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Introduction to Global Megaprojects

It is not the strongest of the species that survives, nor the most intelligent, but rather the one most adaptable to change.

— Charles Darwin

Introduction

Megaproject infrastructure has long been an essential factor in socioeconomic development around the world, yet we still know so little about the phenomenon of these massive endeavors. The objective of this chapter is for readers to learn about the characteristics of global megaprojects and how these projects have evolved over centuries beginning with prehistory up to the present day. We look at the contributions as well as the challenges of these projects and the ways in which these projects are conceived and developed including the benefits of megaprojects to the larger eco system such as the expansion of trade and development globally. While the primary goal of this chapter is to set forth a framework for understanding the importance of megaprojects in the larger economic and social environment, it also analyzes what makes megaprojects unique and worthy of future analysis and research.

Infrastructure of all kinds has become a subject of great importance to governments in every corner of the world from the development of the \$4.75B Hadron Collider at CERN to the Belt and Road Initiative in China (BRI), to the creation of the Smart Cities Projects in India, to the development of London's Crossrail Project, and the implementation of America's Interstate Highway System and the High-Speed Rail System with initial focus on California. The Organization for Economic Cooperation and Development (OECD) estimates global investment needs of \$6.3 trillion per year from 2016 to 2030, without considering further

climate action (Mirabile et al. 2017). To meet this growing demand, there has been a recent call, within the megaproject scholarship, for a better understanding of “what goes on in megaprojects – how they are managed and organized, from within, by the managers who are tasked with bringing them to fruition” (Söderlund et al. 2017).

The goal of this book is to provide insight, based on experience, for more realistically approaching the complex and transformative process of infrastructure investment that the urban world of the twenty-first century demands (Greiman and Sclar 2019). We begin by proposing a definition of global megaprojects based on the extensive research on large-scale projects.

Megaprojects have existed since the beginning of recorded time and have been characterized by great monuments, feats of engineering, and lasting images of something more powerful than had been imagined in the past. Since prehistoric times we have been building megaprojects, so there is much to learn about these remarkable achievements of earlier generations. In this book, we look at projects not just from the traditional cost and schedule perspectives written about in the leading project management journals, but more significantly this book focuses on the great benefits and achievements of these projects so we can learn not just what went right or wrong; but more importantly what are the factors in achieving success and how these projects have evolved and been shaped over time. It is critical that we learn from the past, but we also must apply these important lessons to our megaprojects of the future. This book was written to demonstrate that megaprojects can and have accomplished major economic, social, and technical advancements thought impossible but achieved by successfully confronting the challenges of the time.

This chapter focuses on defining the unique complexity of global megaprojects, assessing the impact of cross-institutional differences, and identifying ways for its sponsors, managers, and other stakeholders to address these challenges.

Globalization and Megaprojects

Globalization presumes sustained economic growth. Otherwise, the process loses its economic benefits and political support.

— *Paul Samuelson, An American economist and the first American to win the Nobel Prize in Economic Sciences in 1970 known as the “father of modern economics”*

Before embarking on a review of global megaprojects over the ages, it is important to understand the influence that megaprojects have had not just on local communities but on globalization worldwide. The modern world is increasingly

being defined by the term “globalization.” Important changes in the global economy have become the main determinants of this phenomenon. Friedman (2000) defines globalization as “the inexorable integration of markets, nation states and technologies to a degree never witnessed before – in a way that is enabling individuals, corporations, and nation states to reach around the world farther, faster, deeper, and cheaper than ever before.”

Globalization means the spread of free-market capitalism to virtually every country in the world. Globalization also has its own set of economic rules – rules that revolve around opening, deregulating, and privatizing your economy (Friedman 2000). Globalization is also used to describe the growing interdependence of the world’s economies, cultures, and populations, brought about by cross-border trade in goods and services, technology, and flows of investment, people, and information (PIIE 2021).

Importantly, globalization encourages the development of megaprojects. First, globalization of financial capital and law facilitates cross-national partnerships. Second, technological innovations secure big, complex constructions (Kardes et al. 2013). Megaprojects occupy an important place in global relations and drive a number of explicit and implicit economic agendas (Pitsis et al. 2018). International public–private partnerships have allowed large-scale government projects, such as roads, bridges, or hospitals, to be completed with private funding and thus expanded opportunities for globalization through interconnectivity among cities, states, regions, and borders. The goal of this book is to provide insight, based on the experience of those who have contributed to these projects, for more realistically approaching the complex and transformative process of infrastructure investment that the urban world of the twenty-first century demands (Greiman and Sclar 2019).

The next generation megaprojects will advance science and technology in a way that has never been done before. The International Space Station and the Hadron Collider Project at CERN are just two examples of unparalleled projects that will increase our knowledge and further our understanding about the universe for centuries to come.

Characterization of Global Megaprojects

As shown in Figure 1.1, megaprojects have been characterized by size, duration, uncertainty, ambiguity, complexity, cultural environments, dynamic governance, large-scale policy making, and significant political and external influences (Greiman 2013; Klakegg et al. 2008; Merrow 2011; Miller and Hobbs 2005). Megaprojects also have a greater magnitude of aspiration, actor involvement, and impact than smaller projects (Flyvbjerg 2017). Despite the massive investment in

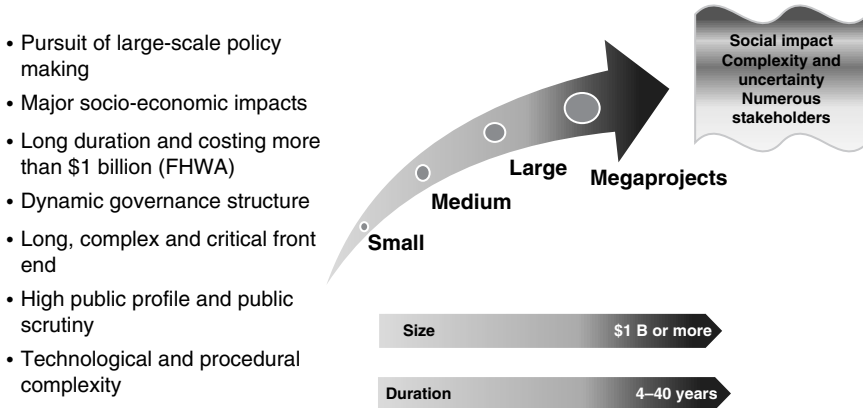


Figure 1.1 Characteristics of a megaproject. *Source:* Greiman (2013)/John Wiley & Sons.

these projects, many of them fail to meet the expected objectives for which they were built (Dimitriou et al. 2014). Large, complex infrastructure projects often delivered via public–private partnerships entail deep uncertainties, considerable economic and political stakes, and have a significant impact on society. Megaprojects proliferate, despite their problematic relation with sustainability (Lehtonen 2019), and have been defined as large ventures requiring enormous investments and are portrayed as too big to fail and too costly to stop (Denicol et al. 2020). Megaprojects are rarely implemented by a single organization; they are characterized by decentralized decision-making power, rapid resource allocation, and complex stakeholders (Müller 2012).

Megaprojects are not confined to large infrastructure or industrial projects but include research and development, cyber infrastructure, scientific discovery, defense, energy, food security, biotechnology, and many other fields. Given the increasing number of megaprojects and the movement toward the professionalization of the discipline, project management practice has struggled to develop workable solutions and practices to address complexities that exceed the technical concerns of engineering (Clegg et al. 2017; van Marrewijk et al. 2016). Gellert and Lynch (2003, pp. 15–16) consider megaprojects as “displacements” by observing that megaprojects are “projects which transform landscapes rapidly, intentionally, and profoundly in very visible ways, and require coordinated applications of capital and state power.” Essentially, looking at society through its megaprojects would reveal its ambitions, problems, as well as its future outlooks. Increasingly, it is evident that the problem areas attached to these projects stretch beyond technical issues: they must be considered as socio-technical endeavors embedded in complex institutional frames. Studying how to deal with institutional differences in the environment of

megaprojects has both theoretical and practical implications (Biesenthal et al. 2018).

Though the project management literature is filled with many characterizations of a megaproject, there is no single agreed upon definition. Over the years megaprojects have been defined by different terms. Some of the more common terms or synonyms used to define or characterize megaprojects include: large-scale project, major project, public private partnership, program or portfolio, international development, economic development, global project, disaster relief project, urban megaproject, urban renewal, transportation infrastructure, critical national infrastructure, sustainable development, complex project, systems of systems, large research and development project, transformational project, large engineering project, mega construction project, capital project, giga project, tera project, public works, civil engineering project, systems engineering project, and project finance.

In the United States, the Federal Highway Administration (FHWA) defines megaprojects as:

Major infrastructure projects that cost more than \$1 billion, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and State budgets. “Mega” also connotes the skill level and attention required to manage the project successfully. (Capka 2004)

Most megaprojects are considered global because of their contribution to trade and economic growth, technology transfer, and regional and international development. Global megaprojects often cross borders and are defined as involving two or more countries.

For example, Levitt and Scott (2017) in their research on institutional and political challenges in projects adopted the formulation developed by Orr and Levitt (2011, p. 17) and defined a “global megaproject” as:

A temporary endeavor where multiple actors seek to optimize outcomes by combining resources from multiple sites, organizations, cultures, and geographies through a combination of contractual, hierarchical, and network-based modes of organization.

While Flyvbjerg (2014) defines “global megaprojects” as:

large-scale, complex ventures that typically cost more than 1 billion US dollars, take many years to build, involve multiple public and private stakeholders, are transformational, and impact millions of people.

As described in this chapter, to better capture the changing nature of global megaprojects along with their complex financing and governance structures the following definition is proposed:

Global megaprojects consist of the creation of a special organizational structure for the purpose of financing a unique multi-billion-dollar investment involving numerous stakeholders and complex interdependencies and interorganizational relations in diverse regions of the world that will provide sustainable and long-term benefits to local communities and the larger eco system of which the megaproject is a part.

Megaprojects: The Global Timeline

The difficult is what takes a little time, the impossible is what takes a little longer

— Fridtjof Nansen, Nobel Peace Prize Winner, 1922

To understand how far we have come in building the great engineering and architectural triumphs of our time, we must look backward to understand the present. Figure 1.2 illustrates the timeline for some of the world’s greatest megaprojects. Though the timeline shows only a small representation of these projects, many of them from long ago eras are still in existence showing that megaprojects can be sustainable long beyond the lives of its creators and some are still rendering benefits today.

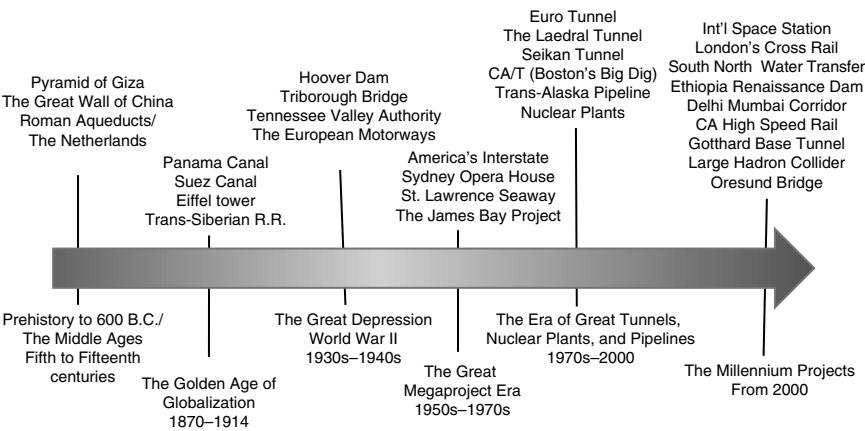


Figure 1.2 Megaprojects: the global timeline.

Prehistory

The Pyramid of Giza (Built Between 2550 and 2490 BCE)

The oldest and last existing Seven Wonders of the Ancient World, the great Pyramid of Giza was built in Egypt. Construction began on the pyramid around 2550 BCE. The Great Pyramid was built over a 60-year period as a tomb, based on markings on an interior chamber referencing fourth dynasty Egyptian Pharaoh Khufu. Originally standing at 481 feet tall, it was the tallest man-made structure in the world for more than 3800 years. Due to erosion, it now stands about 455 feet tall. There is numerous evidence that the Ancient Egyptians were pioneers in geology and geotechnical engineering (Agaby et al. 2014). According to research the workmanship of the Great Pyramid is surprisingly accurate, as the four sides of the base have an average error of only 58 mm. These structures represent the pinnacle of Egyptian pyramid building, built on a foundation of experience from the earlier much smaller pyramids.



Pyramid of Giza. *Source:* Picture Alliance.

The Great Wall of China

Other great medieval projects, include the great wall of China first built in the seventh century as protection against various nomadic groups, and has been proclaimed as one of the most impressive architectural feats in history. Though the

Great Wall, which opened in 220 BCE was built over a 200-year period, it never effectively prevented invaders from entering China, however, it came to function as a powerful symbol of Chinese civilization's enduring strength.

The Aqueducts of Rome

One of the earliest examples of the exploitation of groundwater to sustain human civilization is the aqueduct system of ancient Rome which were being built from 312 BCE to 226 CE. Although some of the aqueducts were fed by surface water, most of them were supplied by springs, usually augmented by tunneling to increase the flow of groundwater (Deming 2020). The Aqueducts were considered a major feat of engineering at that time. Though earlier civilizations in Egypt and India also built aqueducts, the Romans improved on the structure and built an extensive and complex network across their territories. Although there were many more great engineering and architectural achievements during this time demonstrated by the great Cathedrals of the middle-ages, remarkably many of these structures still exist today though some in a different form. For example, the Trevi Fountain is still fed by aqueduct water from the same sources of the ancient Aqua Virgo; however, the Acqua Vergine Nuova is now a pressurized aqueduct.

When we contrast these medieval projects with the megaprojects of today, we wonder if many will even survive the next 20–30 years. The ever-advancing technology we have at present causes us to move more rapidly in building projects, that years ago gave us the luxury of time.

The Middle Ages

The Netherlands

It was during the Middle Ages that some of the most inspiring projects of all time were built. Notably, one of the most impressive engineering feats from the Middle Ages has been “The Netherlands” where the people of this country surmounted near impossible obstacles to reclaim thousands of square kilometers of land from the sea (Butler 1972; Hill 1984). Originating as a fourteenth-century settlement along a small peat river, Rotterdam thanks to the building of The Dam in the Rotte, in 1270, eventually grew into Europe's largest seaport. By 2009, 400 million tons of cargo traveled through the port, but Rotterdam was nearing its capacity. To keep the port competitive, authorities undertook an ambitious project aimed at tripling the port's capacity (Rosenberg 2020). Directly accessible from the North Sea Rotterdam now holds the biggest harbor in Europe that has applied modern, forward-thinking management including serving as a home for the importation of

green hydrogen and the leading port for sustainable energy. Green hydrogen can play a valuable role in the energy transition, which in turn is indispensable for meeting the Paris Climate Agreement objectives (Rotterdam 2020).

The Golden Age of Globalization (1870–1914)

During the period 1870–1914 sometimes referred to as the “Golden Age of Globalization” when international trade, international migration flows and international mobility of financial capital reached historical peaks, the world pursued ambitious infrastructure projects, many of which define our world today such as the Panama Canal, the Suez Canal, The Eiffel Tower, and the Trans-Siberian railroad. Not all were intended for transnational use, but they represented a certain confidence and an unprecedented desire to bind the world together. Megaprojects have arisen from a complex set of geographic, economic and, above all, political processes of restructuring occurring throughout the world since that time. Which raises important questions concerning the obstacles that confronted early engineers and how they coped with limited technology and far fewer resources.

The Panama Canal

Connecting the Pacific and Atlantic oceans, the 77 km shipping canal across the Isthmus of Panama, a key international trade channel, was one of the most difficult engineering projects in history. Twenty thousand people lost their lives (mostly due to disease) one of the worst worksite disasters in history. The Canal was opened in 1914 after 34 years of construction. The construction of the Panama Canal early in the twentieth century dramatically changed trade patterns by opening new routes between countries and regions that traditionally could not trade at competitive prices due to the vast distance between them (Sabonge 2014). The Canal was built mainly for military purposes but, over time, became a facilitator for trade by shortening the time and distance between production and consumption markets. From its inauguration until Fiscal Year 2013, more than one million vessels have transited the Canal with more than 9.4B long tons of cargo (Sabonge 2014). Operating around-the-clock, about 40 vessels pass through each day, including tankers, cargo ships, yachts, and cruise ships. The Canal enhances environmental contribution by reducing GHG (green house gas) emissions on the planet with more efficient transport, reducing fuel consumption per cargo unit and fewer emissions than other routes that combine transportation by land.



The Panama Canal. *Source:* Panama Canal Authority.

The Suez Canal

The Suez Canal, a man-made waterway was built in Egypt by ex-French diplomat and developer, Ferdinand de Lesseps and opened in 1869 after 10 years of construction. At 120 miles long, it connects the Mediterranean Sea to the Indian Ocean by way of the Red Sea and separates most of Egypt from the Sinai Peninsula. It was considered an audacious project of engineering at the time and provided a foundation for geographic relationships by connecting the two most densely populated areas in the world – Western Europe and Eastern Asia (Yackee 2018).

The Eiffel Tower

An object of discord, desire, and fascination, the Eiffel Tower was created by Gustave Eiffel and built in record time – two years, two months, and five days. It was established as a veritable technological feat. Considering the rudimentary means available at that period, this could be considered record speed. The assembly of the Tower, built to be one of the main attractions at the Paris World's Fair in 1889, was a marvel of precision, as all chroniclers of the period agree. The construction work began in January 1887 and was finished on 31 March 1889, at a cost of US\$1.5 million. On the narrow platform at the top, Gustave Eiffel received his decoration from the Legion of Honor (Eiffel 2021).



The Trans-Siberian Railway. *Source:* Regent Holidays.

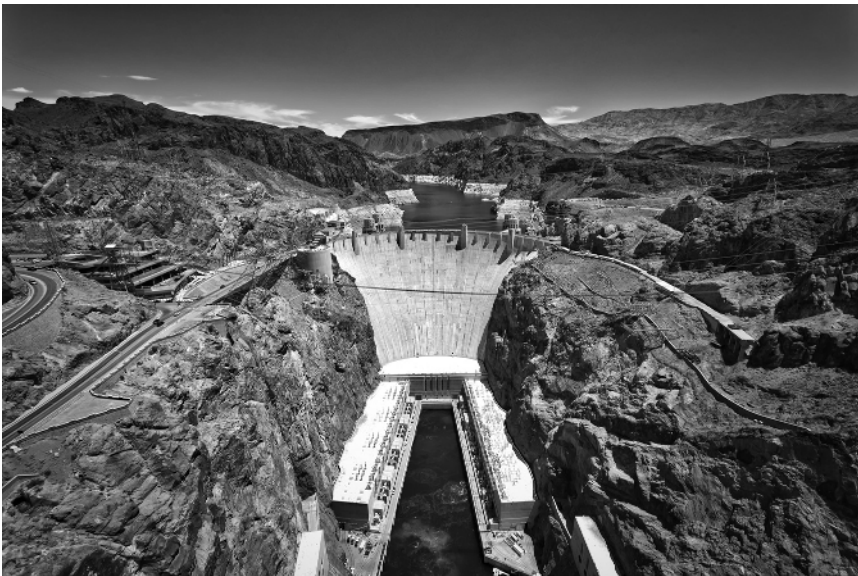
The Trans-Siberian Railway

The “Trans-Siberian Main Railroad,” is the longest single rail system in Russia, stretching from Moscow to Vladivostok or (beyond Vladivostok) to the port station of Nakhodka spanning 6000 miles and 7 time zones. It had great importance in the economic, military, and imperial history of the Russian Empire and the Soviet Union (Bassin 1991; Wolmar 2014). Conceived by Tsar Alexander III, the construction of the railroad began in 1891 and proceeded simultaneously in several sections – from the west (Moscow) and from the east (Vladivostok) and across intermediate reaches by way of the Mid-Siberian Railway, the Transbaikal Railway, and other lines. Throughout the years, the Trans-Siberian Railway (TSR) has been proven to have the longest history of commercial freight operation between Europe and the Far East (Liliopoulou et al. 2005). Originally, in the east, the Russians secured Chinese permission to build a line directly across Manchuria (the Chinese Eastern Railway) from the Transbaikal region to Vladivostok; this trans-Manchurian line was completed in 1901. After the Russo-Japanese War of 1904–1905, however, Russia feared Japan’s possible takeover of Manchuria and proceeded to build a longer and more difficult alternative route, the Amur Railway, through to Vladivostok; this line was completed in 1916. The Trans-Siberian Railroad thus had two completion dates: in 1904 all the sections from Moscow to Vladivostok were linked and completed running through Manchuria. In 1916,

there was finally a Trans-Siberian Railroad wholly within Russian territory. “The completion of the railroad marked the turning point in the history of Siberia, opening vast areas to exploitation, settlement, and industrialization” (Britannica 2021).

The Great Depression (1930–1940s)

During the 1930s, in the United States, the Public Works Administration, (later named the Work Projects Administration) and other New Deal agencies funded projects to build and improve the country’s infrastructure, including roads, dams, schools, airports and parks. Many of the projects funded by the PWA and WPA remain today as part of the U.S. landscape. The New Deal also created new agencies to fund projects across the country that both improved communities and provided jobs at a time when unemployment was high. While the U.S. was building large projects like the Hoover Dam, Europe was building Motorways.



The Hoover Dam. *Source:* Chris/Adobe stock.

The Hoover Dam

The waters of this great river, instead of being wasted in the sea, will now be brought into use by man. Civilization advances with the practical application of knowledge in such structures as the one being built here in the

pathway of one of the great rivers of the continent. The spread of its values in human happiness is beyond computation.

— *Herbert Hoover, November 1932*

The 1930s brought us the Hoover Dam described as an audacious and courageous undertaking. Built during the Great Depression, the dam would tame the flood-prone Colorado River southeast of Las Vegas – protecting cities and farms, generating cheap electricity to supply power to homes and industry, and providing work for thousands who desperately needed jobs. A consortium called Six Companies Inc., won the right to build the concrete arch dam, at a cost of nearly \$49 million – a staggering amount in the early 1930s (roughly equivalent to \$860 million today). Skeptics thought it could not be done. Others were convinced that the contractors would go broke. But the workers in the consortium boldly moved forward, drawing on their considerable, collective knowledge and experience, managing huge risks, and pioneering as they went. The dam was built in five years, two years ahead of schedule and under budget, an amazing feat for its time giving company leaders the confidence that they could take on any project, anytime, anywhere (Bechtel 2001). Today, it generates enough hydroelectric power per year to serve 1.3 million people.

Though the Hoover Dam was one of the larger projects of this era, other megaprojects included several major New York projects including the Empire State Building, the Triborough Bridge, as well as the construction or improvement of roughly 800 airports, including LaGuardia Airport in Queens, New York.

The Triborough Bridge

As Robert Caro wrote in his book, *The Power Broker*, “the man who built the Triborough Bridge would be a man who conferred a great boon on the greatest city in the New World. He would be the man who tied that city together” (Caro 1975). And though the Triborough Bridge was an immense feat of construction, the designer, Robert Moses’ vision for the structure did not end with the bridge. Rather, Moses continued to advocate for new roads and parkways that would feed into the bridge, all of which would be part of an interconnected parkway system. To Moses, the Triborough Bridge promised to “slash at a stroke the immense Gordian knot of the East River traffic problem” by creating a direct link between the Bronx and Queens. The parkways connecting to the Triborough were a vital piece of his steel and concrete puzzle (Caro 1975).

The Tennessee Valley Authority Projects

In 1933, the New Deal legislation created a public corporation to improve the Tennessee Valley. One of the biggest projects that this corporation, the Tennessee Valley Authority (TVA), took on was the Chickamauga Dam, located on the

Tennessee River outside of Chattanooga preventing flood damage and a mosquito infestation. As described by Arthur E. Morgan, Chairman of the Tennessee Valley Authority at the time of its implementation, “[t]he proper way to treat the TVA is not as an isolated undertaking, but as an integral part of the whole program of the present administration” (Morgan 1934). FDR’s ambitious plan transformed the Tennessee Valley by creating dams and reservoirs for electricity and flood control, controlling soil erosion through forest restoration and better farming techniques, and improving navigation and commerce along the Tennessee River. By 1934, more than 9000 people found employment with the TVA. The agency built 16 hydroelectric dams in the Tennessee Valley between 1933 and 1944 though these projects were not without controversy from the local communities.

The European Motorways

On 26 March 1923, in a formal ceremony, construction of the Milan–Alpine Lakes autostrada officially began, the preliminary step toward what would become the first European motorway. In 1935, the year in which the Genoa–Serravalle Truckway was completed, Italy possessed barely 500km of motorway. Germany achieved a network of over 3600km between 1934 and 1941. The last authorizations for construction in Italy were in 1930, that is, three or four years before the German projects got underway (Moraglio 2017). Using the great economic crisis as a dividing line, the Italian motorway projects were mostly realized before the 1929 U.S. stock market crisis made its effects felt in Europe, while in Germany, they were realized after. Italy was not the only nation to propose similar projects. In following the German example, in the second half of the 1930s, France and Holland began construction works on their first motorway trunks, while news of new projects in Denmark, Belgium, Poland, and Czechoslovakia started shortly after.

The Great Megaproject Era (1950–1970s)

In the United States, Altshuler and Luberoff (2003) identify the period between the late 1950s, when the Federal Interstate construction project got underway and the late 1960s when construction peaked, as the Great Megaproject Era in America largely due to the development of the National System of Interstate Highways.

The Interstate Highway System

During the post-war era defined as the period from the late 1940s to the late 1960s growth was defined through several major megaprojects that began the process of connecting cities and states and even countries. In the United States, this was the

beginning of the Dwight D. Eisenhower National System of Interstate and Defense Highways, commonly known as the Interstate Highway System called the “Greatest Public Works project in History” (Weingroff 2017).

As these interstates moved from open countryside into dense urban areas requiring the extensive use of eminent domain to take homes and businesses, they triggered a reaction in the form of widespread anti-highway sentiment (Altshuler and Luberoff 2003). The sentiment quickly became politically manifested in the late 1960s and early 1970s. Anti-highway sentiment soon merged with the then nascent but rising environmental consciousness to create the mix of pro transit ideas that fueled the political consensus that sustained the Big Dig and similar efforts across the nation (Greiman and Sclar 2019). The estimated completion cost of the system was \$129B (Weingroff 2017). The approval of the Federal-Aid Highway Act of 1956 marked the formal beginning of this project. The completion of the Big Dig in 2007 about one-half century later marked its end.

As he looked back on his two terms in office, former President Dwight D. Eisenhower said of the Interstate System that, “[m]ore than any single action by the government since the end of the war, this one would change the face of America.” The impacts of the Interstate System remain controversial, but it did, as President Eisenhower predicted, change the face of America – not simply by altering the landscape during construction, but by supporting changes that transformed our society in the second half of the twentieth century (Weingroff 2017).

The Sydney Opera House



Sydney Opera House. *Source:* Sydney Australia/Wikimedia Commons/CC BY 1.0.

Outside of North America other great projects were under way in the late 1950s. In 1957, when the Sydney Opera House project was awarded by an international jury to Danish architect Jørn Utzon, who left the project almost 10 years later in 1966 and never returned to see his design completed. It marked a radically new approach to construction. Inaugurated in 1973, the Sydney Opera House is a great architectural work of the twentieth century that brings together multiple strands of creativity and innovation in both architectural form and structural design. (Hale and Macdonald 2005).

It cost \$102 million and took 14 years instead of the projected 4 years to build. More than 10.9 million people visit the Opera House each year. A great urban sculpture set in a remarkable waterscape, at the tip of a peninsula projecting into Sydney Harbour, the building has had an enduring influence on architecture. The Sydney Opera House comprises three groups of interlocking vaulted “shells” which roof two main performance halls and a restaurant. These shell-structures are set upon a vast platform and are surrounded by terrace areas that function as pedestrian concourses. Described as a daring and visionary experiment on 28 June 2007 the Sydney Opera House was included on the UNESCO World Heritage List under the World Heritage Convention, placing it alongside the Taj Mahal, the ancient Pyramids of Egypt, and the Great Wall of China as one of the most outstanding places on Earth. It is the youngest cultural site to ever be included on the World Heritage list and one of only two cultural sites to be listed during the lifetime of its architect, Jørn Utzon (1918–2008).

St. Lawrence Seaway

The St. Lawrence Seaway is a multi-country project linking the Great Lakes in the United States and the St. Lawrence River in Canada with the Atlantic Ocean via a system of locks, canals, and channels. Recognized as one of the most challenging engineering achievements in history, construction began on the project in 1954 and the project officially opened on 26 June 1959. This famous Canal serves an international need by moving goods from the Great Lakes basin to international destinations.

The James Bay Project

The James Bay Project involved the construction of a series of hydroelectric power stations on the La Grande River in northwestern Quebec. The project represents a series of major construction, each one of which can be considered a megaproject on its own. La Grande River is located between James Bay to the west and Labrador to the east, and its waters flow from the Laurentian Plateau of the Canadian Shield. The project covers an area the size of New York State and is one of the

largest hydroelectric systems in the world. It cost more than US\$20B to build. The development of the James Bay Project led to an acrimonious conflict with the 5000 Crees and 4000 Inuit of Northern Quebec over land rights, lifestyle and environmental issues. A ruling against the Quebec government in 1973 forced the government to negotiate a far-reaching agreement, known as the James Bay and Northern Quebec Agreement (Peters 1999).

The Era of Great Tunnel, Energy, and Pipeline Projects: (1970s–2000)

The 1970s to 2000 were dominated by mega construction projects such as the Trans-Alaska Pipeline and Boston's Big Dig and the explosion of the nuclear industry. During this time sensitivity developed in the project management industry around sustainability and environmental issues paving the way for the megaprojects of the future. However, sophistication was still lacking in controlling the costs and schedules on these megaprojects as witnessed by the building of Eurotunnel with its private funding and lack of government involvement.

Eurotunnel

Eurotunnel is the largest privately financed infrastructure in history. It is comprised of three tunnels connecting Britain to Continental Europe from terminals in Folkstone in Kent, and Coquelles near Calais in northern France. It had a long history with its first conception in 1802 to its completion in 1994 with lots of stops and starts along the way (Grant 1997). The Tunnel took seven years to build and is still the longest undersea tunnel in the world. It was initially financed by 15 founding shareholders including 5 banks for a 65-year concession. Ultimately growing into a syndicate of 220 banks requiring a massive restructuring of debt and equity due to much higher costs and delays than originally anticipated. The debt will not be fully paid off until 2052 at the earliest.

The Laerdal Tunnel

Opened in 2000, the Laerdal Tunnel is the world's longest road tunnel with a length of 24.5km (15.2miles) replacing the Gotthard tunnel as the longest road tunnel in the world. It serves to connect two cities in Norway, Oslo, and Bergen, eliminating the need to drive through narrow mountain passes that are often blanketed in snow. The tunnel cost \$153 million to build. To construct it, a total of

3.3 million cubic yards of rock were removed during construction from 1995 to 2000. The tunnel is divided into four sections at 3.7-mile intervals. “The disposal of 2.5 million cubic metres of excavated rock from the tunnel was one of the greatest challenges in planning the tunnel” (RTT 2021). From an environmental perspective, the tunnel was seen as a justifiable investment to avoid destroying large sections of the unspoiled natural landscape.

Seikan Tunnel

Opened in 1988, 27 years after construction commenced, the 53.8 km (32.9 mile) \$3.6B Seikan Tunnel in Japan is the world’s second deepest and second longest rail tunnel with approximately 23.3 km below the seabed. The Seikan Tunnel is the world’s longest tunnel with an undersea segment, the Channel Tunnel, while shorter, has a longer undersea segment). Conceptual planning was during 1939–1940, and construction began in 1971. Construction of the tunnel, which runs 240 m below the sea surface at the deepest part, was extremely difficult, with workers facing numerous problems such as frequent landslides and flooding seawater. Thirty-four workers lost their lives (Japan 2018).

It was built to eliminate the often-challenging crossing across Japan’s Tsugaru Strait, which is frequently beset by storms. The tunnel goes to a depth of nearly 800 feet below sea-level and connects the islands Honshu and Hokkaido. Tunneling for this project occurred simultaneously from the northern and southern ends, with the dry land portions using traditional mountain tunneling techniques. For the undersea portion, three bores were used with increasing diameters: a pilot tunnel, a service tunnel, and finally, the main tunnel. Beneath the Tsugaru Strait, the use of a tunnel boring machine had to be abandoned because of the variable nature of the rock. Dynamite blasting and mechanical picking had to be used instead (Japan 2018).

The Central Artery/Tunnel Project (CA/T)

The \$14.8B Central Artery/Tunnel Project is famously known as the Big Dig. This project, like most megaprojects, grew from a vision of a small group of people who saw an opportunity for a city in desperate need of revitalization. The Big Dig has been depicted as one of the great projects of the twenty-first century (Tobin 2001). Because of its scale and impacts, the project has been a major issue in national and local politics for more than three decades (Greiman 2013). The project was first conceived in the 1970s, but initial funding was not secured until the early 1980s, and substantial completion did not occur until 2006 more than a 30-year period (CA/T 1990).

The Big Dig was also a record for the United States – it was the first and largest inner-city construction project ever conceived. It was the most complex urban infrastructure project in U.S. history and included unprecedented planning and engineering (EDRG 2006a; EDRG 2006b). Its list of engineering marvels includes the deepest underwater connection and the largest slurry wall application in North America, unprecedented ground freezing and tunnel jacking, extensive deep-soil mixing programs to stabilize Boston’s soils, the widest cable-stayed bridge, and the largest tunnel ventilation system in the world (Greiman 2013, p. 39). The Big Dig faced highly unusual challenges, including the necessity of working in one of the most congested urban areas in the country. Coordinating more than 132 major work projects added complexity to the tasks of the project constructors and engineers, and moving 29 miles of gas, electric, telephone, sewer, and water lines maintained by 31 separate companies added extraordinary challenges to the project’s utility relocation program (p. 39).



The Trans Alaskan Pipeline. *Source:* Ttstudio / Shutterstock.

The Trans Alaskan Pipeline

By 1920, the American Petroleum Institute estimates there were almost 40 000 miles of pipeline in the country. In the following decade, that number tripled, as welding technology made it easier to build long pipelines. Today, the United States has 2.6 million miles of pipeline crisscrossing the country, more than anywhere else in the world, but that pipeline grid does not work for the shale boom. More than a hundred major pipeline projects are currently

planned for the next five years in North America. The scale could easily rival that of the 1950s.

One of the largest pipelines in the world is the Trans Alaskan Pipeline. Between 1968 and 1970, oil exploration efforts resulted in the discovery of a major oil field on Alaska's North Slope. At the end of 1970, the American Petroleum Institute estimated the potential reserves in this Prudhoe Bay field to be approximately 9.6B barrels. Others predicted that when fully developed, the amount of oil ultimately recoverable from the field could be twice as large. The field's size and potential made it one of the single most important discoveries in the history of the domestic crude oil industry (Cichetti 1993). At the same time that oil exploration was occurring in Alaska, the U.S. Congress enacted the National Environmental Policy Act of 1969 (NEPA). The act requires agencies of the federal government undertaking actions that could adversely affect the environment to file an environmental impact statement analyzing and quantifying the expected environmental effects of the proposed action. The act stipulates that when irreversible deleterious effects might be found, the agencies should consider alternatives to a proposed plan. After a bitter debate, construction of the \$8B Trans-Alaska Pipeline began in 1973.

As noted by Levitt and Scott (2017) "the Alaska pipeline project became a 'megaproject' due to its regional economic and environmental impact and the resulting complexity of its relational subproject interdependencies and challenges, even though it was neatly divisible into nearly autonomous subprojects in terms of its spatial and technological configuration" (pp. 96–97). Concerted efforts by Congress, the State of Alaska, and other stakeholders have resulted in new momentum to proceed with an Alaska gas pipeline project. Serious reconsideration of the construction of a natural gas pipeline from the Alaska North Slope began around 2000. This reconsideration was prompted, in large part, by tightening gas supplies to the lower-48 states and corresponding increases in natural gas prices and price volatility (Parfomak 2009).

The decision on many megaprojects can be heavily dependent upon the political climate at a particular point in time. For example, in recent years, the Keystone XL Pipeline in the United States has created further controversy over the value of these projects. Some legislators have expressed support for the potential energy security and economic benefits, while others have reservations about its potential environmental impacts. There is also concern over how much crude oil, or petroleum products refined from Keystone XL crude, would be exported overseas (CRS 2015). The Pipeline was officially abandoned in June 2021, however, the future of major pipelines in the United States remains uncertain depending on changes in the political climate and public support.



Nuclear Power Plants. *Source:* Ttstudio / Shutterstock.

Nuclear Power

Nuclear Plants: The Buildup, Downfall and Pending Resurgence

The History of the Nuclear Power in a Nutshell
The science of atomic radiation, atomic change and nuclear fission was developed from 1895 to 1945, much of it in the last six of those years. From 1939 to 1945, most development was focused on the atomic bomb. From 1945 attention was given to harnessing this energy in a controlled fashion for naval propulsion and for making electricity. Since 1956 the prime focus has been on the technological evolution of reliable nuclear power plants. <i>Source:</i> World Nuclear Association, Outline History of Nuclear Energy, Updated November 2020

As of 2021, the World Nuclear Association reports 440 nuclear reactors are in operation worldwide in 30 countries generating capacity of 390 (GW) which is equivalent to about 10% of the world’s electricity. The 10 countries with the largest number of reactors include: the United States (95), France (57), China (47), Russia (38), Japan (33), South Korea (24), India (22), Canada (19), the United Kingdom (15), and Ukraine (15). Figure 1.3 shows the global sources of electricity production as tracked by the World Nuclear Association indicating that coal and gas remain the largest sources of power in the world.

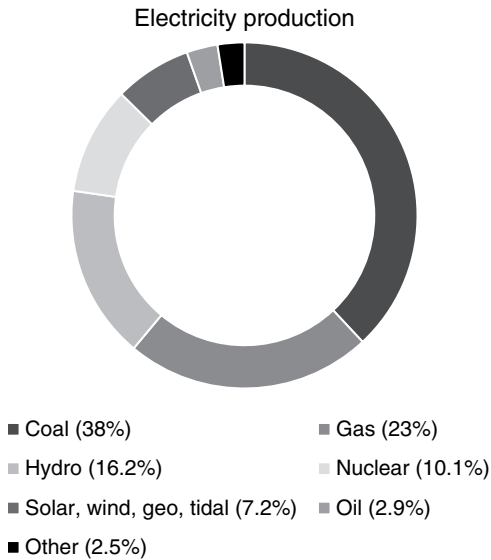


Figure 1.3 Global power sources.
Source: Adapted from The World Nuclear Association (2021).

After hydroelectric power, nuclear is the world's second largest source of low-carbon power. According to the World Nuclear Association, 13 countries in 2020 produced at least one-quarter of their electricity from nuclear. France gets around 70.6% of its electricity from nuclear energy, Slovakia and Ukraine get more than half from nuclear, while Hungary, Belgium, Slovenia, Bulgaria, Finland, and Czech Republic get one-third or more (WNA 2021b). South Korea normally gets more than 30% of its electricity from nuclear, while in the United States, the United Kingdom, Spain, Romania, and Russia about one-fifth of electricity is from nuclear. Japan was used to relying on nuclear power for more than one-quarter of its electricity and is expected to return to somewhere near that level (WNA 2021a). Beyond power generation, nuclear technologies have medical applications that will help combat serious viruses such as COVID-19. The International Atomic Energy Agency (IAEA) is providing diagnostic kits, equipment, and training in nuclear-derived detection techniques to countries asking for assistance in tackling the worldwide spread of the novel coronavirus causing COVID-19. Also, small modular reactors (SMRs) are playing a key role in the clean energy transition.

According to the U.S. Energy Information Administration (EIA), most U.S. nuclear power plants were built between 1970 and 1990. Other forms of energy include hydroelectric, coal, natural gas, wind, solar, and petroleum also progressed during that time. As of 2021, the United States has 55 operating nuclear power plants with 93 nuclear power reactors in 28 states across the country. The oldest operating nuclear reactor in the United States was built in 1969. Watts Bar 2, which entered commercial service in 2016, was the first new reactor added since 1996. An additional two are under construction. Of the 99 gigawatts (GW) of total operating nuclear capacity in the country, 95 GW came online between 1970 and

1990. Planned nuclear capacity additions began to slow as early as the late 1970s because of several factors, including slowing electric demand growth, high capital and construction costs, and public opposition. Costs, schedules, and public acceptance were all influenced by the accident at the Three Mile Island plant in 1979 and, more recently, the Fukushima nuclear disaster in 2011. From 1979 through 1988, 67 planned builds were canceled. However, because of the long duration required for permitting and building new nuclear reactors, many plants that had begun the process in the 1970s continued to come online through the early 1990s.

The Millennium Projects

Since 2000 the world has seen an explosion of megaprojects increasing in size, cost, and scope from what has come before and representing multiple industries and initiatives. These new megaprojects include areas in transportation, energy, climate change, medical research, education, water supply, innovation and scientific projects, roads, bridges, tunnels, dams, and high-speed rail. The projects stand at various stages of completion and continue to drive economic, social, and institutional development. It is during the present era that we see a focus on ecological impact, sustainability, and international project expansion in the developing world through the establishment and growth of international development bank investments. Table 1.1 shows some of the larger and more global megaprojects impacting in some cases multiple countries and regions of the world.



Gotthard Base Tunnel. *Source:* Gavin van Marle.

Table 1.1 The millennium megaprojects.

Project	Description	Cost/Budget	Funding source
International Space Station 1988–2024	An international partnership representing 15 countries to develop a modular space station in low Earth orbit to study the Earth's environment and the universe. As of April 2021, 244 individuals from 19 countries have visited the International Space Station. Top participating countries include the United States (153 people) and Russia (50 people) (NASA 2021)	\$150B to develop; \$48B to operate \$3.6B over budget	Multinational collaborative involving the United States (NASA) (largest contributor), Russia, Europe, Japan, Canada
London's Crossrail 2009–2022	Europe's largest megaproject, Crossrail Limited is delivering the Elizabeth line – a new railway for London and the South-East to increase capacity and improve connectivity running from Reading and Heathrow in the west, through 42 km of new tunnels under central London to Shenfield and Abbey Wood in the east. From end to end the Elizabeth line will stretch over 60 miles (Crossrail 2021)	Cost: £18.9B Budget: £14.8B	UK Parliament DfT and TfL and £600M developer
South North Water Diversion/Transfer Project, China 2002–	A \$79B multi-decade infrastructure megaproject, the objective of which is to divert approximately 44.8B cubic meters of fresh water annually from four rivers in the Southern region of China to the more arid and industrialized northern region. Pollution and resettlement of 333,000 people are major challenges. Society, ecology, and the economy are central to the success of this project (Rogers et al. 2020; Zhuang 2016)	Cost: \$79B Budget: \$62B	Government of China
The Grand Ethiopian Renaissance Dam (GERD) Benishangul-Gumuz Region 2011–2020	The \$5B cost of the GERD is about 7% of the 2016 Ethiopian gross national product. The primary purpose of the dam is electricity production to relieve Ethiopia's acute energy shortage and for electricity export to neighboring countries. With a planned installed capacity of 6.45 GW, the dam is the largest hydroelectric power plant in Africa, as well as the seventh largest in the world (Abtew and Dessu 2019)	Cost: \$5B Budget: \$4.8B	Ethiopian Government via crowdfunding, bonds, and income tax

The Delhi Mumbai Corridor 2006–2037	A planned industrial development project between India's capital, Delhi, and its financial hub, Mumbai, spread across six Indian States along the 1500km long western dedicated Freight Corridor will serve as the corridor's transportation backbone. In addition to infrastructure and airports, it also gives the country a unique opportunity to plan, develop, and build new cities that are economically, socially, and environmentally sustainable (Macomber and Muthuram 2014)	Budget: \$90B	Governments of India and Japan
California High Speed Rail (CHSR) 2015–2033	A publicly funded high-speed rail system under construction in the U.S. State of California. Despite serious funding concerns, the project is projected to connect the Anaheim Regional Transportation Intermodal Center in Anaheim and Union Station in Downtown Los Angeles with the Salesforce Transit Center in San Francisco via the Central Valley, in 2 hours and 40 minutes, which is 380 miles (612 km). The intent of the project is to divert traffic from the congested roads and airports (CHSR 2021). Costs have risen dramatically from an initial plan of 33B to a \$100B and there is uncertainty as to when it will complete due to funding shortfalls	\$33B Budget (2008) \$100B Budget (2021)	Government of California
Gotthard Base Tunnel 1998–2016	Switzerland's largest construction project and the world's longest rail tunnel, with two parallel lines and a total length of 57 km. One of the deepest railway tunnels constructed to date; in some parts, 2300 m separate the tunnel from the earth's surface. The tunnel has a capacity of 50 passenger trains and 160 commodity trains per day. Due to the complexity and size of the project, the Swiss parliament passed a project-related legal framework, which formed the bases for the construction of this corridor and following a 17-year construction period the project was inaugurated on 1 June 2016 on schedule and budget (Drouin and Müller 2021). Sadly, eight workers died in accidents while the tunnel was under construction	(2015 USD) Budget: \$13.2B	The Swiss Government
Hadron Collider, France–Switzerland Border 1998–2008	Designed to study the structure of the subatomic world and the laws of nature governing it, the Collider lies in a tunnel 27 km (17 miles) in circumference and as deep as 175 m (574 ft.) (CERN 2021)	\$4.7B Budget: \$5B	U.S. and EU via CERN (the European Organization for Nuclear Research)
Øresund Bridge 1984–2000	A 10-mile combined rail and road bridge-tunnel spanning the Øresund Strait that links the cities of Copenhagen, Denmark, and Malmö, Sweden.	(2010 USD) Cost: \$4.10B	Loans guaranteed by Sweden and Denmark and User Fees
1984 – Planning	Largest European bi-national project since the Channel Tunnel and the longest concrete tunnel in the world (UCL 2014)	Budget (1991): \$2.96B	
1993 – Construction			
2000 – Completion			

Why Study Megaprojects?

Megaprojects have transformed the way we live in the world and have solved many of the world's great problems, yet we still do not understand much about how they are conceived, implemented, and achieve success, or why some megaprojects fail.

Scholars have expressed the need to know how these megaprojects are initiated, financed, developed, and delivered over a period of many decades. Recent literature on megaprojects searches for answers to the following questions (i) How are megaprojects organized and structured and does it matter? (ii) How do they really perform and is it possible that not all megaprojects are over budget and behind schedule as described in the literature or are there other factors that drive this perception; and (iii) what are the major contributions to society that are often not known for years after project completion (Soderlund et al. 2017).

In this section we review five of the following major reasons to study megaprojects: (i) improving economic prosperity for all; (ii) meeting sustainable development goals; (iii) creating opportunities for economic revitalization, and social, and technological innovation; (iv) understanding how megaprojects impact globalization and contribute to the wider ecosystem; and (v) learning from megaproject theory and practice how all projects can deliver better outcomes.

1) Improving Global Economic Prosperity

Ending poverty and promoting decent work are two sides of the same coin. Decent work is both the major instrument to make development happen and also in effect, the central objective of sustainable development.

— Guy Ryder, Director-General, ILO

One of the major reasons to study megaprojects is set forth in The World Bank's 2020 Flagship Report, *Poverty and Shared Prosperity: Reversals of Fortune* (WB, 2020). This study found that extreme poverty increased globally for the first time in two decades – and that COVID-19, combined with the ongoing effects of climate change and conflict, would impede progress toward ending poverty. Extreme poverty, defined as living on less than \$1.90 a day, is likely to affect between 9.1% and 9.4% of the world's population.

The report provides recommendations for a complementary two-track approach: responding effectively to the urgent crisis in the short run while continuing to focus on foundational development problems, including conflict and climate change. Responding to this crisis is complex and challenging and involves the need for large-scale solutions that involve multiple stakeholders, local, regional, and national governments, technological innovation, and capital market solutions. Chapters 2 and 3 will provide a few specific examples of how megaprojects are addressing the impact of poverty and aiding in the growth of global economic prosperity.

2) Meeting Sustainable Development Goals Through Infrastructure Development

One of the critical ingredients in meeting the new continental and global sustainable development goals, namely the African Union (AU)'s Agenda 2063 and the 2030 Agenda for Sustainable Development Goals (SDGs) is infrastructure (UN 2021). As an example, rural infrastructure investments can lead to higher farm and non-farm productivity, employment and income opportunities, and increased availability of wage goods, thereby reducing poverty by raising mean income and consumption.

According to the McKinsey Global Institute (MGI) the world needs to invest around 3.8% of its GDP, or an average of \$3.3 trillion a year, in economic infrastructure just to support expected rates of growth from 2016 through 2030 (Woetzel et al. 2016). Emerging economies account for some 60% of that need. But if the current trajectory of underinvestment continues, the world will fall short by roughly 11%, or \$350B a year.

Price Waterhouse Coopers (PwC) (2020) Report on Infrastructure Trends, reveals that the infrastructure sector sits at a collision point of global disruptions, including shifts in capital availability, evolving social and environmental priorities, and rapid urbanization. Successful infrastructure delivery demands close alignment and collaboration between a wide range of participants, each with its own agenda and interest.

Oxford Economics (2017) in its detailed analysis of global infrastructure found that the need for infrastructure investment, is forecast to reach \$94 trillion by 2040, and a further \$3.5 trillion will be required to meet the United Nations' Sustainable Development Goals for electricity and water (UN 2021).

The Oxford Economics Outlook (2017) reveals where investment is most likely to fall short, and therefore where the needs are greatest, across 50 countries and seven sectors. It considers what investment is needed and what is likely to occur based on a range of factors, such as a country's historic infrastructure spending levels and how its population and economy is changing, hence identifying investment gaps. The findings are compelling. For instance, Asia has the largest overall need, requiring just over 50% of global investment in infrastructure, however the region is forecast to have a relatively small investment gap. The picture is quite different in other regions where investment gaps are more prominent. The Americas and Africa, by contrast, are forecast to have proportionally much larger infrastructure investment gaps. In these regions the investment gap is 32% and 28%, respectively of investment need. Africa's investment gap is forecast to widen further to 43% if investment need includes SDGs. Quantifying country-level needs is a powerful and positive

step. These insights will help governments identify and respond to infrastructure needs, and guide opportunities for private sector investors. Many countries are increasingly focused on the role of infrastructure to improve economic growth and community wellbeing.

Electricity and roads are the two most important sectors – together they account for more than two-thirds of global investment needs. The investment gap between the two scenarios is greatest in the roads sector, where investment needs are 31% higher than would be delivered under current trends. The gap is also relatively large for ports and airports (Oxford 2017).

3) Creation of Opportunities for Economic Revitalization and Social, and Technological Innovation

Megaprojects can not only make huge impacts at local, regional, and even international scale but can also be significantly affected by the complex project environment. It is inevitable that megaprojects can create opportunities for economic revitalization and technological innovation for a sustainable future. In this book, we look at the past and present of megaprojects, but we also consider the future of megaprojects and its many emerging issues:

- The social, economic, and institutional value of megaprojects
- The global market for infrastructure investment
- Emerging challenges in implementation of international megaprojects
- Megaproject finance and value creation
- Resilience of mega infrastructure
- Megaproject Innovation – digitization, artificial intelligence, and machine learning
- Corporate social responsibility and human rights

“Grand challenges,” related, for instance, to environmental and health issues, have become increasingly pervasive in both policy discourse and in the science, technology, and innovation (STI) policy literature (Ludwig et al. 2021). The appropriate policy responses to these societal challenges differ from mission-oriented policy interventions that relied on large research and development (R&D) programs such as the Manhattan and Apollo projects. These new initiatives will require greater focus on the user perspective to determine whether what is procured is an innovation or not. Today’s equivalent might be the Mars Exploration Program which would call for public procurement of innovation (PPI). Grand challenges call for systemwide transformations where a single instrument is not sufficient (Kuhlman and Rip 2018).

4) The Megaproject Ecosystem: Asphalt, Silk, and the Digital Roads

Infrastructure connectivity has received a significant amount of attention in recent years. Based on country case studies, infrastructure development played a

significant role in the fast economic development of East Asia, including the PRC (Peoples Republic of China), Japan, and the Republic of Korea (Pascha 2020).

The goals of the One Belt Road, the Interstate Highway System, the English Channel, and the Trans-Siberian Rail, all highlight the significant role that megaprojects play in connecting cities, regions, nations, and the world. In this context, the links between megaprojects and development could not be clearer and more dependent on carefully planned national strategies to promote growth and competitiveness.

In addition to regional and urban opportunities for expansion, megaprojects can also create ecosystems that can last for decades even centuries as evidenced by the U.S. Interstate Highway System and High-Speed rail in Europe and Asia (Greiman and Sclar 2019; Nunno 2018; Weingroff 2017).



Øresund Bridge. Source: reduper.com

All megaprojects have the potential to develop an ecosystem of its own or become part of an existing ecosystem. They also can have impacts on an entire Region. For example, the completion and opening of the Øresund Fixed Link in 2000 marked an upturn in mobility at an international, national, regional, and local level for one of the busiest and most important traffic routes between the Scandinavian peninsula and the European continent. The Øresund Fixed Link is a combined bridge and tunnel link across the Øresund Sound between Denmark and Sweden. The fast link to the center of Copenhagen has also had a significant impact on the potential of Copenhagen's Kastrup Airport to attract more international flights. Further, it triggered the formation of a common labor and housing market, which lies at the heart of the political vision of the Øresund Region.

Sustainability normally refers to environmental practices. In megaprojects, a broader definition, including concepts of economic, social, and institutional sustainability, is appropriate (Dimitriou et al. 2012).

The Asphalt Road

One of the most expensive road projects in history and the largest road network in the world is the United States Interstate Highway System that has cost the federal government roughly \$528B, adjusted for inflation. That is almost three times the cost of the International Space Station, and almost five times the cost of the Kashagan oil field in the Caspian Sea. Interstates have transformed the way we move goods and people in the United States. In 1919, then Lt. Colonel Eisenhower traveled in an 80-vehicle military convoy from Washington, DC to San Francisco. The trip took 62 days, inspiring him to create the system. Today that drive could be completed in about three days. Referred to as the greatest public works project in history, the Interstate encompasses 47 000 miles of roadway, and now runs through all 50 states, the District of Columbia and Puerto Rico (Weingroff 2017). But large road projects are not unique to the United States, the estimated \$4.2B Trans-African Highway network comprises transcontinental road projects in Africa being developed by the United Nations Economic Commission for Africa (UNECA), the African Development Bank (ADB), and the African Union in conjunction with regional international communities. The goal of the highway network is to promote trade and alleviate poverty in Africa through highway infrastructure development and the management of road-based trade corridors. The total length of the nine highways in the network is 56 683 km (35 221 miles). India's road project network is estimated as the second-largest in the world with about 6 million kilometres of roads, while China has the world's third-biggest road network, exceeding 4.24 million kilometres.

All of these road projects worldwide have several important goals in common. Advancing trade, accommodating growing populations, and connecting cities and countries are just a few of the reasons why road construction projects are so important, and they all equate to help improve the quality of life at the local, national, and regional level, and permit industries to continue to move their economies forward. Though important, alleviating congestion, providing jobs, and reducing safety risk seem to take a back seat to the holistic social and economic gains of these amazing projects for the entire ecosystem.

China's Maritime and Silk Road: One Belt One Road

Two thousand years ago, the states of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and the four western Chinese provinces of Gansu, Ningxia, Shaanxi, and Xinjiang were at the heart of the ancient Silk Road

(UNCTAD 2014). Over time empires were destroyed, cities fell into ruins, and new forms of transport emerged, while the trade route of antiquity gradually fell into disuse for centuries (p. 1). It was not until after the fall of the Soviet Union in the 1990s, that the Central Asian Countries began their transformation to market economies and became reintegrated into the world economy (p. 1). Importantly, the ancient Maritime Silk Road is becoming a renewed focus for both economic development and for interactions with China and its many neighbors. In recent years, “there has been a new spirit of energy and the Silk Road region has experienced strong economic growth and is emerging as an important foreign investment destination” (UNCTAD 2014). A much-discussed aspect of the Silk Road is the “opening up” of opportunity for China – through its One Belt, One Road Initiative. This initiative consists of two segments – one is centered on the Asian land mass called the Silk Road Economic Belt; the other looks to the South China Sea, the South Pacific, and Indian Ocean and is known as the twenty-first century Maritime Silk Road (Economist 2015). This initiative has many important advantages for sustainable development not least of which is the building of a cohesive policy among different nations, economies, and cultures to facilitate trade and investment, increase financial cooperation, and promote economic development. The plan aims to restore the country’s old maritime and overland trade routes and lift the value of trade with more than 40 countries to \$2.5 trillion within a decade (Economist 2015).

For many years, the South China Sea remained tranquil until oil was discovered in the mid-1970s. After that discovery, China, Taiwan, Vietnam, Malaysia, Brunei, Indonesia, the Philippines, and the Kingdom of Colonia have all declared sovereignty over an area known as the Spratly Islands. Despite recent efforts by international organizations including the Association of Southeast Asian Nations (ASEAN) to calm the waters, the South China Sea continues to cause considerable turmoil among the eight claimants and other interested nations (Greiman 2014). Without a willingness to set aside at least temporarily claims of sovereignty, and to focus on a paradigm shift from sovereign rights to advance the political, economic, and social goals of the Region, an opportunity to change the quality of life for people living in the region forever is sadly missed. Global megaprojects can do great things if we find a common ground to let them happen as they pave the way for a better future for all of society (Greiman 2014).

The Digital Road: The Industrial Revolution 4.0

In a world that is increasingly characterized by enhanced connectivity and where data is as pervasive as it is valuable, Africa has a unique opportunity to leverage new digital technologies to drive large-scale transformation and competitiveness. Africa cannot and should not be left behind (Ndung’u and Signé 2020). The Fourth Industrial Revolution (4IR) – characterized by the fusion of the digital, biological, and physical worlds, as well as the growing utilization of new technologies such

as artificial intelligence, cloud computing, robotics, the Internet of Things, and advanced high-speed wireless technologies, among others – has ushered in a new era of economic disruption with uncertain socioeconomic consequences for our global society (Ndung'u and Signé 2020).

This revolution is powered by electric cars and the ultra-fast train (Prisecaru 2016). In 2020, the European Commission and the Inter-American Development Bank (IDB) made significant efforts to jointly assist Central America and Caribbean countries on issues including the COVID-19 response, sanitation, energy, and digitalization (IDB 2021). Poor bandwidth infrastructure is like traveling on a dirt road. According to the IDB the technological disruption the world is experiencing is something unprecedented as compared to the industrial revolution and the enormous impact it has on per capita gross domestic product (GDP). This explosion of technology occurs in the context of the world of data, data that can only be moved with the necessary infrastructure of digital networks. Thus, just like in any traditional highway infrastructure megaproject, without routes to permit the movement of trucks, buses, and automobiles, we could not connect destinations, trades, and people (Cabañas 2020). In the world of technology, data are the means of mobility such as automobiles, and networks would be the digital highways or routes available in a country, which is directly determined by the country's regulatory framework and capital investments in the country made by mobile or satellite service operators.

Digitization is also critical to the African economy. As reported by the World Bank in its Africa Plan 2019–2023, from mobile money to drones, the digital economy in Africa is driving growth and innovation, bringing more people into the formal economy, and connecting people to each other and to markets. Together, investments in digital infrastructure, skills, and platforms could help Africa accelerate growth while tapping in to the US\$11.5 trillion global digital economy. The World Bank is supporting Africa's vision to connect every African individual, business, and government by 2030 – a vision that, if realized, can boost growth by up to 2% points per year and reduce poverty by 1% point per year in sub-Saharan Africa. In Benin, the World Bank is expanding digital connectivity to around 1.9 million smallholder farmers and increasing use of digital financial services in rural communities (WB 2019).

In order for governments and companies such as Uber, Amazon, Alibaba, and Airbnb to deliver its services we must build and improve digital highways so that this exponential quantity of data can be processed. To ensure the positive effects of the twenty-first century's digital economy, constructing and investing in those digital highways must be the priority for economic development and social inclusion in Africa, Latin America, and the Caribbean.

IDB Invest has invested and will continue to invest in the region in projects that help to expand the digital highway, because we know that 10% penetration by broadband has an average economic effect of 2% to 3% on GDP and 2.6% on productivity. (Cabañas 2020)

As we discuss in this book, innovation and the use of digital technologies including the Internet, AI, machine learning, the Cloud, the Internet of Things, Blockchain, and other digital transformations will depend upon megaprojects to provide the infrastructure necessary for the twenty-first century. For example, recent research shows that the use of artificial intelligence deployment in megaprojects is rapidly advancing and includes AI analytics in the defense industry, occupational safety and health incident tracking in construction projects, and intelligence systems in risk analysis (Greiman 2020). Researchers are recognizing that awareness of the architecture of the 4th Industrial Revolution (4IR) digital tools will be essential to meet the needs of the megaprojects of the future (Whitmore et al. 2020). Megaprojects are becoming the digital platforms of the future. As this development continues, the digital road will become by far the road most traveled.

- 5) Learning from megaproject theory and practice how all projects can deliver better outcomes.

We conclude this section and this first chapter with a brief focus on megaproject theory and practice. As you will learn throughout this book from reviewing the literature and case studies megaproject theory assists policy makers, industry, project stakeholders including contractors, designers, engineers, and government in understanding better the challenges we face in selecting the right projects, implementing these large and complex endeavors, and then ensuring that we deliver the benefits promised. Megaprojects can provide frameworks for structural decision making, strategy alignment, and investment choices that can be beneficial to all projects (Esty 2004). There is now a growing body of research on megaprojects that provides valuable insights that can be applied not only on megaprojects but provides valuable lessons for projects of all sizes large and small. The megaproject literature is interdisciplinary and crosses the fields of engineering, management, law, sociology, psychology, physics, finance, and economics to name a few. The lessons learned will assist all those involved in the future challenges of megaproject management.

Summary

This chapter explores how megaprojects can be used to advance society in unimaginable and innovative ways. They require risk taking, meeting impossible challenges, and the willingness to invest in and manage the power and politics of the time. Lessons from the past will assist in meeting the grand challenges of the future. This may include megaprojects that develop cures for the world's pandemics or infrastructure projects that connect cities, countries, and regions. It also includes technological advancement that helps the human connect with machine

learning to create greater efficiencies and to solve problems that the human mind cannot resolve alone. The impact of these projects on world trade and development is central to the future of all countries. Continued research will assist in helping overcome some of the myths and perceptions about these massive undertakings and will encourage others to take on these challenges and create sustainable and resilient projects for the future.

In Chapter 2, we will explore how global megaprojects are financed. A general overview of the basic project finance concepts, the sources of financing, and the advantages and limitations of project finance, along with the motivations for using project finance will be discussed and global models of project finance will be presented.

Lessons and Best Practices

- 1) Global megaprojects can be transformative and provide insights into opportunities for the wider ecosystem.
- 2) Megaprojects can provide frameworks for structural decision making, strategy alignment, and investment choices that can be beneficial to all projects.
- 3) Partnerships and alliances should be forged to build bonds between countries, companies, and cultures and create better opportunities for investment.
- 4) Global megaprojects create an opportunity to share knowledge across countries and cultures that will make future projects more sustainable and affordable.
- 5) Data collection and statistical analysis should be the primary focus of the upfront planning of projects to better measure performance and outcomes.
- 6) Perceptions of megaprojects should be studied to determine the truth behind the success and failure of megaprojects.
- 7) Megaprojects are shaped over time and cannot be evaluated by a snapshot picture of cost and schedule at a specific point in the project's long life.
- 8) Megaprojects are critical to economic growth and prosperity in both developed and developing countries and can be used to advance societal interests.

Discussion Questions

- 1 To meet the growing demand for megaprojects what are the major challenges we must overcome?
- 2 What are the lessons from the great megaprojects, built over the centuries, that apply to our megaprojects today?

- 3 How can infrastructure development be used to advance and improve societal interests?
- 4 As a project manager in a developing country where half the population lives on a few dollars a day, what strategies would you implement to address poverty alleviation and social improvement?
- 5 What is the meaning of sustainability in today's megaproject practice?
- 6 Why does Paul Schulman an authority in policy making argue that large-scale project policy represents the pursuit of objectives that cannot be fulfilled by a series of individualized, partial, and disaggregated steps?
- 7 How can data collection and statistical analysis be used to transform megaprojects and better connect across cities, countries, and regions of the world?
- 8 How can megaprojects be used to meet the United Nations Sustainable Goals and alleviate poverty the world over?
- 9 What are the types of frameworks that we will need to finance trillions of dollars of infrastructure in the future, based on the OECD's estimates, particularly since private financing depends on a reasonable return on investment?
- 10 Why will the digital road be the one most traveled in the future in infrastructure development?

References

- Abteu, W. and Dessu, S.B. (2019). Financing the Grand Ethiopian Renaissance Dam. In: *The Grand Ethiopian Renaissance Dam on the Blue Nile* (ed. W. Abteu and S.B. Dessu). Springer Geography.
- Agaby, S., El-Ghamrawy, M.K., and Ahmed, S.M. (2014). Learning from the Past: The Ancient Egyptians and Geotechnical Engineering. *4th International Seminar on Forensic Geotechnical Engineering*, Bengaluru, India <https://doi.org/10.13140/RG.2.1.2398.4164>.
- Altshuler, A. and Luberoft, D. (2003). *Mega Projects: The Changing Politics of Urban Public Investment*. Washington, DC, Cambridge, MA: Brookings Institution Press, Lincoln Institute of Land Policy.
- Bassin, M. (1991). Inventing Siberia: Visions of the Russian East in the Early Nineteenth Century. *The American Historical Review* 96 (3): 763–794. <https://doi.org/10.2307/2162430>.

- Bechtel (2001). *Hoover Dam: A Project for the Ages*. Reston, VA: Bechtel <https://www.bechtel.com/projects/hoover-dam/>.
- Biesenthal, C., Clegg, S., Mahalingam, A., and Sankaran, S. (2018). Applying Institutional Theories to Managing Megaprojects. *International Journal of Project Management* 36 (1): 43–54.
- Britannica, The Editors of Encyclopedia (2021). Trans-Siberian Railroad. *Encyclopedia Britannica*, 22 Jan. 2021, <https://www.britannica.com/topic/Trans-Siberian-Railroad>.
- Butler, M. (1972). Netherlands: Dutch Continue to Reclaim Land from the Sea. *Science* 176 (4038): 1002–1004. <http://www.jstor.org/stable/1734091>.
- CA/T (1990). (FEIS/R) Final Supplement Environmental Impact Report, Central Artery (I-93)/Tunnel (I-90) Project. Boston: Commonwealth of Massachusetts, Department of Public Works. November.
- Cabañas, E. (2020). *Digital Highways and Their Similarity to Transportation Highways*. Washington, DC: IDB Invest, Inter-American Development Bank Group.
- California High Speed Rail (CHSR) (2021). *CEO October 2021 Report*. Sacramento, CA: CHSR Authority <https://hsr.ca.gov/about/board-of-directors/ceo-report/2021-ceo-reports/ceo-report-october-2021/>.
- Capka, J.R. (2004). Megaprojects: They Are a Different Breed. *Public Roads* 68 (1): 2–9. Federal Highway Administration, Washington, DC.
- Caro, R. (1975). *The Power Broker: Robert Moses and the Fall of New York*. New York, NY: Vintage Books, Random House.
- CERN (2021). *CERN Annual Report 2020*. Geneva: CERN (European Council for Nuclear Research).
- Cichetti, C.J. (1993). The Route not Taken: The Decision to Build the Trans-Alaska Pipeline and the Aftermath. *American Enterprise, Washington, D.C.* 4 (5), n. p. web. ISSN 1047-3572.
- Clegg, S., Shankar, S., Biesenthal, C., and Pollack, J. (2017). Power and Sensemaking in Megaprojects. In: *The Oxford Handbook of Megaproject Management* (ed. B. Flyvbjerg), 238–258. Oxford: Oxford University Press.
- Congressional Research Service (CRS) (2015). *Keystone XL Pipeline: Overview and Recent Developments*. Updated April 1, 2015. Washington, DC: CRS.
- Crossrail (2021). *Crossrail Project Update November 22, 2021*. Crossrail Ltd. <https://www.crossrail.co.uk/news/articles/crossrail-project-update>.
- Deming, D. (2020). The Aqueducts and Water Supply of Ancient Rome. *Ground Water* 58 (1): 152–161. <https://doi.org/10.1111/gwat.12958>.
- Denicol, J., Davies, A., and Krystallis, I. (2020). What Are the Causes and Cures of Poor Megaproject Performance? A Systematic Literature Review and Research Agenda. *Project Management Journal* 51 (3): 328–345.
- Dimitriou, H.T., Ward, E.J., and Wright, P.G. (2012). *Mega Projects Executive Summary – Lessons for Decision-Makers: An Analysis of Selected International*

- Large-Scale Transport Infrastructure Projects*, OMEGA Project 2, OMEGA Centre, and VREF, Bartlett School of Planning, University College London, December.
- Dimitriou, H.T., Low, N., Sturup, S. et al. (2014). What Constitutes a “Successful” Mega Transport Project? *Planning Theory & Practice* 15 (3): 389–430.
- Drouin, N. and Müller, R. (2021). The Gotthard Base Tunnel: The Work of a Century. In: *Megaproject Leaders: Reflections on Personal Life Stories* (ed. N. Drouin, S. Sankaran, A. van Marrewijk and R. Müller). Cheltenham, UK: Elgar.
- Economic Development Research Group, Inc. (EDRG) (2006a). *Economic Impact of the Massachusetts Turnpike Authority and Related Projects, Volume I: The Turnpike Authority as a Transportation Provider*. Boston, MA: EDRG.
- Economic Development Research Group, Inc. (EDRG) (2006b). *Economic Impact of the Massachusetts Turnpike Authority and Related Projects, Volume II: Real Estate Impacts of the Massachusetts Turnpike Authority and the Central Artery/Third Harbor Tunnel Project*. Boston, MA: EDRG.
- Economist (2015, September 12). *The New Silk Road*. <https://www.economist.com/special-report/2015-09-12>
- Eiffel Tower (2021). *The Origins and Construction of the Eiffel Tower*. <https://www.tou Eiffel.paris/en/the-monument/history>.
- Esty, B. (2004). *Modern Project Finance*. Hoboken, NJ: John Wiley & Sons.
- Flyvbjerg, B. (2014). What You Should Know about Megaprojects and Why: An Overview. *Project Management Journal* 45 (2): 6–19.
- Flyvbjerg, B. (2017). Introduction: The Iron Law of Megaproject Management. In: *The Oxford Handbook of Megaproject Management* (ed. B. Flyvbjerg), 1–18. Oxford: Oxford University Press.
- Friedman, T.L. (2000). *The Lexus and the Olive Tree: Understanding Globalization*. New York, NY: Random House.
- Gellert, P.K. and Lynch, B.D. (2003). Mega-projects as Displacements. *International Social Science Journal* 55 (175): 15–25. https://doi.org/10.1111/1468-2451.5501009_1. Wiley Online Library.
- Grant, M. (1997). Financing Eurotunnel. *Japan Railway & Transport Review* 11: 46–52. http://www.ejrcf.or.jp/jrtr/jrtr11/pdf/f46_gra.pdf.
- Greiman, V.A. (2013). *Megaproject Management: Lessons on Risk and Project Management from the Big Dig*. Hoboken, N.J.: John Wiley & Sons, Inc.
- Greiman, V.A. (2014). A Model for Joint Collaboration in the South China Sea. *The Journal of Asian Finance, Economics and Business (JAFEB)* 1 (1): 31–40. Online ISSN 2288-4645, <https://doi.org/10.13106/jafeb>.
- Greiman, V.A. (2020). Artificial Intelligence in Megaprojects: The Next Frontier. *19th European Conference on Cyber Warfare and Security*, Chester, UK. <https://doi.org/10.34190/EWS.20.123>.
- Greiman, V.A. and Sclar, E. (2019). Mega-Infrastructure as a Dynamic Ecosystem: Lessons from America’s Interstate System and Boston’s Big Dig. *Journal of Mega*

- Infrastructure and Sustainable Development* 1 (2): 188–200. <https://doi.org/10.1080/24724718.2020.1742624>.
- Hale, P. and Macdonald, S. (2005). The Sydney Opera House: An Evolving Icon. *Journal of Architectural Conservation* 11 (2): 7–22. <https://doi.org/10.1080/13556207.2005.10784942>.
- Hill, D. (1984). *A History of Engineering in Classical and Medieval Times*. New York: Routledge.
- Inter-American Development Bank (IDB) (2021). *Annual Report: The Year in Review 2020*. IDB Group <https://publications.iadb.org/en/inter-american-development-bank-annual-report-2020-year-review>.
- Japan Times (2018, March 14) *30 Years on, World's longest Undersea Tunnel Faces Challenges*. <https://www.japantimes.co.jp/news/2018/03/14/national/30-years-worlds-longest-undersea-tunnel-faces-challenges-japan-balances-bullet-trains-freight/>.
- Kardes, I., Oxturk, A., Cavusgil, S.T., and Cavusgil, E. (2013). Managing Global Megaprojects: Complexity and Risk Management. *International Business Review* 22 (6): 905–917.
- Blakeegg, O.J., Williams, T., Magnussen, O.M., and Glasspool, H. (2008). Governance Frameworks for Public Project Development and Estimation. *Project Management Journal* 39 (1): 27–42.
- Kuhlman, S. and Rip, A. (2018). Next-Generation Innovation Policy and Grand Challenges. *Science and Public Policy* 45 (4): 448–454. Oxford University Press.
- Lehtonen, M. (2019). Ecological Economics and Opening up of Megaproject Appraisal: Lessons from Megaproject Scholarship and Topics for a Research Programme. *Ecological Economics* 159 (C): 148–156.
- Levitt, R.E. and Scott, W.R. (2017). Institutional Challenges and Solutions for Megaprojects. In: *The Oxford Handbook of Megaproject Management* (ed. B. Flyvbjerg), 96–116. Oxford: Oxford University Press.
- Liliopoulou, A., Roe, M., and Pasukeviciute, I. (2005). Trans-Siberian Railway: From Inception to Transition. *European Transport* 29: 46–56.
- Ludwig, D., Blok, V., Garnier, M. et al. (2021). What's Wrong with Global Challenges? *Journal of Responsible Innovation*, Routledge 9 (1): 6–27. <https://doi.org/10.1080/23299460.2021.2000130>.
- Macomber, J. and Muthuram, V. (2014). *Delhi-Mumbai Industrial Corridor: India's Road to Prosperity?* Harvard Business School Case 214-077. Brighton, MA: Harvard Business School Publishing <https://www.hbs.edu/faculty/Pages/item.aspx?num=46077>.
- van Marrewijk, A., Ybema, S., Smits, K. et al. (2016). Clash of the Titans: Temporal Organizing and Collaborative Dynamics in the Panama Canal Megaproject. *Organizational Studies* 37 (12): 1745–1769.
- Marrow, E.W. (2011). *Industrial Megaprojects: Concepts, Strategies and Practices for Business*. Hoboken, NJ: John Wiley & Sons, Inc.

- Miller, R. and Hobbs, B. (2005). Governance Regimes for Large Complex Projects. *Project Management Journal* 36 (3): 42–50.
- Mirabile, M., Marchal, V., and Baron, R. (2017). *Technical Notes on Estimates of Infrastructure Investment Needs: Background Note to the Report. Investing in Climate, Investing in Growth*. Paris, France: Office of the Secretary General, Organization for Economic Cooperation and Development (OECD).
- Moraglio, M. (2017). The 1930s: The European Utopia and the Nationalist Fulfillment. In: *Driving Modernity: Technology, Experts, Politics, and Fascist Motorways, 1922–1943* (ed. G. Mom, M. Sheller and G. Clarsen). Oxford, New York: Berghahn Books.
- Morgan, A.E. (1934). The Tennessee Valley Authority. *The Scientific Monthly* 38 (1): 64–72. American Association for the Advancement of Science.
- Müller, R. (2012). *Project Governance*. Aldershot, UK: Gower Publishing, Ltd.
- National Aeronautic Space Administration (NASA) (2021). International Space Station Facts and Figures. <https://www.nasa.gov/feature/facts-and-figures>.
- Ndung'u, N. and Landry Signé, L. (2020). *Top Priorities for the Continent 2020-2030, Capturing the 4th Industrial Revolution: A Regional and National Agenda*. Washington, DC: Brookings <https://www.brookings.edu/research/the-fourth-industrial-revolution-and-digitization-will-transform-africa-into-a-global-powerhouse/>.
- Nunno, R. (2018). Environmental and Energy Study Institute (EESI) Fact Sheet: High Speed Rail Development Worldwide, July 19. <https://www.eesi.org/papers/view/fact-sheet-high-speed-rail-development-worldwide>.
- Orr, R.J. and Levitt, R.E. (2011). Local Embeddedness of Firms and Strategies for Dealing with Uncertainty in Global Projects. In: *Global Projects: Institutional and Political Challenges* (ed. W.R. Scott, R.E. Levitt and R.J. Orr), 183–246. Cambridge, UK: Cambridge University Press.
- Oxford Economics 2017 Global Infrastructure Outlook (2017). <https://oxfordeconomics.com/recent-releases/GlobalInfrastructure-Outlook>.
- Parfomak, P.W. (2009). *The Alaska Natural Gas Pipeline: Background, Status, and Issues for Congress*. Washington, DC: Congressional Research Service (CRS).
- Pascha, W. (2020). *Belts, Roads, and Regions: The Dynamics of Chinese and Japanese Infrastructure Connectivity Initiatives and Europe's Responses*. Asian Development Bank Institute <http://hdl.handle.net/11540/11781>.
- Peters, E.J. (1999). Native People and the Environmental Regime in the James Bay and Northern Quebec Agreement. *ARCTIC Journal* 52 (4): 395–410.
- Peterson Institute for International Economics (PIIE) (2021). *What Is Globalization? And How Has the Global Economy Shaped the U.S.* Washington, DC: PIIE.
- Pitsis, A., Clegg, S., Freeder, D. et al. (2018). Megaprojects Redefined – Complexity vs Cost and Social Imperatives. *International Journal of Managing Projects in Business* 11 (1): 7–34.
- Price Waterhouse Cooper (PwC) (2020S). *Global Infrastructure Trends: The Global Forces Shaping the Future of Infrastructure*. London, UK: PwC <https://www.pwc>.

- com/gx/en/industries/capital-projects-infrastructure/publications/infrastructure-trends.html.
- Prisecaru, P. (2016). Challenges of the Fourth Industrial Revolution. *Knowledge Horizons – Economics* 8 (1): 57–62.
- Road Traffic Technology (RTT) (2021). *The World's Longest Road Tunnel – Laerdal Tunnel, Norway (1992–2000)*. London, UK: Global Data <https://doi.org/10.1108/IJMPB-07-2017-0080>.
- Rogers, S., Chen, D., Jiang, H. et al. (2020). An integrated assessment of China's South—North Water Transfer Project. *Geographical Research* 58 (1): 49–63.
- Rosenberg, M. (2020). *How the Netherlands Reclaimed Land from the Sea*. ThoughtCo <https://www.thoughtco.com/polders-and-dikes-of-the-netherlands-1435535>.
- Rotterdam (2020, May 19). *Port of the Future 7 Building Blocks* [White Paper]. Port of Rotterdam. <https://magazines.portofrotterdam.com/magazine/portofthefuture/lead-on-pipelines/>.
- Sabonge, R. (2014). *The Panama Canal Expansion: A Driver of Change for Global Trade Flows*. Economic Commission for Latin America and the Caribbean, the United Nations.
- Söderlund, J., Sankaran, S., and Biesenthal, C. (2017). The Past and Present of Megaprojects. *Project Management Journal* 48 (6): 5–16.
- Tobin (2001). *Great Projects: The Epic Story of the Building of America, from the Taming of the Mississippi to the Invention of the Internet*. New York, London: The Free Press.
- United Nations (UN) (2021). *The Sustainable Development Goals Report 2021*. New York, NY: The United Nations <https://unstats.un.org/sdgs/report/2021/>.
- United Nations Conference on Trade and Development (UNCTAD) (2014). *Investment Guide to the Silk Road*. Geneva: The United Nations <https://unctad.org/webflyer/investment-guide-silk-road>.
- University College London (UCL) (2014). *Project Profile: Sweden, The Oresund Link, Bartlett School of Planning*. London: The Omega Centre, UCL.
- Weingroff, R.F. (2017). *The Greatest Decade 1956–1966: Celebrating the 50th Anniversary of the Eisenhower Interstate System, Part 1 Essential to the National Interest*. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, (FHWA).
- Whitmore, D, Papadonikolaki, E, and Krystallis, I. (2020). Are Megaprojects Ready for the Fourth Industrial Revolution? *Proceedings of the Institution of Civil Engineers: Management, Procurement and Law*, The University of Leeds, Woodhouse, Leeds, UK. ISSN 1751-4304.
- Woetzel, J., Garemo, N., Mischke, J. et al. (2016). *Bridging Global Infrastructure Gaps*. In collaboration with McKinsey's capital projects and infrastructure practice. McKinsey Global Institute (MGI).
- Wolmar, C. (2014). *To the Edge of the World: The Story of the Trans-Siberian Express, the World's Greatest Railroad*. New York, NY: Public Affairs.

- World Bank (WB) (2019). *Africa Strategy for 2019–2023: Supporting Africa's Transformation*. Washington, DC: World Bank Group.
- World Bank (WB) (2020). *2020 Flagship Report, Poverty and Shared Prosperity: Reversals of Fortune*. Washington, DC: World Bank Group.
- World Nuclear Association (WNA) (2021a). *Press Pocket Guide 2020/21 Edition*. WNA.
- World Nuclear Association (WNA) (2021b). *Nuclear Power in the World Today*. London: WNA.
- Yackee, J.A. (2018). The First Investor-State Arbitration? The Suez Canal Dispute of 1864 and some Reflection on the Historiography of International Investment Law. In: *International Investment Law and History Series: Frankfurt Investment and Economic Law* (ed. S. Schill, C.J. Tams and R. Hofmann), 70–101. Elgaronline.
- Zhuang, W. (2016). Eco-Environmental Impact of Inter-Basin Water Transfer Projects: A Review. *Environmental Science and Pollution Research* 23: 12867–12879. <https://doi.org/10.1007/s11356-016-6854-3>.

