INVESTING IN INFRASTRUCTURE:
WHAT IS NEEDED FROM 2000 to 2010?

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Abstract

This paper estimates demand for infrastructure services over the first decade of the new millennium, based on a model that relates demand for infrastructure with the structural change and growth in income the world is expected to undergo between now and 2010. Predictions are based on estimated demand rather than on any absolute measure of "need" such as those developed in the Millenium Development Goals. The paper also provides estimates of associated investment and maintenance expenditures, and predicts total required resource flows to satisfy new demand while maintaining service for existing infrastructure.

Introduction

The world is expected to grow at 2.7% per annum in the first decade of the new millennium. Accompanying this growth will be an increase in demand for infrastructure services, for both consumption and production purposes. A failure to respond to this demand will cause bottlenecks to growth and hamper poverty alleviation efforts.

This paper sets out to estimate the change in demand for infrastructure services that will spring from the expected structural change and growth in income the world is expected to undergo in the next 7 years. We use the same macro model that links growth and demand for infrastructure services that was developed in Fay (2000.) To our knowledge, this paper is the only one that systematically tries to estimate infrastructure need across a cross section of countries and across a variety of sectors.[1] We then discuss the implication for investment needs across region and income groups. *The word "need" is used here only to refer to the investment necessary to satisfy consumer and producer demand based on predicted GDP growth. It does not refer to any socially optimal measure of need for infrastructure service or infrastructure investment*.

The infrastructure sectors covered in this paper are roads, railroads, telecommunications, electricity, water and sanitation. For lack of comparable data across countries, we excluded ports, airports, and canals – which represent a small share of overall infrastructure endowments – and oil and gas. Table 1 offers a quick review of access to infrastructure services across low, middle and high income groups, showing how infrastructure stocks or access increases along with income. This however, varies somewhat across different types of infrastructure. For water and sanitation, where access, by definition, is bounded at 100, access to water in high income countries is only 1.3 times what it is in poor countries, and 2.2 times higher for sanitation. In contrast, the ratio for mobile phones, a relatively new technology is 91:1 in favor of rich countries. Note finally, that for most types of infrastructure, the difference in access between poor and rich countries is much less than the difference in income (estimated here at about 63:1.)[2]

Table 1. Access to infrastructure by income group – 2000

	GDP per capita	Electricity Generation (kw per capita)	Telecommunications (per 1000 person) Fixed (lines)	Telecommunications (per 1000 person) Mobile (subscribers)	Road (km/1000 person)	Rail (km/1000 person)	Water (% household connected)	Sanitation (% household connected)
LIC	475	0.11	28	5.8	1.06	0.07	76.26	45.58
MIC	1,919	0.40	127	83.7	1.10	0.13	81.82	61.87
HIC	29,808	2.03	582	526.0	10.54	0.44	99.59	98.07
Ratio HIC to LIC	63	18	21	91	10	6	1.3	2.2

Source: see Annex I.

[1] Many countries, in the course of their investment plans, make this kind of estimates. These may be much more accurate inasmuch as they are based on individual country and sector data, although in many cases they are more "wishlists." Also, there are sector studies that typically tackle one type of infrastructure such as one on energy by Moore and Smith (1990.)

[2] Note that we are not taking into account differences in quality. Thus access to water in high income countries usually means reliable, continuous service, while in many developing countries it may only entail sporadic access to water of unreliable quality.

The world's infrastructure endowments today

Using best practice average prices as discussed later on in this paper, the world's infrastructure stock today can be valued at about US$ 15 trillion (table 2.) Of this total, about 60% is in high income countries, 28% in middle income countries and 13% in low income countries. In contrast, the population shares are 16%, 45%, and 39% respectively.

The composition of infrastructure also changes across income groups. In low income countries, roads tend to dominate, accounting for about 50% of infrastructure stocks, whereas in middle income countries, this share falls to 28% while electricity accounts for close to 50%. In high income countries, electricity and roads amount to about 40% to 45% each of overall infrastructure stocks. Everywhere, roads and electricity represent the bulk of investment accounting for 75 to 85 of total infrastructure value. Water and sanitation drop in relative importance as income increases, while the reverse is true for telecom.

Table 2: The composition of infrastructure stocks, 2000

	Low Income	Middle income	High income	World
Electricity	25.6%	48.1%	40.1%	40.4%
Roads	50.9%	28.1%	44.9%	41.0%
Water & sanitation	14.5%	9.9%	4.7%	7.5%
Rail	7.2%	7.0%	4.1%	5.3%
Telecom (fixed)	1.3%	3.2%	2.4%	2.5%
Telecom (mobile)	0.5%	3.7%	3.8%	3.3%
Total (%)	100.0%	100.0%	100.0%	100.0%
Total ($ billions)	1,968	4,194	8,804	14,966

The composition of infrastructure has also changed quite dramatically over time. Whereas in the 1960s, rail accounted for almost a third of the value of infrastructure stocks, today this share has dropped to a mere 6%. In contrast, electricity's importance has doubled from about 22% to 44% and telecom has tripled, albeit from a very low 2%.

Table 3 How the composition of infrastructure stocks has changed over time, all countries:

	1960	1970	1980	1990	2000	2010
Electricity	22%	32%	40%	43%	44%	42%
Roads	47%	46%	45%	44%	44%	43%
Rail	29%	19%	13%	9%	6%	5%
Telecom	2%	3%	3%	4%	6%	10%
Total	100%	100%	100%	100%	100%	100%

Note: water and sanitation are excluded for lack of historical data.

Projecting demand for new infrastructure

The model developed below is from Fay (2000) and seeks to ask the question of what infrastructure levels will be required in the future, either as consumption goods, or as input into production function.

A model of Infrastructure demand

We develop a model to estimate future demand for infrastructure, where infrastructure services are demanded both as consumption goods by individuals and as inputs into the production process by firms. On the consumption side, the amount of service demanded is a function of income and prices:

$$I_j^c = f(Y_j; q_I)$$

Demand for a particular type of infrastructure service I by individual j is a function of j's income, Y_j, and the price of infrastructure service I, q_I. Aggregating over the population, national per capita demand of infrastructure service for consumption, I^c, will then be given as:

$$1. \quad \frac{I^c}{P} = \frac{1}{P}\sum_j I_j^c = F(\frac{Y}{P}; q_I)$$

where Y/P is income per capita.

On the production side, each individual firm's demand for infrastructure service I will be based on a profit maximization decision which yields the usual first order condition:

$$\frac{\partial Y_i}{\partial I_i^p} = \frac{q_I}{w_i}$$

where Y_i is output of good i by the firm, and w_i is the price of that good.

To go any further, we must adopt a specific functional form for the production function. Assuming a Cobb-Douglas, we can rewrite the first order condition as:

$$K_i^\alpha L_i^\beta \phi I_i^{\phi-1} = \frac{q_I}{w_i}$$

where K is physical capital (excluding infrastructure), L is labor or human capital, and I is the flow of infrastructure services consumed by the individual firm in the production of good i. Solving for I_i yields the derived demand for infrastructure services of firm i:

$$I_i^p = \left[\phi \frac{w_i}{q_I} K_i^\alpha L_i^\beta\right]^{1/(1-\phi)}$$

Aggregating over all firms yields the following:

$$2. \quad I^{p} = \sum_i I_i^p = \sum_i \left[\phi \frac{w_i}{q_I} K_i^{\alpha} L_i^{\beta} \right]^{1/(1-\phi)}$$

The derived demand for any given infrastructure service I^p is the sum of weighted individual firms' demands.

Equation 2 is however of limited usefulness since we do not have firm level data. A reasonable proxy for firms' aggregate demand for infrastructure is given by aggregate output. However, it is unlikely that the elasticity of demand for a particular infrastructure service, ϕ, is the same across sectors of the economy. Thus the weight attributable to a given firm's demand depends on the sectoral composition of the economy. Also, as technology changes, ϕ may change. Finally, the weighted average of the relative price w_i/q_I can be proxied by the real price of the infrastructure good -- q_I/w where w is the price level. The reduced form of equation 2, is then given as:

$$3. \quad I^{p} = F\left(Y, \frac{w}{q_I}, Y_{AG}, Y_{ind}; A \right)$$

where Y is aggregate output, Y_{AG} and Y_{IND} are the share of GDP derived from agriculture and industry, and A is a term representing technology level. Combining equations 1 and 3, and expressing infrastructure demand in per capita terms yields the following for overall production and consumption demand for infrastructure services:

$$4. \quad \frac{I}{P} = F\left(\frac{Y}{P}; \frac{q_I}{w}; Y_{AG}; Y_{IND}; A\right)$$

Note that to the extent that the model assumes a competitive market for infrastructure (prices are assumed to be given for any individual firm) and that it assumes a perfectly elastic supply of infrastructure.

Estimating infrastructure demand empirically

The purpose of this paper is to estimate investment needs in infrastructure. For this the variable of interest is the stock of infrastructure, rather than the flow of services that will be produced from it. To the extent that services are proportional to the physical stock (though intensity of use may vary), equation 4 can easily be understood as demand for physical stocks of infrastructure.

Proxies

Lacking measures of technological change or actual real prices of infrastructure services, we use time dummies and country fixed effects as proxy. The country fixed effect allows each country to have a different intercept, which combined with the time dummy allows us to capture (albeit roughly) the price variable.

Note that our interest is not to establish a causal relationship between infrastructure stocks and various economic variables. Instead, since we want to use this regression for projection, our interest is to obtain the best fit possible and the highest explanatory power. Thus, since infrastructure stocks tend to change reasonably slowly over time and have a long life span, we include lagged value of the dependant variable in the regression in order to increase explanatory power.

We therefore estimate equation 4 as follows:

5. $$I_{i,t}^{j} = \alpha_0 + \alpha_1 I_{i,t-1}^{j} + \alpha_2 y_{i,t} + \alpha_3 A_{i,t} + \alpha_4 M_{i,t} + \alpha_5 D_i + \alpha_6 D_t + \varepsilon_{i,t}$$

where all variables are in natural logs to linearize the model, $I^{j}_{i,t}$ is demand for infrastructure stock of type j in country i at time t; $I^{j}_{i,t-1}$ is the lagged value of the infrastructure stock, y is income per capita; A is share of agriculture value added in GDP; M is the share of manufacturing value added in GDP, D_i is a country fixed effect, D_t is a time dummy; and ε is the error term.[3] Given then that there is no modeling of the supply side, equation (5) can be interpreted as a law of motion for infrastructure stock.

Most infrastructure goods are provided through networks so that the price of the service is often reduced with higher population density. Urbanization, in particular, allows easier and cheaper access to electricity and telephone. Average costs of water and sanitation tend to be actually higher in urban areas, but this is because the standard service offered there is typically much higher. Access is however always much higher in cities, partly because of the higher income of the population, and partly because of public health consideration that make piped water and reasonably sophisticated sanitation services necessary. In the case of roads, roads per capita tend to decrease with higher population density. We therefore also estimated a version of equation (5) that included urbanization and population density to capture the density effect and its impact on demand (both direct and through price.)

Data

The infrastructure variables we use are telephone mainlines (lines per 1000 person), mobile phones (subscribers per 1000 persons), KW of installed electricity generating capacity per capita, km of rail per 1000 person, km of paved road per km2 of land and percentage of households with access to water and sanitation. The only reason for using land rather than population as the deflator for roads is that it yielded a slightly better fit. Annex 1 discusses the variables and their source.

For all but the mobile phone data, our data base is organized as an unbalanced panel with observations every 5 years from 1960 to 2000 and includes all independent low, middle and high income countries with population of more than 500,000 in 2000 for which data was available (113 countries). In the case of mobile phones, this is a more recent

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[3] Manufacturing rather than industry was used here because industry includes mining, which has very different implications on the demand for infrastructure.

technology, that appeared in different countries in different years, starting in the eighties. Thus for mobile, we use an annual data base, of different "length" depending on the country (from a minimum of 1 in Sierra Leone to a maximum of 21 in Finland) For these regressions we added a variable called market maturity equal to the number of years the market has existed in a given country.

Results

Using OLS with fixed effects, we ran both the basic model described by equation 5 and an extended model that included density and urbanization on all 5 infrastructure variables. In all cases, we ran regressions both on a full sample of up to 113 countries and then separately for low and middle income as one group and high income countries as another.[4]

As mentioned, country fixed effects proxy for differences in technology and price across nations. Their use also allow us to obtain consistent parameter estimates. Canning (1998), shows that per capita infrastructure levels are nonstationary, which implies that running the regressions in levels may produce misleading results unless the variable variables used in the regressions are cointegrated. Unfortunately, cointegration would not yield an easy system with which to make predictions, leaving us with two possible solutions. One is to run the regressions on first differences, which Canning shows to be stationary. This would reduce our sample size considerably since we only have up to eight time series observations, and the series are often incomplete. The second possibility – which we use— is to include fixed effects. Kao (1997) shows that in this case parameters estimates are consistent even if the estimated relationship is not a cointegrating one.

A Chow test of structural change allows us to determine whether the estimated relationship is the same for developing countries and the high income sample.[5] With the exception of water, sanitation, and mobile we reject the hypothesis that coefficients are equal across samples and therefore present the results separately for developing and high income countries. For water, sanitation and mobile phones however, we cannot reject the hypothesis that they are equal, and therefore run the regression on the world sample.

For mobile phones and rail, we modified the basic regression structure since including a lagged variable or a time dummy resulted in projections that either went to zero (rail) or exploded into infinity (mobile phones.) In the case of mobile, we also found that the sectoral share of GDP did not add any explanatory power so we dropped it.

Table 4 presents the regressions that were subsequently used for the projections. Country fixed effects are not reported. For all but water, we obtain very high R^2 (0.95 and above) which is our goal given that we want to predict infrastructure values as best as possible.

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[4] When explanatory variables, the variable is set to zero and a dummy variable equal to 1 is included in that regression.

[5] Note that the presence of fixed effects somewhat complicated the estimation of Chow test. The hypothesis tested (H_0) was not in fact whether all coefficients were the same across samples, but only whether the coefficients on the explanatory variables other than the country fixed effects and the time dummies.

In the case of water we manage to explain 60% of cross country and over time variation in coverage.

Table 4. Estimated models for infrastructure predictions

	Electricity Generation Capacity		Telephone Mainlines		Rails		Paved Roads		Water	Sanitation	Mobile
	L&MIC	HIC	L&MIC	HIC	L&MIC	HIC	L&MIC	HIC	ALL	ALL	ALL
Lagged Dependant Variable	0.52	0.68	0.22	0.47			0.02	0.28	0.34		
	(18.84)***	(16.43)***	(8.67)***	(11.13)***			-1.01	(6.38)***	(3.78)***		
GDP per capita	0.18	0.11	0.39	0.36	-0.05	-0.28	0.14	0.23	0.11	0.19	0.64
	(2.79)***	(2.26)**	(7.95)***	(4.88)***	-0.32	(4.23)***	(1.87)*	(2.57)**	(2.79)***	(1.78)*	(10.20)***
Agriculture, share of GDP	-0.04	-0.05	-0.02	0	0.5	-0.04	-0.22	0.03	0.02	0.11	
	(-0.74)	(2.04)**	-0.42	-0.07	(3.35)***	-0.8	(2.89)***	-0.53	-0.43	(1.91)*	
Manufacture, share of GDP	0.08	0.05	0.1	0.19	0.29	0.24	0.28	-0.14	0.02	0.11	
	-1.41	-1.18	(2.16)**	(2.71)***	(1.91)*	(2.51)**	(3.88)***	-1.18	-0.4	-1.35	
Year	0	-0.01	0.04	0.01							
	-0.18	(3.26)***	(9.58)***	(1.90)*							
People per Km Square	0.37	0.33	-0.04	0.41	-1.2	-1.19	0.46	0.37	0.04		
	(2.07)**	(3.28)***	-0.22	(2.96)***	(4.47)***	(11.42)***	(3.34)***	(1.96)*	(3.12)***		
% of people in Urban Areas	0.06	0.42	0.51	0.72	0.39	0.32	1.11	2.48	0.12	0.84	
	-0.6	(4.50)***	(6.21)***	(5.29)***	(1.77)*	(1.68)*	(8.92)***	(7.30)***	(1.92)*	(5.48)***	
Market maturity											2.29
											(56.26)***
Dummy for Income Group	-1.43		-0.2		2.82		0.38		-0.01		
	(1.70)*		-0.27		(1.96)*		-0.72		-0.25		
Constant	4.05	11.56	-74.81	-7.88	-12.29	-4.5	-0.72	-2.05	2.05	3.23	-7.02
	-0.38	(3.59)***	(8.10)***	-1.53	(4.76)***	(4.91)***	-0.82	(2.18)**	(4.23)***	(3.33)***	(14.71)***
N	669	200	642	199	542	186	601	163	242	209	980
R-squared	0.96	0.99	0.97	0.97	0.93	0.99	0.95	0.98	0.58	0.93	0.69
Model Type	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Fixed Effects	Random Effects	Fixed Effects	Random Effects
Sample					Quinquennial						Annual

Absolute value of t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include country fixed effects, which are not reported here for lack of space. Dummies for missing observations in explanatory variables were included but not shown here.

Projections

The World Bank calculates an official set of GDP projections for in its annual Global Economic Prospects. No such projections are available for GDP composition (share in agriculture and in manufacturing) so we took take the simplistic and admittedly not so satisfactory approach of keeping them at 2000 values. For urbanization and population we have UN projections. Thus we have projections for up to 113 countries representing about 90% of world GDP.

Data on access to infrastructure are available for the year 2000 for another 34 other countries. We therefore expand our set of projections by using projected infrastructure growth rates for the region/income group to which an individual country belongs, and applying them to the 2000 actual infrastructure stock. As a result, we have projections for up to 147 countries (water, sanitation and rail have poorer coverage.)

Looking at the results of our projections, it appears that the largest increases in coverage will occur in telecommunications, particularly mobile phones (table 5.) Fixed density is expected to more than double in low income countries and nearly triple in middle income countries. As to mobile density, it is projected to quadruple or quintuple in developing countries. Even high income countries should see a steady growth of 3 or 4% per annum in mobile and fixed lines.

Electricity generating capacity and road density should increase by similar orders of magnitude (2.3 to 2.5% per annum) in MICs. In low income countries, instead, electricity is expected to increase by about 3.2% p.a. while road density should only rise by about 1.4% p.a.. Water and sanitation should increase by about 2 to 2.5% p.a. in LICs and about 1.5% p.a. in MICs. For high income countries, increases are expected to be much smaller, except for roads density.

Table 5: Infrastructure stocks, 2000-2010

		Electricity Generation	Telecommunications Fixed	Mobile	Roads	Rail	Water	Sanitation	Total
LIC	2000	0.50	26	9	1,001	142	139	147	1,968
	2010	0.66	67	47	1,143	146	168	182	2,417
Annual Increase		*3.2%*	*15.9%*	*40.1%*	*1.4%*	*0.3%*	*2.1%*	*2.4%*	*2.3%*
MIC	2000	2,01	134	154	1,177	295	178	239	4,194
	2010	2,53	350	562	1,450	298	204	280	5,673
Annual Increase		*2.5%*	*16.2%*	*26.6%*	*2.3%*	*0.1%*	*1.5%*	*1.7%*	*3.5%*
HIC	2000	3,53	213	337	3,951	364	152	261	8,804
	2010	3,92	290	437	4,587	343	157	271	10,005
Annual Increase		*1.1%*	*3.6%*	*3.0%*	*1.6%*	*-0.6%*	*0.4%*	*0.4%*	*1.4%*

Units: Electricity Generation: kilowatts per hab; Telephone Mainlines: lines per 1000 hab. Paved Road Length lineal km by square km of surface Rail Road Length: km per 1000 hab. Mobile: subscribers per 1000 hab Water; % Households with access Sanitation % Households with access

In the case of rail, we show a quasi stagnation in km of tracks per capita in developing countries. This is not particularly surprising as rail construction has largely stopped in the last 20 years and given the fact that in most countries, privatization of the railroads has brought with it the abandonment of unprofitable lines. In high income countries we also see a small decline – note that this is in per capita terms and need not therefore imply an absolute decline. Overall, the implication for the rail sector is not that no new investment will be taking place, but rather that it is more likely to take the shape of upgrading and rehabilitation rather than of an actual expansion of the network. This is indeed what has been happening in a number of countries (Mexico, Brazil) already.

Implications for investment

From our projections for infrastructure stocks in 2010, we can derive the associated flow of required new investment. To do so we simply look at the predicted increase in stock, and price it using best practice prices taking into account associated network costs. This is important notably in the case of power, where generating capacity is only a share of total infrastructure cost.[6]

Table 6. Unit costs for infrastructure investment

Sector	$	Unit
Electricity	$1,900	per kilowatt of generating capacity, including associated network cost.
Roads	$410,000	per kilometer of two lane paved road
Railway	$900,000	per kilometers or rail, including associated rolling stock
Sanitation	$700	per connected household
Water	$400	per connected household
Mainlines	$400 (from 2000 onward)	per line
Mobile	$700 in 2000 and $580 from 2005 on	per subscriber

Source: Mobile, Pyramid Research, World Bank specialists; Mainlines: Ruzzier, Kennet, Benitez, and Estache (2000). Water, Sanitation, Roads, Electricity : World Bank specialists.

It would be misleading however, to only look at investment needs, in the sense that this seriously underestimates the flow of resources needed to maintain or improve access to services. Thus we also look at maintenance needs. These are calculated, in rough estimates, to be 2% of the replacement cost of the capital stock for electricity generation, rail and road; 3% for water and sanitation, and 8% for mobile and mainline. These numbers are not meant to represent an optimum for maintenance expenditures but are broadly seen as being the minimum annual average expenditure on maintenance, below which the network's functionality will be threatened.

An argument can be made that since many developing countries have substantially underinvested in maintenance, we should also include an estimate for rehabilitation. Unfortunately, the data is simply not available to make such an estimate. Nevertheless, it

[6] Depending on the choice of technology and the population density, the proportion will vary, but a decent rule of thumb could be that 60% of the investment cost is for generation, 30% for distribution, and 10% for transmission.

should be noted that our estimates of overall investment needs are probably lower bound estimates since they do not include rehabilitation needs. On the other hand, they may be appropriate estimates of what will actually be spent, except that the resources that in an ideal world would go to maintenance will more likely continue to be used for rehabilitation.

Table 7. Expected annual investment needs 2005-2010

	New		Maintenance		Total	
	US$Mn	%GDP	US$Mn	%GDP	US$Mn	%GDP
By income group						
Low Income	49,988	3.18%	58,619	3.73%	108,607	6.92%
Middle Income	183,151	2.64%	173,035	2.50%	356,187	5.14%
High income	135,956	0.42%	247,970	0.76%	383,926	1.18%
Developing countries by region						
East Asia & Pacific	99,906	3.67%	78,986	2.90%	178,892	6.57%
South Asia	28,069	3.06%	35,033	3.82%	63,101	6.87%
Europe & Central Asia	39,069	2.76%	58,849	4.16%	97,918	6.92%
Middle East & N. Africa	14,884	2.37%	13,264	2.11%	28,148	4.48%
Sub-Saharan Africa	13,268	2.84%	12,644	2.71%	25,912	5.55%
Latin America & Caribb.	37,944	1.62%	32,878	1.40%	70,822	3.02%
All developing countries	233,139	2.74%	231,654	2.73%	464,793	5.47%
World	369,095	0.90%	479,624	1.17%	848,719	2.07%

GDP deflator used is an average of the 2005-10 projections.

New investment needs are estimated to be approximately US$370 Billion per annum for the period 2005-10, amounting to nearly 1% of worldwide GDP. Another $480 billion (1.2% of global GDP) are needed for maintenance. The total resources needed are therefore approximately 2.1% of GDP, excluding any expenditure on rehabilitation or upgrading. Results for each country are presented in Annex III.[7]

The burden for developing countries is much heavier, however, both because of their greater need for new investments and because of their much smaller resource base. Estimated needed new investment decreases with income – from a high of 3.2% of GDP for low income countries to a low of 0.4% of GDP, with a middle point of 2.6% for middle income countries. Maintenance follows a similar pattern, so that total resources needed are 6.9% in low income countries and 5.1% in middle income countries, for a developing country average of 5.5% of GDP.

Our investment estimates are similar to the results obtained elsewhere. The 1994 World Development Report estimated that developing countries spent on average 4% of GDP on

[7] Note however that we are much more confident about regional or income group averages than we are about individual country results. This type of approach is indeed much better suited to producing aggregate results, which usually are fairly accurate, than it is to producing individual country predictions. Thus, whereas we are reasonably confident on the overall estimates, *we do not recommend relying on individual country level estimates except in a very indicative manner.*

investments in infrastructure. Traditionally, most of this was publicly funded: in the eighties for example, public investment in infrastructure was estimated at 4.3% of GDP in middle income countries (Easterly and Rebelo, 1993). This, most certainly included rehabilitation, upgrading, and probably even some maintenance, given that few government budgets in developing countries make a clear distinction between these three categories.[8]

Within developing countries, there is also substantial regional variation from a low of 3% of GDP in Latin America to a high of 6.9% in South Asia and Eastern Europe.

In terms of sectoral allocation, three sectors (electricity, mobile phones and roads) will absorb four fifth of developing country and worldwide new investment. Electricity generation is likely to absorb about 30% of new and total investments. This number is somewhat higher than Easterly and Rebelo's (1993) finding that developing countries in the 1980s were spending about a quarter of their infrastructure investments on the power sector.[9]

Table 8. Sectoral allocation of investments, new and total

	Developing countries		World	
	New	Total	New	Total
Electricity Generation	32%	30%	30%	30%
Roads	17%	19%	31%	31%
Mobile	32%	27%	23%	20%
Telephone Mainlines	13%	14%	11%	11%
Water and sanitation	6%	8%	4%	6%
Rail	1%	2%	0%	2%
Total (%)	100%	100%	100%	100%
Total (US$ Mn)	233,139	464,793	369,095	848,719

Mobile is expected to be the next most important expenditure item, absorbing another third of new and total investments in developing countries. This implies developing countries would spend about 0.9% of their GDP in new investments in mobile but up to 1.5% if maintenance is included.

Finally, roads are projected to require about 17% of new investment (19% of total investment) in developing countries amounting to 0.5% to 1% of GDP depending on whether maintenance is included. This compares well with the estimates of Ingram and Fay (1994) who calculated that on average developing countries spend about 0.8% of GDP on roads (which certainly does not include full funding for maintenance.) As to

[8] Typically the distinction is made on the basis of the amount of resources needed – if the amount is small, it is included in the current budget; if the amount is large (as for periodic maintenance expenditure) it would be included in the capital budget.

[9] At the time, most of the electricity sector in developing countries was in the public sector, so public investment would have represented the quasi totality of investment in electricity.

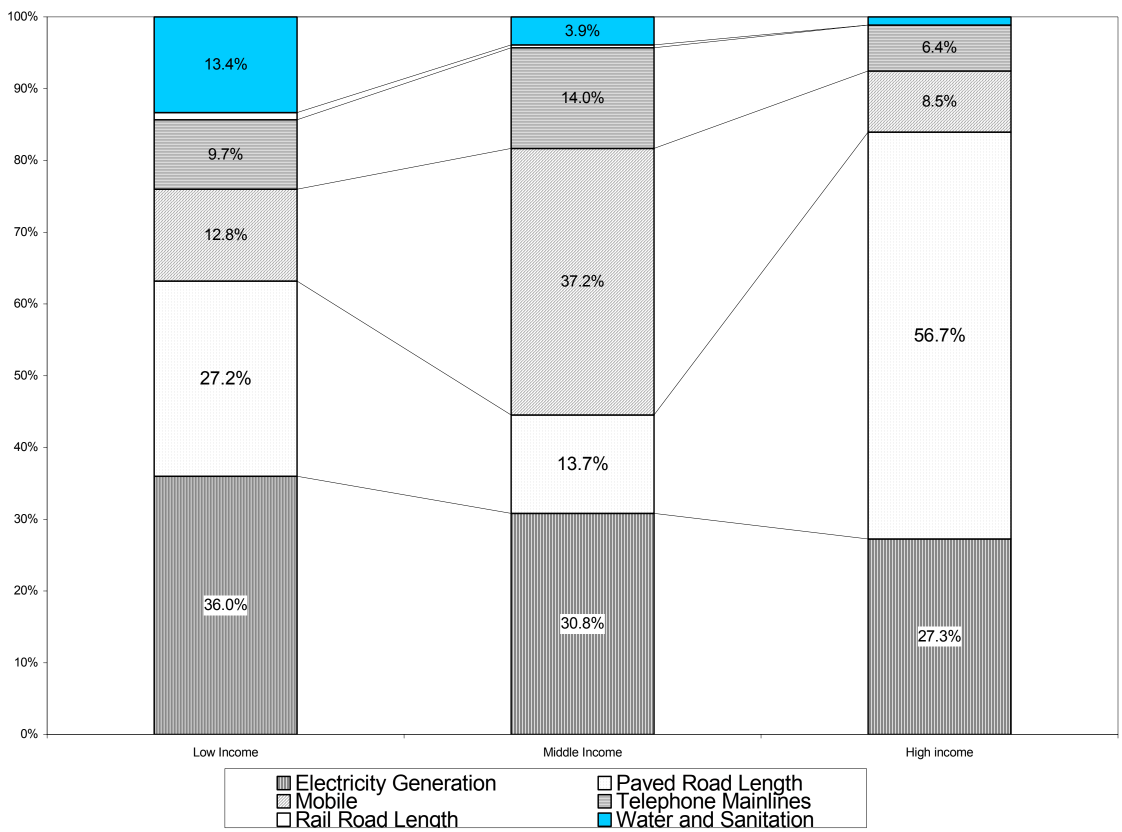
mobile phone, a newcomer in the infrastructure world, is expected to absorb about 32% of developing country new investments.

When including high income countries we see that new investment will be just as concentrated, with power, roads, and mobile absorbing 84% of resources. Mobile, however, will absorb relatively less resources.

Telephone mainline will absorb about 13% of developing countries investment, while water and sanitation together should require about 6%. Including maintenance we expect that water and sanitation should add up to about 2% of GDP. Note that this, as mentioned earlier, is not calculated in relation to some normative goal of water and sanitation coverage. It is however substantially higher than Easterly and Rebelo's (1993) findings that in the 1980s, public investment in water and sanitation in developing countries absorbed about 0.4% of GDP in middle income countries. As to rail, it is expected to absorb very little in new investments but about 2% of GDP in maintenance.

Overall it seems new investment composition is in fact quite different across income groups. We verify that with Figure 1 below which shows expected new investment composition across income groups. The power sector is most important in low income countries where we expect it to require about 36% of all new investments. Mobile dominate in middle income countries accounting for a similar share of new investment. Finally, in high income countries, roads are expected to account for nearly 60% of all new investments.

Figure 1: New investment composition varies across income group



How will this affect overall composition of infrastructure stocks? It will not change dramatically, but continue along the trend established since the 60s of a gradual shift towards telecommunications and power, and away from transport, with road dominating transport more and more.

Figure 2. Changing infrastructure stocks per capita, developing countries 1960-2010

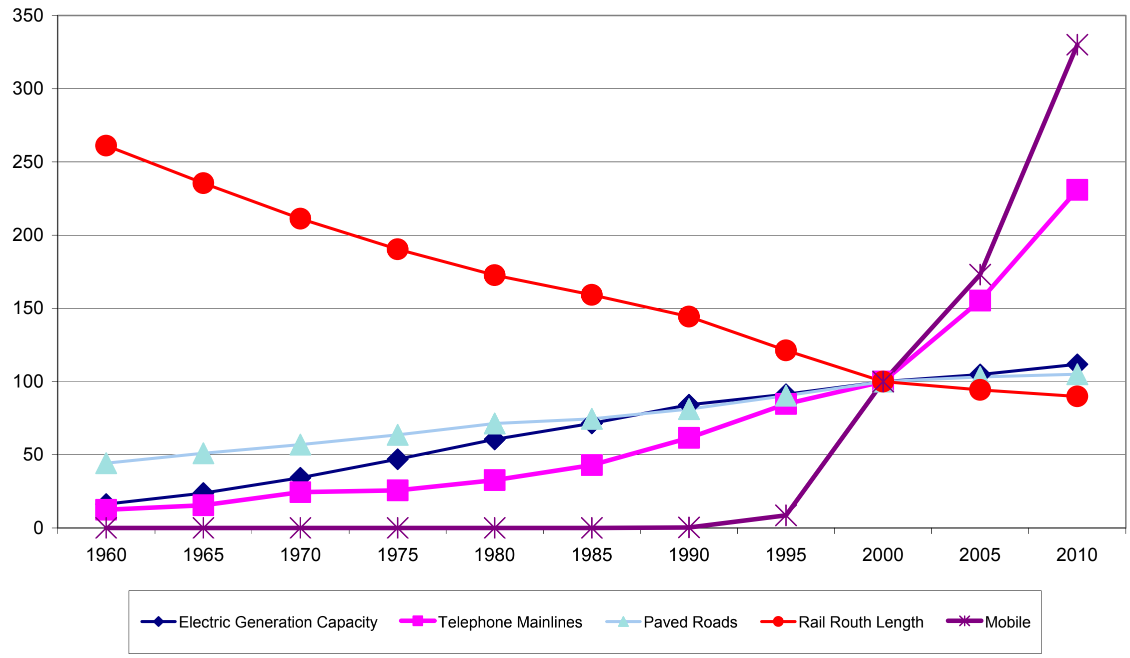


Table 9: The composition of infrastructure stocks in 2010

	Developing countries 2000	Developing countries 2010
Power	41%	39%
Roads	35%	32%
Telephone (fixed)	3%	5%
Telephone (mobile)	3%	8%
Water and Sanitation	11%	10%
Rail	7%	5%
	100%	100%
Total value (US$ Billion)	6,162	8,089

Conclusion

We developed a model to predict future demand for infrastructure, which performs very well in all sectors, even in water and sanitation where poor data usually makes estimation difficult. It should be noted that ours are estimates of *demand*, rather than some absolute measure of "*need*." We also estimate needed resources for maintenance based on what is considered the minimum expenditure necessary to maintain the integrity of a system, and predict total required resource flows to satisfy new demand and maintain service for existing stocks.

Our overall estimates do not include resources that might be needed for rehabilitation (to make up for deferred past maintenance) or for upgrading. As such they are likely to be lower bound estimates. Nevertheless they compare well with other studies estimates, notably with data on public expenditure on infrastructure from the 1980s.

The investments needed should amount to about $ 465 billion per annum or 5.5% of developing countries' GDP over 2005-2010. Most of it will go to the telecommunications sector ($187 billion), followed by the power sector ($138 billion), and roads ($90 billion), including maintenance. Estimates for ports, airports and canals are not available, but since these types of infrastructure represent but a fraction of the total, it is unlikely that including them would change our total estimates.

This study is an interesting, albeit limited, first foray into trying to systematically estimate investment needs. Like many study of its kind, it is surely broadly accurate in the order of magnitude that it projects – notably concerning the inability of private investment to satisfy demand in the near future. This work would however greatly benefit from complementary studies, notably at individual country level.

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Annex I

Data source and description

Telephone, number of main lines; **electricity generating capacity** in millions of watts; **rail track** length, in kilometers; and, **paved roads** length, in kilometers are from Canning (1998) for 1960 to 1995, available at: http://www.worldbank.org/html/dec/Publications/Workpapers/WPS1900series/wps1929/canning1.xls.

Telephone, paved roads, mobile phones (in subscribers per 1000 inhabitants) are from the World Development Indicators (WDI) database of The World Bank (http://www.worldbank.org/data/.)

Rails for 2000 are from International Railways Statistics, available at http://www.uic.asso.fr/d_stats/stats_en.html.

Electricity generating capacity for 2000 are from US Energy Information Administration, available at http://www.eia.doe.gov/neic/historic/hinternational.htm.

Safe water is defined as percentage of population with reasonable access to an adequate amount of safe water, including treated surface water and untreated but uncontaminated water such as from springs, sanitary wells, and protected boreholes. In urban areas this may be a public fountain or standpipe located no more than 200 m from the dwelling. In rural areas, the definition implies that members of the household do not have to spend a disproportionate part of the day fetching water. **Sanitation** is defined as percentage of population with at least adequate excreta disposal facilities that can effectively prevent human, animal and insect contact with excreta. Suitable facilities range from simple but protected pit latrines to flush toilets with sewerage connection. Data are from the WDI database of The World Bank (http://www.worldbank.org/data/.)

GDP and GDP per capita are from the World Development Indicators and are expressed in constant 1995 dollars. Data are from the WDI database of The World Bank (http://www.worldbank.org/data/.)

Agriculture share and **manufacture share** of value added are expressed in percentage are from the WDI database of The World Bank (http://www.worldbank.org/data/.)

Total population and **urban population**, in percentage are from the United Nations Population Projections (http://www.un.org/popin/wdtrends.htm)

Annex II
Expected annual investment needs 2005-2010, $ millions

	Electricity Generation	Telephone Mainlines	Paved Road Length	Rail Road Length	Mobile	Water	Sanitation	Total
New								
East Asia & Pacific	25,005	17,041	12,133	164	41,155	1,799	2,608	99,906
South Asia	11,124	3,233	6,575	126	3,392	1,912	1,707	28,069
Europe & Central Asia	12,643	5,157	9,800	743	9,740	235	750	39,069
Middle East & North Africa	7,307	1,278	3,308	51	1,850	399	691	14,884
Sub-Saharan Africa	3,273	539	4,094	140	3,275	689	1,256	13,268
Latin America & Caribbean	15,034	3,276	2,791	0	15,049	645	1,147	37,944
High income	37,051	8,706	77,056	1	11,595	565	982	135,956
Low Income	17,990	4,835	13,598	491	6,393	2,974	3,706	49,988
Middle Income	56,396	25,690	25,104	733	68,068	2,707	4,454	183,151
Developing Regions	74,386	30,525	38,702	1,225	74,461	5,681	8,160	233,139
WORLD	111,436	39,231	115,758	1,225	86,056	6,246	9,143	369,095
Maintenance								
East Asia & Pacific	18,373	16,838	8,475	1,426	26,070	3,602	4,202	78,986
South Asia	6,986	3,404	15,753	1,372	1,815	3,286	2,417	35,033
Europe & Central Asia	20,333	6,677	16,454	4,035	7,298	1,436	2,616	58,849
Middle East & North Africa	4,625	1,569	3,616	450	1,344	629	1,030	13,264
Sub-Saharan Africa	2,941	653	3,429	873	2,181	949	1,619	12,644
Latin America & Caribbean	10,593	4,175	4,128	733	10,015	1,245	1,989	32,878
High income	78,403	23,181	91,742	6,858	34,934	4,719	8,133	247,970
Low Income	13,293	5,321	22,858	2,918	3,730	5,036	5,462	58,619
Middle Income	50,558	27,995	28,998	5,970	44,994	6,111	8,410	173,035
Developing Regions	63,852	33,315	51,856	8,888	48,724	11,147	13,872	231,654
WORLD	142,254	56,496	143,598	15,746	83,658	15,866	22,005	479,624

Annex II
Expected annual investment needs 2005-2010, as % of GDP

	Electricity Generation	Telephone Mainlines	Paved Road Length	Rail Road Length	Mobile	Water	Sanitation	Total
New								
East Asia & Pacific	0.92%	0.63%	0.45%	0.01%	1.51%	0.07%	0.10%	3.67%
South Asia	1.21%	0.35%	0.72%	0.01%	0.37%	0.21%	0.19%	3.06%
Europe & Central Asia	0.89%	0.36%	0.69%	0.05%	0.69%	0.02%	0.05%	2.76%
Middle East & North Africa	1.16%	0.20%	0.53%	0.01%	0.29%	0.06%	0.11%	2.37%
Sub-Saharan Africa	0.70%	0.12%	0.88%	0.03%	0.70%	0.15%	0.27%	2.84%
Latin America & Caribbean	0.64%	0.14%	0.12%	0.00%	0.64%	0.03%	0.05%	1.62%
High income	0.11%	0.03%	0.24%	0.00%	0.04%	0.00%	0.00%	0.42%
Low Income	1.15%	0.31%	0.87%	0.03%	0.41%	0.19%	0.24%	3.18%
Middle Income	0.81%	0.37%	0.36%	0.01%	0.98%	0.04%	0.06%	2.64%
Developing Regions	0.88%	0.36%	0.46%	0.01%	0.88%	0.07%	0.10%	2.74%
WORLD	0.27%	0.10%	0.28%	0.00%	0.21%	0.02%	0.02%	0.90%
Maintenance								
East Asia & Pacific	0.67%	0.62%	0.31%	0.05%	0.96%	0.13%	0.15%	2.90%
South Asia	0.76%	0.37%	1.72%	0.15%	0.20%	0.36%	0.26%	3.82%
Europe & Central Asia	1.44%	0.47%	1.16%	0.29%	0.52%	0.10%	0.18%	4.16%
Middle East & North Africa	0.74%	0.25%	0.58%	0.07%	0.21%	0.10%	0.16%	2.11%
Sub-Saharan Africa	0.63%	0.14%	0.73%	0.19%	0.47%	0.20%	0.35%	2.71%
Latin America & Caribbean	0.45%	0.18%	0.18%	0.03%	0.43%	0.05%	0.08%	1.40%
High income	0.24%	0.07%	0.28%	0.02%	0.11%	0.01%	0.02%	0.76%
Low Income	0.85%	0.34%	1.46%	0.19%	0.24%	0.32%	0.35%	3.73%
Middle Income	0.73%	0.40%	0.42%	0.09%	0.65%	0.09%	0.12%	2.50%
Developing Regions	0.75%	0.39%	0.61%	0.10%	0.57%	0.13%	0.16%	2.73%
WORLD	0.35%	0.14%	0.35%	0.04%	0.20%	0.04%	0.05%	1.17%