BUILDING GLOBAL INFRASTRUCTURE: FORECASTING THE NEXT 50 YEARS

PATTERNS OF POTENTIAL HUMAN PROGRESS

VOLUME 4

EXECUTIVE SUMMARY

Dale S. Rothman
Mohammod T. Irfan
Eli Margolese-Malin
Barry B. Hughes
Jonathan D. Moyer

PARDEE CENTER for International Futures

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The Patterns of Potential Human Progress (PPHP) series is the work of the Frederick S. Pardee Center for International Futures at the University of Denver's Josef Korbel School of International Studies. The PPHP series is jointly published by Paradigm Publishers and Oxford University Press India. This executive summary of the fourth volume in the series, *Building Global Infrastructure: Forecasting the Next 50 Years*, was prepared by Eli Margolese-Malin and Dale S. Rothman, members of the IFs team and volume authors.

Cover Art

The cover art is a representation of an oil painting by Margaret Lawless, artist for the PPHP series. Ms. Lawless is a contemporary abstract artist whose works in various media portray aspects of the human condition, human progress, and the interaction of humans with nature. In this painting, she emphasizes the connections between people and the physical structures around them—connections that are vital to the fulfillment of human potential. The S-curve suggested by the landscape highlights the focus of this volume, which is how societies transition from low to high levels of physical infrastructure and access to infrastructure's benefits.

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Preface

Building Global Infrastructure: Forecasting the Next 50 Years is the fourth volume in **Patterns of Potential Human Progress** (PPHP), a series exploring the prospects for human development and improvement of the global human condition over the next 50 years. The PPHP series is the flagship publication of the Frederick S. Pardee Center for International Futures at the University of Denver's Josef Korbel School of International Studies, the home of the International Futures (IFs) computer simulation and modeling project. For more than three decades, the IFs modeling and analysis team has worked to develop IFs into the strongest possible tool for the exploration of interacting global issues over the long term.

While IFs and its applications are constantly evolving, the system rests on four defining characteristics:

1. It is long-range, with a forecasting horizon currently extending to the year 2100.
2. It encompasses multiple domains of human and social systems (population, the economy, health, education, energy, agriculture, and important aspects of sociopolitical systems) and the interaction effects across these systems for 183 countries.
3. It is not a predictive tool. Rather, IFs forecasts represent explorations of what might happen under different assumptions about trends and driving variables, not what will happen.
4. Although the issues it addresses are complex and, as such, so is the system itself, IFs is packaged within an interface designed to facilitate ease of use.

IFs can help us understand the consequences of changes already underway in human and social systems and of interventions that could help shape the future in desired directions. In summary, the use of IFs highlights the importance of human agency in interaction with environmental contexts in influencing human futures. In addition, the long-range nature of its forecasts allows us to consider the possible consequences of our choices over a longer time-frame than that addressed by most policy studies.

The first three volumes of **Patterns of Potential Progress** focused, respectively, on reducing global poverty, advancing global education, and improving global health. The fourth volume focuses on building global infrastructure, and the fifth will address strengthening domestic governance around the world. Each volume concludes with extensive country- and region-specific tables containing forecasts of key demographic, economic, health, education, infrastructure, and governance variables over a 50-year period from 2010 to 2060. The volumes are published by Paradigm Publishers and Oxford University Press India.

This executive summary conveys the key messages and other highlights from the fourth volume, ***Building Global Infrastructure: Forecasting the Next 50 Years***. The key questions addressed in the volume are:

- Considering the interaction of demand and supply-side forces, what is a likely future for basic infrastructure in countries across the globe?
- What might this likely future of infrastructure stocks mean for access to infrastructure services around the world?
- What might such changes in infrastructure stocks, access rates, and associated infrastructure spending mean for future human development?
- How realistic are the infrastructure targets that have been specified in policy discussions, and what are the implications of pursuing these targets for the broader economic and social prospects of countries, regions, and the world?
- Can we develop a set of aggressive but reasonable infrastructure targets that enable countries to provide important infrastructure services to more of their citizens?

We begin the summary with several key messages about longer-term infrastructure futures: the often-overlooked role infrastructure plays in development, the context for explorations with IFs, and the implications of alternative infrastructure scenarios for human development more broadly. These messages arise from our analyses of the history and current state of global infrastructure, what infrastructure access might look like in the future under a Base Case scenario that builds on recent trends, and what it might look like should countries give greater priority to infrastructure development. The summary concludes with additional information about the IFs system and the infrastructure submodel, as well as our thoughts about what next steps are needed for further modeling of global infrastructure futures.

For more information about IFs and the PPHP series, as well as technical documentation of the model, please go to www.IFs.du.edu or email Pardee.Center@du.edu. The PPHP volumes themselves, their executive summaries, and the full IFs modeling system are all freely available and downloadable from www.IFs.du.edu.

Key Messages

Motivations for Forecasting Infrastructure

- *Millions of people around the world lack access to even basic infrastructure, and many countries suffer from inadequate and poorly maintained networks.* In 2010, 62 percent of the rural population of low-income countries did not live within two kilometers of an all-season road, 76 percent of all people in low-income countries lacked household access to electricity, 34 percent to improved water, 63 percent to improved sanitation, and 78 percent to modern forms of communication, as represented by mobile telephone subscriptions. As a result of this lack of access, a number of international targets have been set for expansion of basic infrastructure, including Millennium Development Goals (MDGs) for increased access to improved water and sanitation.
- *Sufficient, well-maintained infrastructure underpins economic growth, facilitates education, improves human health, and supports effective governance.* The benefits of infrastructure often accrue to citizens directly in forms such as access to clean water, removal of waste, and household electricity. Populations also enjoy indirect benefits through the improved productivity, better health systems, and enhanced national security that infrastructure fosters at the societal level and in the broader economy.
- *The world is in the midst of several major transitions in infrastructure.* The rapid deployment of ICT continues to accelerate, further connecting the globe and bringing the promise of smart infrastructure. Also, for the first time, the concentration of global infrastructure is beginning to shift from developed to developing countries as the latter work to close gaps in infrastructure stocks and access.
- *Few attempts have been made to forecast infrastructure development for a wide range of countries or beyond the short term.* Furthermore, most past studies have not explicitly linked their forecasts of infrastructure demand to the expected availability of resources to meet these demands, nor have they formally integrated the impacts of infrastructure development on broader social and economic development.
- *Forecasts can help individual countries and international donors determine appropriate levels and foci for investment in infrastructure.* While infrastructure provides numerous benefits, public investments in infrastructure compete with other investments, such as direct investments in health and education. Optimal choices related to infrastructure development almost certainly differ across countries given varying country-level circumstances, and forecasts made using a dynamic structural model allow for the consideration of both direct and indirect costs and benefits of alternative patterns of infrastructure development.

A Tool for Forecasting Infrastructure

- *The International Futures software tool produces annual, country-specific results of infrastructure stocks, levels of access, and levels of spending for 183 countries starting from the year 2010 and extending to any horizon up to the year 2100.* Our approach draws from past studies by the World Bank and others that forecast the demand for infrastructure. Unlike these previous studies, however, our forecasted paths of infrastructure development are determined jointly by the demand for infrastructure and the funding available to meet that demand. Furthermore, we model infrastructure as part of an integrated whole, with both forward and backward linkages to demographic, economic, health, education, and other systems.
- *IFs forecasts stocks and access rates for a wide array of basic infrastructure types.* This includes paved and unpaved roads, electricity generation capacity and connections, area equipped for irrigation, improved water and sanitation access, wastewater collection and treatment, fixed and mobile telephones, and fixed and mobile broadband. Furthermore, IFs forecasts these in an integrated fashion that includes consideration of selected links between different forms of infrastructure.
- *IFs includes a unique package of strengths for the detailed exploration of the future of infrastructure.* In addition to the extensive geographical coverage, long forecasting horizon, and representation of many complex and dynamic relationships, IFs contains a very large underlying database, provides tools for investigating alternative assumptions, and offers flexible formats for exploring and displaying results.
- *We first use the International Futures software tool to produce a country-specific Base Case to 2060 for 183 countries and then explore several alternative scenarios of infrastructure spending and prioritization.* This process allows us to explore where current trends appear to be taking us, the likelihood of meeting proposed targets, the costs and benefits of pursuing these targets, and the relative advantages of pursuing alternative targets.

Infrastructure and Human Development Futures

- *Our Base Case forecast indicates that we can expect countries to improve their infrastructure networks substantially* *over the next 50 years*. By 2060, developing regions (with the exception of sub-Saharan Africa) will achieve access rates to improved water and electricity that approach or even exceed those of high-income countries today, while access to mobile phones and mobile broadband will approach near universality.

- *These improvements will still leave millions of people without access to basic infrastructure, even by 2060*. The vast majority of these people will be in low-income and lower-middle-income countries in sub-Saharan Africa and elsewhere. The pace of infrastructure advance in the Base Case is not fast enough for most developing countries to achieve universal access to basic infrastructure by 2060, much less by the year 2030, the target date specified in a number of existing goals.
- *The costs of achieving universal access are not just financial; they also take the form of tradeoffs that arise through diverting limited domestic public resources from other important contributors to human development*. Public spending on infrastructure competes for resources with other categories, including health and education, which also have direct impacts on development. In our exploration of a Universal Targets Pursuit scenario, in which public resources are shifted in an attempt to meet universal access to all basic infrastructure types by 2030, we find the costs of doing so outweigh the benefits in a large number of countries. Furthermore, even with the added push on infrastructure development, some countries are still unable to achieve the targets.
- *The additional private or international funding that would be required to achieve universal access by 2030 is large enough to raise serious questions about the reasonableness of these targets*. We estimate that the amount of resources required to achieve universal access by 2030 without the diversion of domestic public resources from other sectors to be on the order of 200 percent of expected official development assistance or 10 percent of expected foreign direct investment between 2010 and 2030. That these amounts of funds could be made available seems highly improbable.
- *Some acceleration of infrastructure development beyond that seen in the Base Case is warranted in almost all countries*. In exploring alternative targets, that is, targets with a longer time horizon, less than universal access, or that focus on a subset of basic infrastructure types, we find that almost all countries would benefit from some acceleration of infrastructure development beyond that seen in the Base Case.
- *The optimal rate and focus of acceleration efforts differs across countries and depends, among other factors, on the length of the policy horizon adopted*. For example, focusing on developing ICT infrastructure makes sense for many countries at different income levels when using a short time horizon, but not when a longer-term perspective is adopted. Focusing on water and sanitation provision provides significant benefits for low-income countries, but will have little impact on high-income ones. Finally, the benefits of a broader suite of targets take time to manifest, requiring longer policy horizons for countries to see them as attractive options.

The Story of Global Infrastructure

The Story So Far

Infrastructure is fundamental to economic and human development and has been with us in one form or another ever since the appearance of homo sapiens. The story of infrastructure is, in many ways, the story of humanity. The first information communication technologies took the form of spoken language, cave paintings, and stone carvings, and were accompanied by the first roads—well-trod footpaths. By around 9,000 years ago, the first permanent settlements prompted the development of the first buildings, walls, and irrigation systems. Over time, these infrastructure projects became more ambitious, requiring central planning and better mobilization of resources to complete, which helped give rise to the first city-states and kingdoms. Civilizations rose on a foundation of roads, waterways, and irrigation canals.

Further advances in transportation and communication enabled city-states to grow into the first empires, from Egypt and Mesopotamia, China and India, to Central America, and then spurred them on to ever increasing size. By the time of the Roman Empire (c. 27 BCE), many modern infrastructures were already in use, including vast networks of paved roads, viaducts, indoor plumbing with running water, centralized heating, concrete buildings and dams, and even post offices. Empires, in turn, maintained such infrastructure. After Rome fell (393 CE), many modern forms of infrastructure would not return to widespread use in Europe until the Industrial Revolution of the eighteenth century, even as China went on to construct some of the largest-scale infrastructure ever built.

The Industrial Revolution brought back many lost infrastructures and saw the advent of new forms of energy, transportation, and communication. The development of steam power led to the rise of the railroads that would crisscross continents and steam-powered ships that could more rapidly transport manufactured goods around the world and enforce ever-larger maritime empires. The Industrial Revolution and its associated infrastructure also made possible the wave of European colonization in the 1800s and early 1900s, brought about modern warfare, and laid the foundation for today's globalized world.

By the end of the nineteenth century, the age of steam had given way to the age of electricity and the infrastructures most familiar to our contemporary perspectives. Electrical stations provided light and power to homes and businesses, and spawned new industries. In the twentieth century, the automobile and the airplane gave rise to entirely new modes of transport and spurred the construction of today's superhighways and airports. New shipping technologies allowed for greatly increased and globalized trade; new information and communication technologies like the wireless telegraph, radio, and television, transformed how we communicate; and advances in water infrastructure led to major reductions in disease.

Today, we live in the midst of an ongoing digital revolution that began in the 1960s and 1970s with the digitization of phone networks, the invention of fiber optic cables, and the development of the first computer networks. The information age, and the infrastructures that have come with it, have resulted in the creation of an ever-more-integrated world, and have initiated the transition to increasingly complex networks that integrate multiple forms of infrastructure, like smart electrical grids and smart highways. Where all this will take us is one of the great uncertainties as we look to the future of infrastructure.

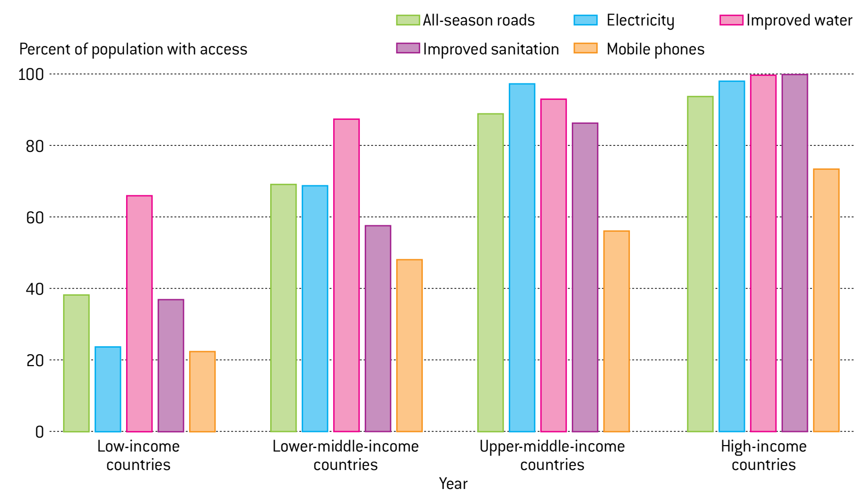
We now live in a world in which the scope of infrastructure is vast. In 2010, there were over 20 million kilometers of paved roads globally (enough to circle the Earth 500 times), enough electricity generation capacity to produce the 5 billion kilowatts of electricity used in that year, 1.2 billion fixed telephone lines, 5.3 billion mobile phone subscriptions, and just under 1 billion household piped water connections.

Despite the truly tremendous extent of modern infrastructure, significant percentages of the population, primarily in low- and lower-middle-income countries, still did not have access to even basic infrastructure (see Figure 1). In 2010, 62 percent of the rural population of low-income countries did not live within two kilometers of an all-season road,[1] compared with only 7 percent in high-income countries. For electricity, 76 percent of people in low-income countries lacked household access to electricity, while only 2 percent did in high-income countries. Similarly, 34 percent of people in low-income countries lacked access to any form of improved water and 63 percent to improved sanitation, while virtually everyone in high-income countries had access to both. And 78 percent of people in low-income countries lacked access to mobile telephones, compared with only 27 percent in high-income countries. Globally, such disparities in access translated to over 950 million people not having access to an all-season road, 1.5 billion people living without electricity, nearly 800 million people without improved water, and 2.5 billion without sanitation.

These disparities reflect historical differences, but also recent patterns of growth in infrastructure. Many upper-middle-income countries (e.g., China) have

1 For a standard measure of adequate transport access, see Peter Roberts, Shyam KC, and Cordula Rastogi, "Rural Access Index: A Key Development Indicator," (Transport Sector Board Paper TP-10, Washington, DC: World Bank, 2006) p. 2.

Figure 1 Selected infrastructure access rates by income group: 2010



Note: Access to all-season roads refers to the percentage of the rural population living within two kilometers of an all-season road. Since historical data for all-season road access extends only to 2004, we have used the IFs Base Case to estimate the 2010 data. Access to mobile phones is estimated from subscription rates per 100 people. Note that subscription rates can exceed 100 because of multiple subscriptions per person; we rescale subscription rates from 0–100 by multiplying them by 2/3, which assumes that 150 subscriptions per 100 persons approximates universal access.

Source: IFs Version 6.61 using data from the World Bank Rural Access Index available at http://www.worldbank.org/transport/transportresults/headline/rural-access/rai-updated-modelbasedscores5-20070305.pdf.; the International Energy Agency World Energy Statistics 2011 available at http://www.iea.org/stats/index.asp; the World Health Organization and United Nations Children's Fund Joint Monitoring Programme for Water Supply and Sanitation Data and Estimates 2011 available at http://www.wssinfo.org/data-estimates/table/; and the International Telecommunication Union World Telecommunication/ICT Indicators 2011 database available at http://www.itu.int/ITU-D/ict/statistics/.

experienced rapidly increasing access to all forms of infrastructure in recent years, while the gains have been much slower elsewhere. For many countries, progress in recent decades has been subject to fits and starts, reflecting the inherent challenges of infrastructure provision: high upfront costs, long time-frames required for new construction, and the important roles that governments (sometimes poorly functioning governments) need to play in infrastructure's development and provision. In addition, there have been uneven efforts to increase private participation in infrastructure development and, in some countries (e.g., Haiti and Iraq), natural disasters and conflict have taken a severe toll on existing infrastructure. Looking forward, we can expect that similar processes will result in highly variable country-specific patterns of infrastructure development driven by idiosyncratic geographies, historical foundations, and public and private choices, even as the overall pattern will be one of continued expansion of infrastructure stocks and access rates.

Base Case Forecast for the Next 50 Years

The IFs Base Case is the output of the full, integrated IFs system (see pages 14–16). It is not a simple extrapolation of variables, but rather an internally consistent, dynamic, nonlinear depiction of the future that appears to be reasonable given current paths. Thus, the Base Case presents a co-evolutionary picture, with numerous interactions and feedbacks across all component systems included in the model. It further assumes that countries make no special effort to accelerate the development of infrastructure.

What might the future of infrastructure look like if the current path continues to unfold?

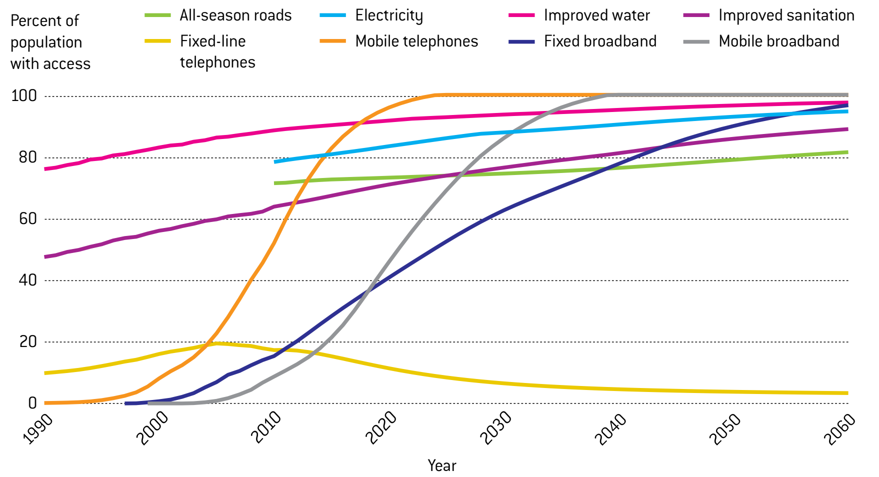
In the Base Case forecast, global access to all forms of infrastructure increases, with the exception of fixed-line telephones (Figure 2). While not completely disappearing, access to fixed-line telephones gradually falls as they are replaced by, and skipped over, in favor of newer technologies. In fact, the most rapid growth in infrastructure access in the future will occur in the newer ICT forms, particularly over the next two decades. This growth reflects both the relatively recent introduction of these forms of infrastructure and the speed at which markets are expanding across the globe. These rapid growth rates will obviously slow as countries reach saturation. Meanwhile, we forecast steady but less-dramatic growth in other, more established forms of infrastructure.

While rapid, the pace of infrastructure advance in our Base Case is not fast enough for many countries to meet existing goals. For example, while the world as a whole has already met the MDG 2015 target for reducing by one-half the numbers of those without access to improved water,[2] half of all developing countries, including two-thirds of low-income countries, will not meet the target. Regionally, sub-Saharan Africa and the Middle East and North Africa as a whole will not achieve the target. The situation for improved sanitation is even more serious, both in terms of absolute

2 The World Health Organization and the United Nations Children's Fund have announced that the global drinking water target was met by 2010. See WHO and UNICEF Joint Monitoring Programme for Water Supply and Sanitation, *Progress on Sanitation and Drinking Water: 2012 Update* (Geneva: WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012).

levels of coverage and the achievement of the MDG target. Not only will the sanitation target not be met globally, four-fifths of all developing countries will not meet the target domestically. This includes almost all low-income countries and all sub-Saharan African countries. On a positive note, upper-middle-income countries as a whole will meet the sanitation target, as will the East Asia and Pacific and Middle East and North Africa regions.

Figure 2 Global access rates to infrastructure: History and forecast



Note: History for access to all-season roads and electricity is not represented because of inadequate historical data, Even though we assume that fixed broadband subscriptions will saturate at 50 per 100 persons, and that mobile telephone and mobile broadband subscriptions will saturate at 150 per 100 persons, all access series are scaled from 0 to 100 to facilitate comparison (that is, 50 fixed broadband subscriptions per 100 persons are assumed to indicate universal access, as are 150 mobile telephone and broadband subscriptions).

Source: Historical data from the World Health Organization and United Nations Children's Fund Joint Monitoring Programme for Water Supply and Sanitation Data and Estimates available at http://www.wssinfo.org/data-estimates/table/; and the International Telecommunication Union World Telecommunication ICT Indicators 2011 database available at http://www.itu.int/ITU-D /ict/statistics/. Forecasts from IFs Version 6.61 Base Case.

Table 1 Forecast shares (percentages) of global total spending on infrastructure by income group and region: 2010, 2030, and 2060

By income group	**2010**	**2030**	**2060**
Low-income countries	1.6	3.4	5.5
Lower-middle-income countries	11.9	17.8	23.3
Upper-middle-income countries	35.2	41.5	41.3
High-income countries	51.3	37.3	29.9
By region, developing countries only			
East Asia and Pacific	24.5	28.5	30.5
Europe and Central Asia	4.9	4.9	4.5
Latin America and the Caribbean	7.1	9.5	7.3
Middle East and North Africa	3.1	3.8	3.8
South Asia	6.5	10.6	14.8
Sub-Saharan Africa	2.6	5.4	9.3
World	**100.0**	**100.0**	**100.0**

Note: Total spending includes public and private spending on core infrastructure and public spending on other infrastructure.

Source: IFs Version 6.61 Base Case.

If we look beyond the MDGs to proposed targets for achieving universal access to most forms of basic infrastructure by 2030, the prognosis is not promising. In our Base Case, we forecast global universal access by 2030 only for mobile telecommunications, and this is if we define access to include only mobile phones and not broadband, which we forecast will take until 2040. For all-season roads, electricity, and improved water, only approximately half of all countries (30 percent of developing countries) will achieve universal access by 2030 and just three-quarters (65 percent of developing countries) will do so by 2060. Access to improved sanitation lags even further in our Base Case, with just over a quarter of all countries achieving the target by 2030 (6 percent of developing countries), reaching only 34 percent (16 percent of developing countries) by 2060.

Thus, significant numbers of people continue to lack access to basic infrastructure services in our Base Case. It forecasts that more than half a billion people will still not live within two kilometers of an all-season road by 2060, and a similar number will not have access to electricity (see Figures 3a and 3b). Approximately 250 million people will not have access to an improved source of drinking water, and more than 1 billion people will not have access to improved sanitation. Over time, those lacking access will be increasingly concentrated in low-income and lower-middle-income countries, particularly in sub-Saharan Africa and South Asia. This pattern reflects, in part, lower access rates in sub-Saharan Africa and South Asia, and also the fact that much of the continued growth in population will occur in these regions.

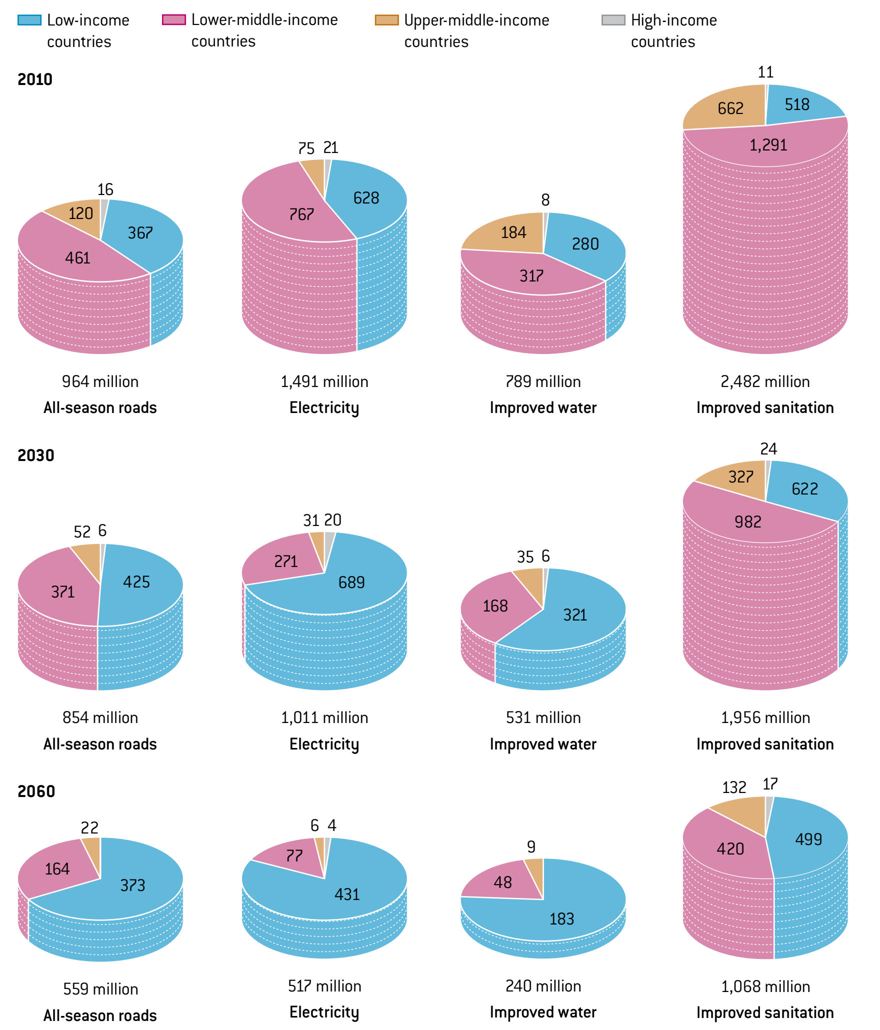
Turning to spending on infrastructure, in our Base Case, we forecast global spending to gradually increase from $1.8 trillion in 2010 to $5.6 trillion annually in 2060 (in year 2000 constant dollars). This translates into more than $170 trillion spent on infrastructure over the next 50 years. A large share of this amount reflects public spending on "other" infrastructure, that is, those infrastructure types that either do not yet exist or are not explicitly included in the IFs model, like seaports, airports, and railroads. Annual spending on these forms of infrastructure is projected to grow from just over $700 billion annually in 2010 to $4 trillion per year in 2060. Annual public and private spending on "core" infrastructure, that is, those forms of infrastructure that we consider explicitly, increases more slowly, but still grows from $1.1 to $1.6 trillion over the same period. Our focus in *Building Global Infrastructure* was on the spending on core infrastructure, but the size and growth of the forecast spending on other forms of infrastructure points to an important area for future forecasting.

Over time, global spending on infrastructure shifts toward the developing countries, who accounted for just under 50 percent of total infrastructure spending in 2010[3] but whose share rises to 70 percent in 2060 (see Table 1). By that time, East Asia and Pacific, by itself, will account for a larger share of global spending than will the high-income countries as a group. Also, spending in sub-Saharan Africa will exceed that in Europe and Central Asia, Latin America and the Caribbean, or the Middle East and North Africa. The forecast spending level in sub-Saharan Africa reflects the larger population growth there as well as the fact that more countries in the region will still be striving to achieve broad infrastructure access across their populations.

The rising absolute levels of total expenditures on infrastructure tell only part of the story, however. If, instead, we look at infrastructure spending as a share of GDP in our Base Case, global spending falls from approximately 4.3 to 3.3 percent of GDP between 2010 and 2060 (see Figure 4). This decline is entirely related to a decline in spending on core infrastructure, which falls from 2.5 to less than 1 percent of GDP. Global public spending on other infrastructure as a share of GDP, which grows with average incomes, increases from 1.7 to 2.4 percent of GDP over this period.

The forecasted decline in spending on core infrastructure as a percentage of GDP is in line with historical trends in many countries and is generally consistent across regions and income groups (see Figure 4). The near-term exception for low-income countries, especially in sub-Saharan Africa, is related to the rapid build-out of ICT infrastructure that is expected to continue for the next two decades. Figure 4 also shows that poorer countries generally spend more on core infrastructure as a percentage of GDP than richer countries.

Figure 3a Persons (in millions) without access to basic infrastructure services by income group: 2010, 2030, and 2060

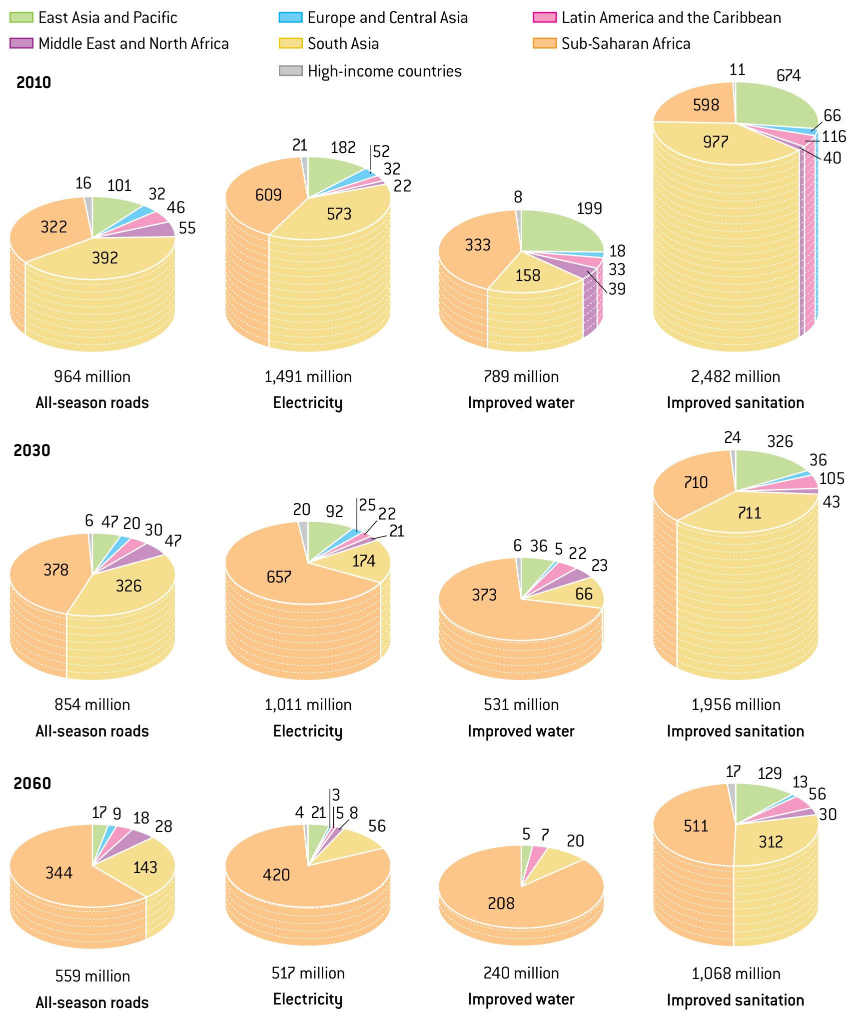


Note: Numbers may not exactly add to totals due to rounding.

Source: IFs Version 6.61 Base Case.

3 Includes public and private spending on basic infrastructure and public spending on other infrastructure.

Figure 3b Persons (in millions) without access to basic infrastructure services by region: 2010, 2030, and 2060



Note: High-income countries are included as a group in the regional analysis in order to sum to the world total. Numbers may not exactly add to totals due to rounding.

Source: IFs Version 6.61 Base Case.

Three important and related factors explain the general pattern of greater spending as a share of GDP in poorer countries and the decline in spending on core infrastructure as a percentage of GDP over time:

1. Because poorer countries have lower levels of GDP, any specific level they spend on infrastructure represents a larger share of GDP than in richer countries. All else equal, as the GDP of poorer countries increases, their spending as a share of GDP will also decrease.
2. Poorer countries tend to have lower levels of infrastructure, thus they need to put a larger share of their infrastructure dollars into new construction, which is generally more expensive than maintenance.
3. The amount of infrastructure a society needs for a given population tends to saturate (this is not the case for other development categories, such as education and health, on which countries tend to increase spending as a share of GDP as they become wealthier).

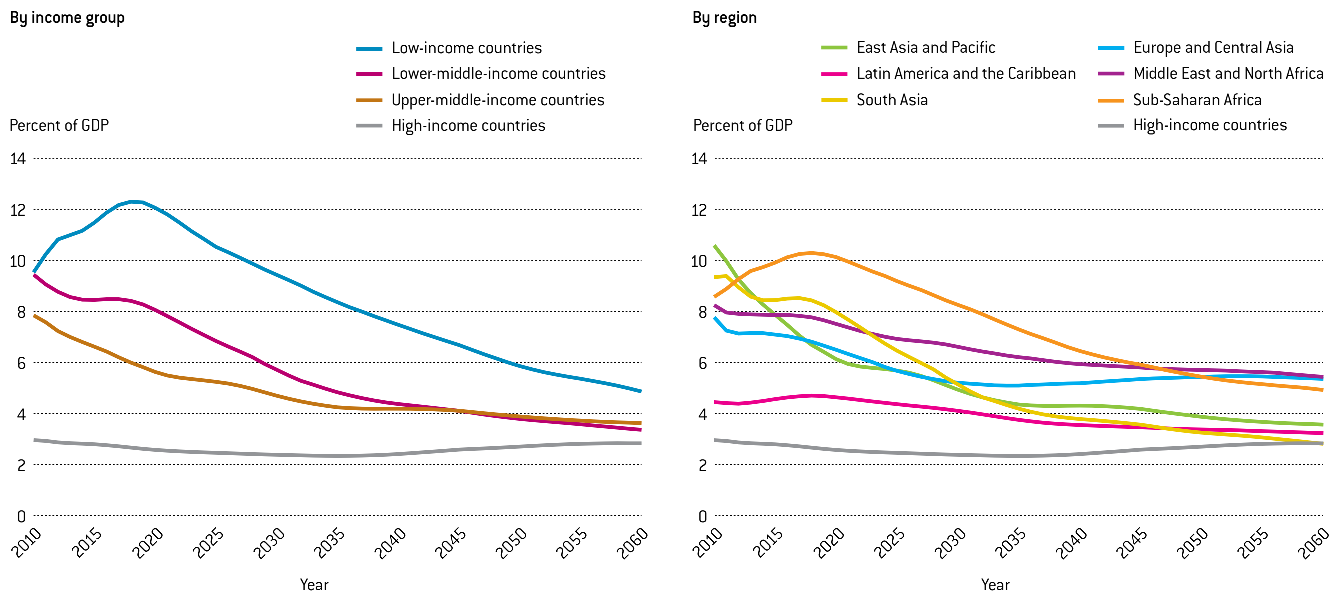
Exploration of Alternative Infrastructure Scenarios

Creating alternative infrastructure scenarios

The Base Case forecasts rapid progress in infrastructure development, but this progress is not enough to achieve universal access to basic infrastructure across the globe by the end of our time horizon. This situation caused us to ask how progress might be accelerated. We needed to be careful, however, as accelerating the deployment of infrastructure can have negative as well as positive impacts. Specifically, if rapid development is to be done by increasing public spending in the absence of foreign assistance, some funds are likely to be redirected from other categories of spending (e.g., education and health) that also contribute to human development. Some high-income countries may well be able to raise enough additional revenues to avoid such tradeoffs, but most countries will likely be unable to do so, due to weak governance or already high levels of taxation. Since the magnitude and timing of any developmental losses due to the reduced spending on these other categories and the benefits from the additional infrastructure will differ, whether the net impacts of accelerated infrastructure investment will be positive or negative for any given country at any given time is an empirical question. The integrated IFs system allows us to consider such trade-offs.

Using IFs, we created a series of alternative scenarios in order to explore the effects of actively pursuing accelerated infrastructure development. We started with the target of achieving universal access to all basic infrastructure types by 2030 and considered both a case in which countries had to achieve the target with domestic resources and one in which money was assumed to be available from an alternative, unspecified source. The results of these scenarios (discussed below) led us to explore scenarios in which we modified the universal targets by: (1) relaxing the time horizon for achieving the targeted level

Figure 4 Total infrastructure spending as a percentage of GDP by income group and region: Forecast to 2060



Note: Total spending includes public and private spending on core infrastructure and public spending on other infrastructure.

Source: IFs Version 6.61 Base Case.

of access; (2) specifying the target level for each country as being a function of its general level of development, measured primarily by its average GDP per capita (in purchasing power parity dollars); and/or (3) prioritizing some forms of infrastructure over others.

Table 2 (on page 10) summarizes the scenarios we explored. The Base Case is included as a point of reference. The Universal Targets Pursuit (UTP) scenario uses existing targets for universal access by 2030.[4] The remaining scenarios fall into two broad classes:

- Altered target scenarios reflecting three different approaches:
  - Delayed Universal Targets—extends time horizon for meeting universal access goals to 2050 instead of 2030.
  - Meet Expectations—links targets to a country's level of development as measured by average GDP per capita, with countries aiming to provide the level of infrastructure expected for their level of GDP per capita.
  - High Performance—links targets to a country's level of development as measured by average GDP per capita, with countries aiming to provide the level of infrastructure expected for the best performing countries with the same level of GDP per capita.
- Prioritized target scenarios: These scenarios use the same targets as in Universal Targets Pursuit, but each one prioritizes a single infrastructure form (all-season road access, improved water and sanitation, electricity, or ICT).

In all cases, while countries strive to meet the specified targets, their success is not guaranteed because we assume that they attempt to do so using domestic resources, and the needed resources simply may not be available.

The Universal Targets Pursuit scenario

In the Universal Targets Pursuit scenario, access to the targeted infrastructures increases compared to the Base Case. Still, other than for ICT, not all countries are able to achieve universal access by the target date of 2030. Global access to all-season roads in 2030 is 93 percent, compared to 87 percent in the Base Case; for electricity the equivalent values are 92 percent versus 88 percent; for water they are 97 percent versus 94 percent; and for sanitation they are 91 percent versus 76 percent.

These improvements dramatically reduce the number of persons without access to infrastructure, even as the global population is approximately 30 million persons larger in the UTP scenario than in the Base Case as a result of the health benefits associated with the improved infrastructure. The number of persons without access to all-season roads, electricity, improved water, and

4 See the note in Table 2 for the special treatment of road access.

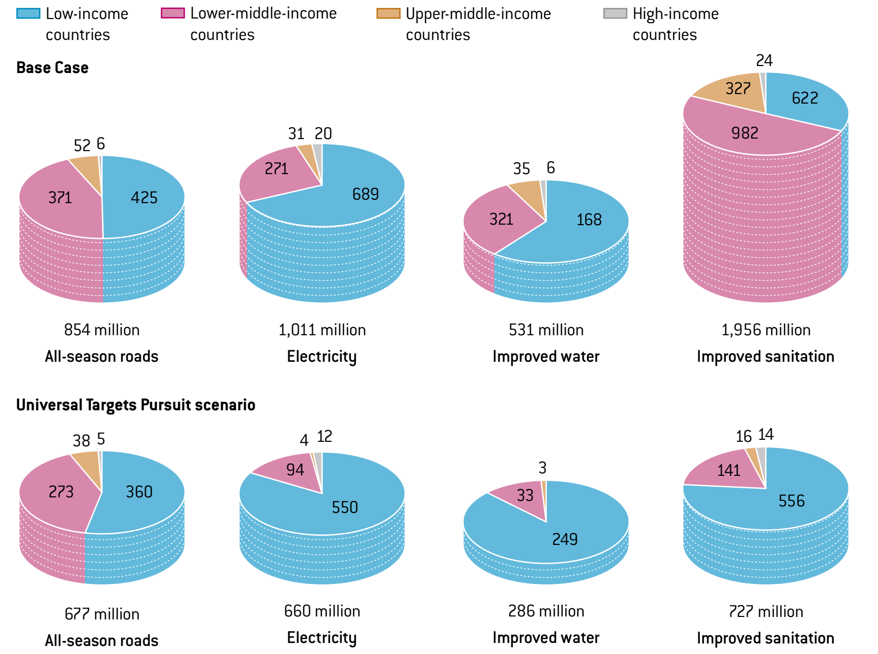
Table 2 Alternative IFs infrastructure scenarios and associated targets

Scenario name	Scenario code	Targeted core infrastructure	Year of target	Level of target
Base Case	Base	NA	NA	NA
Universal Targets Pursuit	UTP	All	2030	100%, except for road access, where target is based on a 90% cap
Delayed Universal Targets	DUT	All	2050	100%, except for road access, where target is based on a 90% cap
Universal Target–Roads Only	UT-R	Road access	2030	Reduce lack of access by one-half up to cap of 90% access
Universal Target–Energy Only	UT-E	Electricity access	2030	100%
Universal Target–Water and Sanitation Only	UT-W	Improved water and sanitation	2030	100%
Universal Target-ICT Only	UT-I	Mobile broadband	2030	100%
Meet Expectations	ME	All	2030	Expected level given general level of development
High Performance	HP	All	2030	One standard error above expected level given general level of development
Delayed High Performance	DHP	All	2050	One standard error above expected level given general level of development

Note: For the first three scenarios, the target for roads is to reduce by one-half the share of the rural population living more than 2 kilometers from an all-season road, with a maximum target (cap) of 90 percent because of extremely high marginal costs beyond that point. Access levels for the final three scenarios are determined by cross-sectional analysis of expected levels of access at varying levels of development and by a one-standard-error increment above that level in the final two scenarios; access rates for roads in those scenarios are again capped at 90 percent.

Source: IFs Version 6.61.

Figure 5 Population (in millions), by income group, without access to selected core infrastructure forms in 2030 in the Universal Targets Pursuit scenario and the Base Case



Note: The global population in 2030 is forecast to be approximately 30 million persons larger in the Universal Targets Pursuit scenario than in the Base Case, primarily due to the health benefits of improved infrastructure. Numbers in the pie charts may not exactly add to totals due to rounding.

Source: IFs Version 6.61.

improved sanitation are approximately 180, 350, 245, and 1,230 million fewer, respectively, in the UTP scenario than the Base Case in 2030 (see Figure 5).

In terms of increased spending on infrastructure, the financial costs of these improvements are significant. Compared to the Base Case, global spending on infrastructure increases immediately, eventually growing to approximately $220 billion annually around the target year of 2030. Cumulatively, the additional spending is $2.9 trillion between 2010 and 2030 and $9.6 trillion from 2010 to 2060. These amounts represent increases of 6.3 and 5.6 percent for these periods, with substantially larger increases in some countries. The additional spending comes, in part, from increased revenue as a result of increased economic growth, but also from reducing public spending on other categories, such as health and education. The low- and lower-middle income countries see diversions of greater than 10 percent across these categories.

We considered the net benefits of pursuing the universal targets by looking at the changes in the components of the Human Development Index (HDI). Compared to the Base Case, under the UTP scenario, global GDP per capita declines slightly until after 2020; by 2060, it is forecast to be almost 9 percent higher. The expected years of schooling and educational attainment also see declines in the early years, but these take much longer to recover, and do not do so by 2060 in many countries. Finally, the health benefits from increased access to water and sanitation offset any redirection in health spending to the point that there is an almost immediate small gain in additional life expectancy with the UTP scenario. Overall, under the UTP scenario, the HDI in low-income countries is negatively affected for much of the time horizon, although the impact is minor, averaging 0.002 points on a 0 to 1 scale. As the benefits of additional infrastructure accrue, the net reduction in the HDI shrinks and by 2050 disappears, turning into net gains for the rest of the period. The tradeoff between the shorter-term costs of accelerating infrastructure development and the longer-term benefits is something that countries need to consider carefully.

As a point of comparison, we created a Universal Targets with Additional Funding (UTAF) scenario. This is a scenario in which we kept the universal access by 2030 targets but removed the financial constraints by assuming an unspecified source of funds that enables countries to achieve the targets while avoiding the diversion of funds from other categories. This allowed us to estimate the total cost for countries to meet the targets.

Under this scenario, we find that, globally, an additional $6.1 trillion would be needed above Base Case spending levels to reach universal access rates by 2030. As in the UTP scenario, some of these funds are generated from increased revenues related to increased economic growth. Still, $3.6 trillion would have to come from the unspecified source of funds (see Table 3). For low-income countries, this additional spending would amount to 12 percent of their total GDP; for lower-middle-income countries, an additional 1.6 percent of their total GDP would be needed.

The possible sources for these funds include additional private spending or external sources such as official development aid and foreign direct investment. However, whether external assistance or investment would be able to provide these extra funds is questionable at best. Official development assistance is forecast to be approximately $1.8 trillion over the 2010–2030 period, so it would have to double and be completely devoted to infrastructure development. Alternatively, a 10% increase in foreign direct investment targeted solely to infrastructure could provide the needed funds. In either case, national governments would have to be willing to accept the money while recognizing the potential problems associated with an influx of such a large sum of funds.

Table 3 Additional funds required to achieve infrastructure universal targets without diversion of government funds from other expenditure categories by income group and region: 2010–2030

	Additional funds	
By income group	**Billion $**	**As percent of GDP in Base Case**
Low-income countries	1,501	12.6
Lower-middle-income countries	1,525	1.6
Upper-middle-income countries	574	0.2
High-income countries	4	0.0
By region, developing countries only		
East Asia and Pacific	177	0.1
Europe and Central Asia	220	0.6
Latin America and the Caribbean	412	0.5
Middle East and North Africa	333	1.5
South Asia	868	1.4
Sub-Saharan Africa	1,590	7.5
World	**3,604**	**0.3**

Note: All values are cumulative for the years 2010–2030. Percent of GDP is calculated by dividing the additional funds by cumulative GDP in the Base Case.

Source: IFs Version 6.61 Base Case and Universal Targets with Additional Funding scenario.

Exploring the alternative infrastructure targets

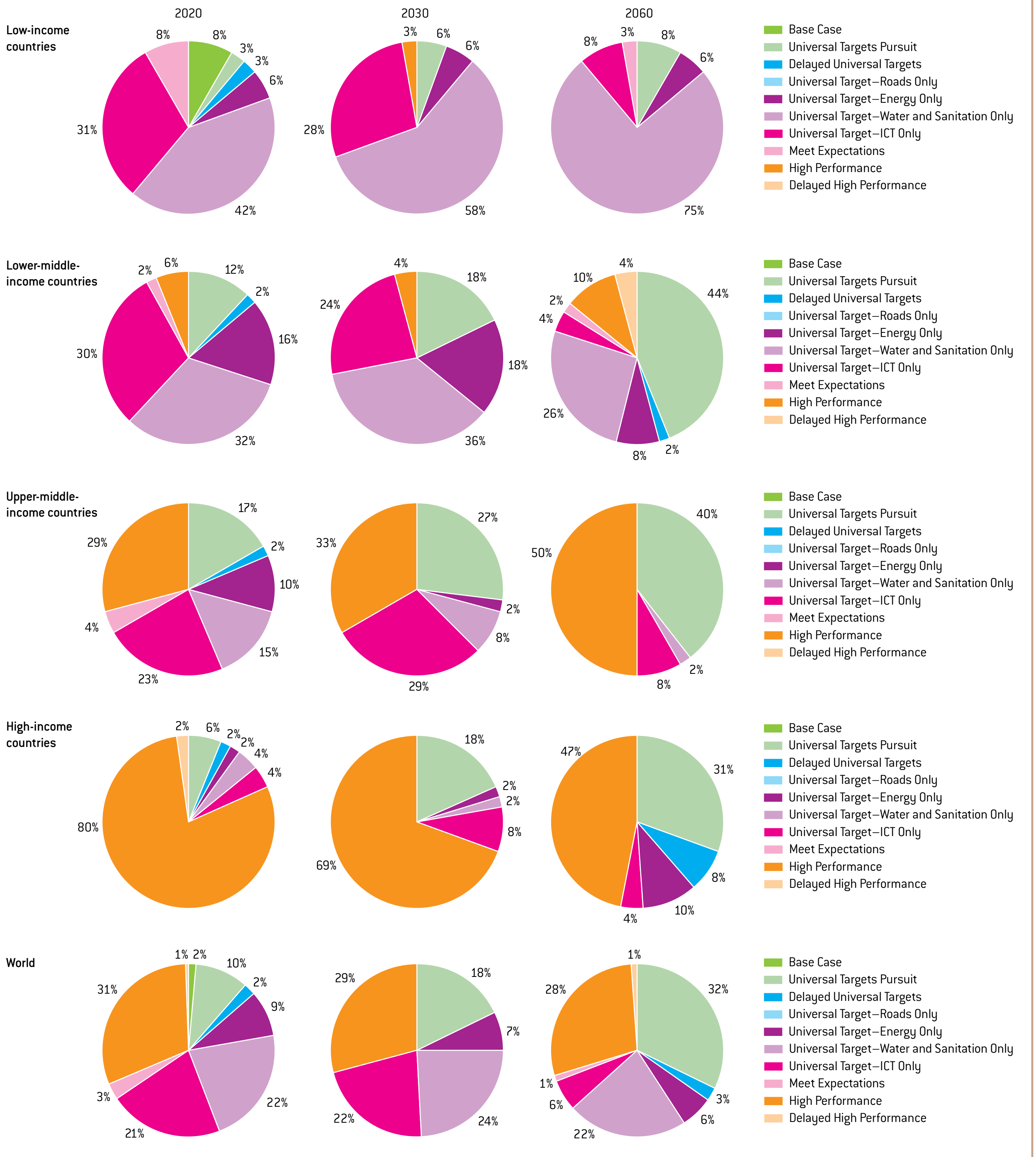
The challenge of achieving universal access to basic infrastructure by 2030 suggested the need for us to consider alternative infrastructure targets. These were laid out in Table 1. We used two basic metrics, cumulative discounted GDP per capita and cumulative discounted HDI,[5] to compare the desirability of these alternative targets to our Base Case (not having any targets) and our UTP scenario (the pursuit of universal access by 2030). We also considered different policy horizons by looking at the results after 10 years (i.e., out to 2020), 20 years (i.e., out to 2030), and 50 years (i.e., out to 2060).

Our analysis indicated that no one set of infrastructure targets is optimal for all countries across all time horizons (see Figure 6, on p. 12). At the same time, the Base Case was rarely the highest ranked option. This implies that pursuing some acceleration of infrastructure development makes sense for almost all countries, but the choice of which targets to pursue depends on the country and on the policy horizon.

Still, some interesting patterns do emerge. In general, the Universal Targets Pursuit and High Performance scenarios, which have targets for a wide range of infrastructure types, lead to better results for more countries as the policy horizon increases and, therefore, there is more time for the benefits of these scenarios to make up for their short-term costs. This is less notable among the low-income

5 The results presented here are based on a discount rate of 3 percent. We obtained similar results when we used discount rates of 1 percent and 5 percent.

Figure 6 Percent of countries, by income group, with alternative infrastructure scenarios ranked highest, based on HDI outcome: 2020, 2030, and 2060



Note: Choice of preferred scenario is based on discounted cumulated streams of annual values of the HDI. Discount rate is 3 percent and values are discounted to 2010.

Source: IFs Version 6.61.

countries, however. For those countries, a focus on increasing access to improved water and sanitation ranks highest among a large proportion of countries, with the number growing as the policy horizon lengthens. This result reflects two factors: (1) the significant sacrifices these countries would have to make in order to pursue a full suite of infrastructure targets without outside assistance; and (2) the notable health benefits that come from clean water and the provision of improved sanitation.

Another general pattern is the declining preference for a focus on improving ICT infrastructure as the policy horizon lengthens. However, the declining importance of ICT infrastructure as the policy horizon lengthens is due, at least in part, to our inability to envision and capture potential future developments in ICT and the longer-term benefits of those developments. Finally, for almost no countries is a focus on road infrastructure given the highest rank, regardless of the policy horizon.

The Future of Global Infrastructure: Challenges and Opportunities

Providing access to basic infrastructure for an entire population presents a number of challenges. Our analyses tell us that many developing countries will be unable to provide universal access to their populations even by 2060 without undertaking major, concerted efforts to do so, efforts that may pose economic hardships in the short run.

Challenges arise from the particular characteristics of infrastructure as well as from the large investments required. For instance, much infrastructure has the nature of a collective good, one that requires collective action to provide. Such goods are routinely underprovided relative to the true desires of individual members of a population because of the logic of collective action (all actors can benefit from the provision of the good by others, whether or not they help pay for it).[6] In addition, infrastructure projects are generally large-scale, expensive, require long time-frames for completion, and have long payback periods. Long-range systemic planning, professional execution, and sustained funding are all required for success. However, most political processes do not favor such requirements. Consequently, all too often, the outcome is frequent delays, cost overruns, and redundant, inappropriate, and/or poor quality infrastructure. Further, political processes often favor large-scale infrastructure projects that can bring attention to, and boost the prestige of, politicians or foreign donors. Thus, less glamorous projects, like a water treatment plant or bringing piped water to households, can lose out to bold projects like a new dam or motorway. The political attraction of attention-getting large-scale projects also manifests itself in an orientation to new construction versus vitally important but seemingly mundane maintenance programs.

While the infrastructure characteristics and related challenges described above are common to all countries, developed and developing countries face somewhat different challenges as we look to the future. For developed countries, the primary challenge is one of upkeep. Infrastructures have a natural lifecycle, and many infrastructures in rich countries are deteriorating and/or reaching the end of their useful lives. Such deterioration is often allowed to occur without plans or provisions of funds for needed renewal or replacement. At the same time, developed countries will still need to contend with new infrastructures as they arise (for example, the rollout of ICT-networked electrical grids and possible energy storage systems for large-scale use of renewable energy). For developing countries, the primary challenge remains building out basic infrastructure and expanding access to the services it provides, while at the same time facing important competing demands (such as continued development of health and education systems) for limited public resources. In reality, developing countries are faced with an extraordinary challenge: they are trying to build in decades what more developed countries have built over centuries.

Amidst these challenges are bright spots, though, many of which are related to the revolution in information and communication technologies. ICTs are enabling lower-income countries and regions to leapfrog the development of expensive older technologies, greatly accelerating the deployment of systems based on modern computing and telecommunications capabilities—including banking services, market information, and specialized health resources—even in remote areas where other infrastructure is lacking. In the developed and developing world alike, the more efficient use of infrastructure through sophisticated monitoring and communication systems (smart infrastructure) embedded in roads and other forms of infrastructure has the potential to improve the efficiency and environmental footprint of infrastructure, as well as to deliver critical services to households, firms, and governments.[7] To a large degree, the future of global infrastructure and its implications for overall development will depend on the ability of countries and the international community to take advantage of these opportunities.

6 Mancur Olson, *The Logic of Collective Action* (Cambridge, MA: Harvard University Press, 1965); David L. Weimer, and Aidan R. Vining, *Policy Analysis: Concepts and Practice*, 4th ed. (Upper Saddle River, NJ: Pearson Prentice Hall, 2005).

7 Ludwig Siegele, "It's a Smart World: A Special Report on Smart Systems," *The Economist*, November 6, 2010; Guy Félio, "Project to Develop an Infrastructure Report Card for Canada" (Project Summary and Update presented at the AM-BC Workshop; The Changing Culture of Asset Management, January 24, 2011, Vancouver, Canada).

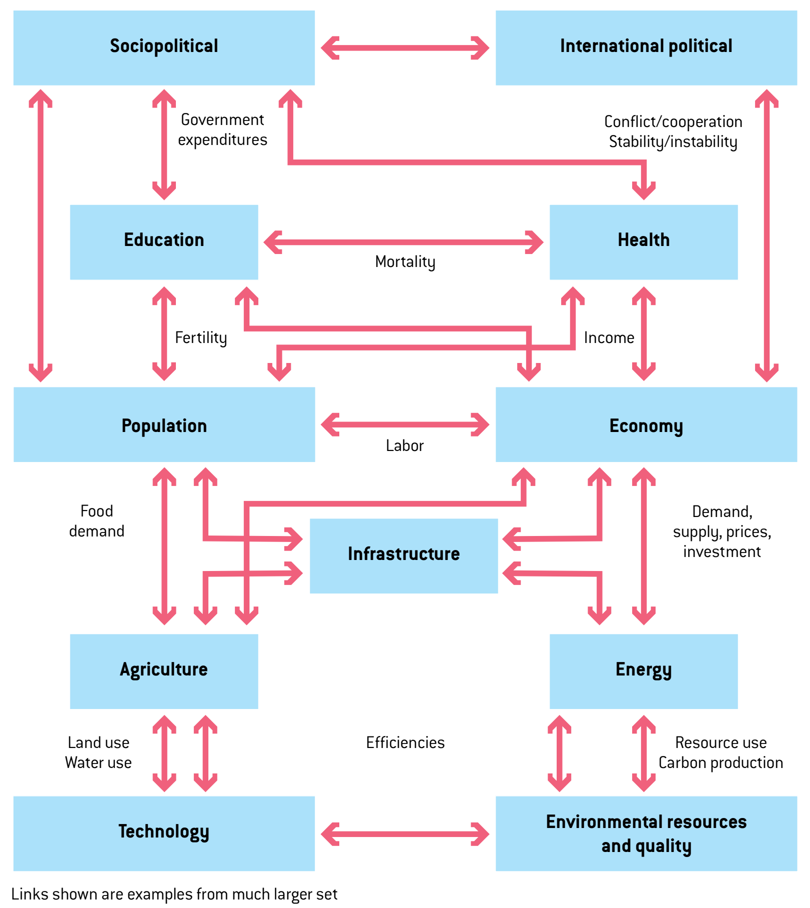
The International Futures Forecasting System

The System of Models

IFs is a software tool whose central purpose is to facilitate exploration of possible global futures through the creation and analysis of alternative scenarios. IFs is a large-scale, long-term global modeling system that incorporates and integrates modules of population, economics, energy, agriculture, the environment, and sociopolitical change. In support of **Patterns of Potential Human Progress**, we have added education and health models to the system, and now, with the fourth volume in the series, an infrastructure module that forecasts future levels of infrastructure, access to that infrastructure, and the implications of additional infrastructure in interaction with the other components of the modeling system. Figure 7 shows the major conceptual blocks of the IFs system.[8]

IFs represents the dynamic connections among all these systems for 183 interacting countries, drawing on standard approaches to modeling specific issue areas whenever possible, extending those as necessary, and integrating them across issue areas.[9] Underlying the model is an extensive database of country-specific data for the issue areas drawn from the family of the United Nations member organizations and other sources covering the time period from 1960 to the present. The model itself can produce forecasts from its base year of 2010 out to 2100. Most important, the forecasts it produces, although grounded in historical data, are not extrapolations, but rather represent the results of the dynamic interplay among variables in multiple domains of human development systems.

Figure 7 Major models in the IFs modeling system and example connections



Source: Authors' conceptualization.

Fundamentally, IFs is a thinking tool for exploring human leverage in pursuit of key goals in the face of great uncertainty. IFs assists with:

- understanding the state of the world and the future that appears to be unfolding by:
  - identifying tensions and inconsistencies that suggest political, economic, or other risk in the near or middle term;
  - exploring long-term trends and considering where they might be taking us;
  - working through the complex dynamics of global systems.
- thinking about the future we want to see by:
  - clarifying goals and priorities
  - developing and exploring alternative scenarios ("if–then" analyses)
  - investigating what leverage we may have in shaping the future.

8 The technology components are embedded throughout the model; all the rest of the conceptual blocks are represented by specific modules and linked to other modules. The named linkages in Figure 7 represent only a small illustrative subset of the dynamic connections between the block components.

9 For example, the population model in IFs is based on a typical "cohort-component" representation, tracking country-specific populations and events (including births, deaths, and migration) over time by age and sex; IFs then extends this representation by adding education and health.

The Infrastructure Model

Figure 8 provides an overview of the infrastructure module within IFs. Unlike many previous studies, which only estimated the demand for infrastructure, IFs focuses on the path jointly determined by both the demand for infrastructure and the funding available to meet that demand. Therefore, the amount of infrastructure forecast in the IFs Base Case explicitly accounts for expected fiscal constraints.

In the IFs infrastructure module, we forecast stock size, access rates, and spending levels for the following infrastructure forms:[10]

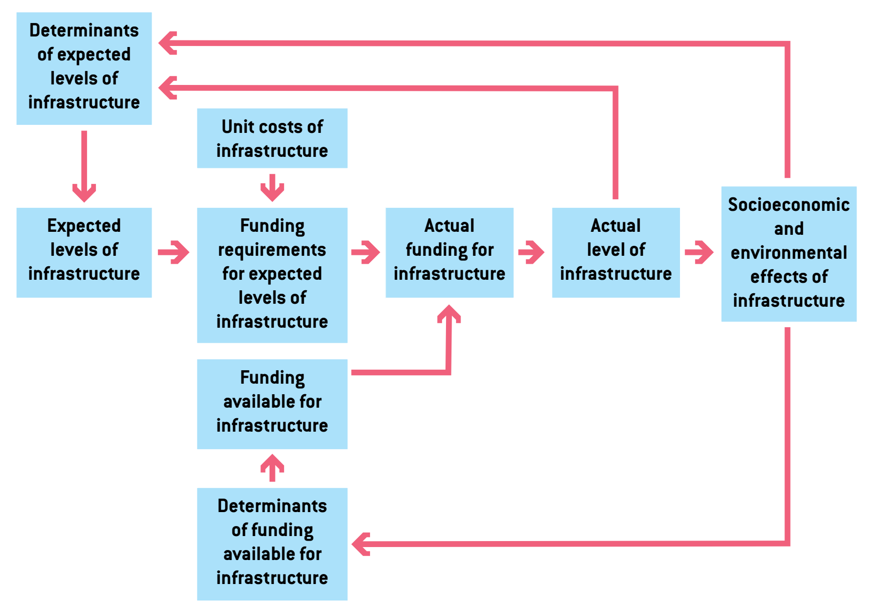
- roads (paved and unpaved)
- electricity generation capacity and electricity connections (rural and urban)
- water connections (other improved and piped), sanitation connections (shared and improved), wastewater treatment, and the area equipped with irrigation
- fixed telephone lines, fixed broadband subscriptions, mobile telephone subscriptions, and mobile broadband subscriptions

We begin by forecasting the expected amounts of infrastructure and access levels for each country. Expected levels are determined by the country's economic, demographic, geographic, and political characteristics, the interdependencies between different forms of infrastructure, and the size of the infrastructure stock in previous years.[11] At the core of the forecasts of expected levels is a set of estimated equations embedded within a set of accounting relationships. Each equation relates one physical infrastructure form to specific economic, structural, and demographic drivers; some also include explicit linkages across infrastructures. Our selection of the driving variables ultimately included in the equations was influenced by theoretical considerations, previous efforts, the availability of data, and, of course, the analytical results themselves. While a number of earlier studies provided equations for forecasting future levels of some of the types of physical infrastructure we include, we chose to derive our own. This allowed us to use more recent data to drive the relationships and to better integrate the resulting relationships within the broader IFs system.

Once the model calculates the expected levels of infrastructure, it then estimates the financial requirements to achieve the expected levels. For this, we adopted the approach introduced by Fay and Fay and Yepes.[12] The cost of achieving an expected level of infrastructure each year is based on the cost of new construction (estimated as the expected net change in infrastructure over the year multiplied by the unit cost of that infrastructure) and the cost of maintenance/renewal (estimated as the amount of infrastructure at the start of the year multiplied by an assumed rate of depreciation and the infrastructure's unit cost). The total financial requirements then become part of the public and private spending accounting systems. Infrastructure is just one of many demands on a country's budget; thus a given country may not have the resources required to actually reach its expected level of infrastructure.

Once expected levels and financial constraints are determined, the forecasted actual level of infrastructure determines access rates. These changes then feed forward to other systems in the model, affecting such things as economic productivity and health. These, in turn, affect the next year's calculation of expected infrastructure levels and the ability to pay for them.

Figure 8 The dynamic, integrated, infrastructure modeling system in IFs



Source: Authors' conceptualization.

10 The choice of this set of infrastructure indicators reflects the volume's focus on access to basic infrastructure services, the availability of historical data, and the authors' determination of what could be modeled within IFs at this time.

11 Given the long lead times for construction and long lifetimes of much infrastructure, there is a significant degree of path dependence. Thus the amount of infrastructure in a specific year will strongly influence the amount in the next year.

12 Marianne Fay, "Financing the Future: Infrastructure Needs in Latin America, 2000–05" (WB Policy Research Working Paper no. 2545, World Bank: Washington, DC, 2001); Marianne Fay, and Tito Yepes, "Investing in Infrastructure: What Is Needed from 2000 to 2010?" (WB Policy Research Working Paper no. 3102, World Bank, Washington, DC, 2003).

The development of the IFs infrastructure module has advanced the exploration of global infrastructure futures by:

- covering a wider array of infrastructure forms than previous studies, including all-season rural road access and mobile broadband;
- incorporating driving variables related to income inequality, geography, and governance, variables identified as important but not used in previous forecasting efforts;
- taking into account fiscal constraints to the construction of new infrastructure and maintenance of existing networks;
- assembling the most comprehensive global database on infrastructure stocks and access available to the general public;
- developing separate indices for "traditional" and ICT infrastructures in order to better calculate infrastructure's impact on economic productivity;
- exploring selected impacts of different infrastructure scenarios on future development and human well-being and, in turn, the role that human development plays in the further demand for, and development of, infrastructure;
- providing an in-depth exploration of possible infrastructure futures in order to determine the feasibility of existing infrastructure goals.

We recognize that much can be done to further strengthen infrastructure forecasting. Some areas for future efforts include:

- treating more forward linkages than are currently handled by IFs, in particular the impact of different infrastructures on the environment;
- expanding the forms of infrastructure covered, for example, transportation categories like rail, water, and air, as well as inter-country and global infrastructure linkages;
- exploring a fuller range of interconnections between infrastructure forms, for example, the role of ICT in the development of smart energy grids and smart highways;
- adopting country-specific unit costs of construction and public-private funding splits for each infrastructure type.

Infrastructure is vital for development. Over the coming decades, countries around the world will continue to build out and upgrade their infrastructure networks, and the global community will continue to propose goals for increasing access to infrastructure. Based on our analysis, such goals are necessary because current trends, as reflected in our Base Case, will leave many millions without access to basic infrastructures, even by 2060. We believe IFs and the analysis contained in ***Building Global Infrastructure*** offer the tools and insights necessary for policy makers to explore and evaluate alternative infrastructure futures and their implications for broader human well-being. Such insights can help guide the formulation of future infrastructure goals that are at the same time both reasonable and aggressive.

Author Notes

Dale S. Rothman is an Associate Professor at the Josef Korbel School of International Studies and Senior Scientist with the Frederick S. Pardee Center for International Futures, University of Denver. His work focuses on global long-term interactions between environment and human development.

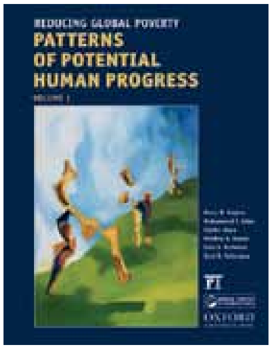
Mohammod T. Irfan is a Research Scientist at the Frederick S. Pardee Center for International Futures at the Josef Korbel School of International Studies, University of Denver. His research focus is on long-term computer simulation of education and knowledge systems around the world.

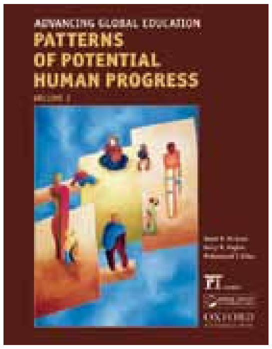
Eli Margolese-Malin is a Research Associate at the Frederick S. Pardee Center for International Futures at the Josef Korbel School of International Studies, University of Denver. His interests span a range of topics related to the long-range future of humanity.

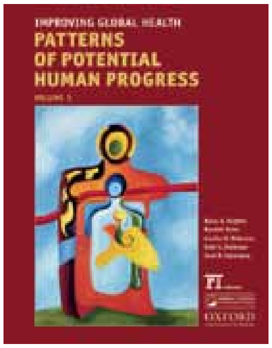
Barry B. Hughes is John Evans Professor at the Josef Korbel School of International Studies and Director of the Frederick S. Pardee Center for International Futures, University of Denver. He initiated and leads the development of the International Futures forecasting system and is the Series Editor for the Patterns of Potential Human Progress series.

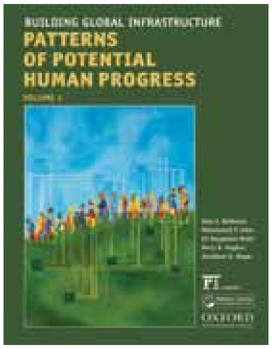
Jonathan D. Moyer is the Associate Director of the Frederick S. Pardee Center for International Futures at the Josef Korbel School of International Studies, University of Denver. His research focus is on operationalizing international relations theory so that it can be measured and modeled.

Patterns of Potential Human Progress









The **Patterns of Potential Human Progress Series** explores prospects for human development—how it appears to be unfolding globally and locally, how we would like it to evolve, and how better to ensure that we move it in desired directions.

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PATTERNS OF POTENTIAL HUMAN PROGRESS

VOLUME 4

BUILDING GLOBAL INFRASTRUCTURE: FORECASTING THE NEXT 50 YEARS

Dale S. Rothman, Mohammod T. Irfan, Eli Margolese-Malin,
Barry B. Hughes, Jonathan D. Moyer

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*—**Harpaul Kohli**, Manager of Information Analytics,
Centennial Group International and the Emerging Markets Forum*

Barry B. Hughes, series editor, is Director of the Frederick S. Pardee Center for International Futures and Professor at the University of Denver's Josef Korbel School of International Studies. He is coauthor of numerous books and founder of the International Futures computer model accessible at www.ifs.du.edu.

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