US$). This is between one-eighth and one-fortieth the cost of building a fixed-rail transit line. BRT lines are also less expensive to operate than light-rail or metro lines. Based on a limited sample of transit systems for which detailed operating cost information is available, the typical BRT line cost about $4.73 (in 2000 US$) per vehicle revenue mile to operate. This compares to $12.22 per vehicle revenue mile for light rail service and $8.54 for subway service.

In addition to looking at the broader BRT experience, this chapter describes three BRT case studies in Latin America and three in Asia. The Latin America cases include Curitiba (Brazil), Quito (Ecuador) and Bogotá (Colombia). The Latin America BRT experience informed subsequent BRT projects elsewhere in the world, including those in Jakarta (Indonesia), Seoul (South Korea), and Guangzhou (China).

BRT Configurations and Planning Processes: Broadly speaking, most BRT networks are organized into one of three route configurations: (i) trunk-only, also called closed systems, in which BRT routes are largely independent of local bus routes; (ii) trunk-feeder service, in which local bus routes feed into BRT trunk lines at key points; and (iii) direct-service, also called open systems.

The BRT planning process typically follows one of two models. The first involves a government agency undertaking a citywide comprehensive transportation or urban mobility plan that identifies the transportation needs of different groups and proposes an appropriate mix of facility investments and service improvements to meet those needs. Among the case study cities, this was the approach taken in Bogota and Jakarta with their TransMilenio and TransJakarta BRT systems. The other BRT planning model takes a more incremental and corridor-centric approach. This typically involves city officials wanting to respond to worsening traffic congestion levels in one or two urban travel corridors.

Financing Sources: Some transit operators have been able to pay for BRT service out of their existing capital budgets. Others have required new infusions of equity or debt. In a study of BRT financing in nine countries, ITDP found on-budget funding (i.e., equity) to be the most common source of system financing, followed by commercial bank loans and loans from multi-national development agencies like the World Bank. Among transit systems that rely on debt financing to pay for BRT service, debt service costs can account for upward of 30 percent of operating deficits. As a rule, BRT is more dependent on equity and debt financing than are urban rail systems, which were more likely to receive grants and forgivable loans from national or state governments.

Market Performance and Ridership: BRT service is mostly used by commuters, so how well a system performs in terms of usage and ridership will depend on its relative speed compared to other commuting modes. In their review of 11 Latin American BRT systems, Hidalgo and Graftieaux (2008) found that BRT service increased average travel speeds by between 14.5 km/h and 26 km/h, depending on the quality of busway and how quickly riders can get on and off BRT vehicles.

In terms of ridership, BRT has performed best in Latin American cities, principally because of their monocentric urban forms that are better served by exclusive lanes for long trips, severe and persistent traffic congestion problems and less-than-reliable conventional bus services. In Asia and Latin America, most BRT passengers previously used another form of public or para-transit. In Australia, by contrast, researchers found that as many as 40% of new BRT commuters previously drove (Levinson, Zimmerman, Clinger, Rutherford, et al., 2002) Combining ridership with supply-side data, Cervero (2013) found that Latin American BRT systems averaged more than 2 ½ times as many weekday riders per kilometer of corridor length as Asian systems and more than 5 times as many as North American systems.

Key Takeaways: With BRT systems currently up and running in more than 180 cities worldwide, there is ample opportunity to observe what works when it comes to implementing BRT service, as well as to make more general observations about the efficacy of BRT-like megaprojects. Major takeaways include:

- Creating learning chains. Quito's BRT planners learned from Curitiba's BRT experience; Bogotá officials learned from both Curitiba and Quito; and BRT planners in Jakarta, Seoul, and Guangzhou all learned from Bogotá. This type of learning chain is rare in the megaproject world and should be emulated more widely.
- Focus on meeting daily travel needs instead of "silver bullet" technologies. Transportation megaproject project sponsors are overly focused on innovative technological solutions rather than on cost-efficient approaches to moving large numbers of transit-dependent travelers.
- The virtues of managed competition. The managed competition model provides significant cost and contracting advantages when government regulators and private transit operators both think in terms of transit service corridors rather than individual lines or services.

- <u>The importance of entrepreneurial political leadership</u>. Whereas professionals typically think inside the boxes defined by their professions, elected officials must be more entrepreneurial and less bound to conventional wisdoms and practices.

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7. Bridge and Tunnel Projects I: The Seattle Alaska Way (SR 99) Tunnel

Chapter Authors: Molly Riddle and Jan Whittington

Primary Sponsors: Washington Department of Transportation, City of Seattle, Seattle-Tacoma Port Authority.

Summary Description: The Alaska Way Viaduct, a 2.2-mile long elevated highway running parallel to Seattle's waterfront experienced minor damage from the 2001 6.8-magnitude Nisqually Earthquake. Worried that a stronger earthquake could cause the Viaduct to collapse—as happened in Oakland in 1989 to the similarly-designed Cypress Street Viaduct—officials at Washington State's Department of Transportation (WSDOT) began a nearly decade-long process to identify a replacement facility.

The Alaska Way Viaduct Replacement Program (AWVRP) planning process, described in greater detail below, resulted in an agreement by WSDOT and the City of Seattle to replace the Viaduct with a new single-bore, double-decked tunnel that followed a comparable route. Tunneling operations began in June 2013, but were halted six month later when "Bertha," the world's biggest tunnel boring machine hit a long-buried drainage pipe. With no contingency plans in place, Bertha's breakdown caused the project to be delayed by two years. The new Alaska Way Tunnel was finally opened to drivers in February 2019, and the Viaduct was demolished shortly thereafter.

The Viaduct's demolition resulted in 26 acres of land along Seattle's waterfront being made available for public use and redevelopment. In anticipation of this opportunity, Seattle city officials in 2012 adopted a new Waterfront Seattle Concept Plan developed by their landscape architecture and planning consultant, James Corner Field Operations. Intended to be implemented incrementally over a 10+ year period, the plan emphasized public access and use over private redevelopment. Implementation of the plan is ongoing.

Planning and Approval Process: Washington State DOT's initial AWVRP planning process was fairly top-down in its design, resulting in its two recommended replacement alternatives both being rejected by Seattle voters in a March 2007 referendum. Resolving to do better, WSDOT then undertook a more collaborative and stakeholder-based "Partnership Process," which resulted in a 2009 proposal to build a single-bore tunnel. Endorsed by Washington Governor Christine Gregoire and Seattle's City Council (but not by its newly-elected mayor), the single-bore tunnel proposal was approved by Seattle voters in August 2011. The project also required the approval of the Federal Highway Administration which was forthcoming in September 2011.

Certification and Due Diligence: A Draft Environmental Impact Statement (EIS) for the project was approved in October 2010, and a Final EIS was approved in September 2011. As agreed to by Governor Gregoire, state funding for the project was to be limited to $2.8 billion. Since it was being undertaken for safety reasons to replace an existing facility, the project did not require the preparation of a market demand or feasibility study.

Project Financing: Excluding litigation costs stemming from Bertha's breakdown, the AVWRP cost $3.35 million to complete, which was $250 million, or eight percent over its original budget. All cost overruns were born by WSDOT. In terms of individual funding sources, $2.23 billion of the AWVRP's costs were paid for by WSDOT, FHWA provided $0.78 billion, and the Port of Seattle provided $0.34 billion of revenue bond financing. The Port's contribution is to be repaid out of user tolls, which were put in place in November 2019.

Construction/Delivery Issues: The AWVRP construction program was managed by WSDOT. A Request for Qualifications/Request for Proposals (RFQ-RFP) process was used by WSDOT to identify a design-build contractor for the tunnel project. Other than the construction delays caused by Bertha's two year breakdown and repair, the project proceeded on schedule and budget.

Key Takeaways: The AWVRP offers two big takeaways sponsors of similar projects should consider. The first concerns the superiority of a collaborative and stakeholder-based planning process over the more traditional top-down technocratic process, especially in circumstances where government jurisdictions and institutions overlap. The second concerns the need for better contingency planning and budgeting in situations where new or untested construction technologies are to be used.

8. Bridge and Tunnel Projects II: The Hong Kong-Zhuhai-Macau Bridge

Chapter Authors: Anthony G.O. Yeh, Fang Bian, and Jiangping Zhou

Project Sponsors: Guangdong Province, Hong Kong Special Administrative Region, Macau Special Administrative Region

Summary Description: Opened to traffic in October 2018 and located at the entrance of the Pearl River Delta in Southeastern China, the Hong Kong-Zhuhai-Macau (HKZM) Bridge is the longest open-sea fixed structure in the world. Fifty-five kilometers in length, the HKZM Bridge includes three cable-stayed bridges, multiple causeway sections, an undersea tunnel, and four artificial islands. The HKZM Bridge's dual 3-lane carriageways are designed to accommodate cars and trucks at an average travel speed of 100km/h. Properly maintained, the HKZM Bridge is engineered to remain in service well into the 22nd century. Paid for principally by the governments of China and Hong Kong, the HKZM Bridge cost 127 billion CNY (US$ 18.8 billion) to build.

History: The prospect of building a bridge that would connect Hong Kong to Macau and Zhuhai was first advanced in 1983 by Gordon Wu, a Hong Kong-based real estate and infrastructure developer. Looking ahead 14 years to a time when Hong Kong would revert to Chinese political control, Wu proposed building a bridge that would connect Zhuhai's emerging low-cost manufacturing industries to Hong Kong's world-class air and sea ports. Wu's proposal was snubbed by the governments of both China and Hong Kong who viewed it as a needless and expensive distraction.

Wu was later proved prescient: once Hong Kong's handover back to China was complete, China's Communist Party Government in Beijing did indeed begin looking for ways to economically bind Hong Kong to the mainland. The new Hong Kong SAR (Special Administrative Region) government was less enthusiastic, seeing a new bridge as contributing to the region's rapidly worsening air quality. Only after the government of Guangdong Province announced that it planned to build a freight rail link between Zhuhai and Shenzhen, effectively bypassing the Port of Hong Kong, did Hong Kong begin to come around. Even if a Bridge was possible in concept, the real question was where and how it would connect to Hong Kong. After four years of back and forth, it was finally decided that the Bridge should touch down on Lantau Island where it would connect directly to the Hong Kong Airport.

With the connection question finally resolved, China's ruling State Council approved the Bridge's preliminary engineering feasibility report in October 2007; and two years later, on December 15, 2009, Vice-Premier Li Keqiang announced that construction of the HKZM Bridge was imminent. Hong Kong would be financially responsible for constructing 12 km of bridge roadway and an artificial island housing the border-crossing facilities between Hong Kong and Zhuhai. Zhuhai would take responsibility for constructing 13.4 km of roadway including 3 bridge structures, 2 tunnels, and 3 highway interchanges, and together with Macau, an artificial island which would serve as the Bridge's eastern anchorage. Macau would pay for a connecting link between the eastern anchorage and the Macau Peninsula.

Financing: According to a 2008 English-language press kit issued by the Hong Kong government, the HKZM Bridge was projected to cost CNY 72.6 billion ($10.6 billion). This included CNY 37 billion ($5.4 billion) for the main bridge link, which was to be financed by a CNY 22 billion ($3.2 billion) loan from the Bank of China; with the balance provided by the governments of Hong Kong (50.2%), China (35.1%) and Macau (14.7%) The specifics of this cost-sharing arrangement were based on estimates of how the Bridge's economic benefits were likely to be distributed among the three countries. When the HKZM Bridge was finally completed in 2018, construction costs had ballooned to CNY 127 billion ($18.8 billion). The largest cost overruns were associated not with bridge structures but with the undersea tunnel built by connecting 33 pre-cast concrete tubes end to end. With a length of 180 meters, a width of 38 meters, and a height to 11.4 meters, each tube section weighed 80 thousand tons, roughly the same size and bulk as an aircraft carrier. Assembling the tubes into a single watertight structure, especially during the stormy months of winter, would prove to be a time-consuming and expensive endeavor.

Market Indifference: Predicting exactly how China's competing urban economies will evolve is always a fraught proposition, and in the years safter the HKZM Bridge was approved for construction, the economy of the Pearl River Delta region changed considerably. Macau became a global gambling mecca reached principally by air. Shenzhen became China's foremost technology center, and Guangzhou emerged as the southern terminus of China's rapidly-expanding high-speed rail network. These changes had the effect of economically marginalizing Zhuhai and thus lessening the need for a bridge that would gambling coaches to Macau or truckloads of low-cost manufacturing products from Zhuhai to Hong Kong. Forecasts of HKZM Bridge traffic completed in 2006 projected that by 2020 the Bridge would carry between 15,350 and 22,300 vehicles per day, with two-thirds of the vehicle traffic flowing between Hong Kong and Zhuhai. Even before Covid-19 and civil unrest reduced travel in and out of Hong Kong, traffic on the HKZM Bridge never came close to these projections. As of January 2020, vehicular traffic on the HZKM Bridge was averaging just 3,660 vehicle per day.

Key Takeaways: Now viewed widely as a white elephant, the Hong Kong-Zhuhai-Macau Bridge offers a number of lessons for those considering undertaking large single-mode transportation projects:

1. <u>Focus on the economic activity assumptions behind the traffic projections</u>. Rather than focusing on numerical truck traffic and coach projections, as HKZM Bridge advocates did, they should have looked more closely at the economic activity and competitiveness assumptions behind the projections. If they had, they would have realized that Zhuhai's role in the Pearl River Delta region was declining even as Shenzhen's continued to grow.
2. <u>Sensitivity analysis can be advantageously used to identify critical project vulnerabilities.</u> The usual practice when developing demand forecasts for large scale infrastructure project is

to put forth a "low" projection under which the project is infeasible, a "high" projection which is universally understood to be too optimistic, and "middle" projection which must be correct because it is neither too high nor too low. In the case of the HKZM Bridge, a more robust approach would have involved conducting sensitivity tests around a series of scenarios identifying combinations of trip activity patterns, traffic volumes, and toll revenues that would lead to the Bridge underperforming its minimum financial performance targets.

3. <u>One-of f projects don 't lend themselves to construction economies of scale, especially when salt water is involved</u>. Chinese infrastructure designers and engineers have demonstrated themselves to be especially talented assembling large transportation networks using highly- standardized components and construction practices. Unfortunately, one-off open sea bridge projects do not lend themselves to this type of approach.

4. <u>When complex projects underperform, multi-national financing consortiums can quickly become a liability</u>. Unlike air and seaports, open water bridges can't easily generate positive physical or economic spillovers. So, instead of sharing potential spillover benefits, the partnership behind the HKZM Bridge had to share adverse risks and potential losses. The fact that the HMZ Bridge was financed by a partnership that combined three semi-sovereign states with a financial institution that was effectively backed by one of those states only added to the uncertainty about how much financial liability each partner would be able to take on.

9. Airport Projects I: Singapore's Jewel Changi Airport

Chapter Author: John Landis

Project Sponsors: Singapore Civil Aviation Authority (CAAS), Changi Airport Group (CAG), CapitaLand (Investor)

Project Description: Jewel Changi Airport is a nature-themed entertainment and retail complex built atop a multi-level 2,500-car parking garage amidst Singapore Changi Airport's three main passenger terminals. Five stories tall and with a gross floor area of 1,461,000 square feet—a bit more than the Chrysler Building in New York City--the glass and steel toroidal-shaped Jewel Changi includes a full-height indoor waterfall and garden, a 130-room luxury hotel, an 11-screen movie theatre, a shopping arcade that includes Marks & Spencer, Muji, Zara, Uniqlo and the only Apple Store in any airport, a 30-restaurant dining, and extensive passenger check-in and baggage-drop facilities. It does not, however, include any passenger arrival or departure gates. For those, passengers must walk to the three adjacent terminals or take a shuttle bus to Terminal 4. Opened to the public in April 2019,designed by a consortium of architects led by Moshe Safdie, who also designed Singapore's iconic Marina Bay Sands Hotel, and developed at a cost of US $1.3 billion as a joint venture between airport operator Changi Airport Group (CAG) and property developer CapitaLand, Jewel Changi is intended to re-establish Singapore as the home of the world's foremost destination airport. In this respect, it was successful: six months after opening, Jewel Changi had welcomed 50 million visitors, including many Singaporeans just wanting to experience its spectacle.

Building on a Successful Track Record: Jewel Changi's is the next step in the evolution of Changi Airport, which opened in 1981 as a single-terminal facility replacing Singapore's landlocked Paya Lebar Airport. At the insistence of Singapore Prime Minister Lee Kuan Yew, Changi was designed and built by the Singapore Department of Public Works rather than a consortium of international architects and contractors, as was the usual practice at the time. Along with Singapore's flagship airline, Singapore International Airlines (SIA), Changi quickly gained a reputation for high-quality service, and as a result, the number of passengers flying in and out of Changi rose continuously. Changi opened a second international terminal in 1990, and a third in 2008, with each later terminal being more efficiently designed and luxurious than the prior one. Changi also opened a budget airline terminal in 2006 but closed it six years later to make room for Terminal 4, which introduced the garden motif that has become Changi's hallmark. In 2009, the airport operations and planning division of Singapore's Civil Aviation Authority was spun-off and corporatized as the publicly-controlled Changi Airports Group (CAG). CAG brought in international firms to help with the design and construction of Terminal 4 and the redevelopment and upgrading of Terminals 1, 2 and 3, all the while remaining firmly in charge.

With the global destination airports business growing ever more competitive, Singapore Prime Minister Lee Hsien Loong announced in 2013 that Changi would replace a surface parking lot adjacent to Terminal 1 with an underground parking facility and a new “city-in-the-garden” branded concourse that would re-establish Changi as the world’s foremost destination airport. Three years later, CAG announced that it had selected architect Moshe Safdie, who had designed Singapore’s iconic three-tower Marina Bay Hotel and Casino, to design Changi’s “crown jewel.” Safdie’s design inserted a bowl-shaped garden and forest amphitheater into torus shaped glass and steel structure and topped the whole thing with a five-story circular waterfall to be known as the Vortex. The newly-named Jewel had multiple functions. It served as a common concourse for Terminals 1, 2, and 3; a garden respite for wary travelers, and a huge shopping mall with international retailers like Apple, Marks & Spencer, Muji, Zara, Uniqlo. To manage Jewel Changi’s retail operations, CAG brought in Asian mall developer CapitaLand as a 49% equity partner.

Key Takeaways: The critical question whenever using Singapore as a case study is whether the results can be generalized to other places and situations. Singapore is a prime example of what political economists refer to as a “developmental state,” meaning that the full range of the government’s planning, investment, and regulatory powers are used in concert to promote national economic development imperatives. Once a particular goal or priority is identified by government officials, all relevant public and private sector actors are mobilized to achieve it. Infrastructure projects undertaken by developmental states may certainly run into difficulties, but they are typically the result of unanticipated events or external constraints, and not because all the principals are not all on the same page. Would another country, province or city lacking Singapore’s developmental state ideology or track record of successful infrastructure investments been able to execute a project like Jewel Changi with such ease and success. Probably not, but it is still worth identifying the factors that contributed to its success. These include:

- <u>A Longstanding Commitment to Transformative Infrastructure Investments</u>: Even before its formal establishment as an independent country in 1965, Singapore’s one-party government—largely due to the technocratic biases of its Prime Minister, Lee Kuan Yew—was committed to undertaking transformative infrastructure investments. These started in the early 1960s as investments in public housing and as coastal landfill projects to create sites for industrial development. They continued throughout the 1970s and 1980s as a series of transportation investments, including national road and public transport networks, and seaport and airport facilities; and in the 1990s as human capital investments in parks and universities. They broadened again in the early 2000s, to include major ecological and environmental investments. In each case, these infrastructure investments have yielded the promised economic or quality-of-life returns. Jewel Changi fits right into this favorable investment narrative: it accelerated Changi’s lead over competing airports in Dubai, Doha, Istanbul and Hong Kong while also reinforcing Singapore’s brand as the only place in Asia that seamlessly integrates global commerce, cosmopolitan living, and the natural environment in equal parts.
- <u>Investing in Public Sector Expertise</u>: Lee Kuan Yew’s 1975 insistence on giving the job of designing the new Changi Airport to Singapore’s Public Works Department—rather than hiring contractors from the U.S. or U.K. as was the prevailing practice at the time--began a

30-year process of building public sector airport planning expertise. This intentional capacity-building approach yielded significant benefits when it later came to designing and building Changi Terminals 2 and 3; and it continued to pay off when the corporatized Changi Airport Group (CAG) assumed the responsibility for planning and developing Terminal 4 and Jewel Changi. No other country in Asia has gone as far as Singapore in investing in its own technical expertise, whether in the public or private sectors.

- Benchmarking Everything: Much of the secret to Singapore's sixty-year history of economic growth and success is that it is constantly comparing itself to friends and competitors big and small looking for any competitive advantage. Every Singapore public agency is continually comparing its performance to recognized leaders in the U.S., Europe, and Asia, looking for ways to improve. Changi Airport Terminal 4 was benchmarked against Terminal 3 (as well as Dubai Airport and Heathrow's Terminal 5), just as Terminal 3 was benchmarked against Terminal 2. Jewel Changi continued that competitive benchmarking practice.
- Incremental Privatization: Hoping to make its public ministries and agencies more entrepreneurial, Singapore's government undertook a major privatization effort in the late 1990s. In most instances, this took the form of corporatizing existing governmental departments with project planning and implementation responsibilities to make them leaner and better able to compete for work outside Singapore. In the case of Changi Airport, this took the form of spinning off the Changi Airport Group from Singapore's Civil Aviation Authority. This partial approach to privatization has not only enabled Singapore to bring its airport planning, development and operations expertise to the world, it has also allowed Changi to keep an eye out for new practices to bring back home.
- Quality-of-Life-Enhancing Infrastructure Investments: Many airports are designed for the benefit of the large air carriers who fly in and out of them. Changi is different: its focus is first and foremost on the passenger experience. This is partly an extension of Singapore International Airline's customer service brand, and partly a reflection of the fact that Singapore itself is organized to compete. As flying became more commoditized in the 1980s, airports began competing by providing passenger amenities, including frequent flyer club space, stores and restaurants, and a more seamless check-in experience. Changi was an early leader in all these areas, but as other airports caught up, Changi differentiated itself by providing a unique traveler experience. This was the motivation behind Changi management's decision in the early 2000s to add themed gardens to each terminal and ultimately to build Jewel Changi.

10. Airport Projects II: Berlin-Brandenburg Airport

Chapter Author: John Landis

Project Sponsors: Flughafen Berlin Brandenburg GmbH (FBB), a public corporation.

Summary Description: Berlin-Brandenburg Airport Willy Brandt (BER) finally opened to air travelers in November 2020, nine years behind schedule. Named after former West Berlin mayor and West German chancellor Willy Brandt, BER is located 18 kilometers southeast of Berlin City Center and is easily accessible to travelers by road and subway. BER's two 1,900-meter runways and terminal and service facilities occupy 1,470 hectares (3,632 acres). With 25 jet bridge gates, BER's U-shaped main terminal (Terminal 1) serves Lufthansa, easyJet, Air France, British Airways, Turkish Airlines, United Airlines and Qatar Airways amongst others. A second terminal building with 15 gates is reserved for low-cost carriers. BER's biggest carrier, RyanAir still uses an older terminal at the adjacent Schonefeld Airport. BER's three terminals can currently accommodate as many as 27 million passengers per year, and there is sufficient expansion space to eventually serve 50 million passengers per year.

Planning and Approval Process: Berlin's need for additional airport capacity was apparent well before the fall of the Berlin Wall in 1989. Passenger volumes were on the rise at both Tegel Airport and Tempelhof Airport and neither had space to expand. With Berlin set to completely replace Bonn as Germany's capital by 1999, the race was on to find a location for a new international airport. As a first step, in May 1991, the German states of Berlin and Brandenburg agreed to form Berlin Brandenburg Flughafen Holding GmbH (BBF), a jointly-owned public airport development corporation. A second step involved establishing a study group composed of planners and former public officials from East and West Berlin to identify potential airport sites. After evaluating 53 alternative locations, the study group whittled the list down to three finalists: existing airfields at Sperenberg and Jüterbog, and the area immediately south of the existing Schönefeld Airport in the former East Berlin. After several months of back and forth, government officials announced in May 1996 that they had reached a "consensus decision" in favor of the Schönefeld site. To protect their investment and minimize controversy over the choice of the Schönefeld site, BBF announced that Tempelhof and Tegel would close, Tempelhof in 2008, and Tegel when the new airport was completed.

Project Financing: With Germany's federal and state governments weighed down future by the costs of reunification, it was the original hope of BBF officials that the new airport could be built and financed by private investors through a public private partnership. After two failed attempts to attract private investors, Berlin Mayor Klaus Wowereit and Brandenburg Minister-President Matthias Platzeck took control of the project on behalf of their city governments in October 2003. Declaring that they would build the new airport themselves, Wowereit and Platzeck reconstituted BBF as a government-owned airport development and operating corporation and renamed it Flughafen Berlin Brandenburg GmbH (FBB). Berlin and Brandenburg each own 37 percent of FBB and the German federal government owns the balance. All of the bank financing obtained for by FBB is 100-percent government-guaranteed.

Construction/Delivery Issues: After waiting two years for the project architect to deliver an acceptable program and design, FBB put the job of building Terminal 1 out to bid in mid-2006. FBB's tender listing attracted four bidders, all of whom were rejected. After a second failed attempt to hire a lead building contractor, FBB decided to take on the job itself, despite having no in-house project management experience. In order to keep to its promised October 2011 completion date, FBB officials issued construction tenders even before a final Terminal 1 design was approved. This was a major error and one that would repeatedly come back to haunt the FBB in the form of frequent change orders, building permit resubmissions, and ultimately, failed inspection tests. In June 2010, with construction of the terminal lagging, the FBB acknowledged that BER's opening would be delayed, most likely until late 2011. A series of problems with BER's ventilation and fire safety systems, contractor disputes, and continuous turnover among FBB's senior leadership would postpone the airport's opening day for another eight years.

BER's original construction budget as approved in 2006 by the Berlin and Brandenburg state governments was set at €2.2 billion. By the end of 2016, BER's estimated construction cost had increased to €5.4 billion, and by the time BER opened in 2019, its cost exceeded €6 billion. All of the additional costs were paid by the FBB's three government partners.

Key Takeaways: BER's slow-motion progress provided outside evaluators with plenty of opportunity to figure out what had gone wrong and why. BER's problems were presciently summarized in a 2015 report to the German Airport Performance (GAP) Group by Berlin School of Economics and Law Professor Jurgen Mueller, as well as in a 2016 book chapter on German infrastructure projects written by Jobst Fiedler and Alexander Wendler of Berlin's Hertie School of Governance. Among their principal conclusions:

- BER's ownership structure was inherently unstable, with each of the FBB's three government partners at times pursuing their own political objectives. Because of its minority ownership position, the German federal government never stepped up to exercise proper political or financial leadership, preferring to instead act entirely as a regulator.
- Because all of their loans to the FBB were 100 percent government-guaranteed, the airport's private lenders exercised minimal financial oversight.
- The FBB's lack of airport construction management experience coupled with its repeated mistakes bidding the project created a situation in which no single contractor or project manager could properly coordinate the entire construction job. Particularly troubling was the fact that almost no one on the FBB's supervisory board—the equivalent of a board of directors in a private corporation—had significant project management experience.
- By hiring too many subcontractors—50 at one count—and no supervisory contractor, the FBB created a situation in which program and design change orders and contractor disputes

spiraled out of control. The lack of a single project supervisor also made it impossible to keep the project on budget.

11. Airport Projects III: The New LaGuardia Airport

Chapter Author: John Landis

Project Sponsors: The Port Authority of New York and New Jersey, LaGuardia Gateway Partners

New York's Own "Third World Airport:" Lauded as cutting-edge and contemporary when it first opened in 1939, LaGuardia Airport has been the object of a love-hate relationship with New Yorkers since the dawn of the jet age. The city's crowded expressways make getting there by car too difficult. There is no direct subway service. The terminals are too small and run-down. Parking is at a premium. LaGuardia's short taxiways exacerbate ground delays. Birds drawn to its waterfront runways present a safety problem, as vividly illustrated in real time and on national TV when a bird strike forced US Airways Flight 1549 with Captain Chesney Sullenberger at the controls to ditch in the Hudson River. Being disliked has not meant that LaGuardia has gone unused. Despite the 1984 adoption of a Sunday-thru-Friday "perimeter rule" banning nonstop flights from LaGuardia to cities more than 1,500 miles away, and the FAA's imposition of its own flight operations limits in 2007, the number of passengers using LaGuardia has grown continuously, reaching 25 million in 2000 and 28 million in 2015.

A Tough Nut to Crack: After years of favoring the higher-profile JFK and Newark Airports over LaGuardia, by 2010, the Port Authority of New York and New Jersey was finally ready to do something about LaGuardia's worsening crowding and capacity problems. In April 2010, Port Authority Director Christopher Ward announced that the agency had hired consultants to explore a full rethink of LaGuardia Airport. The rebuilding job was projected to be a difficult one, not only because of its cost--expected to be in the range of $2.4 billion—but because there was no possibility of physically expanding the airport's footprint, and the fact that the airport would have to remain fully operational throughout the rebuilding process. Moreover, of LaGuardia's four terminals, the Port Authority controlled just Terminals A and B; Terminals C and D were controlled by Delta Airlines.

A Public Private Partnership Emerges: The Port Authority's rethinking LaGuardia plan was never made public. Nonetheless, in 2013, the Port Authority issued a draft Request for Proposals covering the demolition and replacement of LaGuardia's Central Terminal building. Along with a list of design and programmatic requirements, the Port Authority's draft RFP included a solicitation for potential partners who could provide construction financing for the project in exchange for an agreement to maintain, operate, and potentially own the rebuilt terminal once completed. This type of public private partnership arrangement or PPP had become increasingly popular among airport authorities, and the Port Authority itself had used it in 2012 to renovate Terminals C and D for Delta Airlines.

Among the stakeholders the Port Authority had specifically neglected to consult when developing its LaGuardia reconstruction scheme was New York's governor and all-around infrastructure can-do guy, Andrew Cuomo. In an effort to guard his own prerogatives, in January of 2014, Cuomo announced his own plan for the future of LaGuardia Airport, one in which New York State and not the Port Authority or some yet-to-be-constituted PPP would take the lead. The only problem with Cuomo's announced LaGuardia plan was that it didn't exist, at least not yet. Never one to dwell on details, Cuomo quickly assembled his own advisory panel composed of prominent figures in the construction, real estate, and infrastructure planning fields.

Determined not to reinvent the proverbial wheel, Cuomo's panel wisely took as its starting point the Port Authority's LaGuardia rebuilding plan as well as the results of a 2014 JFK and LaGuardia design competition. On June 27, 2015, with Vice-President Joe Biden at his side—it was at this announcement that the Vice-President publicly compared LaGuardia to a third-world airport—Cuomo released his advisory panel's recommendations. in June of 27, 2015, noting that fully implementing them would cost in the neighborhood of $4 billion. Not lost on anyone who attended was the fact that Cuomo's design scheme and financing plan was essentially the same as the Port Authority's. By standing quietly by while Cuomo took public credit for what was essentially its plan, the Port Authority converted a so-so supporter into a vigorous ally who could champion the project as it moved forward.

Financing, Construction and Delivery Issues: To build what was now being referred to as the New LaGuardia, the Governor's advisory panel recommended continuing the process established by the Port Authority a year earlier which had used a competitive RFP process to create a construction partnership comprised of HOK and Parsons Brinckerhoff, which would design the facility; Skanska and Walsh Construction, which would build it; and Vantage Airport Group, which would operate it. Financing would be provided by Vantage, Skanska, and the Meridiam Group in a format yet to be determined. Mirroring the Port Authority's proposed PPP approach, the new LaGuardia Gateway Partners (LGP) entity would be responsible for designing, building, financing, operating, and maintaining the new terminal as part of a 35-year lease.

Conceptually, New LaGuardia is organized into two phases, each costing roughly $4 billion. Phase I, which began in 2016 and is scheduled for completion in 2022, is organized around rebuilding LaGuardia's Central Terminal, also known as Terminal B or CTB. Demolition of the LaGuardia's original Arrivals and Departures Hall began in 2018 and has progressed in sections in to allow continued access to available airline gates. The new Arrivals and Departures Hall, which is closer to the street, wider, and more modern in every respect opened in June 2020. A new western concourse is also being opened in sections and is currently scheduled for completion in mid-2022. Although Phase I won't be fully completed for another year, so far, all of its pieces have been completed on time and on-budget

While the Port Authority has been overseeing Phase I of the New LaGuardia, work has also been progressing on Phase II, which involves combining the current Delta-owned Terminals C and D into a single structure. Like Phase I, Phase II is being completed in sections in order keep current flight and passenger operations up and running. The first of four new concourses opened in November 2019, with subsequent concourse openings projected at two-year intervals. Delta currently anticipates completing Phase II sometime in 2026 at an estimated cost of $3.6 billion

Takeaways: Among the reasons the New LaGuardia project has progressed so well is that its major design, engineering and construction contractors are all highly experienced. HOK, the lead project architect, had successfully completed terminal rebuilding projects at the nation's two busiest airports, O'Hare in Chicago, and Hartsfield-Jackson in Atlanta. WSP, the prime engineering contractor, had successfully designed and engineered the baggage-handling and terminal operations systems at the new JetBlue terminal at nearby JFK airport, which is also operated by the Port Authority. With operations throughout the US and Europe, Skanska, the lead construction contractor, had developed a highly successful practice redeveloping airport terminals while maintaining flight operations at full capacity. Started in Vancouver in 1994, Vantage Airport Group specialized in medium-sized airport asset management and operations. Perhaps most importantly, for all its reported difficulties managing its real estate assets and serving its political masters in Albany and Trenton, the Port Authority of New York and New Jersey is a top-notch airport owner and operator, having profitably managed three of the nation's busiest airports through floods, recessions, security threats, and a constantly changing airline industry. If any organization could successfully structure a public-private partnership with financial staying power, it is the Port Authority.

12. Urban Development Projects I: London's Canary Wharf

Chapter Author: David Gordon and Patricia Warren

Project Sponsors: Olympia and York (1987-1992), The Canary Wharf Group (1995-present day), The London Docklands Development Corporation (1981-1997)

Summary Description and Development History: Canary Wharf was the first urban development project to demonstrate the modern day possibility of developing a second central business district (CBD) within a global metropolis. With over 17 million square feet of commercial space, forty buildings and more than 120,000 employees as of this writing, Canary Wharf is a prominent example of urban regeneration rising from one of England's most distressed communities, as well as an illustration of the importance of foresight, patience, and luck—both good and bad—when it comes to developing urban megaprojects.

Located on the Thames River five miles due east of the City of London, London's traditional financial center, Canary Wharf site was part of the West India Docks, built in 1802 and considered an engineering marvel in their day. After 150 years of up and down economic fortunes, including being heavily damaged during the London Blitz of 1941, Canary Wharf was finally rendered obsolete by the global adoption of containerized shipping in the 1960s. One by one the great shipping docks closed, the last one shuttering in 1982. London's East End economy was devastated, with high unemployment and thousands of acres of abandoned docks and industrial buildings. Redevelopment plans were stalled political squabbles between local councils and by the UK's 1976 financial crisis. Appalled by the extent of the dereliction and the inaction of the local authorities, Conservative Government Environmental Minister Michael Heseltine proposed that the Liverpool and London docklands be placed in the hands of independent urban development corporations (UDCs) with broad powers to facilitate private development.

Established by Parliament in 1981, the London Docklands Development Corporation (LDDC) imported the public-private partnership (P3) model for waterfront redevelopment that had been pioneered in Baltimore, Boston and Toronto. After several years of failing to attract a private developer, Canary Wharf's prospects began to change in February 1985, when Credit Suisse First Boston investigated the dock warehouse as a site for the bank's back office operations, assisted by American developer Ware Travelstead. Unable to attract sufficient market interest or financing, Credit Suisse First Boston's option on Canary Wharf was taken over by Olympia and York (O&Y), a private firm owned by Toronto's Reichmann family. Brought into the Canary Wharf project through the personal intervention of British Prime Minister Margaret Thatcher, the Reichmanns and O&Y brought instant credibility to the project, having completed the World Financial Center in Battery Park City, a waterfront site in Lower Manhattan.

O&Y had timed its New York market entry perfectly, but got it drastically wrong in London, starting work on Canary Wharf only a few months before the 1987 stock market crash, and commencing leasing commercial leasing during the 1991 recession. With Britain's Conservative

Government facing its own financial difficulties, O&Y was forced into bankruptcy in 1992, ceding control of Canary Wharf to its creditors. Two years later, the London economy entered a 13-year growth period in which Canary Wharf's modern and large footprint office buildings were especially in demand. As of 2019, 120,000 people were employed in Canary Wharf 's 16 million square feet of office and retail space.

Project Financing Issues: The standard, low-risk approach to developing office buildings is to secure a development site, prepare plans , find tenants willing to sign leases to occupy the building when completed, and then use the signed leases as security to obtain permanent financing. The Reichmann took a different approach, issuing their own commercial bonds, and then using the cash flow from the bonds to finance construction of their next project. This approach worked as long as office demand was growing, but it left the developer highly exposed to market risk. When the London office market collapsed in 1992, and some Canary Wharf office tenants began backing out of their lease commitments, the O&Y were left hold four million square feet of unfinished office space.

O&Y's failure and the collapse of the Canary Wharf project was viewed by many observers as proof that the P3 financing model was ineffective or corrupt. The development industry was equally pessimistic and there was little immediate interest in purchasing Canary Wharf's buildings from the bankruptcy trustees after the creditors were paid off. But where other developers saw a saw a failed office park, Paul Reichmann saw planning approvals in place for 15 million square feet of high-quality office space and a new Underground line nearing completion that could transport 100,000 workers to Canary Wharf from all over London. Hoping to take back control of Canary Wharf, Reichmann committed his family's remaining $150 million as a minority share in a consortium of New York and Saudi investors that acquired Canary Wharf from its bankruptcy trustees in 1995. The new company, Canary Wharf Limited (CWL), operated with more conventional financing techniques, leasing the remaining 70% of the project within three years and starting new buildings with standard construction loans only after tenants were secured.

Key Takeaways: Canary Wharf demonstrates many of the advantages of mega-project development and some glaring disadvantages. The project was able to take advantage of planning, engineering and construction economies of scale to build London's second business district with remarkable speed and at a much lower cost than new buildings in the City. Canary Wharf's business tenants reaped productivity benefits by consolidating previously far-flung operations in large floorplate buildings in a single location, allowing London to secure its place as Europe's leading financial center. Canary Wharf also benefited from the streamlined project review process put in place by the LDDC, obtaining planning approvals in weeks that elsewhere in London would have taken years.

Canary Wharf clearly did not benefit from *financing economies of scale and scope* or the g*reater re-distributive potential* seen in other mega-projects. Infrastructure megaprojects often use sophisticated financial structures to spread risk and uncertainty to parties that can best absorb them. The Reichmann family's strategy was to concentrate risk upon themselves to increase control and concentrate rewards. When it worked in Toronto and New York, this strategy made them billionaires, but in London it made them bankrupt.

Construction of a second CBD in the middle of a low-income municipality had the potential to shower benefits on the surrounding community, but this did not happen in Canary Wharf's early days due to the Thatcher government's neo-liberal stance, the LDDC's restricted mandate, and O&Y's sole focus on its cash-flow bottom line. As a result, Canary Wharf's early phases attracted political opposition from the Greater London Council and local councils that delayed its launch and soured potential British tenants. The reputational damage was not undone until Tony Blair's "New Labour" government ordered the LDDC to pursue social regeneration as vigorously as economic revitalization.

Constructing a new business district is an unusual type of megaproject, with few precedents for comparisons. Paris' La Défense built the high capacity transportation systems earlier but was slower than Canary Wharf to develop a critical mass of employment. Capable and powerful development corporations like the LDDC can indeed accelerate the urban regeneration process, but they are less skilled at the sorts of placemaking activities that enables large-scale business-oriented regeneration projects to weather periodic economic downturns.

13. Urban Development Projects II: HafenCity Hamburg

Chapter Author: John Landis

Project Sponsors: HafenCity Hamburg GmbH (HHG), Hamburg City Government

P**roject Description**: Conceived in 1996 as an urban waterfront regeneration initiative, HafenCity Hamburg (in English, Port City) is currently Europe's largest urban redevelopment project. Located along the northern banks of the Elbe River adjacent to Hamburg's historic Speicherstadt quarter, HafenCity is built atop two irregularly-shaped islands constructed out of landfill between the 15th and 19th centuries. Four kilometers long, one kilometer wide, and with a land area of 157 hectares (390 acres), when fully built-out, HafenCity will be home to 15,000 residents and up to 45,000 jobs. As of 2019, roughly half of HafenCity's planned 140 building projects had been completed, including 3,000 residential units and working space for 15,000 employees. Planning-wise, HafenCity is organized into ten distinct neighborhoods known as quarters, each with its own mix of land uses and to a lesser degree, public facilities. All are connected by a network of parks and pedestrian ways.

Planning and Development History: The waterfront area now called HafenCity has been central to Hamburg's history since the 13th century when it became the preferred port for the newly-established Hanseatic League, a free trading union between German and Baltic city-states lining the Baltic Sea. For the next five centuries, Hamburg's growth and prosperity were tied to its status as a free port where shippers could escape the high tariffs assessed at other European ports. Shipping operations ceased almost entirely during World War I, picked up modestly following the War's end, but fell again with the onset of the Great Depression. Once World War II began, Hamburg's many factories and munition plants made it a favored target for Allied bombers. In July 1943, in a series of bombing raids known as Operation Gomorrah, allied bombers undertook what until then was the most intensive bombing campaign of the War. Lasting for eight straight days, Operation Gomorrah left 42,000 civilians dead and Hamburg's port facilities entirely in ruins.

Like many German cities, Hamburg's prospects changed completely following the fall of the Berlin Wall and German reunification. Before reunification, Hamburg was a regional port city on the eastern edge of a Europe whose population growth, economic energy, and trading activity were concentrated in its western realms. After reunification, Hamburg suddenly found itself at the heart of a continent growing eastward as well as westward, and in possession of a deep-water port with the potential to rival Rotterdam as Europe's largest. Hoping to get ahead of rapidly changing events, Hamburg First Mayor Henning Voscherau commissioned an unofficial study to explore how best to reuse the city's historical port area. Instead of renovating the city's traditional piers on the north side of the Elbe River, the study recommended building an entirely new container port along the Elbe's southern bank, which already had good rail and truck connections. This would leave Hamburg's traditional port areas available for redevelopment and re-use.

Once the city had gained sufficient waterfront site control, Mayor Voscherau commissioned Hamburg architect Volkwin Marg to develop port reuse and regeneration study. Marg's draft recommendations, which were first presented in confidential session in December 1996, laid out many of the land use and development principles that would guide HafenCity's eventual redevelopment. Foremost among these were avoiding superblocks in favor of short street blocks, limiting on-street and off-street parking to encourage greater walking and public transportation use, and requirements that buildings as well as blocks mix land uses. With less area needed for cars, additional land could be devoted to parks, public spaces, and environmental features. This was the urban form, Marg believed, that would be most attractive to innovative businesses and their creative class workers, thereby boosting HafenCity's long-term economic prospects. Six months later, in May 1997, Voscherau released the results of Marg's study to the public as *Vision HafenCity.* The public response was immediate and enthusiastic, leading Hamburg's Bürgerschaft (City Council) to quickly approve further planning efforts.

Subsequent planning and development work proceeded along two tracks. The first involved converting Marg's largely conceptual scheme into a detailed masterplan. Along these lines, the Hamburg Senate and Mayor's Office announced in December 1998 that the city would sponsor an international competition to select a design and planning team to create HafenCity's new masterplan. The winner of the masterplan competition, the Dutch-German team of Kees Christiaansee/ASTOC, was announced in October 1999. The Kees masterplan pushed the planning envelope in several notable ways. Unprecedented shares of HafenCity were to be reserved for parks, open space, environmental features, and pedestrian and bicycle circulation. In terms of land use mix, more than half of HafenCity buildings were to include more than one major land use. Given the large amount of land to be reserved for public use, the remaining privately-owned land would have to be developed at higher-than-usual-for Hamburg densities. Would there be a market demand for all this additional density? Marg clearly believed so, but no one could say for sure.

The second track in the HafenCity planning and development process involved connecting appropriate sites with capable developers. This was to be the job of HafenCity Hamburg GmbH (HHG) and it would use three mechanisms to do so. The first and most conventional involved selling or leasing individual parcels to private owners who agreed to develop them as proscribed by the masterplan. This had the advantage of speed but sacrificed public input into the final project design. Alternately, HHG could offer an option to a developer, giving itself and the developer more time to come up with an appropriate building program, site plan and design. Third, HHG could initiate a competition for a project-level development plan. This last approach was intended for large, multi-parcel sites, and it enabled HHG to solicit multiple designs from different developers and to select the combined project-developer deemed to be most appropriate for a given site or situation.

Streamlined Approvals and Financing Arrangements: HHG's biggest advantage is that all the land in HafenCity was initially publicly owned, having been acquired in a land swap with Hamburg's Port Authority in the early 1990s. Free land is the holy grail of real estate development, and with so much of it in hand, HHG could take its time selecting combinations of building proposals, tenants, and developers that best served HafenCity's long-term prospects for success, selling off individual parcels as needed and only when appropriate. In addition to controlling the land supply pipeline, HHG also administered the development review and approval process. This combination of ready-to-build sites and entitlement certainty was appealing not only to developers and prospective tenants, but also to construction and mortgage lenders, making it easier to put together timely development deals. These market and financing advantages were immediately capitalized into land value premiums, allowing HHG to charge top euro for HafenCity sites. As of October 2019, HHG has either sold or leased sufficient land to accommodate 2 million square meters (about 20 million square feet) of building area. With about half of HafenCity's 127 hectares of developable land available for sale, HHG projects that HafenCity land sales will ultimately generate upwards of €10 billion in private investment.

Proceeds from land sales are used by HHG to pay for HafenCity's transportation, environmental and public realm infrastructure, including roads, bridges, promenades, parks, and waterfront facilities. So as not to let infrastructure spending get too far ahead of land sales revenues, HHG has been careful to phase HafenCity's development. HHG was sufficiently accomplished at getting top euro for its sites that by 2005 it could begin pivoting away from its initial focus on infrastructure development and commercial land sales and toward broader community building and sustainability concerns.

Key Takeaways: HafenCity offers three fundamental lessons to other cities considering about undertaking comparable urban regeneration megaprojects. Three spring to mind. The first concerns the importance of having complete site control. The second involves the importance of having a realistic and robust infrastructure financing model. And the third pertains to not being afraid to push on conventional wisdoms about market demand and environmental performance.

The fact that Hamburg's municipal government and its sub-entities—most notably HafenCity Hamburg GmbH (HHG)—was initially able to acquire complete physical, legal and regulatory site control over the entire HafenCity site greatly simplified and sped up HafenCity's master planning and site preparation timeline. It also made it possible for HHG to create an efficient process for selling fully-entitled sites to prospective developers in a manner that maximized sales revenues and potential public benefits.

Too often, sponsors of large urban redevelopment projects underestimate the up-front costs of providing essential infrastructure while overestimating absorption and sales rates. To its immense credit, HafenCity Hamburg GmbH's avoided both of these pitfalls. It didn't overspend up-front on unneeded infrastructure, and its projections of land sales rates (and prices) were always conservative and well-considered

When asked about a product that is beyond their experience, most people cannot answer reliably. To someone just looking at numbers and trends, nothing about HafenCity seemed favorable. Behind the numbers, both consumer and business preferences were changing. After decades of decline, Hamburg's population was finally growing again, and that growth was concentrated among the young. An increasing number of younger and better-educated workers were looking to live in urban neighborhoods where they wouldn't need a car on a daily basis. And with a growing share of their expenditures going to labor rather than rent, companies were more willing to pay higher rents for a building and location more attractive to employees. These shifts were occurring across North America and Europe, not just in Hamburg, but as architect and town planner Professor Volkwin Marg surely realized when given the job to come up with the concept plan for HafenCity, they could be harnessed to work to Hamburg and HafenCity's advantage.

14. Urban Development Projects III: Korea's Songdo International Business District

Chapter Author: John Landis

Project Sponsors: City of Incheon, Gale International, POSCO E&C

Songdo in Perspective: Songdo International Business District (IBD) in Incheon, Korea is a city of multiple identities. Projected to cost upwards of US$50 billion by the time it is finally finished in the mid-to-late 2020s, Songdo is the most expensive real estate development project in modern history. It is also the largest mixed-use master planned community in the world, and one of the largest public-private partnership projects ever undertaken. Thanks to its energy and water-saving design, Songdo is widely touted as one of the world's greenest cities, and because of the ubiquity of its sensors and digital control systems, one of its smartest cities as well.

Of its many identities, Songdo is foremost a master-planned community or MPC. This means that its mix of land uses, buildings, and public facilities are designed in such a fashion so as to maximize the quality of life for its residents and the productivity of its businesses and developed in such a way as to take maximum advantage of construction and financing economies of scale. In terms of physical area, Songdo IBD is about the size of downtown Boston. Located 36 kilometers west of Seoul and 12 kilometers from Korea's Incheon International Airport, Songdo is built atop a 1,415 acre site that was reclaimed from the sea off the Incheon coast during the 1990s. Songdo IBD serves as the commercial and residential center of a larger 13,000 acre new town project known as Songdo City that is ultimately expected to have more than 300,000 residents. The New Songdo City Masterplan, which was developed by the U.S. firm of Kohn Pederson Fox (KPF) in 2003, projects that Songdo will ultimately include 40 million square feet of office space, 35 million square feet of residential buildings, 10 million square feet of retail space, 5 million square feet of hotel and hospitality space, and 9 million square feet of public space. With a current population of 35,000 and a population density of roughly 25,000 persons per square mile, Songdo is about as dense as New York City and half as dense as Seoul.

Early Planning and Development History: The idea of reclaiming the sea around Songdo Island off Korea's west coast to create an entirely new city--hence the origin of the name Songdo City—was first floated in 1962 by Woojin Mulsan, a Korean construction company that proposed to undertake the project on its own. The idea knocked around in different forms without result until April 1988, when, on a visit to Incheon by South Korean President Roh Tae-Woo, Incheon city officials raised it anew, this time proposing to reclaim 48 km^2 around Songdo Island to build an international trade and information technology business hub. With China on the rise, Korea's leaders believed the best way to maintain their country's economic momentum was to sponsor the construction of a series of new high technology and business hubs linked to Seoul by highway and high-speed rail service. With this decentralized growth model in mind, South Korea's government announced in 1990 announced that it would build a giant airport on reclaimed land between Yeongjong and Youngyu islands just off the Incheon coast.

With the new airport expected to generate economic spinoffs of its own, Incheon officials quickly pulled their Songdo plan out of the drawer and expanded it in size and ambition to accommodate a new city of 300,000 residents with a built-from-scratch trade and technology hub at its center. Approvals were gained from the Ministry of Construction, and land reclamation activities around Songdo Island began in September 1994. Bolstering Incheon's hopes, Korean officials announced that they would consider designating Incheon as a potential Free Economic Zones (FEZ), which would make corporate tenants of the new city eligible for government tax breaks. In December 1997, Incheon announced that it had signed a memorandum of understanding with a consortium of 17 private companies to build a 3.5 km^2 "knowledge information industrial complex" to accommodate global IT firms and create a Korean version of California's Silicon Valley. To finance the project, Incheon officials announced they would increase the size of the new Songdo business district to 6.8 km^2 and begin leasing or selling individual land parcels to prospective developers.

Korea Tries a New Approach: Incheon's timing proved to be terrible. The arrival of the Asian Financial Crisis in July 1997 sent Korean financial and real estate markets tumbling and quickly mooted Incheon's piecemeal development plans for Songdo. Instead, city officials decided to develop Songdo as a public-private megaproject and began searching for a capable private developer with which to partner. Although not uncommon in the United States, this type of real estate deal would have been unthinkable in South Korea just a few years earlier. Korea was a proud and relatively insular country, and the Alien Land Acquisition Act had long prohibited foreign companies from owning Korean real estate. In a nod to IMF pressure to open up its economy in the aftermath of the Asian Financial Crisis, the Korean government had modified the Alien Land Acquisition Act to enable foreign investors and developers to buy and own land, and the New Songdo City deal would be the first to take advantage of those changes.

In terms of finding a developer, Incheon and South Korean officials were especially keen to secure the involvement of an American company. A U.S.-based developer, they reasoned, was more likely to have the mixed-use development and public-private partnership experience they were looking for, as well as have ready access to Wall Street investors and lenders. In the interim, so as not to lose momentum, Incheon city officials hired POSCO E&C, the development subsidiary of the Korean Steel giant POSCO, to serve as Songdo's temporary developer. POSCO subsequently reached out to John B. Hynes, III, the President of Gale International, based in New York City. Hynes, along with his boss Stan Gale, had recently finalized a deal to build One Lincoln Square in Boston, the marquis office project of the year, and both men were looking for new opportunities. Convinced that the Korean government would always be there to backstop the project financially if need be, Hynes and Gale signed a memorandum of understanding with POSCO E&C to develop what was now being called New Songdo City. The partnership, named New Songdo City Development LLC (NSCD) was set up as a 70/30 joint venture with Gale International as the controlling interest. Gale would serve as the project developer and POSCO E&C would be the construction manager.

A High Risk Development Strategy Unravels: KPF's New Songdo City Masterplan was conditionally approved by Incheon city officials in November 2002. Ten months later, in August 2003, New Songdo City was formally designated by the South Korean government as part of the Incheon Free Economy Zone, or IFEZ, which would henceforth handle all New Songdo City development approvals. Instead of purchasing the entire 1500-acre New Songdo IBD site outright, which would have been prohibitively expensive, Gale planned to acquire the site as a series of five separate land parcels. This would enable NSCD to use the revenues from Parcel I residential presales as security for a loan to buy Parcel II, and so on. By combining presale revenue with borrowing, Gale figured he would have just enough working capital to begin building the signature office towers that would provide Songdo IBD with its international identity. The key to successfully executing this strategy would be to match residential completions and sales with land purchases. If Gale let his land acquisition and predevelopment costs get too far ahead of residential sales, his financing gap and interest costs would balloon upward. If he erred in the other direction and was too slow in acquiring land, he would run the risk of missing the market. There was also pressure from the Korean government, which wanted NSCD to begin office construction as soon as possible.

Over the next ten years, Gale and POSCO would find themselves falling further and further behind. Residential sales would lag projections, causing Gale to have to refinance their loans, reducing their access to capital needed to undertake the next phase of development. Despite some early interest by U.S. technology firms in Songdo's cheaper office rents, most chose eventually to locate in Seoul.

The arrival of the Global Financial Crisis (as the Great Recession was known in Asia) in Korea in October 2008 upended all of Gale's finely-timed financial plans. New home sales collapsed and many who had pre-bought homes demanded their money back. Gale and POSCO E&C were forced to give 50 percent of any future profits back to Incheon. Beyond these barest of details, neither NSICD nor their lenders nor any government agency was required to publicly disclose the details of the restructuring. In September 2018, with no Songdo completion schedule in sight, POSCO unilaterally ended the NSCID partnership and sold Gale's majority share to two Hong Kong companies. Gale responded in March 2019 by filing a breach of contract lawsuit against POSCO in U.S. District Court in New York alleging the POSCO had overcharged the partnership more than $300 million in construction costs and improperly seized and sold Gale's stake in the project. In June 2019, Gale filed a $2 billion lawsuit against the government of South Korea with the International Centre for Settlement of Investment Disputes alleging that South Korea had expropriated a substantial portion of Gale's investment. Meanwhile, construction activities in Songdo continue—mostly in accordance with the original KPF Masterplan-- and final completion now expected for some time in the mid-2020s.

Key Takeaways: Songdo offers many lessons to governments, private developers, and financing entities lured by the siren song of very large-scale urban development projects. The first and most obvious is that projects of the size and complexity of Songdo should not be developed as single-deal projects or via a single partnership. The greater-than-anticipated time it always takes to finish real estate megaprojects and the market uncertainties that are sure to arise within that time are simply too great for one developer or one development partnership to bear. Had Songdo been developed as a smaller series of projects and through a series of partnerships, its inherent risks would have been easier to manage. Second, the infrastructure planning and construction scale economies that characterize large real estate megaprojects rarely translate into cost savings: the tendency to want to build every piece of infrastructure to the highest possible (and most costly) standard is just too great. Third, government agencies should not get involved as financial partners in large-scale commercial real estate deals unless they are willing to guarantee project occupancy or are willing to wait out the real estate cycle. Office and retail markets are by their nature competitive and ever-changing, so building a lot of office or retail space at any one time is necessarily a risky endeavor. To the extent that government agencies wish to promote office or retail development, they should only do so by subsidizing the underlying land cost, paying for supportive infrastructure, or providing favorable bridge financing. Finally, to the extent that real estate megaprojects are developed as public-private partnership deals, they should be subject to rigorous risk and contingency analysis to evaluate how the project and the partnership is likely to perform under different market and financial scenarios.

15. Urban Parks: New York City's Brooklyn Bridge Park

Chapter Authors: John Landis

Primary Project Sponsors: Brooklyn Bridge Park Development Corporation (BBPDC), New York City Mayor's Office, Brooklyn Borough President's Office.

Summary Description: Brooklyn Bridge Park (BBP) occupies an 85-acre dogleg-shaped site along the Brooklyn waterfront between the Manhattan Bridge and Atlantic Avenue. The park lies immediately to the west of and below Brooklyn Heights, one of New York City's oldest and wealthiest residential neighborhoods. South of the Brooklyn Bridge, BBP consists mainly of six former shipping piers that are today used for a variety of recreational and cultural purposes. North of the Brooklyn Bridge, BBP includes a series of three small embankment areas which also include recreation and meeting facilities. The piers and embankment areas are connected to each other (as well as to the Park's north and south entrances) by a meandering series of pedestrian pathways. BBP also includes six private development sites. The three largest such sites are One Brooklyn Bridge Park, a historic warehouse building converted to condominium use in 2008; Pier 1, a mixed-use project located adjacent to the park's northern-most pier that includes a 200-room hotel and 100 residential units; and Empire Stores, a complex of late 19th century shipping warehouses in the process of being redeveloped into a mixed-use retail-restaurant-office project.

With a final cost expected to be in the range of $250 to $300 million, BBP is too small to be included on most megaproject lists. Foremost among the considerations that argue for its inclusion is the fact that BBP is the largest new urban park to be constructed in the midst of a major world city in more than 50 years. BBP Park is also a preeminent example of how old and obsolete industrial waterfronts are being repurposed as urban amenities, thereby supporting the resurgence of nearby urban neighborhoods. Finally, a substantial share of BBP's construction and operating expenditures are (and will be) derived from on-site land sales (so-called "development in the park") as well as from special tax assessments. These are common enough financial mechanisms when used to finance urban development and transportation projects, but until the 1980s, were rarely used to finance public parks.

Development History: For most of the 19th century, the Brooklyn waterfront served as New York City's foremost cargo port. Like other fast-growing American industries during the 1890s and 1890s, New York City's maritime businesses were largely unregulated, and by the early 20th century, most of Brooklyn's waterfront piers and warehouses were owned by a single maritime conglomerate, the New York Dock Company. In 1955, the New York Dock Company's Brooklyn waterfront piers and buildings were acquired by the Port Authority of New York and New jersey. Brooklyn's industrial waterfront was able to hold its own amidst two world wars and the Great Depression, but the arrival of shipping containerization in the 1960s heralded its gradual decline. By 1983, having shifted all of its cargo operations to Bayonne in New Jersey, the Port Authority had shut down all of its Brooklyn shipping facilities.

With no potential uses of its own for Brooklyn's waterfront piers and warehouses, the Port Authority began actively planning to sell them. Recognizing that such a move would be politically fraught, in 1984, the Port Authority reached out to New York City officials about co-sponsoring a working group to be called the Brooklyn Piers Task Force to discuss the waterfront's future. Simultaneously, the Port Authority contacted a nearby community group, the Brooklyn Heights Association, to solicit their input. For its part, the Port Authority was not opposed to using parts of the waterfront for public purposes, but it was also counting on potential commercial development along the waterfront to raise the market value of its remaining waterfront assets.

Hoping to identify common ground between itself and the Port Authority, the Brooklyn Heights Association's leadership hired its own consultant to come up with what it termed a consensus plan, which was presented to the public in February 1987. The consultant's plant made no specific reuse recommendations but instead put forth a common set of six redevelopment goals as well as four illustrative reuse schemes. Predictably perhaps, the Brooklyn Heights Association coalesced around the pure public park alternative while Port Authority and the City supported the two schemes that included additional commercial or residential development. Anxious to be rid of the contentious pier site and believing no agreement to be possible, the Port Authority announced that it would sell the piers to a qualified developer with or without an approved plan. This effort was soon stymied by Community Board 2—before they can be approved by the city, land use proposals in New York City must obtain the approval of their local community boards, which function as mini planning commissions—which unanimously endorsed the Association's pure park alternative. There was just one problem, the Association had no funds with which to implement their plan.

Start, Stop, Repeat: Over the next fifteen years, from 1988 until 2002, the Port Authority, the Brooklyn Heights Association, the Office of the Brooklyn Borough President, the New York State Governor's Office, and a new state-sponsored development/conservation entity, the Downtown Brooklyn Waterfront Local Development Corporation (LDC), would all struggle to put together a financing package that could cover the proposed BBP's operating costs as well as its capital costs. Each time LDC leadership thought it had achieved agreement on an appropriate balance between development—which was needed to provide operating revenues—and conservation, one or more stakeholders would back out of the deal

Finally, in 2003, New York Governor Pataki and New York City Mayor Bloomberg agreed to establish yet another entity, the Brooklyn Bridge Park Development Corporation (BBPDC), in the hope of moving the planning process forward. The BBPDC hired a design team led by landscape architect Michael van Valkenburg to produce a new BBP Illustrative Master Plan, and by all accounts the van Valkenburg team did a terrific job.

Yet instead of speeding up, things again slowed down. To get the park through New York City's byzantine development approval process, the Illustrative Master Plan would first have to be converted into a land use proposal, or, as it is known in New York City, into a general project plan. This would involve another ten years of debate, litigation, and looking for funding. Even without full approval, the BBPDC moved ahead with the van Valkenburg plan, figuring that once a specific facility or development project had been paid for and built, it would be difficult to undo. In the end, the BBPDC's incremental strategy turned out to be the right approach, and by the 2015, most of the plan's major facilities were either under construction or about ready to get underway.

Key Takeaways: The Brooklyn Bridge Park case offers a number of cautionary takeaways about how not to develop large public purpose facilities, especially those located in densely-populated urban environments. One key takeaway centers on the issue of framing. Early on in the process, Brooklyn community groups succeeded in framing the future of Brooklyn's waterfront as an existential conflict between a public park and private development. This early framing stuck, and in subsequent years was used to try to beat down any and all private development projects, even when all involved conceded there was no vehicle other than private development that might pay for the park's ongoing operation. The lesson for megaproject sponsors is that early on, they must persuasively frame their projects in terms of delivering public benefits lest those projects come to be seen as primarily serving private interests. A second key lesson concerns the importance of gaining project support across the political aisle. In the BBP case, every transfer of gubernatorial and mayoral power from one party to another initiated a one to two year transition period in which all approval and funding decisions were put on hold. In each case, the project ultimately got back on track, but not before losing valuable time. Had the park's sponsors in Albany and New York City made greater attempts to reach across the aisle to secure wider geographic and bipartisan support, the numerous transition slowdowns would have been less onerous. These institutional and political problems obscured some otherwise excellent planning and design work. The urban design, landscape architecture, and financial consultants hired by the LDC and BBPDC were all top-notch and consistently produced high-quality and imaginative work. Had the political context in which the Brooklyn Bridge Park found itself situated been more reliable and less prone to stakeholder conflicts, instead of characterizing the BBP planning and development process as problematic, we might instead be praising it as a model.

16. Five World-Class Renewable Energy Megaprojects

Chapter Authors: Oscar Serpell

Included Projects: Walney Extension Wind Farm, Noor Ouarzazate Solar Complex, Pavagada Solar Park, Bath County Storage Station, China's Ultra-high Voltage Transmission Lines

The Walney Extension Wind Farm: When the 87-turbine Walney Extension (WE) wind farm was completed in September 2018 at a cost of 1.3 billion GBP ($1.58 billion), it was the largest offshore turbine array in the world. (It has since been surpassed by Hornsea 1 and Hornsea 2 located 15 miles east of Hull in the North Sea). The WE wind farm currently delivers up to 659MW of renewable energy to over 600,000 households in the Northern United Kingdom. As its name suggests, WE was designed to augment the existing Walney 1 and Walney 2 wind farms, both completed in the early 2010's and with a combined capacity of 367 MW. WE is owned and operated by Orsted Energy, a multinational Danish power company that specializes in offshore and on-shore wind, solar, energy storage, and bioenergy plants.

WE was financed through the use of investment-grade bonds representing a 50% stake in the project. These bonds were purchased by PFA and PKA, two Danish pension funds, and broke new ground in the acquisition of non-bank debt by renewable energy projects. Because of their size and recognition as an established developer of renewable energy projects, Orsted was able to offer these low-risk bonds in a way that smaller, less established developers would never be able to do successfully. This financing method allowed Orsted to undertake a far larger and more ambitious project than would have otherwise been possible.

WE's attraction to potential investors was aided by its use of the United Kingdom's Contracts for Difference (CfD) system for financing offshore wind power projects. This government program effectively guarantees Orsted wholesale revenues of £150/MWh for the first 15 years of operation. The CfD program is based around a given strike price, and if wholesale process drops below that price within the 15-year term period, the government pays the difference. If the wholesale price rises above the strike price, Orsted and the minority owners are responsible for paying the difference back to the government. This significantly lowers the risk to developers investors.

Morocco's Noor Ouarzazate Solar Complex: The 580 MW Noor Ouarzazate Solar Complex in the Sahara Desert in Morocco is largest operational solar project to use concentrated solar power (CSP). As opposed to photovoltaic (PV) projects, which use rows of photovoltaic panels to convert photons directly to electricity, CSP designs reflect sunlight towards a single collection point, where it is used to heat water into steam which can be used to drive a conventional steam turbine. Although less thermodynamically efficient than a PV project, the heat produced in a CSP project can be stored (typically in molten salt) for use after the sun goes down.

Though CSP projects are more expensive to build and operate than PV projects, the flexibility allows for a more consistent and reliable revenue stream. With an initial capital cost of just $4.3 million/MW, Noor Ouarzazate is one of the more affordable CSP projects ever undertaken, allowing it to deliver electricity to customers at lower rates than has previously been achieved with CSP technology.

Perhaps more important than Noor Ouarzazate's technology was the way it was financed. Noor Ouarzazate was built using a build-own-operate-transfer (BOOT) public-private partnership model in which a private entity designs, constructs, finances and operates what is essentially a public project before ultimately transferring or selling it back to a government entity. The BOOT model allows the private developer to access capital at a lower price than is available to the government, keeps public expenditures off the government's balance sheet, and takes advantage of the private partner's improved risk management abilities, especially during construction. The BOOT model also gets the government off the hook if and when any rate increases are required. In the case of Noor Ouarzazate, Morocco's BOOT agreement with the project's private developer (ACWA Power, a power generation and desalination developer headquartered in Saudi Arabia) included several power-purchase agreements (PPAs) guaranteeing the developer with a reliable and stable revenue stream for BOOT agreement's duration. In addition to offering ACWA a 25-year PPA valued at over $1 billion, the Moroccan government also provided strategic and debt funding services.

India's Pavagada Solar Park: Few countries have adopted as ambitious a renewable energy agenda as India, which in 2016 announced that it planned to install 100 gigawatts (100,000 MW) of solar energy generation capacity by 2022. While it remains to be seen whether India will meet its goal by the announced deadline, the progress that India has made so far deploying renewables is noteworthy. Between 2016 and 2019, India added 31 GW of new solar capacity to its grid on top of a prior 18 GW.

Much of India's recent solar generation capacity has been added using the "solar park" model in which multiple private developers bid for, develop, and then operate sections (or blocks) of a much larger photovoltaic solar park. The Pavagada Photovoltaic Solar Park in the Indian state of Karnataka was completed in 2019 using this model at a cost of US $2.1 billion. With an installed capacity of 2,050 MW—Pavagada is currently the second largest photovoltaic solar park in the world, behind only the 2,245 MW Bhadla Solar Park in Rajasthan, also in India.

Pavagada's ten blocks are owned, and operated by ten separate companies, including TATA Power, Azure Power, SoftBank Energy, and Avaada Energy. The initial right to develop and operate each farm was allocated through an auction process carried out by the Karnataka Solar Park Development Corporation (KSPDCL), a joint venture established in 2015 by the State of Karnatka and the Indian government. Under the terms of the India's solar park auction process, power purchase agreements (PPAs)—the same mechanism used in the Noor Complex case—and access to the national transmission infrastructure are offered to private developers in exchange for commitments to sell specific blocks of power at "lowest and best" tariff rates.

This reverse auction mechanism not only benefits consumers in the form of low prices, but it also benefits individual developers by allowing them to take advantage of construction and operating economies of scale related to the use of government-financed ancillary facilities such as access roads and transmission lines. It also relieves developers from the responsibilities and risks associated with assembling the land on which the photovoltaic arrays sit. In the Pavagada case, that responsibility was undertaken by KSPDCL, which assembled the 11,000 acre site—an area equivalent to three-and-a-half Heathrow Airports—by offering 25-35 year leases to 2,000 individual farmers. By leasing instead of buying land, KSPDCL was able to prevent individual farmers from demanding exorbitant prices for their parcels. Leasing also gives landowners an annual income source, thus creating a sense of community 'buy-in' for what could otherwise be seen as a disruptive technology.

Bath County Storage Station: Not all renewable energy megaprojects are recent. Located along the amidst the Appalachian Mountains just east of the Virginia-West Virginia border, the Bath County Storage (BCS) station has been using pumped hydroelectric power to help balance electricity loads for nearly four decades, earning it the title of the "world's largest battery." With a maximum generating capacity of 3,003 MW and a total storage capacity of 24,000 MW-hours, the BCS facility is designed with two storage reservoirs, one located 1,200 feet above the other. Other than through evaporation losses, the BCS facility operates as a closed system, with an overall efficiency of 79%; meaning that 79% of the energy used to pump water uphill is recovered through the downhill flow.

The BCS facility was completed in 1985 by the Virginia Electric and Power Company (VEPCO, now Dominion Energy) at a cost of $1.6 billion to meet the utility's need for daily load balancing between day time and night time users. Having begun construction on a number of nuclear power plants in the late 1970's, VEPCO expected to be able to generate surplus electricity at night, when most of its customers were asleep. Rather than building additional nuclear or coal power plants just to meet daytime peak demand, VEPCO opted instead to invest in grid level storage that could begin generating electricity within five minutes and could shift supply from night to day.

When the BCS facility was conceived and built, pumped hydro power was seen as the only viable form of grid-scale energy storage and load balancing. Today, other technologies, including lithium ion batteries, hydrogen storage, and compressed air flywheels are filling this need. Even so, pumped hydro storage still remains the most popular approach to load balancing, especially in sufficiently mountainous or hilly regions. On the disadvantage side, pumped storage systems are land intensive, costly to construct, and ill-suited to hot, dry regions where evaporation losses and drought can limit system productivity.

Construction of the BCS facility began in 1977 before being stalled because of a longer-than-anticipated environmental impact assessment process and lower than expected peak demand. To complete the project, VEPCO sold a 40% share in the facility to Allegheny Power System, another regional utility that had been exploring the potential of pumped hydro storage. Neither utility required BCS's full generating capacity, but by sharing the station' capacity and capital costs, the two utilities were able to finance construction based on their combined customer rate bases over a 30-year intended life.

China's Web of Power: Storing electrical power is expensive, so having a robust, efficient, and extensive transmission system that allows surplus energy to be seamlessly transported to locations where it is needed has become an important component of renewable energy planning. No country in the world has leveraged the efficiency and flexibility benefits of investing in modern and high-capacity electricity transmission facilities more than China. Since 2004, China has constructed 22 ultra-high voltage (UHV) direct current (DC) and Alternating current (AC) power lines spanning more than 30,000 kilometers throughout the country. Just one of these transmission projects, a 1,100 kV DC line connecting the northwestern autonomous region of Xinjiang to eastern demand centers, cost $5.9 billion.

To complement its existing high-performance grid, China currently has plans to build as many as 30 additional UHVDC and UHVAC power lines as part of a national strategy to connect the sunny and windy provinces in the west to large cities and demand centers in the east. These new power lines will have greater capacity and be more technologically advanced than transmission line megaprojects anywhere else in the world. In the United States, for example, transmission voltages more or less cap out at about 500 kV. In addition to connecting future solar and wind generating megaprojects in China's arid western provinces to coastal population centers, China's high-performance grid will connect its renewable energy generating facilities to 21 pumped hydroelectricity storage plants, representing 19 gigawatts of electricity storage potential. This secure supply of power will provide additional flexibility to China's economic development planners in terms of where to locate future industrial and infrastructure investments.

China's efforts are not without risk. By connecting regional grids with UHV lines, China has created a single national "supergrid" which requires regional distribution networks to perform with a comparable level of capacity and efficiency. If they do not, some parts of the grid might temporarily have to be taken off line, resulting in rolling blackouts. Even here, China is taking a long-term view. By requiring that at least 90% of the equipment needed to build its enhanced grid is produced domestically, China is positioning itself as the world's leader in designing and manufacturing 21st century electricity transmission and distribution infrastructure.

China has only been able to undertake these huge investments because of its highly-controlled political, legal and economic environment. Unless otherwise specified, land in China is owned by the government, so the job of acquiring land for transmission line rights-of-way is streamlined. Nor do governments in China have to compensate any nearby property owners for any adverse spillovers associated new power line construction. The other condition that makes building new transmission lines easier in China is the fact that State Grid, the owner and operator of the system, is a state-owned utility company with direct access to financing from government ministries and banks. In FY2019, State Grid earned revenues in excess of $380 billion, making it the second largest company by revenue in China and the third largest in the world.

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17. Improving Megaproject Practice and Performance

Perhaps the best way to learn from the case studies presented in this volume is to compare them side by side. This chapter presents four such comparisons. The first compares megaproject success levels based on 12 performance criteria. The second compares how well each case study performs on Flyvbjerg's ten problem area list. The third identifies the decisions, actions and conditions that contributed to each megaproject's performance level. The fourth identifies a common series of megaproject lessons and takeaways that apply across multiple megaproject types and in multiple locations.

Performance Criteria and Summary Scores

The bottom line for any capital project is how well it performs. With this in mind, we identified twelve cross-cutting project performance criteria and used them to score each completed case study megaproject. We note that these criteria are drawn from the literature and are not necessarily reflective of the definitions of performance or project success used by each of the case study project's sponsors. Most of these criteria are "ex post," or after-the-fact criteria, meaning that they can only be applied after a project is completed and has entered service. The twelve performance criteria include:

1. Achieves project goals in a timely manner: Most infrastructure projects are undertaken to achieve a particular set of goals or purposes as listed in the project prospectus or funding documents. This *ex post* rating determines the extent to which a project achieves its stated purposes or goals. A "4" rating indicates most goals or purposes were achieved. A"3" rating indicates a majority of goals were achieved. A "2" rating indicates only a few goals were achieved. A "1" rating indicates most goals are not achieved, and a "0" rating indicates no goals were achieved.

2. Uses appropriate, innovative, and cost-efficient technologies: Most infrastructure projects involve a combination of hard and soft technologies to achieve their purpose. Hard technologies involve physical materials or machines or devices. Soft technologies involve the use of information and human service delivery practices. A "4" rating indicates that a project uses hard and/or soft that are appropriate to its purpose; innovative and up-to-date; and efficient with respect to minimizing capital and operating costs. A"3" rating indicates that a project's technologies are reasonably appropriate and cost-efficient. A "2" rating indicates that a project's technologies are appropriate or cost-efficient but not necessarily both. A "1" rating indicates that a project's technologies are neither appropriate or cost efficient, and a "0" rating indicated that a project's technologies are inappropriate and unnecessarily costly.

3. Avoids significant design, construction and delivery delays. Infrastructure projects should be finalized, built, and delivered within their scheduled timeframes as specified when they are approved or funded. A "4" rating indicates that a project met its planning, construction, and delivery schedule. A"3" rating indicates that a project experienced unexpected delays of 25% or less compared to its original schedule. A "2" rating indicates that a project

experienced unexpected delays of between 25% and 50% compared to its original schedule. A "1" rating indicates that a project experienced delays of between 50% and 75%, and a "0" rating indicated that a project experienced delays in excess of 75%. Note that this criteria does not reference how long it initially takes to get a project approved and funded.

4. Avoids significant design, construction and delivery cost overruns. Infrastructure projects should be finalized, built, and delivered within their proposed budgets as specified when they are approved or funded. A "4" rating indicates that a project was less than 10% over budget. A"3" rating indicates that a project was between 10% and 25% over budget A "2" rating indicates that a project was between 25% and 50% over budget. A "1" rating indicates that a project was 51 - 100% over budget, and a "0" rating indicates that a project was more than 100% over budget. A "U" indicates that a project's budget is or was not public knowledge.

5. Subjected to a formal needs assessment or willingness-to-pay study. Complex infrastructure projects should be undertaken only when there is a willingness to pay for their benefits as expressed through the private, quasi-private, or public good marketplace. A "4" rating indicates that a project passed a formal ex ante (before the fact) cost-benefit or economic feasibility analysis that properly measured demand or need. A "3" rating indicates that a project was subjected to a rigorous analysis of consumer or public demand or need. A "2" rating indicates that a project was subjected to some form of ex ante multi-criteria evaluation in which economic demand or need played a significant role. A "1" rating indicates that some form of ex ante project evaluation study was undertaken but that it may not have involved economic or willingness-to-pay criteria. A "0" rating indicates that no ex ante needs assessment or demand analysis was undertaken. A "U" indicates that a needs assessment or willingness-to-pay analysis may have been undertaken, but that its results were never made public.

6. Manages major sources of development and financial risk. Big projects are by nature risky and face numerous unknowns. Project planners have tools and techniques available to identify various sources of risk, as well as to reduce and mitigate those risks. A "4" rating indicates that project sponsors and managers undertook a robust risk analysis and management study prior to undertaking a project, and that they continued to update it throughout the development and construction process. A "3" rating indicates that a project was subjected to a rigorous risk analysis and management study prior to approval and construction. A "2" rating indicates that a project was subjected to an ad hoc risk analysis and mitigation study prior to approval and construction. A "1" rating indicates that there was some ex ante identification of risk sources, but no identification of possible risk management approaches. A "0" rating indicates that no ex ante risk analysis or mitigation study was undertaken. A "U" indicates that a risk analysis study may have been undertaken but that its results were never made public.

7. Utilizes a robust revenue projection and financing model. Many a megaproject had been undertake only immediately underperform economically and require unanticipated and continuing subsidies. In the worst of such cases, projects are abandoned or removed from

service. To avoid such fates, project sponsors should undertake careful and realistic projections of project revenues to determine whether those revenues will be sufficient to pay back investors or lenders as indicated in the project prospectus. A “4” rating indicates that project sponsors developed robust revenue projections that drove how the project was financed. A “3” rating indicates that project sponsors developed appropriate revenue projections but that they were not fully stress-tested or evaluated at different discount rates. A “2” rating indicates that project sponsors developed revenue projections but did not fully document the assumptions behind the projections. A “1” rating indicates the use of ad hoc revenue projections, and a “0” rating indicates that no revenue analysis was undertaken. A “U” indicates that a revenue projection and financing analysis may have been undertaken but that its results were never made available.

8. Provides for ongoing operations and management activities. Once completed, projects don’t operate or manage themselves. They require adequate operations and maintenance funding and staffing as well as management and information systems that anticipate and minimize potential problems. A “4” rating indicates that project sponsors have provided adequate funding, staffing, and management systems for the project to operate at peak efficiency on an ongoing basis. A “3” rating indicates that project sponsors have provided sufficient funding and staffing to support project operations for at least 10 years. A “2” rating indicates that project sponsors have provided sufficient funding and staffing to support project operations for at least 5 years. A “1” rating indicates project sponsors have identified the need to support ongoing operations but have not necessarily made sufficient provisions to do so. A “0” rating indicates that project sponsors have not made provisions for continuing operation. A “U” indicates that a project operating plan may have been prepared but that it has not been made public.

9. Promotes innovation, synergies, and positive externalities. In the best of all worlds, megaprojects have emergent properties, which is to say that they promote positive synergies and externalities—including technical innovation—over and above the level initially envisioned. Identifying such benefits requires some form of *ex post*, or after-the-fact assessment. A “4” rating indicates that an ex post assessment has been undertaken and identified the emergence of sizeable positive synergies and externalities. A “3” rating indicates that an ex post assessment has been undertaken and identified the emergence of minor positive synergies and externalities. A “2” rating indicates that a project is associated with some level of external synergies or benefits but they have not been carefully documented. A “1” rating indicates that no project synergies or external benefits have been identified, and a “0” rating indicates that a project is commonly associated with external costs and/or negative externalities. A “U” indicates that the incidence of synergies and side benefits is unknown.

10. Minimizes environmental and social costs. Minimized negative externalities is the flipside of promoting positive externalities. All large projects create unwanted side effect. Sometimes they are physical or spatial as in the case of noise or pollution, and sometimes they are social or economic, as in the case of unwanted gentrification and displacement. A

"4" rating indicates that a project generates few negative externalities/social costs, and that its development or management program includes provisions for minimizing them. A "3" rating indicates that a project generates few negative externalities/social costs but that no provision has been made for identifying the ones it does. A "2" rating indicates that a project generates unwanted adverse effects but that they don't constitute a physical or health hazard. A "1" rating indicates that a project generates a significant number or magnitude of undesirable side effects and that they constitute a substantial health or social hazard. A "0" value indicates that a projects side effects are almost entirely negative and dangerous. A "U" indicates that the incidence of negative side effects and social costs is unknown.

11. Incorporates measurable sustainability, resilience, and/or equity benefits. Good projects leave the natural environment better than they found it and those suffering from economic or social disadvantages better off. To the extent that a resilient system is better able to cope with external or adverse shocks, and is therefore more sustainable, we couple sustainability with resilience. Sustainability and equity benefits are similar in concept to positive externalities but are typically more broad-based and enduring in nature. A "4" rating indicates that a project generates measurable sustainability/resilience benefits for natural systems and the natural environment, as well as significant equity benefits for those who are economically or socially disadvantaged. A "3" rating indicates that a project generates significant sustainability/resilience benefits or significant equity benefits. A "2" rating indicates that a project generates some sustainability/resilience benefits and/or equity benefits but that they are relatively small. A "1" rating indicates that a project generates no sustainability or equity benefits, and a "0" rating indicates that a project adversely impacts natural systems or generates negative equity effects. As with previous criteria, a "U" indicates that a project's sustainability, resilience, and equity effects are unknown.

12. Generates positive and transferable lessons & experience. Learning save valuable time and reduces the likelihood that avoidable mistakes are repeated. As with external benefits and costs and issues of sustainability and equity, resolving whether a project generates transferable lessons or experiences is best determined in hindsight. A "4" rating indicates that a project generates valuable lessons that can be productively applied in a wide variety of contexts. A "3" rating indicates that a project generates important but less widely applicable lessons. A "2" rating indicates that a project generates few or exceedingly narrow lessons, and a "1" indicates that a project is strictly a "one-off" in terms of transferable lessons or experience. A "U" indicates that on cannot assess whether a project offers useful or transferable lessons. or a project's sustainability, resilience, and equity effects are unknown.

All of these criteria and scores are relative. None are absolute, meaning that they can't be reliably measured using project independent scales or indexes like benefit-cost ratios.

Table 4 scores each case study megaproject or megaproject type according to each performance criteria. It also includes a total score, which adds together the individual category scores, and a percentage score, which divides the total score by the maximum possible score. Note that the scoring categories are not weighted, meaning that each counts the same when determining the total and percentage scores.

Key findings include:

- Performance levels vary widely among the megaproject case studies, both across and within project categories. Compared across all 13 case study projects or project types, total scores vary from a low of 29 for Songdo to a high of 41 for HafenCity. Percentage scores vary from a low of 35% for Songdo (meaning that Songdo's total score amounted to 35% of its maximum attainable score) to a high of 85% for HafenCity. The biggest variation in scores is among the three urban development projects, with HafenCity achieving a high percentage score of 85%, and Songdo achieving a low percentage score of just 35%. There was also significant scoring variation within the airport, and bridge and tunnel project categories. Whereas Jewel Changi Airport achieved a 78% score and LaGuardia Airport achieved a 73% score, Berlin-Brandenburg earned a percentage score of just 38%. Likewise, whereas Seattle's Alaska Way Tunnel project earned a 73% score, the Hong Kong-Zhuhai-Macao Bridge earned a 38% score. All three of the rail or bus projects or project types scored fairly well, with their percentage scores varying from a high of 73% for China's national high speed rail network, to a low of 68% for the 68% for the Beijing, Shanghai, Guangzhou, and Shenzhen metro systems when evaluated as a group.
- Few projects performed consistently well or consistently badly. Most of the case study projects performed mid-pack in terms of performance consistency across the different scoring categories. (We measured performance consistency by dividing the standard deviation of the score categories for each project by the average score.) HafenCity, Jewel Changi Airport and the six BRT projects did consistently well across all of the scoring categories while the Hong Kong-Zhuhai-Macao Bridge and the Berlin-Brandenburg Airport were the most inconsistent in terms of their cross-category performers. None of the projects were complete duds in terms of performing poorly across all categories. In terms of project types, the rail and transit projects were much more consistent in terms of cross-category performance than the bridge and tunnel, airport, or urban development projects.
- Collectively, the case studies performed well using appropriate technologies and achieving their goals, and poorly in terms of promoting sustainability and equity and managing risk. Among individual scoring categories, the case study projects performed best in terms of using appropriate and cost-efficient technologies, earning an average score to 3.5 out of 4. The other category in which most of the case study projects performed well was the goal achievement category, earning an average score of 3.2. At the other end of the performance spectrum, the case study projects earned an average sustainability, resilience, and equity score of just 2.0 (out of 4) and an average risk management score of just 2.1. As a group, the case studies also performed poorly in terms of minimizing environmental and social costs, posting an average score of 2.2; and providing for ongoing operations and asset management activities, posting an average score of 2.5. In terms of within-category performance consistency (as measured by dividing the standard deviation of the within-category score by the average within-category score), the case studies performed most consistently in terms of

their use of appropriate and cost-efficient technologies; and least consistently in terms of avoiding major delivery delays. The other scoring categories in which projects performed inconsistently were the promotion of synergies and positive externalities, and the minimization of environmental and social costs.

- The project scores are all fairly robust. Applying weights to the category scores to reflect the greater importance typically attached by project sponsors to goal-achievement, and the lesser importance commonly attached to issues of equity, sustainability and transferability does not change the overall or percentage project scores.

Table 4: Case Study Megaprojects: Success Performance Scores

	Performance Criteria	Rail and Transit Projects				Bridge & Tunnel Projects		Airport Projects			Urban Development Projects			Other		Summary Statistics	
	Key to ratings: 4=yes, 3=mostly yes, 2=somewhat, 1=mostly no, 0=no, U=unknown)	London Crossrail	Beijing, Shanghai, Guangzhou & Shenzhen Metro Systems	China's High Speed Rail Network	Bus Rapid Transit in 6 Latin America & Asian Cities	Seattle Alaska Way Tunnel	Hong Kong-Macao-Zhuhai Bridge	The Jewel at Singapore Changi Airport	Berlin Brandenburg Airport	LaGuardia Airport Terminal B Reconstruction	London Canary Wharf	HafenCity Hamburg	Songdo, Korea	Brooklyn Bridge Park (New York City)	Diverse Renewable Energy Projects	Average Score	Coefficient of Variation (St.Deviation/Average)
1	Achieves project goals and objectives in a timely manner	Project is not yet completed	4	4	3	4	1	4	2	4	4	4	1	3	3	3.2	0.4
2	Uses appropriate, innovative, and cost-efficient technologies		4	4	3	4	4	4	3	4	4	4	2	3	3	3.5	0.2
3	Avoids significant design, construction and delivery delays.		4	4	4	2	4	4	0	4	2	3	1	1	3	2.8	0.5
4	Avoids significant design, construction and delivery cost overruns.		U	U	3	3	3	4	0	4	2	3	2	2	3	2.6	0.4
5	Subjected to a formal needs assessment, ex ante evaluation, or willingness-to-pay study.		2	2	3	3	1	1	3	3	2	3	1	3	2	2.2	0.4
6	Manages major sources of development and financial risk		U	U	3	2	1	U	2	3	1	3	1	3	2	2.1	0.4
7	Utilizes a robust revenue projection and financing model		2	U	3	2	1	U	2	3	2	3	1	3	2	2.2	0.3
8	Provides for ongoing operations and management activities		2	3	2	3	1	4	2	3	2	4	1	3	3	2.5	0.4
9	Promotes innovation, synergies, and positive externalities		3	3	2	4	1	3	1	2	3	4	1	3	4	2.6	0.4
10	Minimizes environmental and social costs		3	3	3	3	1	2	1	1	1	3	2	3	3	2.2	0.4
11	Incorporates sustainability, resilence, and/or equity concerns		3	3	2	2	0	2	1	1	1	3	2	3	3	2.0	0.5
12	Generates positive and transferable lessons & experience.		3	3	3	3	1	3	1	3	2	4	2	3	3	2.6	0.3
	Total Success Score		30	29	34	35	19	31	18	35	26	41	17	33	34	29.4	0.3
	Percentage Success Score		68%	73%	71%	73%	40%	78%	38%	73%	54%	85%	35%	69%	71%	0.6	0.3

Avoiding Megaproject Problem Areas

How do the case study megaprojects perform when it comes to avoiding Flyvbjerg's ten megaproject problem areas? As Table 5 indicates, quite well in fact. Three of the four rail and transit cases, including both the Chinese metro and a high speed rail cases, managed to avoid all ten of Flyvbjerg's megaproject planning and delivery problem areas. The Singapore and LaGuardia airport cases also performed extremely well, as did HafenCity. At the opposite extreme, Songdo fell into nine of Flyvbjerg's ten megaproject traps, and the Berlin-Brandenberg Airport fell into eight. In between these extremes, Brooklyn Bridge Park fell into five of Flyvbjerg's pitfall areas, and London Crossrail, the Seattle's Alaska Way Tunnel, and the Hong Kong-Zhuhai-Macao Bridge each fell into three.

Of Flyvbjerg's ten potential problem areas, the two that the various case studies fell into most frequently were not anticipating low-probability-but-high cost adverse events—what Flyvbjerg terms "black swans"—and not including adequate contingency funds or delay times in project contracts. In six of the case studies, project planners did not adequately anticipate the extent to which an overly-long planning and delivery time horizon would exacerbate downstream physical and financial performance risks. There was also a tendency to view projects as "one-offs," which reduced opportunities for sharing knowledge and learning from past experiences. Less common but not infrequent problems included difficulties aligning all stakeholders around project goals and timetables and finding knowledgeable and experienced senior managers. As a general rule, the more local governments or stakeholders that were involved in the project planning or delivery process, the more problems a project experienced. Because they had fewer resources to deal with market downturns, projects run by private developers (e.g., Canary Wharf and Songdo) experienced more problems than those run by experienced public agencies or clearly-circumscribed public private partnerships (e.g., HafenCity and LaGuardia Airport). Among the case study projects, new airports were more problematic than existing ones, and ambitious bridge and tunnelling projects were also more problem prone. Chinese megaprojects undertaken by the central government (e.g., high-speed rail) or by city governments (e.g., metro and BRT systems) experienced fewer problems than those undertaken by multiple provinces or special administrative region (e.g., the Hong Kong-Zhuhai-Macao Bridge).

Table 5: Case Study Megaprojects: Avoiding Flyvbjerg's Ten Megaproject Problem Areas

	Flyvbjerg Megaproject Problem Areas Encountered (Key: N=No, Y=Yes, P=partially, U=unknown)	Rail and Transit Projects				Bridge & Tunnel Projects		Airport Projects			Urban Development Projects			Other	Number of case study megaprojects experiencing this problem area
		London Crossrail	Beijing, Shanghai, Guangzhou & Shenzhen Metro Systems	China's High Speed Rail Network	Bus Rapid Transit in 6 Latin America & Asian Cities	Seattle Alaska Way Tunnel	Hong Kong-Macao-Zhuhai Bridge	The Jewel at Singapore Changi Airport	Berlin Brandenburg Airport	LaGuardia Airport Terminal B Reconstruction	London Canary Wharf	HafenCity Hamburg	Songdo, Korea	Brooklyn Bridge Park (New York City)	
1	Long project planning and delivery horizon exacerbates risks of physical and/or financial under-performance.	N	N	N	N	N	Y	N	Y	N	Y	P	Y	Y	6
2	Megaprojects planners and managers may lack “deep domain” experience, creating management problems and adding to the frequency of staff turnover.	Y	N	N	N	N	N	N	Y	N	N	N	Y	N	3
3	Project sponsors and stakeholders are not fully aligned around project purpose, goals, objectives, budget, and construction timetable.	P	N	N	N	N	N	N	Y	N	N	N	Y	Y	4
4	Megaproject technologies and designs are viewed as “one-offs,” which impedes learning from the results of other projects.	N	N	N	N	Y	Y	P	Y	N	N	N	Y	Y	6
5	Many megaprojects do not initially undergo a rigorous alternatives analysis, resulting in the wrong technology or scale or scope of project being selected.	N	U	U	P	N	Y	Y	Y	N	N	N	Y	N	5
6	Because of the large sums of money involved in delivering megaprojects, principal-agent and rent-seeking behavior are common, as is optimism bias.	N	U	U	U	N	U	N	N	N	Y	N	Y	N	2
7	The megaproject scope or ambition may change over time.	N	N	N	N	N	N	N	Y	N	N	Y	Y	Y	4
8	Megaproject planners and managers systematically underestimate the potential for low likelihood-but-extremely adverse “black swan” events.	P	N	U	N	Y	P	P	P	N	Y	U	P	N	7
9	Megaproject planners, managers, decision-makers and contractors don’t include adequate time or budgetary contingency provisions in project contracts.	Y	U	U	U	Y	U	U	Y	P	Y	U	Y	Y	7
10	As a result, internal and external misinformation becomes the norm throughout the megaproject development and decision-making process.	Y	N	P	N	N	N	N	Y	N	N	N	Y	N	4
Total Problem Areas Avoided (out of 10)		7	10	9.5	9.5	7	6.6	7	1.5	9.5	6	8.5	0.5	5	
Percentage Score (from Table 4)		na	68%	73%	71%	73%	40%	78%	38%	73%	54%	85%	35%	69%	

Connecting Good Practice to Good Outcomes

Having identified some megaproject case studies as performing better than others, we now turn now to identifying possible sources of those performance differences. Researchers have identified numerous practices and conditions that increase the likelihood that a megaproject will perform successfully. Among the most notable of these conditions are:

- Ensuring the project sponsor or owner has effective site control;
- Ensuring that the project should has a politically powerful champion;
- Ensuring that all project sponsors and stakeholders are aligned around a project's purposes, goals, budget, and delivery timetable;
- Ensuring that the project has undergone a thorough and independent review before it is approved and funded;
- Ensuring that the project's planners, designers, engineers and managers all have experience and a track record of success with respect to similar projects;
- That all contracts are clear and unambiguous, precisely detailing the responsibilities of sponsors and contractors;
- Ensuring that contracts properly anticipate and budget for adverse contingencies;
- Ensuring that an integrated and robust project management and control system is in place that reflects the budgets, schedules, and the work obligations of all parties;
- Ensuring that project risks are assigned to the parties best able to manage, control, or reduce them; and
- Putting in place procedures for monitoring project performance on an ongoing basis.

To what extent is adherence to these and other "good project management" practices associated with the success of each case study megaproject?

To find out, we first reviewed the degree to which each of the case study projects adhered to 27 "good project planning and management" practices identified from the literature and organized into seven practice groups: planning, design and engineering; financing; contracting; project management; risk management; construction and delivery; and operations and asset management). Adherence is assessed using a nominal scoring system where a "1" rating is used to indicate general adherence, a "0.5" rating is used to indicate partial adherence, and a "0" value indicates no adherence. In situations where the necessary adherence information could not be assessed, we gave a project a "U" (for unavailable) rating. The good practice adherence scores are presented in Table 6.

Next, we totaled up each case study project's within-category and total adherence ratings. Projects that adhered to all six good planning, design and feasibility study good practices earned a maximum score of 6. Projects that adhered to all three good financing practices earned a score of 3. Projects that adhered to all six good contracting practices earned a maximum score of 6.

Projects that adhered to the three good project management practices earned a maximum score of 3. Projects that adhered to the three good project delivery practices earned a score of 3, and those that adhered to the four sets of good operations and asset management practices earned a score of 4. A perfect score of 27 indicates a project adhered to every good practice.

Among the twelve megaprojects summarized in Table 6, total good practice adherence scores vary from a high of 24 for HafenCity—meaning that HafenCity's sponsors adhered to 24 of 27 good practice scores—to a low of 6.5 for Songdo. The average good practice adherence score for all twelve megaprojects is 17.2. Comparing average adherence scores across the seven good practice categories, the case study projects did best adhering to good project planning practices, and to good project delivery practices, earning an 82% adherence percentage score in each. The case study megaprojects did poorly adhering to good financing practices and good contracting practices, earning percentage adherence scores of 52% and 56%, respectively. The other three categories (project management, risk management, and operations and asset management) all posted adherence percentages in the mid-60s. Except for the three rail and BRT projects—which were consistently mid-pack in terms of their total adherence scores—adherence scores varied widely among megaproject types. HafenCity, for example, posted the highest total adherence score of any megaproject (24) while another urban development megaproject, Songdo, posted the lowest (6.5). Canary Wharf, the third urban development megaproject was firmly mid-pack, with a total adherence score of 18.5. Projects within the airport and bridge and tunnel categories also varied widely in terms of their adherence to good megaproject practice. Although one can certainly quibble with how individual adherence scores were assigned, the fact that Table 3 lists so many diverse good practices means that the variation in adherence scores should reasonably reflect an underlying variation in practices.

In an effort to connect practices and outcomes, we graphically compared each project's within-category good practice adherence scores as tabulated in Table 6 to its performance percentage scores as summarized in Table 4. The results of those comparisons are presented as scatterplots and trend lines in Figure 1. To the extent that a project sponsor followed good planning, financing, contracting, project management, and delivery practices, and that those practices resulted in a more successful project, the summary trend lines indicated in Figure 1 should be positive. To the extent that following good practice does not necessarily result in better outcomes, the trendlines indicated in Figure 1 will be flat or negative.

Based on the results presented in Figure 1, and subject to all the caveats inherent in assigning project success scores and good practice adherence ratings to a small sample of highly diverse megaprojects, we offer the following conclusions about the relationships between megaproject planning, financing, project management and delivery practices and the likelihood of project success. These results are based on observations of the case study megaprojects summarized in this volume and care great care should be taken in extending them to other projects and situations. limited in their:

- Among the case study megaprojects, there is a positive and moderate relationship between adhering to good <u>megaproject planning, financing, contracting, project management, risk</u>

management, and operations management practices, viewed in total, and positive megaproject outcomes. This relationship is evident across megaproject category types.

- Among the case study megaprojects, there is a strong and positive relationship between adhering to good megaproject planning, design, and feasibility assessment practices and good megaproject outcomes. This relationship is also evident across megaproject category types.
- Among the case study megaprojects, there is a positive and moderate relationship between adhering to good megaproject contracting practices and good megaproject outcomes.
- Among the case study megaprojects, there is a positive and moderate relationship between adhering to good megaproject risk assessment and management practices and good megaproject outcomes.
- Among the case study megaprojects, there is a positive but weak relationship between adhering to good megaproject financing practices and good megaproject outcomes.
- Among the case study megaprojects, there is a positive but very weak relationship between adhering to good project management practices and good megaproject outcomes.
- Among the case study megaprojects, there is a positive but very weak relationship between adhering to good project delivery practices and good megaproject outcomes.
- Among the case study megaprojects, there is a positive but very weak relationship between adhering to good project operations and asset management practices and good megaproject outcomes.

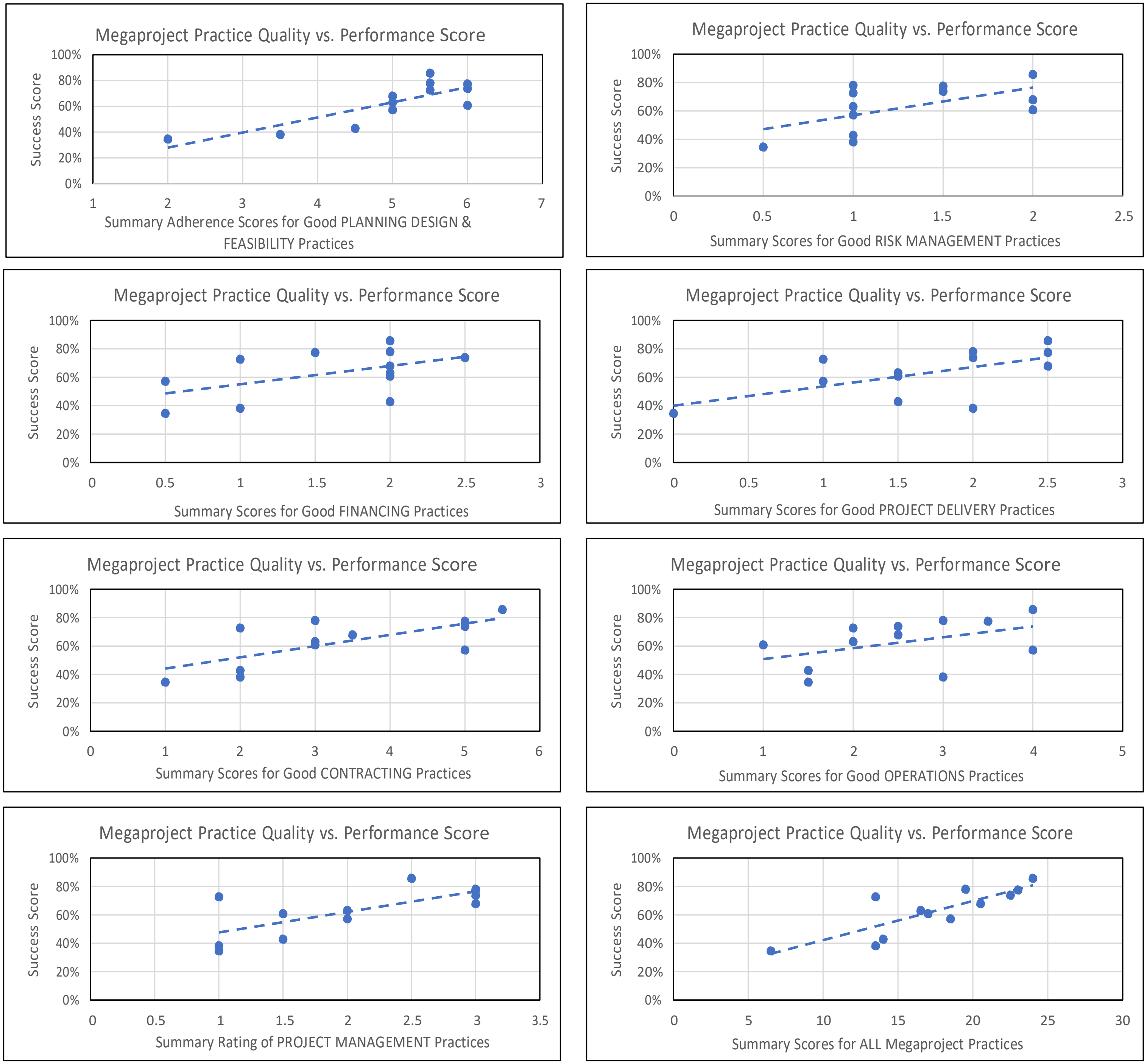
Table 6: Case Study Megaprojects: Adherence to Good Practice Ratings

Practices that Ensure or Promote Megaproject Success (Key: 1 = adherence; 0.5 = partial adherence; 0 = no adherence; U = unknown)			Rail and Transit Projects				Bridge & Tunnel Projects		Airport Projects			Urban Development Projects			Other
			London Crossrail	Beijing, Shanghai, Guangzhou & Shenzhen Metro Systems	China's High Speed Rail Network	Bus Rapid Transit in 6 Latin America & Asian Cities	Seattle Alaska Way Tunnel	Hong Kong-Macao-Zhuhai Bridge	The Jewel at Singapore Changi Airport	Berlin Brandenburg Airport	LaGuardia Airport Terminal B Reconstruction	London Canary Wharf	HafenCity Hamburg	Songdo, Korea	Brooklyn Bridge Park (New York City)
Initial Project Planning, Design & Feasibility Activities	1	Project sponsors have site control and take responsibility for securing necessary permits, approvals, and financing.	Project is not complete as of this writing	1	1	1	1	1	1	1	1	1	1	0	0.5
	2	The project has a champion in the sponsor's organization who is able to supports the project as necessary.		1	1	1	1	1	1	1	1	1	1	1	1
	3	Project sponsors and stakeholders are aligned around project purpose, goals, objectives, budget, and construction timetable		1	1	1	1	1	1	0.5	1	0.5	1	0	0.5
	4	Proper initial due diligence has been performed with respect to physical and institutional constraints, market demand, cost and financial feasibility, and sources and types of risks.		U	1	0.5	1	0	0.5	0.5	1	0.5	1	0	1
	5	Project technologies have been properly tested or vetted.		1	1	1	1	0.5	1	0.5	1	1	0.5	0.5	1
	6	Project is properly divided into deliverable pieces.		1	1	1	1	1	1	0	1	1	1	0.5	1
Project Financing	7	Project financing has been independently reviewed, underwritten and stress-tested.		0	0	0	1	0	U	0	0.5	0	0.5	0	0.5
	8	Project capital stack properly reflects capital source contributions and capabilities.		1	1	0.5	1	1	1	0.5	0.5	0.5	1	0	1
	9	Avenues for additional financing (if needed) have been identified and secured as necessary.		1	1	0.5	0.5	1	1	0.5	0.5	0	0.5	0.5	0.5
Contracting	10	Project planners, designers and contractors have experience and a track record of success with respect to similar projects.		1	1	1	1	0.5	1	0.5	1	1	1	0	1
	11	Contractors are brought onto the project as early as feasible to participate in the planning and design process as appropriate.		1	1	0.5	1	0.5	1	0.5	1	1	1	1	1
	12	Project sponsors fully understand the contractors' work program, schedule, and cost structure. Project milestones have been properly identified.		1	1	0.5	1	1	1	0.5	1	1	1	0	0.5
	13	Contracts are clear and unambiguous, precisely detailing the responsibilities of sponsors and contractors		U	U	U	1	U	U	0	1	1	1	0	U
	14	Contract incentives and performance requirements are appropriate to objectives and project sponsor and contractor capabilities and roles.		U	U	U	0.5	U	U	0.5	1	0.5	1	0	1
	15	Contract properly anticipates adverse contingencies.		U	U	U	0.5	U	U	0	U	0.5	0.5	0	U

Table 6 (Continued): Case Study Megaprojects: Adherence to Good Practice Ratings

Practices that Ensure or Promote Megaproject Success (Key: 1 = adherence; 0.5 = partial adherence; 0 = no adherence; U = unknown)			Rail and Transit Projects				Bridge & Tunnel Projects		Airport Projects			Urban Development Projects			Other
			London Crossrail	Beijing, Shanghai, Guangzhou & Shenzhen Metro Systems	China's High Speed Rail Network	Bus Rapid Transit in 6 Latin America & Asian Cities	Seattle Alaska Way Tunnel	Hong Kong-Macao-Zhuhai Bridge	The Jewel at Singapore Changi Airport	Berlin Brandenburg Airport	LaGuardia Airport Terminal B Reconstruction	London Canary Wharf	HafenCity Hamburg	Songdo, Korea	Brooklyn Bridge Park (New York City)
Project Management & Accountability Systems	16	Sponsor and contractor project managers are qualified and experienced.	Project is not complete as of this writing	1	0.5	0.5	1	1	1	0	1	1	1	0.5	1
	17	An integrated and robust project management and control system is in place that reflects the budgets, schedules, and obligations of all parties. The project management system explicitly allows for contingencies.		U	0.5	0	1	U	1	0.5	1	1	1	0	1
	18	Procedures exist to document and evaluate project scope or design changes with respect to program goals, costs, and delivery times.		1	0.5	0.5	1	0.5	1	0.5	1	0.5	1	0.5	1
Risk Management & Mitigation	19	Project risks are assigned to the parties best able to manage, control, or reduce them.		1	1	0.5	1	1	1	0.5	1	0.5	1	0.5	1
	20	Provisions are in place to minimize and manage project-level risks rather than just shifting them about.		U	1	0.5	0.5	U	U	0.5	0.5	0.5	1	0	1
Project Delivery & Commissioning	21	Test component systems as they come on line and in concert with other systems		1	1	1	1	1	1	1	1	0	1	0	0.5
	22	Identify resiliency and responses to unexpected events or occurences		U	0.5	U	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	1
	23	Ensure proper asset management procedures and systems are in place before delivery		0.5	U	U	0.5	U	1	0.5	1	0.5	1	0	1
Operation & Asset Management	24	Monitor use patterns and costs to plan for maintenance, upgrading & service changes		0.5	0.5	0.5	1	0.5	1	1	1	1	1	0.5	1
	25	Monitor revenue and cost trends to benchmark financial health and identify how usage patterns are changing		1	U	0.5	1	0.5	1	1	1	1	1	0.5	1
	26	Monitor positive and negative spillover effects		0.5	U	0.5	0.5	0.5	1	0.5	0.5	1	1	0.5	0.5
	27	Undertake periodic SWAT analyses to identify potential modifications, expansions, and investments		U	0.5	0.5	U	U	U	0.5	1	1	1	U	U
Total Adherence Score				16.5	17	13.5	22.5	14	20	13.5	23	18.5	24	6.5	20.5

Figure 1: Comparisons of Case Study Megaproject Performance Scores with Best Practice Adherence



Cross-cutting Takeaways

Having constructed an elaborate rating and evaluation system to connect megaproject planning and delivery practices to successful megaproject outcomes, Table 7 takes a more qualitative approach by summarizing each case study's positive and cautionary takeaways.

Among the rail and bus transit projects, China's metro systems and high-speed rail cases provide strong support for standardizing planning, construction, and procurement processes across multiple lines and projects as a means for staying on schedule and budget and for learning from experience. The six bus rapid transit projects in Latin American and Asian cities also demonstrate the benefits of learning from experience from prior adopters, as well as for having a single coordinating organization—the non-profit Institute for Transportation Development and Policy—whose mission is to disseminate successful practice guidelines. London Crossrail may offer additional positive takeaways once it is completed in 2022, but until then, its principal positive lesson concerns the care taken by Crossrail planners to document its full benefits and costs.

Among the bridge and tunnel projects, Seattle's Alaska Way Tunnel example provides support for intentionally connecting transportation facility construction projects to urban redevelopment opportunities, especially those involving the public realm. Among airport projects, the Singapore Jewel Changi and LaGuardia Airport cases both demonstrate the value of building permanent project planning and project management capacity within responsible government agencies. In Singapore's case, the expertise the Civil Aviation Authority and Department of Public Works, and then later the corporatized Changi Airport Group gained in planning and developing earlier projects allowed them to continually raise the bar for later projects. Likewise, the experiences the Port Authority of New York and New Jersey gained previously renovating both JFK and Newark Airports enable them to effectively manage the logistical challenges involved in keeping an airport fully operating while rebuilding it from top to bottom. Indeed, the principal reason the Berlin-Brandenburg Airport went so far over budget and schedule was that its governmental sponsor, Flughafen Berlin Brandenburg (FBB) was totally lacking in airport planning and construction experience.

The three urban development case studies also point to the importance of local experience. Olympia and York, the initial developer of Canary Wharf had successfully developed similar projects in Toronto and New York City but was totally unprepared for the cascading uncertainties they would face in London. The situation was even more problematic in Songdo where neither the project sponsor (Incheon City) nor the project developer (Gale International) had previously undertaken a project of comparable scale or risk. In HafenCity by contrast, both the innovative project master plan and the multi-faceted implementation strategy were developed by experienced local actors.

The principal positive lesson of the Brooklyn Bridge Park case centers on the value of importance of incremental implementation, even when a top-quality comprehensive master plan is well in hand.

The case studies also offer cross-cutting cautionary lessons. The London Crossrail and Berlin-Brandenburg Airport cases both speak to the difficulties of coordinating dozens of construction contractors, especially when new and untried technologies are involved.

The China high-speed rail case and the Hong Kong-Zhuhai-Macau (HKZM) Bridge case both indicate the difficulties inherent in undertaking large-scale transportation investments in the hope of reallocating regional economic investments. Connecting China's fast-growing coastal cities to its slower-growing inland cities by high-speed rail did little to redirect private investment into the country's interior. Likewise, the HKZM Bridge did little to redirect the investment and economic activity occurring in Hong Kong and Shenzhen on the eastern side of Lingdingyang Bay and the Pearl River Delta to Zhuhai on the western side.

The examples of China's high-speed rail (HSR) network and urban metro systems attest to the downsides of standardization as well as the upsides: In the HSR case, the lack of coordination between HSR station construction activities and nearby property development has caused many economic and development synergies to go unrealized. In the metro examples, the insistence on following uniform station spacing and line connection criteria, particularly in Beijing, has limited the ability of metro investments to favorably shape land use and development patterns.

The Berlin-Brandenburg, Songdo, and Brooklyn Bridge examples all indicate the problems inherent in developing megaprojects when the different sponsors and stakeholders' interests are not properly aligned.

The Canary Wharf and Alaska Way Tunnel cases both indicate the importance of anticipating adverse contingencies, In the Canary Wharf example, Olympia and York relied on a bank financing arrangements that had little room for error should the company's aggressive leasing schedule not be met. Likewise, in the Alaska Way Tunnel case, neither the lead project sponsor (the Washington Department of Transportation) nor the lead tunneling contractor had included minimally adequate scheduling or budgeting contingencies in their $1 billion tunneling contract.

Table 7: Positive and Cautionary Takeaways from the Case Study Megaprojects

Megaproject	Positive Takeaway	Cautionary Takeaway
London Crossrail	Economic feasibility case can reliably include secondary and induced benefits if clearly identified	Beware large and complex projects with numerous contractors and untested project management coordination and accountability mechanisms.
Beijing, Shanghai, Guangzhou & Shenzhen Metro Systems	Standardized planning construction, and procurement practices across lines keeps projects on schedule and budget.	Over-standardization of financing arrangements and related land use and development practices reduces local flexibility and initiative.
China's High Speed Rail Network	Nationally-standardized planning, construction, contracting and procurement practices kept projects on schedule and budget.	Achieving secondary economic and spatial development goals is difficult.
Bus Rapid Transit in 6 Latin America & Asian Cities	Sponsors of later BRT systems learned from experiences of earlier adopters.	Even in the best of circumstance, it is difficult to match BRT supply and service characteristics to shifting traveler demands and volumes.
Seattle's Alaska Way Tunnel	Large transportation projects create opportunities to think creatively about public realm possibilities and improvements.	It is critically important to plan and budget for adverse contingencies.
Hong Kong-Zhuhai-Macao Bridge		Beware very large highway projects that are principally justified on the basis of economic development, especially in a dynamic and fluid economy (like China's).
Singapore's Jewel Changi Airport	Singapore's early investments in government airport planning and construction capacity had large and continuing benefits.	
Berlin-Brandenburg Airport		It is impossible to overstate the importance of experienced project managers and contractor management and accountability systems.
LaGuardia Airport Terminal B Reconstruction	There are significant redundancy advantages to undertaking and opening complicated projects in phases.	Politics and personalities can complicate even the most thorough of project planning efforts.
London Canary Wharf	Secondary CBDs may make sense for congested and expensive global megacities.	Even the best-planned commercial real estate megaprojects are highly vulnerable to macro-economic downturns.
HafenCity Hamburg	Transformative urban development projects can succeed when thoughtful planning and design initiatives are accompanied by capable implementation.	Even the best implemented of redevelopment projects may take longer to reach build-out than initially anticipated.
Songdo, Korea	World-class physical development plans may have long-term merit even amidst fiscal or market difficulties.	Beware undertaking projects that are the "biggest" or "most," especially when there is no local precedent/Never hire an outside project developer/manager who doesn't understand local political and performance expectations/ Branding alone can't ensure megaproject success.
Brooklyn Bridge Park (New York City)	Big and controversial projects are sometimes best undertaken in smaller increments.	Project approval and funding provisions need to align, especially in political systems with competing power centers.