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Projecting Infrastructure Needs and the Financing Mechanism: A Review of Estimations by ADB, McKinsey, and the OECD

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Abstract: *How much does a country, a region, and the world need to spend on infrastructure development to fulfil demand? This question has been asked frequently because governments try to see it as a reference for budget allocation and evaluation of development progress. Since infrastructure consists of a wide range of types, qualities, and sizes, it is difficult to come up with a number that represents these variants. Several widely cited attempts have been made to provide estimations of infrastructure needs. This paper aims to assess the features, scope, methods, and suggested financing mechanism of the projections made by the Asian Development Bank (2017), the Organisation for Economic Co-operation and Development (2017), and the McKinsey Global Institute (2016). It is not meant to focus on the limitations of these projections, but to understand the process used to put these estimates together and the extent to which they provide comparative information.*

Key words: infrastructure projection, asset forecasting comparison, infrastructure for climate change adaptation, infrastructure financing

JEL Classifications: H, O, R

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1. Introduction

There is a constant question concerning how much in total is needed to develop infrastructure, especially in developing economies. This is related to another question on the mix of financing sources. Governments across the world are worried about widening gaps between infrastructure supply and demand. The quality, accessibility, and adequacy of infrastructure are amongst the most important indicators in constructing world indexes and rankings. Infrastructure is regarded as a major factor influencing a country's investment climate and competitiveness.

Several academic questions are relevant in projecting infrastructure needs. What is the optimal level of infrastructure spending? How much infrastructure for improving the quality of living and quality of life should be provided given limited resources? Does a country need futuristic and high-tech infrastructure? How much can infrastructure deficiency erode potential growth? Will the supply of new infrastructure create additional infrastructure demand? These questions reflect the need for reliable estimates of infrastructure projections together with awareness of the need for non-absolute estimations.

Several widely cited attempts have been made to provide estimations of infrastructure needs. This paper is aimed at assessing the features, scope, methods, and suggested financing mechanism of selected projections. This is not meant to highlight the limitations of the projections but instead to provide an understanding of the process used to put these estimates together and the extent to which they provide comparative information.

The discussed projections are from *Meeting Asia's Infrastructure Needs* by the Asian Development Bank (ADB, 2017); *Investing in Climate*, *Investing in Growth* by the Organisation for Economic Co-operation and Development (OECD, 2017); and *Bridging Global Infrastructure Gaps* by the McKinsey Global Institute (Woetzel et al., 2016). The rest of this paper discusses the common features of the estimates, followed by reviews of each estimate, including the model, data, and methodology, and the suggested financing mechanism. The paper ends with some concluding remarks.

2. Common Features of the Estimates

The three estimates share both commonalities and differences in their scope, period of assessment, methodology, and other features. Table 1 provides a summary of the estimations, which will be discussed further in the subsequent sections.

Table 1. Key Features of Estimations of Infrastructure Needs

Descriptions	ADB	OECD	McKinsey
Coverage	Asia Pacific DMCs	World	World
Period	2016–2030	2016–2030	2016–2030
Climate-change scenario	Limiting the temperature rise below 2°C*	Limiting the temperature rise below 2°C	Not included in own estimate
Methodology	Ordinary least squares	Methodologies explained by the IEA as 'a large-scale technology- and data-rich simulation model, designed to replicate how energy markets function.'	Historical projection, perpetual inventory model, plus some adjustments based on the assumptions.
Data	Historical and projections. Sources: ADB's own estimates (agriculture), WDI World Bank (GDP), United Nations (population)	Energy: IEA (2017) Road and Rail: IEA (2016) Airports and Ports: OECD (2012) Telecoms: McKinsey (2016) Water and sanitation: Booz Allen Hamilton	International Transport Forum data for road, rail, port, and airport spending; IHS Global Insight for GDP projection, power and telecommunications spending; Global Water Intelligence

		(2007), McKinsey (2016), OECD (2006)	for spending on water and sanitation. African Development Bank (2005) for Africa data.
Total Investment (baseline)	$1.503 trillion per year (5.1% of GDP)	$6.3 trillion per year	$3.3 trillion per year (3.8% of GDP)
Total Investment (climate-change adjustment)	US$1.744 trillion per year (5.9% of GDP)	US$6.9 trillion per year	Quoting other resources: additional US$1.1 trillion per year (*World Investment Report 2014: Investing in the SDGs: An Action Plan*, UNCTAD, June 2014)
Sector disaggregation:			
Energy	US$779 billion	US$2.1 trillion	US$1.0 trillion
Transport	US$520 billion	US$2.7 trillion	US$1.3 trillion
ICT	US$152 billion	US$0.9 trillion	US$0.5 trillion
Water & Sanitation	US$52 billion	US$0.9 trillion	US$0.5 trillion

DMCs = developing member countries (45 countries), IEA = International Energy Agency, SDGs = Sustainable Development Goals, UNCTAD = United Nations Conference on Trade and Development, WDI = World Development Indicators.

Source: Compilations from ADB (2017), OECD (2017), and Woetzel et al. (2016).

The studies share some common features:

a. Data reliability: in many developing economies, the data has been lagged, incomplete, and presented or collected in different standards. Data may be taken at different periodic samplings or censuses, and the scope or the formula to obtain the indicators across countries might be different. Data supplied in aggregate numbers need to be decomposed, and this can influence the data quality, especially if the method uses proxies.
b. Methodologies. The methodology is simplified to make it applicable to all countries but at the cost of some important features.

The models used many assumptions and, thus, result in present high uncertainties on projected numbers. However, the reports clearly make readers aware of this limitation.

The data requirements typically involve large numbers of observations sourced from various databases, complemented with efforts for collecting, cleaning, and arranging the data so that they are ready for tests and regressions. The projections usually take the existing infrastructure data as a starting point. This data can be highly variable from country to country in terms of the availability, the period of data provision (monthly, quarterly, annual, biennial, or others), the measured criteria, and classifications. Exchange rate conversion might be challenging for historical data where the average annual exchange rates are not provided by the authority. Hence, uncertainty already occurs from the current estimates, and these estimates are then used for future estimations by using projected figures. Forecasting the independent variables is paramount in the future estimations.

The projected figures are made based on assumptions, especially on gross domestic product (GDP) and population. These numbers are highly uncertain but are viewed as critical. Other uncertain numbers are the investment needs resulting from summing up the sector-based projected needs. The typical assessments are based on a global or regional set of assumptions, such as the depreciation rate, elasticity of infrastructure spending to growth, and the quality of infrastructure, which in fact varies from one country to another. In this case, ADB's estimates have advantages because they are made at the regional level and provide disaggregation of groups with more similar characteristics.

Woetzel et al. (2016) indicated that better management of infrastructure will lower investment needs. But the differences in management quality are not captured in these estimations. The McKinsey Global Institute (MGI, 2013) provides notes to highlight this issue and presents some suggestions to tap the opportunities to save.

It appears that given the above uncertainties, a set of range estimates, perhaps under two to three scenarios, would be more appropriate than the point estimates made in the three studies. For the OECD and the McKinsey studies, even though the coverage is the whole world and the time period for the projections is the same, there is a difference of US$3 trillion in total investment needed. This is quite large, and it underscores the need for range estimates.

3. Reviews of Specific Studies

3.1. Asian Development Bank Model

There are two steps in the estimation. First, a 'top-down' methodology is used to estimate infrastructure needs. This formula is an ordinary least squares (OLS) estimation of the infrastructure stock of each sector. There are 11 types of infrastructure in these estimates, as depicted in the following Table 2.

Table 2. Infrastructure Sectors Covered in the ADB Study

Sector	Infrastructure stock variables
Road	Kilometres of road per 1,000 km^2 of land area
Rail	Kilometres of railroad per 1,000 km^2 of land area
Airport	Number of passengers per 100 population
Ports	TEU per 100 population
Electricity	Kilowatts of installed electricity generation capacity per capita
Telephone	Number of subscriptions per 100 population
Mobile	Number of subscriptions per 100 population
Broadband	Number of subscriptions per 100 population

Water	Percentage of population with access
Sanitation	Percentage of population with access

Note: km^2 = square kilometre; TEU = twenty-foot equivalent unit.
Source: ADB (2017).

The formula for the estimation is:

$$I_{it} = \alpha_0 + \alpha_1 I_{it-1} + \alpha_2 y_{it} + \alpha_3 Agr_{it} + \alpha_4 Ind_{it} + \alpha_5 Urban_{it} + \alpha_6 Popden_{it} + \delta_i + \gamma_t + \epsilon_{it}$$

The independent variables consist of the previous year's infrastructure stock (I_{it-1}), GDP per capita (y_{it}), the shares of the agriculture (Agr_{it}) and industrial sectors (Ind_{it}) to GDP, the urbanisation rate (represented by the share of population in urban areas, $Urban_{it}$), and population density ($Popden_{it}$). All variables are converted into natural logs, and the regression model considers both country- and time-fixed effects. Fixed effects are variables that are constant across individual countries. The model includes both country- and time-fixed effects to allow the model to eliminate bias from unobserved variables that change over time but are constant over countries. It also controls for factors that differ across countries but are constant over time.

After specifying the model, the next step is to forecast the future investment need. This need is defined as the sum of both investments in new infrastructure and the maintenance costs associated with the existing infrastructure stock. The formula for calculating the new investment need in the future is:

$$M_{it} = c\Delta I_{it} = c(I_{it} - I_{it-1})$$

where M is the amount of new investment need in country i at time t, and c is the unit cost for the type of infrastructure. The unit cost is derived from the total project cost in each sector divided by the project output. It then takes the median of the sample as the sector unit cost to eliminate the impact of outliers.

The maintenance cost is calculated as the product of the depreciation rate, the previous year's stock, and the unit cost of each type of infrastructure. The total infrastructure investment need for a country is a sum of the new investment needs and maintenance costs across different sectors and over the forecasting period of 2016–2030.

Further, the estimates show that ceteris paribus, a country's infrastructure stock increases with GDP per capita, but incremental needs decrease with the existing stock. This statement is interesting, since the estimates, as many others, emphasise the impact of infrastructure on economic benefits, represented by GDP per capita. In advanced economies, where major infrastructure is adequate, the marginal demand for infrastructure may decrease because of the mature economies. But this does not show the impact of social infrastructure on maintaining an important socio-economic status (such as education and health), which influences economic productivity. The estimations capture only some social infrastructure (water and sanitation) and, hence, not all infrastructure needs are reflected in this statement.

Another possible missing point here is that the estimates also do not represent the higher quality infrastructure demanded by people in areas with only adequate infrastructure. People with adequate clean water supplies will demand potable water, or in urban areas there will be requests for a more comfortable and faster MRT system. Advanced technology and higher-quality infrastructure may make significant contributions to the economy, as demonstrated by Yoshino and Abidhadjaev (2015) in the case of the Kyushu high-speed rail lines. There are also some research studies indicating the positive impact of information and communications technology (ICT) on the economy (amongst others are Clarke and Wallsten (2006); Deloitte, GSMA, and Cisco (2012); and Qiang, Rosotto, and Kimura (2009)).

Data and Methodology

The period of the data used in the model estimation is from 1970 to 2011. The report explains that 'the model estimates unreasonably high or low infrastructure needs for Southeast Asia, the Kyrgyz Republic, Tajikistan, Bhutan, and Afghanistan.' There is a short description on the possible causes of this anomaly: the Asian financial crisis for low public investment in Southeast Asia, the Soviet Union's interventions in Tajikistan and Kyrgyz Republic, very large hydroelectric power projects in Bhutan, and substantial aid provided to Afghanistan. Since the hypothesis is that these patterns will not be sustained, the estimations then used regional rather than country-specific fixed effects for the countries in the projections. This shows that important adjustments were made to these estimations. However, it is not clear if the adjustments applied to the fixed-effects only or also to other assumptions.

Obtaining data for forecasting is always a challenge because both the independent variables and dependent variable (investment needs) should be forecasted. The data are generated from a forecasting based on formulas or models and use various sets of assumptions that typically have their own caveats. Often the data are projected by other institutions and usually have some scenarios of possibility.

In this estimation, according to the report, the forecasted independent variables are taken from the following sources. i) GDP projections (2016–2030) are based on staff estimates. (ii) For the agricultural share of GDP, using actual data for the latest year (2012) and Briones and Felipe’s (2013) projections for 16 Asian Development Fund countries for 2040, while values for the in-between years (2013–2039) were derived by linear interpolation for these countries. The sub-regional average change rates were applied for countries with no projected data in Briones and Felipe (2013) from 2013 onward. The projected share is held constant when it declines to 5%. (iii) For the industrial share of GDP, data for the most recent year available from the WDI were used across years due to the absence of any projections. (iv) Population projections (medium variant) come from the 2015 Revision of World Population Prospects, United Nations. (v) Urban population shares are derived on the basis of linear interpolation based on five-year projections of the World Urbanization Prospects, 2014 Revision, United Nations.

On the climate-change adaptation model, the model is adjusted to factor in two additional infrastructure-related investments: mitigation and climate proofing. For mitigation, the estimation refers to the model developed by ADB (2017) to estimate additional investments needed in the power sector to limit warming to 2 degrees. The study estimates that additional investments required for the power sector’s carbon mitigation for 2016–2030 amount to US$2,488 billion in 2005 prices and US$2,938 billion in 2015 prices for developing Asia, excluding Central

Asia, equal to 26% of the baseline projection for the power sector. The estimates for each year and subregion are added to the baseline power investments. For Central Asian countries, the estimate equals an additional 26% of their baseline power investments.

To estimate the additional investments for climate proofing, the report refers to an ADB project database (see ADB (2014); United Nations Framework Convention on Climate Change (2007); World Bank (2010)) that provides an estimation of 1.9% of the total baseline investments in the water and sanitation sector. Other estimates applied to the baseline are 7.8% for road, 0.6% for rail, seaports, and airports, and 0.4% for power.

The effort to include climate-change adaptation as another plausible condition in visioning long-term needs merits appreciation. While the figures do not present the actual money needed, as explained by the report, the baseline and climate-change adaptation scenarios could remind the readers that we need to deal with this important issue to achieve sustainable development.

There is no report on the comparative statistics between the forecast errors in the validation period and the forecast errors in the estimation period, hence we cannot check if the numbers are close enough or 'over-fitted.' Over-fitting data could likely happen when a model with a large number of parameters is fitted to a small sample of data.

The depreciation rates used in the estimates are 2% for power, railway, ports, and airports; 3% for roads, water supply, and sanitation; and 8% for telecommunications. These numbers may be the best possible depreciation rates. However, there are large variations in particular situations and contexts. The depreciation rate depends on several factors, such as the quality of infrastructure when it is built, the environment, maintenance efforts, and operational burden. For sectors with rapid changes in technology, such as telecommunications and airports, the depreciation rate might jump in some years. Changes in regulations and market trends also influence the infrastructure life cycle.

The report also briefs the readers that the estimates are not to be read as the forecasted optimal investments needed in the respective countries or regions. Individual countries should carry out assessments on their own specific needs at the national, subnational, and project-based levels. The specificities of each country, including the climate, geographical conditions, and demographic and economic structures, as well as the project's type, objectives, users, and financing structure, will give more concrete figures to support well-planned and better-executed infrastructure projects. Thus, while each country works on its own detailed numbers, ADB's estimates provide a bird's eye view of the infrastructure landscape in the covered regions and countries. This view is not static; there are several applicable scenarios as alternatives, and the paths can also be influenced by regulatory changes. ADB's projections are, thus, indicative, and therefore policy makers and advisors must base their decisions on the specific context in each sector in each decision-making process.

Financing Mechanism

The ADB (2017) report estimates that the financing gap, which is defined as the difference between the estimated infrastructure investment needs and current infrastructure investment and is limited to the period 2016–2020, reaches 2.4% of projected GDP, or 5% if China is excluded (Table 3). The reason for limiting the period of assessment is to get more detailed and accurate data on public investments for infrastructure as well as on the government's planning and financing. A longer period would use more projected data and, hence, increase the uncertainties.

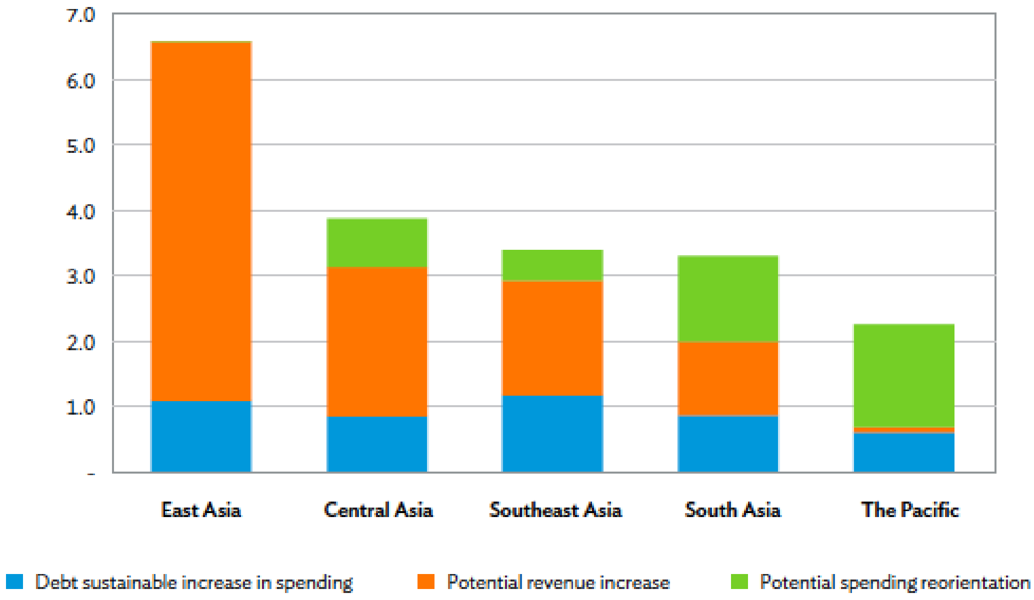
Table 3. Infrastructure Investments and Gaps, Selected Economies and Subregions, 2016–2020 (US$ billion in 2015 prices)

Country or Countries Groups	Estimated Current Investment (2015)	Baseline estimates			Climate-adjusted Estimates		
		Annual Needs	Gap	Gap (% of GDP)	Annual Needs	Gap	Gap (% of GDP)
Total (25)	881 [5.5]	1,211	330	1.7	1,340	459	2.4
Total without China (24)	195 [3.8]	457	262	4.3	503	308	5.0
Selected Low to Lower Middle Income Countries (18)	178 [4.2]	422	244	4.7	465	287	5.6
Without India (17)	60 [2.9]	192	132	5.4	203	43	5.9
Selected Upper Middle Income Countries (17)	703 [6.0]	789	86	0.6	876	172	1.2
Without China (6)	17 [2.0]	35	8	1.8	39	21	2.2
Selected Central Asia Countries (3)	6 [2.9]	11	5	2.3	12	7	3.1
Selected South Asia Countries (7)	134 [4.8]	294	160	4.7	329	195	5.7
Selected Pacific Countries (5)	55 [2.6]	147	92	3.8	157	102	4.1
India	118 [5.4]	230	112	4.1	261	144	5.3
Indonesia	23 [2.6]	70	47	0.7	74	51	5.1
China	686 [6.3]	753	68	0.5	837	151	1.2

GDP = gross domestic product.
Notes: Numbers in parentheses refer to the number of selected countries. Numbers in brackets refer to investment as a percentage of GDP.
The gap as a percentage of GDP is based on the annual average of projected GDP from 2016 to 2020.
Source: ADB (2017).

ADB estimates that the public sector currently provides over 90% of the region’s overall infrastructure investment. The report uses a mainstream approach, as also suggested by the International Monetary Fund (IMF), in three ways: (i) to increase spending for infrastructure by increasing revenues, mainly from taxes, (ii) to revisit the priorities of public spending and reorient towards infrastructure, and (iii) to use additional loans but maintain sustainable public debt. The report also provides the estimated fiscal space of opportunities for the public sector, which is useful for readers, especially policy makers (Figure 1). It is drawn from the most recent IMF country staff reports.

Figure 1. Fiscal Space for Developing Asia (% of GDP)



Note: Fiscal space is defined as the 'room in a government's budget that allows it to provide resources for a desired purpose without jeopardizing the sustainability of its financial position or the stability of the economy' (Heller (2005), as in ADB (2017)).
Source: ADB estimates and IMF (2017) as in ADB (2017).

Apart from an applicable but standard approach, the report also suggests that user fees are a potential source but are underutilised in many developing economies. The types of infrastructure that can generate substantial revenue by applying a right-pricing mechanism are typically piped water, energy, highways, and solid waste management. Another suggestion provided in the report is the utilisation of land-value capture (LVC), especially for projects that are (i) new land developments; (ii) major capital projects, particularly in transportation; and (iii) infrastructure that supports basic services, such as water supply, wastewater treatment, and drainage. These types of project typically have direct effects on raising the value of the surrounding land.

LVC allows governments to charge upfront some of the expected future value of the land appreciation and use the funds to finance the infrastructure. The projected increasing property values resulting from the project development can also be viewed as betterment levies that are monetised into the project's planning. LVC is not applicable to all projects because some projects may have low commercial value. It also depends on external factors, such as the local population growth, economic conditions, and supplies from substituting and complementary facilities. The projection can also become a source of disputes due to different assessments of the assumed variables. However, LVC should merit consideration, particularly for projects with strong factors of growing values.

While the efforts can increase the capacity of public funds to fulfil the demand for infrastructure investment, gaps will still exist, leaving room for private sector contributions. The estimates for future private finance are 2.3% for the baseline estimate and 3.0% for the climate-adjusted estimate. The period of assessment is 2016–2020. The report also provides suggestions to improve the performance of public–private partnerships (PPPs) in attracting private investments. It is centred on enabling regulatory frameworks, institutions, and proper instruments to provide a conducive environment for the private sector to participate in project finance.

3.2. McKinsey Global Institute (MGI): Bridging Global Infrastructure Gaps Model

The estimate of investment need is US$3.3 trillion per year, with a cumulative of US$49 trillion for the period 2016–2030. The model is built to estimate infrastructure investment needs to maintain the average global GDP growth rate of 3.3%. Thus, if global growth increases by one percentage point, the investment estimate would require an additional US$14 trillion. If the growth were one percentage point lower, the figure would be reduced by about US$13 trillion.

The estimate uses the same methodology as in McKinsey's estimation world infrastructure spending for 2013. There is no specific explanation of the model employed in the estimates, but it uses three methods: (i) a historical projection of global investment needs, (ii) the Perpetual Inventory Model (PIM) for investment stock,[1] and (iii) estimates from other institutions for a future needs' projection. The following are short descriptions and results from each method:

(i) For the historical projection, McKinsey looks at data from 84 countries on historical infrastructure spending. The data acquired are from the International Transport Forum, IHS Global Insight, and Global Water Intelligence. The average spending level is about 3.8% of global GDP. This ratio is applied to GDP projections from IHS to estimate a total investment need from 2013 to 2030 of US$63 trillion, or US$3.4 trillion annually.

(ii) For the PIM method, the report explains that it takes investment spending over a number of years, back-casts that information to generate a sufficiently long timeline, and applies a depreciation rate to calculate the value of installed stock.

The European System of Accounts, known as ESA 1995 (Eurostat, 1995), recommends the PIM method for the calculation of the stock of fixed assets whenever direct information is missing. The calculation of the consumption of fixed capital can be based on these stocks of assets. The gross capital stock is calculated as the sum of gross fixed capital formation in previous years, as long as the stock is not expired. The stock will be fully discarded once it reaches the expected service life. In this estimate, MGI applies a 2% depreciation rate in the PIM for investment stock.

The following formula is based on ESA 1995[2]:

$$GCS_t = \sum_{i=0}^{d-1} I_{t-1} \times P_{t-i,t}$$

where

GCS_t = stock of fixed assets (gross) in year *t* in prices of year *t*

I_t = gross fixed capital formation in year t in current prices

P_{t-1} = price index of year *t* with base year *t-1*

d = expected service life

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[1] PIM is a method of inventory management that records real-time transactions of received or sold stock. It is considered more sophisticated than a periodic inventory model, which relies upon an occasional physical count of the inventory to determine the ending inventory balance and the cost of goods sold. PIM requires much more data than the periodic system.

[2] Derived from ESA95. The MGI report does not explicitly explain the model.

Then, the consumption of fixed capital (CFC) is calculated by applying the depreciation rate. There is no explanation about the method used for computing the CFC; either it is a straight-line depreciation applied at the end of the year *t*, or an average of the current year *t* and the previous year, *t-1*. The latter is viewed as better than the former as there is less bias.

The net capital stock (NCS) in any given year is calculated as the gross capital stock minus the accumulated consumption of fixed capital. In formula:

$$NCS_{i=0}^{d-1} = GCS_t - \Sigma CFC$$

McKinsey (2013) uses the PIM to assess the investment stock across asset classes from 12 countries and finds that the value of infrastructure stock in most economies averages around 70% of GDP. This 70% ratio is then used as a reference; for infrastructure to remain at an asset-to-GDP ratio of 70%, US$67 trillion of investment would be required from 2013 through 2030.

(iii) The third method is compiling external estimates from the OECD, International Energy Agency (IEA), and Global Water Intelligence for future estimates. These estimates suggest that the world needs to invest US$57 trillion for the period 2013–2030, or US$3.2 trillion annually, for infrastructure investment. Almost half of this figure is contributed by the roads and power sectors.

Data and Methodology

The application of the PIM requires a long time series of data on gross fixed capital formation. The length of the time series must exceed the expected service life. Because the service lives vary by type of asset and by sector, the analysis requires detailed data on the GCS. This is a challenging task, especially for global accounting, since country-specific conditions, such as national quality standards, climate, and usage loads, are influential but impossible to obtain in detail for each country. Again, MGI applies a 2% depreciation rate for all types of industry globally.

MGI populates the model with data only from countries with at least 15 years of data between 1992 and 2011 (for 2013 estimates) across each asset class, except for water (which are available since 2007 onwards). The sample countries are Brazil, Canada, China, Germany, India, Italy, Japan, Poland, South Africa, Spain, the

United Kingdom, and the United States. The missing data were filled by multiplying the weighted average of a country's spending for that asset class by its GDP as an approximation for what the country had probably spent.

A similar approach is applied in back-casting, with the assumption that a country historically spent the same share of GDP on infrastructure as in the 15–19 years of data that were available. MGI then inflate the historical spending data using construction-sector deflators for each country to obtain real values of infrastructure investment in 2010 currency. There is no explanation in the 2016 report on whether MGI recalculated the whole data projection or updated only the inflation rate to get 2015 constant prices.

For future estimates, the assumptions of GDP growth use GDP data available from IHS Global Insight. There is no explanation on how the model is expanded or extrapolated to the global data given the sample consisting of only 12 countries. In the sample, there is not enough representation from emerging Asia and Pacific economies, except China and India. China and India have some characteristics that do not exist in other Asian developing economies. For climate-change adaptation investment, the Oceania region is unique and demanding because of its vulnerability. Additionally, Indonesia as one of the top-20 economies is persistently growing and at the same time vulnerable to climate change effect, so it can actively influence the below-two-degree scheme.

The MGI report (2013), however, gives a hint on the sector-based data validation, as follows:

a. **Road**. Assumptions: future needs will follow historical spending as a percentage of GDP. The OECD estimates the investment need for the road sector, but it equates to only 40% of the historical spending level. MGI then adjusts the figures by applying the 1% of GDP that countries have historically spent for this purpose to projected GDP growth.

b. **Rail**. MGI uses the OECD estimates (2012) by using the combination of inputs: current stock of rail infrastructure, GDP growth, and recent and anticipated policy changes.

c. **Ports**. MGI refers to the OECD estimates (2012) and uses the United States as a proxy for advanced economies and China and India as proxies for the developing world, and scales them up to global levels.

d. **Airports**. MGI refers to the OECD estimates (2012) for airport investment needs and calculates these estimates using a combination of air traffic growth projections, capital spending surveys, and identification of planned capital projects.

e. **Power**. MGI uses 2011 IEA estimates that employ macroeconomic conditions, population growth, energy prices, government policies, and technology.

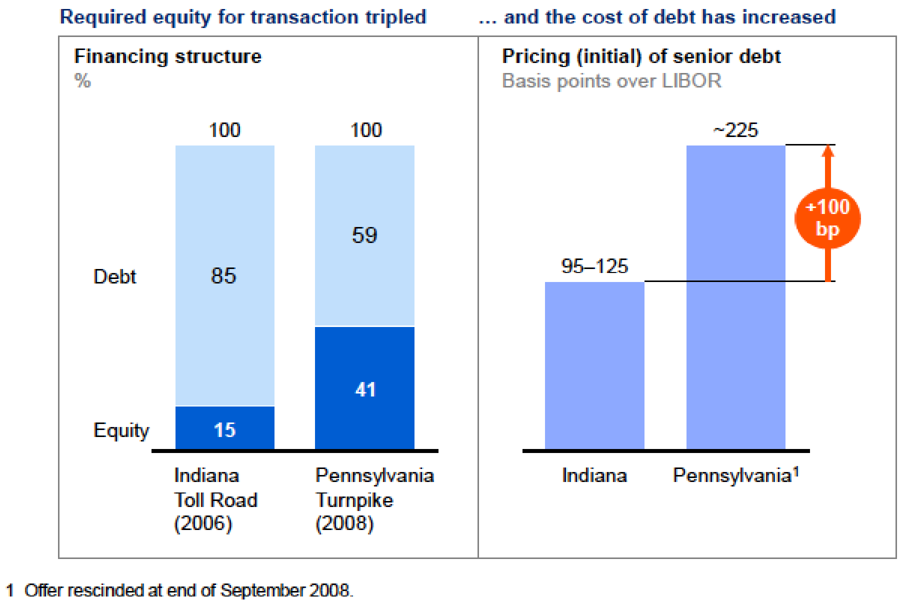
f. **Telecommunications**. MGI uses 2006 OECD estimates on mobile, fixed-line, and broadband infrastructure in OECD countries plus Brazil, China, and India. MGI converts these estimates to a percentage of GDP and uses them for the global projections.

Hence, MGI does not apply a macroeconomic approach as in ADB estimates, even though the methodology includes GDP variables in the estimates. Compared to the OECD's estimates, MGI does not include investments in primary energy supply chain infrastructure or energy demand (OECD, 2017).

Financing Mechanism

The report highlights several important challenges in financing infrastructure. It is noteworthy to mention that these challenges are often put aside by many reports. These four challenges have already made it more challenging to sustain infrastructure investment at the current levels relative to GDP. They are: (i) fiscal pressure that limits direct public investment; (ii) the cost and availability of financing; (iii) a higher proportion of higher-risk projects (i.e., greenfield projects in developing countries) that are in the investment pipeline, discouraging equity-type investment opportunities; and (iv) growing resource-related costs as the demand for construction-related commodities rises faster than their supply. In particular, the challenge of the cost and availability of financing underlines the shifting debt-equity ratio. Figure 2 illustrates the case of the shifting leverage ratio of two similar projects structured only two years apart. The combined effects of a lower leverage ratio and the higher cost of debt will increase the cost of capital for infrastructure in the future. It also adds that ‘over the longer term, today’s historically low interest rates may prove unsustainable’ (MGI, 2013, p.22).

Figure 2. Equity Requirements and the Cost of Capital Have Increased for Many Infrastructure Investments (with Examples from US Road Toll Projects)



Notes: Senior debt is a debt that takes priority over other debts.
Source: *Infrastructure Journal* and Bloomberg Data, computed by McKinsey Global Institute (MGI, 2013).

Another important concern is on (iv) ‘resource constraints’, which examines the effects of huge demand for input goods for infrastructure projects from large economies, such as China and India, that exceed the supply growth. The prices of commodities such as steel are likely to rise by 2030 by between 30% and 80% depending on the commodity (MGI, 2011).

Concerning the current and future financing gaps, the report also recognises the importance of the private sector’s role but not as a panacea. It also adds that ‘if institutional investors were to increase their allocations for infrastructure financing to their target levels, this would result in an additional $2.5 trillion in infrastructure investment capital through 2030; which is sizeable, but still only a fraction of global infrastructure investment needs’ (MGI, 2013, p.4). MGI suggests several funding tools that are typically under-exploited, namely road pricing, property value capture, and capital recycling.

3.3. OECD: Investing in Climate, Investing in Growth Model

The OECD's estimates are sourced from various reports as mentioned in Table 1. The breakdown of the sector estimates is depicted in Table 4 under the baseline and low-carbon scenarios. The low-carbon scenario refers to a 66% probability of limiting the increase in the global average temperature to well below 2°C above pre-industrial levels, hereafter the 66% 2°C scenario. This scenario is more ambitious than the previous target set at a 50% likelihood. The 66% 2°C scenario is an effort to achieve the objectives of the Paris Agreement, which was set out in IEA (2017) based on the report to the German G20 Presidency.

Table 4. OECD Estimates of Global Infrastructure Investment Needs (2015 US$ trillion)

Sectors		Reference case	Low-carbon	Source
Energy supply	Power and Transmission & Distribution	0.7	1.0	IEA (2017)
	Fossil fuel supply chain	1.0	0.6	IEA (2017)
Energy demand		0.4	1.1	IEA (2017)
Transport infrastructure	Road	2.1	2.1	IEA (2016)
	Rail	0.4	0.4	IEA (2016)
	Airports and ports	0.2	0.2	OECD (2012)
Water and sanitation		0.9	0.9	BAH, Woetzel, OECD*
Telecoms		0.6	0.6	Woetzel, OECD*
TOTAL		6.3	6.9	

Note: BAH = Booz Allen Hamilton (2007); Woetzel J. et al. (McKinsey, 2016); OECD (2006).
Source: OECD (2017).

It is difficult to analyse the models since the reports do not provide the technical notes. The explanation on the IEA World Energy Model is that 'it is a large-scale technology- and data-rich simulation model, designed to replicate how energy markets function' (IEA and IRENA, 2017). The report finds that achieving the 66% 2°C scenario is technically feasible but would require an energy transition of exceptional scope, depth, and speed. It includes 'significant policy reforms, aggressive carbon pricing, and additional technological innovation.'

The World Energy Model comprises three modules: final energy consumption, energy transformation, and energy supply. Investment needs are amongst the main outputs from the model. The model covers several end-use sectors, such as industry, transport, and buildings. The IEA reports that transport accounts for 27% of the final energy demand and for almost 40% of direct fossil fuel use in end-use sectors. Since the IEA does not cover airports and ports, the OECD uses its 2012 report for airports and ports. Unfortunately, the model is not explicitly provided.

Estimates for the water and sanitation sector are derived from averaging the estimates provided by Booz Allen Hamilton (2007), Woetzel et al. (2016), and OECD (2006). There is no publicly available document on the model and methodology used by Booz Allen Hamilton for this sector. The estimates in the water and sanitation sector from McKinsey are discussed in Section 2 in this paper.

Data and Methodology

The IEA estimates cover the world, as they are also used as data for the World Energy Outlook. There are various modelling techniques used in the projections. There are also variations based on the regional approach. The models incorporate other models established by well-known institutions, such as from the OECD (on macroeconomic impacts) and the International Institute for Applied Systems Analysis (on future prospects for energy-related air pollutants and the impact on human health) to allow for assessments based on other influential factors.

Financing Mechanism

The OECD suggests innovative approaches to finance consisting of the following recommendations:

a. Encourage PPPs as a means of raising additional financing for infrastructure investment and diversifying business models.
b. Encourage the investment of pension funds and other large institutional investors in infrastructure.
c. Make greater use of user charges for funding infrastructure. They should be designed to signal prices, reflect real costs, and contribute to demand management.
d. Diversify and expand the traditional revenue-raising sources.
e. Explore the funding possibilities offered by land value capture.

Since innovative finance is a relatively new concept, there are differences across countries in their stage of innovation. PPPs are innovative and progressive for countries that have relied on traditional financing, and learning from other countries' experiences will speed up the process and can minimise failures. The OECD also warns on the declining public capital spending shifted to social expenditure because of ageing populations and shrinking labour. In the OECD area, government capital spending fell from 9.5% of GDP in 1990 to approximately 7% of GDP in 2005, while social expenditures rose from 16% of GDP in 1980 to 21% of GDP in 2003. Therefore, spending on public capital will be more constrained in the future.

The above recommendations on financing are accompanied by several policy principles, namely improving the regulatory and institutional framework, strengthening governance and strategic planning, developing and integrating technology, and expanding and improving the toolkit.

In its extended projections towards 2050, the findings provide interesting illustrations on the benefit of avoiding damages from climate change (Table 5). A decisive transition under scenario 50% 2°C will have a 1% net impact on GDP in 2021 and a 2.8% net impact in 2050. Under 66% 2°C, the long-term (2050) benefit will be 2.5% of GDP. If the benefit of avoiding damages from climate change is included, the impact will reach 4.7% and 4.6% under the 50% 2°C and 66% 2°C scenarios, respectively.

Table 5. Net Impacts on GDP (%)

Change in GDP (%)	**50% 2°C**		**66% 2°C**
	2021	**2050**	**2050**
Effect of net investment to decarbonise	0.07	0.7	1.4
Additional fiscal initiative supportive of the transition	0.1	0.9	0.7
Structural reforms & green innovation	1.3	2.1	3.1
Energy prices, stranded assets & regulatory settings	-0.4	-0.9	-2.6
Net effect on GDP	1	2.8	2.5
Net effect on GDP with avoided damages		4.7	4.6

Source: OECD (2017).

4. Conclusion

All estimates provide useful references for reviewing the future infrastructure landscape. The ADB estimates use both a macroeconomic approach and an incremental accounting method for each of the sector estimates. MGI uses PIM with several adjustments, interpolations, and proxies to obtain the missing data and to generate global figures from the selected sampling countries. The OECD also emphasises that the benefits of avoiding climate-change damages can be a significant leverage of growth.

While the scope of the ADB estimates covers only ADB developing member countries in Asia and the Pacific, they are more solid in terms of methodology, data, and validation. MGI, on the other hand, covers global estimates with substantial adjustments, hence increasing the uncertainties. The OECD's estimates taken from the IEA and IRENA are data-rich and have worldwide coverage.

Estimates from ADB and the OECD are also expanded to cover climate-change adaptation and mitigation costs, which MGI does not include. ADB estimates for mitigation policies focus on 'climate proofing' investments in the covered sectors by adding certain percentages from the baseline estimates based on ADB project experience and other recent studies (ADB, 2014; United Nations Framework Convention on Climate Change, 2007; World Bank, 2010). Some sectors are not covered, such as irrigation for food security, disaster risk management, and coastal protection. The OECD provides longer-term projections, towards 2050, which are important for raising awareness that 30 years is not a lengthy span of time to halt climate-change effects. Recent reports suggest that the world has not been fully compliant with the Paris Agreement. Global current emissions increased by 1.7% in 2017 and 2.7% in 2018.[3] The last five years have been the hottest years on record, but if the world acts quickly now, the target of keeping the temperature raise below 2°C can be achieved by 2030.

[3] https://www.nationalgeographic.com/environment/2019/09/climate-change-report-card-co2-emissions/

The important insights come from the MGI report on the part of financing schemes. While ADB addresses the financing gaps through a standard mechanism, which is always relevant and important as well, MGI highlights some aspects of constraints, especially the higher equity demanded, the higher cost of debt, and the resource constraints. This suggests that accelerating productivity growth in the construction industry could substantially contribute to addressing the problems of resource constraints. Additionally, it expects as much as 40% savings from improving project selection and the delivery and management of existing assets. MGI also brings up important but often underestimated financing tools as ways to increase project funding.

Both ADB and the OECD suggest LVC as a possible financing mechanism, which at the moment is barely utilised. This merits consideration as it not only has potential and is feasible but can also be a good trigger for governments to enhance their capacity. Utilising LVC requires the ability to make good impact projections, and, therefore, the chosen projects must have highly beneficial impacts. Choosing a project entails capability in both the investment and procurement decision-making processes. If governments would like to have successful LVC, they need to do it from the very beginning of the infrastructure planning stages.

The OECD offers an interesting view that captures the benefits of avoiding the damages from climate change. If the actions refer to climate change adaptation, then the benefits are also incorporated in the net economic growth estimation. This is a fair scheme, given that the efforts to adjust the plan with climate change scenarios require higher investments. Providing this view offers support for governments to pursue climate change-adjusted infrastructure investment.

All estimates are highly aggregative, and hence they should not be read as the absolute amounts of the optimal level of infrastructure financing but instead as a big picture of the infrastructure landscape that shows that the world continuously needs significant investment in infrastructure and it is not only about finding the money. There are also other important factors in managing the financing mechanism, especially the management of infrastructure projects, the usability of infrastructure facilities, and the re-utilisation of existing idle or under-capacity projects.

The picture is dynamic, and there are interactions amongst the players and active key variables that shape the demand and supply. Additionally, investing in climate-change adaptation and mitigation can sustain the environment and infrastructure facilities, and its benefits will compensate the adaptation-related costs.

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