Adaptation options for infrastructure in developing countries

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CONTENTS

1. Introduction 1
2. The scope of this paper 2
3. The deficit in infrastructure 3
4. Overview of current sources of financing (domestic, international, public-private) 4
Introduction 4
Private sector investments 5
Priorities to infrastructure by official development assistance agencies 7
5. Climate change impacts on infrastructure, covering coastal infrastructure, water management and "other non-emitting infrastructure" (roads, bridges, airports) 10
Adaptation options, covering coastal infrastructure, water management and "other non-emitting infrastructure" (roads, bridges, airports) 12
6. Costs of adaptation and how these might differ between the two scenarios 14
Infrastructure adaptation costing 15
Addressing infrastructure deficits 18
7. Assessment of how current financing arrangements need to change to meet the requirements of the adaptation scenario 20

1. Introduction

The importance of adapting infrastructure to climate change impacts is obvious – both in relation to the importance of infrastructure for all economic activities (and any nation's economic success) and in relation to infrastructure's role in protecting people and their assets from the direct and indirect impacts of climate change. The IPCC Fourth Report noted that "climate change can threaten lives, property, environmental quality and future prosperity by increasing the risk of storms, flooding, landslides, heat waves and drought and by overloading water, drainage and energy supply systems" (Wilbanks, Romero et al 2007 page 40); the key role of infrastructure in reducing or removing these threats is obvious.

Experience in high-income nations suggests that it is relatively easy and uncostly to adapt most forms of infrastructure for most locations to the likely impacts of climate change up to 2030 – although increasingly less so with longer term horizons, especially where mitigation is unsuccessful. There are also particular locations at high risk and/or with particularly high-adaptation costs. But the basis for estimating the costs of infrastructure adaptation is not present in developing countries for at least two reasons:
1: There are very large deficits in infrastructure provision in most developing countries – which means that the issue is not only infrastructure adaptation but provision for infrastructure that does not currently exist to standards that make sufficient allowance for the direct and indirect impacts of climate change.
2: There is very little detailed location-specific elaboration of what it would cost to ensure there is climate-resilient infrastructure in place (which includes adapting existing infrastructure and filling infrastructure deficits). Conventional methods for estimating adaptation costs for infrastructure are generally based on the cost of modifying existing climate-sensitive infrastructure – but this cannot produce valid estimates if there are very large deficiencies in infrastructure provision. In addition, since so much adaptation requires local investments rooted in very particular local contexts by local authorities, households and community organizations, estimates for the investments needed for adaptation are impossible without detailed local costings – yet no detailed local costings for adaptation were found in any developing country. In part, this is because of the lack of interest among local governments in developing countries in adaptation. But this is even the case in the (very few) local governments that have considered this issue. As discussed in section 4, even in cities such as Durban

[1] This paper draws on a series of background papers prepared for the Rockefeller Foundation for a discussion it is planning on Building Climate Change Resilience in Urban Areas and the author is grateful to the Rockefeller Foundation for permission to use these in this paper.

which have developed climate change adaptation strategies or cities such as Cape Town where there is discussion of a Municipal Adaptation Plan, there are no costings. It is obviously not possible to cost adaptation to climate-change in any location when there is no robust information on the local direct and indirect impacts of climate change. This explains why there is so little detail in regard to infrastructure adaptation costs in the latest IPCC Working Group II report, the Stern Report and reports on National Adaptation Programmes of Action (which also only cover relatively few nations).

2. The scope of this paper

The terms of reference for this paper requested a consideration of adaptation options for infrastructure in developing countries. The term infrastructure is generally considered to include "the structural elements of an economy that facilitate the flow of goods and services between buyers and sellers"[2] and thus include roads (of all sizes from highways to streets and lanes) and bridges, railways, airports, ports, electric power systems, telecommunications, water, sewerage and drainage/waste water management systems. It may also include pipes to transport or distribute petroleum and gas and solid as well as liquid waste management systems. These may also be considered as 'economic infrastructure' and most may also be considered public works infrastructure, even if private enterprises are involved in their financing and/or construction and/or management. The definition of infrastructure is sometimes broadened to include services which make economic and social activities possible – so it would include services such as public transport, health care, education and emergency services (which collectively are sometimes termed social infrastructure). Broader definitions of infrastructure may even include housing; they may also include the 'institutional infrastructure' needed to operate, manage and invest in the economic and social infrastructure. For instance a National Research Council panel in the United States noted that the term infrastructure should include not only public works facilities but also "the operating procedures, management practices, and development policies that interact together with societal demand and the physical world to facilitate the transport of people and goods, provision of water for drinking and a variety of other uses, safe disposal of society's waste products, provision of energy where it is needed, and transmission of information within and between communities" (National Research Council 1987, page 4). Note should be made that a considerable proportion of what might be considered 'public works infrastructure' in low- and middle-income nations is constructed and managed by private enterprises because of the inadequacies in public provision – for instance for water supply (eg own wells), electricity (own generators), telecommunications and waste disposal.

This paper will limit itself to what is often termed 'economic infrastructure' – but it is still difficult to know where to draw the boundaries. For instance, electricity grids may be unambiguously infrastructure – but are power stations? Water mains are considered infrastructure, as are water treatment plans but what about the services that draw on them (for instance water-vendors) or private or community-managed wells used because of the inadequacies in provision for piped supplies? Roads may be considered infrastructure – but what about public transport? (Railways are generally considered as infrastructure along with the tracks but generally roads are considered infrastructure but not motor vehicles). Ports, airports, roads and bridges are considered as infrastructure – but does the 'infrastructure' include only the physical facilities or the institutions needed to manage them – for instance navigation and traffic control for air and maritime transport? (Ministry of Economic Development 2007).

The comments received on the first draft suggested that this paper should look only at the hard infrastructure and not at the governance systems needed to provide, maintain and manage them. But discussions of infrastructure provision within development have long recognized that this has to include the systems for the expansion, extension, maintenance and management of infrastructure – largely because of the failure of official development assistance to do so and the consequent deterioration or failure of so much infrastructure that they have funded. In addition, it is not possible to consider adaptation to climate change without considering the adaptation capacity of governments; as this paper will stress, all low-income nations and most middle-income nations have very serious deficiencies and inadequacies not only in provision for the hard infrastructure but also in the institutions that should be

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[2] The Macmillan Dictionary of Modern Economics quoted in http://www.med.govt.nz/templates/MultipageDocumentPage____9202.aspx

investing in and managing infrastructure. As important as the lack of funding for infrastructure is the lack of the political or institutional capacity to ensure provision of infrastructure. This actually poses a more serious challenge to adaptation than the availability of funding.

3. The deficit in infrastructure

All low-income nations and most middle-income nations have very large deficiencies in provision for infrastructure. This is perhaps most clearly seen in urban areas – which for most nations contain a much higher proportion of economic activities than the proportion of population they concentrate. For instance, a high proportion of the urban population in Africa and Asia and a significant proportion in Latin America live in homes and settlements with little or no infrastructure – i.e. no all weather roads, no drains, no piped water supplies or sewers and no provision for electricity (Hardoy, Mitlin and Satterthwaite 2001). Most urban centres have no sewers, including many with several million inhabitants. An assessment in 2000 suggested that around 920 million urban dwellers in developing countries live in 'slums', most of which have inadequate or no provision for infrastructure (UN–Habitat 2003). The lack of provision or inadequacies in provision for protective infrastructure is perhaps the main reason for the very rapid increase in the number of flood and windstorm 'disasters' since the 1950s.[3] The number of windstorm disasters increased more than tenfold from 1950 to 2004; the number of flood and related disasters increased more than 20fold in this same period (CRED 2005).

The information base on the quality and extent of most forms of infrastructure in developing countries is very limited – which is surprising, given the importance of infrastructure for economic success. There are data for most nations on the percentage of roads paved; typically high-income nations have virtually all their roads paved while in middle-income nations, half are paved and for low-income nations or the least-developed nations, little more than 10 percent are paved (World Bank 2006a).[4] There are also statistics on the number of telephone mainlines per 1000 persons which show a 70fold difference between high-income nations and the least developed nations (ibid). It may be that with expanding mobile phone networks, these particular statistics have less relevance – but they are indicative of the very large deficit in provision for basic infrastructure, especially in the lower income nations.

Various sources point to the under-funding of infrastructure in relation to GDP. One suggested that infrastructure deficiencies in Latin America during the 1990s reduced long-term growth by 1-2 percentage points, depending on the country (Easterly and Serven 2003). Another suggested that the public sector is spending between 2 to 4 percent of GDP on infrastructure in developing countries; this is 3% lower than the estimates for their investment needs. During the 1990s, government investment in infrastructure dropped in many nations, perhaps because of an expectation of private investment which was not realized (Briceno-Garmendia, Estache and Shafik 2004). A third source suggested that improving infrastructure networks and service delivery requires 7.5-9 percent of GDP for low-income countries for the next five years (Kikeri and Kolo (2005). Meeting these needs would require far more funding that is currently allocated.

This large deficit in infrastructure limits the validity of the conventional means by which many cost estimates are made for infrastructure adaptation. As discussed in more detail later, many cost-estimates are based on some (small) percentage increase in construction investments to allow for higher standards in infrastructure and for refurbishing existing infrastructure. The UK government has suggested that adaptation costs for flood management could lead to a 1-5% increase in current construction costs. But if there are large deficiencies in existing infrastructure – for instance no roads, no drains, no electricity supplies, no coastal defences protecting at-risk settlements – this methodology cannot be used. To stress the obvious, adapting infrastructure needs infrastructure in place to adapt. If adaptation costs for infrastructure include the costs of remedying infrastructure deficits, the total costs increase dramatically. Adaptation needs the infrastructure deficits to be addressed – and integrated into this the needed actions to make these resilient to likely climate change impacts.

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[3] Note that this refers to the number of events that meet official criteria for being classified as a disaster: 10 or more people reported killed; 100 people reported affected; a call for international assistance; and/or declaration of a state of emergency; CRED EM-DAT; see http://www.em-dat.net/.

[4] Some caution is needed in interpreting these statistics in that nations with large areas and low average population densities will generally have lower percentages. For instance, the figure for Canada in 1995 was 35.3%; for Brazil it was 8.9% in this same year.

There is also another more problematic issue; conceiving of the problem of adaptation for infrastructure as primarily one of too little funding (or investment) is to miss the problem of a lack of adaptation capacity. In most nations, the infrastructure deficit has much to do with a lack of capacity and accountability by local governments. For this, increased funding flows are only a partial solution (and in many nations, may not provide any solution). The key issue that needs consideration in relation to climate change adaptation is how to address the widespread failure to develop local government structures and local governance systems that can and do act 'in the public good' to reduce risk (and vulnerability). The policies and actions of many local governments not only do little or nothing to do this but are often key reasons for creating or exacerbating risk. The high risks and extreme vulnerabilities of large sections of the population to extreme weather events should be understood as governance failures or development failures. It is difficult to conceive of a local government that is currently refusing to provide half its population with basic infrastructure and services and undertaking large forced eviction programmes that destroy the homes and neighbourhoods of large sections of the population (so often justified by 'city development') as a government likely to invest in appropriate infrastructure adaptation.

Within discussions on climate change adaptation, there is still a search for figures on the funding needed for adaptation – for instance, how much will it cost to protect coasts from a 50 cm sea-level rise or climate-proof key lifeline infrastructure? But within discussions of development, there has been a move away from this approach of characterizing problems by their costs, in recognition of the many other factors that influence what can be done. There is also the issue that almost all adaptation must be designed, implemented and managed locally yet the international funding system channels most funding to national governments, not local governments.

4. Overview of current sources of financing (domestic, international, public-private)

Introduction

In regard to sources of funding for the forms of infrastructure that are the focus of this paper, most comes from governments (including local governments); most of the rest comes from official bilateral and multilateral development assistance agencies. Private investment is important for some nations and for some forms of infrastructure. The UK Government's Department for International Development (DFID) suggested that during the 1990s, government or public utilities financed 70% of total infrastructure spending from their own resources or from non-concessional loans with overseas development assistance financing less than 5 percent and the private sector 20-25% (DFID 2002). But as discussed in more detail later, most of this private investment is not in the infrastructure that is the focus of this paper. This probably over-states the role of the private sector by counting the funding provided by bilateral agencies or multilateral development banks to privatisation as 'private sector' funding; for instance, this is a confusion common in reporting on funding flows into water and sanitation (Budds and McGranahan 2003). It is also important not to confuse private sector investments and private sector engagement – for instance as private sector firms get management contracts for (for instance) ports or airports which does not imply that they provide any investment.

Perhaps the roles of international agencies and private investments in infrastructure have been exaggerated because there are so little data on government flows. There are no statistics on government funding by sector comparable to those reporting on international donor funding. In most middle-income nations and some low-income nations (including India and China), government funding is likely to be much the most important source of funding for infrastructure, even if there are large deficiencies in its provision, so the proportion of total funding into infrastructure that comes from aid agencies and multilateral development banks is likely to be relatively small. One analysis published in 1990 suggested that total capital investments by sub-national governments in Latin America were 45 times that of World Bank loans (Guarda 1990) even though the World Bank was much the largest source of development assistance for infrastructure within the region during the 1980s and early 1990s (Satterthwaite 1997). This also serves as a reminder of the importance of sub-national government investments – although the extent of the role of local governments in total government spending on infrastructure will vary greatly both within nations and between nations. This can be seen in the statistics on the investment capacity per person per year in different urban centres in developing countries which vary from almost nothing (the case in most urban centres where almost all government funding goes to recurrent costs and sometimes to debt burdens) to several hundred US$ (UNCHS-Habitat 1996, Stren and White 1989). In many nations, state or provincial governments that come between national and 'local' governments also have great importance in total funding flows to infrastructure.

The DFID figures are also misleading in that they give general figures for all low- and middle-income nations and the relative importance of official development assistance (and non-concessional loans) in infrastructure provision varies so much between nations. In many low-income nations, the relative contribution of such external assistance is more significant, but often only because of so little investment by national and local governments. Here, the scale of donor funding for infrastructure in relation to the deficits in infrastructure provision is generally very small. It is worth noting the very large differences between nations in what proportion of central government expenditures are provided by aid – from a few nations where aid flows have been higher than total central government expenditures for some years – to nations such as India and China and most middle-income nations where aid is equivalent to less than 1 percent of central government expenditures (World Bank 2006a).

Private sector investments

Table 1 shows the cumulative private investment commitments in some forms of infrastructure between 1990 and 2002. Perhaps not surprisingly, most is concentrated in forms of infrastructure for which private enterprises can most easily charge all users – for instance in telecommunications and electricity. These are also forms of infrastructure where the costs of reaching customers and of controlling their access are lower. Private sector investments in roads are obviously limited to that generally very small proportion of a nation's network of roads to which access can be controlled and charged for – although such toll-roads may have importance in reducing congestion on some key highways. The main forms of transport infrastructure – airports, ports, roads - get a low priority. So too does water and sanitation (which also generally means a low priority to storm and surface water drainage).

These tables also show how most private infrastructure investment has been in the wealthier regions; Latin America and the Caribbean gets half of all private investments in infrastructure over this period and it is likely that this was concentrated in the wealthier nations in the region. Sub-Saharan Africa gets a very low percentage of all investments, yet this is the region with the largest infrastructure deficits. It is also likely that in all regions, most private sector investment went to the wealthier nations or the nations with the best economic performance.

Table 1: Cumulative private investment commitments in Infrastructure from 1990 to 2002 by U$ billion; (US$ 2002) and by the percentage by forms of infrastructure and by region

Region	Telecom	Elect-ricity	Natural Gas	Airports	Railways	Sea-Ports	Toll-Roads	Water & sanitation	Total
East Asia and Pacific	56.2	68.3	6.8	2.8	10.3	11.2	26.8	17.0	199.4
Europe & Central Asia	68.1	21.1	11.3	1.5	0.3	1.8	2.6	3.5	110.2
Latin America & Caribbean	182.9	100.4	19.5	7.5	18.3	6.9	40.6	21.3	397.4
Middle East and North Africa	10.6	8.4	3.9	0.9	0.2	1.2		1.3	26.5
South Asia	19.7	22.6	0.2	0.2		2.1	0.8	0.2	45.8
Sub-Saharan Africa	18.5	5.0	1.3	0.4	0.3	0.4	2.0	0.2	28.1
TOTAL	355.9	225.7	43.0	13.2	30.3	22.6	72.8	43.6	807.4

Region	Telecom	Elect-ricity	Natural Gas	Airports	Railways	Sea-Ports	Toll-Roads	Water & sanitation	Total
East Asia and Pacific	28.2	34.3	3.4	1.4	5.2	5.6	13.4	8.5	100.0

Europe & Central Asia	61.8	19.1	10.3	1.4	0.3	1.6	2.4	3.2	100.0
Latin America & Caribbean	46.0	25.3	4.9	1.9	4.6	1.7	10.2	5.4	100.0
Middle East and North Africa	40.0	31.7	14.7	3.4	0.8	4.5	0.0	4.9	100.0
South Asia	43.0	49.3	0.4	0.4	0.0	4.6	1.7	0.4	100.0
Sub-Saharan Africa	65.8	17.8	4.6	1.4	1.1	1.4	7.1	0.7	100.0
TOTAL	44.1	28.0	5.3	1.6	3.8	2.8	9.0	5.4	100.0

Region	Telecoms	Elect-ricity	Natural Gas	Airports	Railways	Sea-Ports	Toll-Roads	Water & sanitation	Total
East Asia and Pacific	15.8	30.3	15.8	21.2	34.0	49.6	36.8	39.0	24.7
Europe & Central Asia	19.1	9.3	26.3	11.4	1.0	8.0	3.6	8.0	13.6
Latin America & Caribbean	51.4	44.5	45.3	56.8	60.4	30.5	55.8	48.9	49.2
Middle East and North Africa	3.0	3.7	9.1	6.8	0.7	5.3	0.0	3.0	3.3
South Asia	5.5	10.0	0.5	1.5	0.0	9.3	1.1	0.5	5.7
Sub-Saharan Africa	5.2	2.2	3.0	3.0	1.0	1.8	2.7	0.5	3.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SOURCE: Briceno-Garmendia, Estache, and Shafik 2004.

Data were also available for private sector investments, 1995 to 2005 and for FY2000 and FY 2005. For 1995 to 2007, for the categories in Table 1, telecoms and electricity got much the largest share of investment. Among the other categories, roads were the most favoured

Table 2: Annual private investments in infrastructure (US$ billions)

	Average 1990-2002	Average 1995-2007	FY 2000	FY 2005
Telecommunications	27.4	28.7		
Airports	1.0	3.9	1.8	7.1
Railways	2.3	3.9	1.0	0.2
Sea-ports	1.7	1.4	3.0	4.4
Roads (mostly or all toll-roads?)	5.6	10.0	3.6	4.1
Water and sanitation	3.4	1.6		
Electricity	17.4	39.6		

NB It would be good to try for a table that has annual private investments in each of the above categories and if possible for some others such urban railway/LRT/MRT, bridges and tunnels (which were on one of the tables provided to me) for all years 1990 to 2007 – converted into US$ constant

When reviewing how private investment commitments to infrastructure changed, for the period 1990 to 2003, it peaked at around $128 billion in 1997 and then fell; it was only $48 billion in 2003 (Briceno-Garmendia, Estache, and Shafik 2004).

The data for FY 2000 and 2005 included details of which nations received the investments. For 2000, the investments totalled $9.48 billion for airports, railways, sea-ports and roads with investments in 27 nations; 38% went to toll roads and 31% to seaports. Perhaps not surprisingly, these private sector investment flows were heavily concentrated in the wealthier and more economically successful nations. China received 29.6% of this with Brazil receiving 16.5% and Colombia 8.4%. Very little went to sub-Saharan Africa or to the least developed nations. For 2005, total investments were $15.8 billion – above the average for 1990 to 2002 – and this went to 19 nations. 45% went to airports with 28% to seaports and 26% to toll roads. Again, middle-income nations got most funding; Turkey got 23% of these total investments with Hungary and China both getting 17 percent. India received 9 percent and Mexico 6 percent. Again, very little went to sub-Saharan Africa and to the least developed nations.

Large private investment flows had been expected into water and sanitation, especially with the support given by many international agencies to privatisation and private sector involvement – but generally the international companies that became important in this did not bring major new capital sources to this (Budds and McGranahan 2003).

Some consideration should be given to enterprises who invest in aspects of their own infrastructure where there is no general provision – for instance in their own infrastructure for water supply and waste water treatment or electricity generators. This is known to be important in some nations (Lee 1988) but it is difficult to get a sense of its scale and relative importance. Private sector investments in infrastructure in particular spatial locations serving enterprises (for instance industrial estates and business parks) and middle and upper income groups (for instance gated communities) will have importance in relation to total private investments into infrastructure but with these serving very specific and generally very small sectors of the population and the production system.

Some consideration should also be given to household and community-investments in some forms of infrastructure in some locations. But a large part of this would relate to provision for water and sanitation which is the focus of another paper. There are case studies of community-organizations investing in sewers that also serve as storm drains – for instance, in Pakistan, these have contributed to much improved drainage for hundreds of thousands of low-income households, much of this supported by the Pakistan NGO the Orangi Pilot Project's Research and Training Institute. These certainly have had importance in particular locations for what they provide and the fact that they provide this for low-income groups that are inadequately served or unserved by government infrastructure provision although in total funding flow terms, these are not likely to be large (although they would be significant in terms of their contribution to the housing stock).[5]

Priorities to infrastructure by official development assistance agencies

In regard to development assistance, it has always been difficult to do any detailed comparative analysis of the sectoral priorities of different multilateral and bilateral agencies. In their official reports of their work, each agency uses different categories to report on its sectoral priorities – and often with high levels of aggregation. For instance, they may report on the priority to 'infrastructure' but not on which kinds of infrastructure. One category of funding that has had increased importance from many agencies is 'good governance' and in some agencies, an important part of this is supporting better funded, more competent local governments which could have considerable importance for increasing investment in infrastructure – but these agencies do not report on what proportion of this funding goes to this.

For total official development assistance flows, it is possible to draw on the data that each agency provides to the OECD Development Assistance Committee but here too, many of the categories are so aggregated that any detailed analysis is not possible. An alternative method of monitoring the sectoral priorities of bilateral and multilateral agencies was developed by IIED, working with United Nations Human Settlements Programme (UN Habitat) during the 1980s and first half of the 1990s which was based on a database with details of all projects and project commitments (and other commitments) made by each agency. This was developed to provide the information that UN Habitat was mandated to provide to its governing body on development assistance flows to human settlements.[6] This allowed a far more detailed analysis of sectoral priorities, to the level of detail that UNFCCC is now seeking. For

[5] Individual, household and community investment in housing that is reponsible for building most housing in rural areas and most housing in informal or illegal settlements in urban areas is likely to represents a very considerable proportion of all investments in housing but this is not counted in official construction statistics.
[6] See for instance UNCHS 1996 and UNCHS Habitat 1986, 1988 and 1991.

instance, this could report exactly how much funding was committed to ports or airports or bridges or city-drainage systems in any nation or region and how this varied over time; this database also had spatial locators, so if needed, this could analyze what proportion of each of these investments was in low-elevation coastal zones. For the agencies covered, this database went back to 1970 so analyses of long-run trends were possible. The analyses drawn from this database highlighted how low a priority most development assistance agencies gave to the infrastructure that is the focus of this paper and to building the financial and administrative capacity of local governments (who are or should be responsible for most infrastructure construction and maintenance). For instance, between 1980 and 1993, ports, airports and city-transport received less than 4% of total commitments from concessional financing from the World Bank and the African, Asian and Inter-American Development Bank. The proportion of these agencies' non-concessional loan programmes going to this varied from 2.5 to 7 percent of total commitments (Satterthwaite 1997). In an analysis of the investment priorities of the multilateral development banks and of Japan's official development assistance up to 2000, infrastructure gets a low priority, except from what was then called the Overseas Economic Cooperation Fund of the Japanese Government which was the largest bilateral agency (Hardoy, Mitlin and Satterthwaite 2001). Thus, up the late 1990s, the evidence suggested a declining priority to infrastructure.[7] In part, this was a reaction to an over-concentration on new infrastructure that had failed to ensure provisions for maintaining it (Warner and Laugeri 1991). During the late 1980s and the 1990s, there was a shift in interest from financing infrastructure to increasing local government management capacities in agencies that had major urban programmes (for instance the World Bank and the Inter-American Development Bank). For the last ten years, available data suggests a declining priority to infrastructure from most official development assistance agencies and an increasing priority to budgetary support and to 'good governance' which in theory should support more government capacity to invest in, upgrading and maintain infrastructure. However, there is little evidence of this actually strengthening and supporting local governments (Bigg and Satterthwaite 2005, Crespin 2006).

The OECD Development Assistance Committee provides some information on development assistance flows and priorities to infrastructure. But the categories used in this are to a high level of aggregation – for instance, for economic infrastructure, it reports on the percentage allocations to 'transport and communications', 'energy' and 'other'. This is too aggregated to allow much sense of
1: what priority is given to different kinds of infrastructure
2: what proportion of total infrastructure investment this provides
3: what impact this makes on infrastructure deficiencies

Some infrastructure gets reported under 'social and administrative infrastructure' – for instance 'water supply and sanitation' includes water supply infrastructure (reservoirs, intakes, storage, treatment, pumping stations) and sewers and sewage treatment. One critical aspect of infrastructure in relation to climate change is city storm and surface drainage systems but there is no reporting on funding to this.

'Infrastructure' does not include reporting on provisions to strengthen the investment capacity in infrastructure or more generally to strengthen the government bodies responsible for infrastructure investment and management (this is included within 'government and civil society). There is also no reporting on funding for housing; funding for this gets included in an 'other' category within social and administrative infrastructure.

The OECD data show that most bilateral donors give a low priority to 'economic infrastructure' – for instance for transport and communications and energy. For total bilateral commitments among all OECD nations, these received 10.6 percent of total commitments in 2005 – but much less than this in most bilateral programmes (Japan being the main exception). The European Community's aid programme and the development finance provided by the World Bank and the regional development banks gave economic infrastructure a higher priority – although this still constituted less than a fifth of the EC funding and just over a fifth of the World Bank funding. One reason why Japan is the exception

[7] However, funding for maintaining and expanding this database was never forthcoming, after the late 1990s. Discussions were held with the statistical division of OECD Development Assistance Committee to see if the official data provided to it by bilateral and multilateral agencies could contribute to this – but the form in which member governments present their data to OECD did not allow this.

is that its main aid agency has always seen one of its key roles as improving the economic infrastructure of nations that are or could be its main trading partners.

Table 3 shows the changes in the priorities of all the bilateral programmes 'by major purpose' by comparing 1984/85 to 2004/2005. This shows the decline in the priority to economic infrastructure (for all bilateral agencies from 18.4 to 13.3 percent of commitments). Also the very considerable increase in priority to social and administrative infrastructure (from 26.5 to 33.4 percent) which is likely to reflect increased funding for health and education and 'better governance'; there is no evidence of increased priority to water and sanitation. There are very large declines in the priority to agriculture and to industry and very large increases in the priority to humanitarian aid (from 1.9 to 10 percent) and 'other' (from 17.4 to 34.8 percent). Almost all bilateral donors decreased the priority they gave to economic infrastructure; the only large programme that is an exception is the United States.

In general, most bilateral and multilateral aid agencies have moved away from a focus on economic infrastructure – in part because of the difficulties they had in ensuring that new infrastructure was maintained, in part because of pressures on them from governments in high-income nations to cut their administrative expenses which encouraged 'balance of payments' support or budgetary support (which is far less staff intensive to manage, per dollar provided). Many bilateral agencies now channel a considerable proportion of their funding to 'budgetary support' in the hope that this will increase recipient government buy-in and improve coordination between all the different international funding agencies. Table 3 shows that by 2004/2005, some donors were providing more than half of all their commitments to 'other' – including the UK, Portugal, Italy and Austria – with France, Germany and Spain providing nearly half to this. Most of this is presumably driven by the increased priority to budgetary support and perhaps to funding for Iraq (which received 12.3% of all DAC nations' bilateral commitments in 2004/05). With so much development assistance going to budgetary support, if national governments prioritise economic infrastructure, this will increase donor funding to it, but the official statistics would not show this. Donor support for 'good governance', if effective, might increase the competence and capacity of local governments to invest in, maintain and adapt infrastructure – but most support for 'good governance' is for national government, not for local governments that have much of the responsibility for infrastructure provision and maintenance.

Table 3: changes in priority to infrastructure comparing 1984/85 to 2004/05
(percentage of total commitments)

	Social and administrative infrastructure		Economic infrastructure		**Comments on changed funding priorities when comparing 2004/5 to 1984/5**
	1984-1985	**2004 2005**	**1984-1985**	**2004-2005**	
Australia	31.5	46.0	6.0	4.4	Very large increase in humanitarian aid and 'other'
Austria	35.1	21.4	43.2	0.9	Two thirds of aid in 'other' by 2004/5; humanitarian aid much increased
Belgium	49.2	34.5	13.6	6.8	42% of aid in 'other' by 2004/5; humanitarian aid much increased
Canada	16.1	40.8	25.1	3.8	Large increases in humanitarian aid and 'other'
Denmark	22.4	42.0	21.8	14.8	23% of aid in 'other' by 2004/5
Finland	14.8	38.0	28.6	6.6	27% of aid in 'other' by 2004/5; humanitarian aid much increased
France	47.0	29.4	17.6	8.0	50% of aid in 'other' by 2004/5; humanitarian aid much increased
Germany	31.2	27.0	36.7	15.2	50% of aid in 'other' by 2004/5; humanitarian aid increased
Greece	..	58.8	..	7.3	20% of aid in 'other' by 2004/5
Ireland	29.0	56.9	0.3	2.0	Very large increase in humanitarian aid, reduction in 'other'
Italy	18.3	13.5	23.2	8.8	69% of aid in 'other' by 2004/5
Japan	24.8	21.4	33.9	26.8	39% of aid in 'other' by 2004/5; humanitarian aid much increased
Luxembourg	..	49.2	..	2.7	Very large increase in humanitarian aid and 'other'
Netherlands	28.8	39.6	14.7	11.4	Very large increase in humanitarian aid; less to 'other'
New Zealand	21.9	38.8	30.9	2.0	Very large increase in humanitarian aid and 'other'
Norway	32.4	43.1	25.5	8.2	Very large increase in humanitarian aid and 'other'

Portugal	..	21.7	..	3.4	70% of aid in 'other' by 2004/5
Spain	..	29.6	..	11.7	46% of aid in 'other' by 2004/5
Sweden	17.7	36.2	17.7	6.5	30% in 'other' by 2004/5 (priority not changed) increase in humanitarian aid
Switzerland	20.7	19.6	14.5	7.0	Very large increase in humanitarian aid and 'other'
United Kingdom	24.2	30.0	23.1	4.8	52% of aid in 'other' by 2004/5
United States	18.6	43.6	4.7	13.5	Very large increase in humanitarian aid, priority to 'other' down
TOTAL DAC	**26.5**	**33.4**	**18.4**	**13.3**	

Source: Based on statistics in OECD 2007

5. Climate change impacts on infrastructure, covering coastal infrastructure, water management and "other non-emitting infrastructure" (roads, bridges, airports).

IPPC 2007 noted the following, all with high confidence:
"The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events, especially where rapid urbanization is occurring

Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas. They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies
*Where extreme weather events become more intense and/or more frequent, the economic and social costs of those events will increase, and these increases will be substantial in the areas most directly affected. Climate change impacts spread from directly impacted areas and sectors to other areas and sectors through extensive and complex linkages" (*Adger, Aggarwal, Agrawala et al 2007, page 7)

In regard to coasts, the IPCC states that

"coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas" (Adger, Aggarwal, Agrawala et al 2007 page 6) (very high confidence).

"Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s. Those densely-populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk.

The numbers affected will be largest in the mega-deltas of Asia and Africa while small islands are especially vulnerable" (Adger, Aggarwal, Agrawala et al 2007page 7) (very high confidence)

The infrastructure that is the focus for this paper obviously has the main role in adaptation to most of the direct and indirect impacts of climate change – for instance to increasing risk of storms, flooding, landslides, heat waves and drought and to the possibility of overloading water, drainage and energy supply systems (Wilbanks, Romero Lankao et al 2007).

It is difficult to estimate with any precision how many people are at risk from the increased frequency and intensity of extreme-weather events and the sea-level rise that climate change will bring. A recent analysis of the number and proportion of urban dwellers (and total populations) living in the low-elevation coastal zone showed the high concentration of population there (McGranahan, Balk and Anderson 2007). This zone, the continuous area along the coast that is less than 10 metres above sea level – represents 2 percent of the world's land area but contains 10 percent of its total population (i.e. over 600 million people) and 13 percent of its urban population (representing around 360 million people). This zone also concentrates non-agricultural economic activities and thus also the infrastructure that these draw on - as can be seen by the fact that almost two thirds of the world's large cities with more than 5 million inhabitants fall in this zone, at least partly. Obviously, all major sea-ports are within this zone and most of the largest cities in developing countries are ports. Most major airports are also likely to be within this zone.

Developing countries have a higher proportion of their urban population in this zone than high-income nations – which also implies a higher proportion of economic infrastructure. The least developed nations, on average, have a higher proportion of their total population in this zone than high-income nations; they also have nearly twice the proportion of their urban population in this zone, compared to high-income nations (ibid). Obviously, only a proportion of those within this zone are at risk from the sea-level rises that are likely over the next few decades. Estimates for sea level rise vary from 18 to 59 cm up to the end of the 21st century; these will certainly multiply the number of people flooded by storm surges. One estimate suggested that some 10 million people are currently affected each year by coastal flooding and that the numbers will increase under all the climate change scenarios (Nicholls 2004)

There are also many case-studies of particular cities, highlighting their vulnerability to storm surges and sea-level rise or to windstorms – for instance Alexandria (El-Raey 1997), Cotonou (Dossou, Krystel and Bernadette Glehouenou-Dossou (2007), Dhaka (Alam, Mozaharul and MD. Golam Rabbani (2007), Lagos (Aina 1995, Iwugo, D'Arcy and Andoh 2003; Adeyinka et al 2006), and Banjul (Jallow, Toure, Malang et al 1999). There also appears to be increasing population concentrations in low-elevation coastal zones in most nations (McGranahan, Balk and Anderson 2007). China has a very strong trend towards increasing population concentration in this zone, often supported by government incentives. The coastal provinces experienced a net in-migration of about 17 million people between 1995 and 2000, creating pressures in an already crowded coastal zone (ibid).

Half of Africa's 37 'million cities' are within or have parts within the low-elevation coastal zone. Banjul, Lagos and Alexandria are among the cities most at risk although many others are also likely to face much increased risks from storms and flooding but because of the lack of local analysis, the scale of these risks has yet to be documented.[8]

Many Asian cities are also particularly at risk. Asia has many of the world's largest cities/metropolitan areas that are in the floodplains of major rivers (eg Ganges-Brahmaputra, Mekong and Yangtze) and cyclone prone coastal areas (Bay of Bengal, South China Sea, Japan and Philippines). The IPCC has emphasized how river deltas are among the world's most valuable, heavily populated and vulnerable coastal systems (IPCC 2001). Examples of cities that are very vulnerable to storms and sea-level rise include Mumbai, Dhaka and Shanghai (de Sherbinin, Schiller and Pulsipher 2007). Large sections of these cities are only 1 to 5 metres above sea level. Much of central Mumbai is built on landfill, as the city developed on seven islands with these islands becoming joined into a single land mass over time, as the city expanded. Mumbai is also likely to suffer from more serious storm surges and increased frequency and intensity of extreme weather (cyclones) as a result of climate change. The likely long-term trend of sea-level rise is likely to prove very damaging as this combined with storm surges may make large areas of the city uninhabitable. It is mostly low-income households living in informal or illegal settlements that face the greatest risks from flooding. Cyclone and storm surge could have a devastating impact on other large urban centres in India including Chennai, and the million-cities of Vishakapatnam, Surat, Bharuch, Bhavnagar and Jamnagar (GSDMA/TARU 2005).

[Should this chapter or another chapter discuss the high vulnerability of many water supply abstraction and treatment works which are sited beside rivers and are often the first items of infrastructure to be affected by floods. Electrical switchgear and pump motors are particularly at risk. In severe riverine floods with high flow velocities, pipelines may also be damaged. Also potential damages to sanitation infrastructure.]

IPCC 2007 also pointed to the complex inter-connections between different kinds of infrastructure; for instance as loss of electricity hampers communications and pumps and loss of roads and bridges greatly limits the effectiveness of disaster responses.

Good infrastructure management is also important in relation to the control of certain disease vectors whose range is likely to expand. For instance, good drainage systems are important for limiting the potential breeding grounds for *anopheles* mosquitoes that spread malaria, good provision for water and

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8 http://www.grida.no/climate/ipcc/regional/index.htm; IPCC Special Report on The Regional Impacts of Climate Change An Assessment of Vulnerability

for solid waste removal helps limit the potential breeding grounds for *aedes* mosquitoes that spread dengue and yellow fever and good provision for sanitation helps limit the potential breeding grounds for *culex* mosquitoes that can be vectors for bancroftian filariasis (Cairncross and Feachem 1993). Many disease vectors thrive where there is poor drainage and inadequate provision for rubbish collection, sanitation and piped water supplies (Hardoy, Mitlin and Satterthwaite 2001).

Reviewing data on disasters also gives some indications of the kinds of impacts that extreme weather events can have on infrastructure – within the larger costs in terms of death, injury and economic disruption – and loss of livelihood for large numbers of people. For instance, the floods in Mozambique in 2000 destroyed or damaged roads, bridges and other forms of infrastructure, within the larger impacts with several hundred killed and over three million people displaced. Reviewing the 'disasters' registered on the international database between 1996 and 2005 shows not only thousands of people killed and tens of millions affected by floods and windstorms – but also hundreds of billions of dollars worth of damage. For instance, in Asia, floods and windstorms between 1996 and 2005 caused over 70,000 deaths and around US$ 191 billion worth of economic loss. (A more detailed elaboration on this is possible by region and by nation). The IPCC Working Group II chapter on settlements noted some estimates for the impacts of extreme weather events on nations' GDPs which include a 4-6 percent loss for Mozambique for the flooding in 2000 (Cairncross and Alvarinho, forthcoming) a 3 percent loss for central America from El Nino and a 7 percent loss for Honduras from Hurricane Mitch. These national aggregations can obscure the fact that for specific regions or locales, the impact can be considerably greater – ranging from more than ten percent of gross domestic product and gross capital formation in larger, more developed and diversified impacted regions to more than 50 percent in less developed, less diversified, more natural resource dependent regions (Zapata-Marti 2004).

Adaptation options, covering coastal infrastructure, water management and "other non-emitting infrastructure" (roads, bridges, airports)

The city of Durban has a programme considering future climate impacts and this gives a good indication of the kinds of adaptations that will be needed for infrastructure.[9] This has three phases:

1. Developing an understanding of global and regional climate change science and translating this into an understanding of the implications of climate change for Durban
2. Developing a 'Headline Climate Change Adaptation Strategy' for the city to highlight how key sectors within the municipality should begin responding to unavoidable climate change
3. Incorporating climate change into long-term city planning which includes developing a model that will enable the simulation, evaluation and comparison of strategic urban development plans within the context of climate change. This seeks to develop a greater understanding of the effects of climate change in Durban and allow a model-based assessment of the effectiveness of alternative strategic approaches to mitigation and adaptation.

A report on Climate Change Adaptation Strategy (Hounsome and Iyer 2006) following detailed discussions with municipal line departments, highlighted predicted changes and likely effects 2070-2100. This makes clear the relevance of climate-change issues for virtually all departments and agencies within Durban. Below are some of its findings (with those related to infrastructure emphasised).

Human health: Recognition that the municipal government would have to respond to greater risks of heat-related deaths and illnesses, extreme weather (noting the vulnerability of sewage networks and of informal settlements to flooding); possible increases air quality problems; impacts of changes in precipitation, temperature, humidity, salinity… on quality of water and vector borne diseases. Need to educate public, develop community responses, ensure electricity can cope with peaks, promote more shade, water efficiency… develop extreme climate public early warning system and local knowledge and capacity to act.

Water and sanitation: Adaptation is needed within the context of existing constraints on water supplies and water resources already under threat. Measures identified that need consideration include increasing

[9] This is based on notes and materials provided by Debra Roberts, deputy head of the Environmental Management Department at eThekwini Municipality for the Rockefeller Foundation.

the water absorbing capacity of the urban landscape, making improvements to urban drainage, increasing the height of natural shoreline stabilization measures, utilizing storm water retention/detention ponds and constructed wetlands, adjusting storm sewer design and land use planning and zoning to avoid locating structures/buildings in risky areas.

Coastal zone: Coastal environments, settlements and infrastructure are exposed to a range of marine and land-based hazards such as storms, associated waves and storm surges, river flooding, shoreline erosion and influx of bio hazards eg algal blooms. Possible that that these existing impacts will intensify under climate change. The possible impacts of sea level rise has already been incorporated into the work of the municipality's Coastal, Storm Water and Catchments Management Department, over the last two decades and this is expected to continue. New developments need catchment management plans to ensure excess run off is contained on site. Development set back lines and potential erosion lines have been identified that incorporate 1:50 sea storm and a 50 year sea level rise prediction. Durban's port does not have development setback lines. The municipality is investing in developing the city's coastline in support of tourism. There are various key development areas along the coastline planned for the next 10-20 years which rises in sea level could affect, if not properly taken into account. Natural systems in Durban are capable of adapting to a 20 cm rise (Turpie et al 2002) – but they may need to cope with much more than this.

Key infrastructure at risk: Need for built systems to endure greater exposure to extreme weather events including extreme precipitation and windstorms. Infrastructure design is generally based on past climatic conditions – but these are no longer accurate indicators for planning, maintenance and upgrades. New guidelines are needed for municipal infrastructure to ensure safety and quality of life and reduce long term costs. Electricity supplies should be able to adapt to gradual change but there may be problems from extreme events. For transport, perhaps it is necessary to revise road construction standards and avoid routes at high risk of flooding; also many measures available to reduce emissions within transport.

Disaster risk reduction: Durban has disaster management strategies but these have largely focused on technological disasters (the city is an important industrial centre) and flooding; these have not engaged with the need for extreme weather disaster management strategies or city health emergency response plans for climate change. There is also a need to shift from being responsive to disasters to being pro-active in minimizing hazards, reducing exposure and susceptibility, and enhancing coping and adaptive capacity. This implies more attention to early warning, more resistance in construction, the avoidance of risky sites and attention to accidents in potentially dangerous industries.

Adaptation options for infrastructure in most localities in developing countries would need attention to the issues raised above for Durban. Implementing these depends so much on local governments with the competence and capacity to provide and maintain infrastructure – and to adjust provision and maintenance to higher risks from extreme weather events and from changes in temperatures, precipitation and sea levels. It implies a planning and land-use management framework that steers development away from sites that are particularly at risk. It also implies appropriate frameworks to encourage private sector, household and community investments to take climate-change risks into account. Clearly, Durban is developing these – although the author of the paper from which the example is drawn (who is Deputy Head of the municipality's Environmental Management Department) noted the difficulties in getting the key infrastructure providing agencies engaged in these issues. Even Durban's detailed discussion of adaptation included no costings; these would only be possible when knowledge of the local impacts of climate change were more certain.

Adaptation to sea-level rise can include building coastal defences, realigning coastal defences by relocation landwards, abandoning coastal areas that are difficult or expensive to protect, reducing energy of near shore waves and currents (various measures, including beach nourishment, offshore barriers, energy converters..) and coastal morphological management; it can also include modifying existing exposed settlements and infrastructure (Bosello, Kuik, Tol et al 2007). But costings for all these need detailed local research.

A recent paper presented the justification for the city of Cape Town developing a Municipal Adaptation Plan for climate change and what this should entail (Mukheibir and Ziervogel 2007) but this had no costings for infrastructure adaptation; like the study in Durban, it emphasized the need for a much stronger local knowledge base before such costings could be developed. This was also emphasized in a community-based adaptation plan developed in Cavite City in the Philippines – which has faced many problems from tropical cyclones, drought and sea-level rises. Some 10% of the population is vulnerable to sea-level rise, but a one metre increase would put around two thirds of the population at risk. This community based adaptation plan has identified which socio-economic groups have homes or livelihoods at risk. It notes how various government planned adaptation strategies (relief assistance, resettlement, shoreline protection measures, etc.) have reduced the vulnerability of coastal households, but the measures are inadequate and costly (US$ 2.15 million per kilometre of shoreline protection structures, and US$ 4.2 million for drainage systems). Perhaps the most interesting point of this adaptation plan is its focus on needed institutional reforms and on building the local knowledge base (Faustino 2007).

From a temporal perspective, adaptation to climate risks can be viewed at three levels, including responses to current variability (which reflect learning from past adaptations to historical climates), observed medium and long-term trends in climate; and anticipatory planning in response to model-based scenarios of long-term climate change. The responses across the three levels are often intertwined, and might form a continuum (Adger, Agrawala, Mirza et al 2007). The fact that there is little or no locally-relevant information on climate variability and trends is obviously a huge constraint on planning for adaptation (and costing this).

6. Costs of adaptation and how these might differ between the two scenarios

"Only a few credible estimates are now available of the costs of adaptation in developing countries, and these are highly speculative. In a world of rapid climate change, it is increasingly difficult to extrapolate future impacts from past patterns, so historical records are no longer reliable guides. Furthermore, the discussion above has shown that conceptually this is a difficult calculation to solve: adaptation is so broad and cross-cutting – affecting economic, social and environmental conditions and vice versa – that it is difficult to attribute costs clearly and separately from those of general development finance. Adaptation should be undertaken at many levels at the same time, including at the household/community level and many of these initiatives will be self-funded" (Stern 2007, page 501-502)

The difference between a Business as Usual (BAU) and a mitigation climate change scenario in relation to infrastructure is best understood in terms of:
1: the differences in the risks they pose to lives, property, environmental quality and future prosperity by increasing the risk of storms, flooding, landslides, heat waves and drought and by overloading water, drainage and energy supply systems
2: the resulting difference in infrastructure requirements to protect against these risks (and the difference in costs) and differences in other costs (i.e. those that increased investment in infrastructure cannot protect against).

Table 4 draws on the categories in IPCC Working Group II's chapter on industry, settlements and society on climate-driven phenomena and includes comments on differences between the two scenarios and differences in costs.

Table 4: Differences between the BAU and the mitigation scenarios in infrastructure adaptation

Climate-driven phenomena	**Difference between the two scenarios**	**Comments on costings**
Changes in extreme		
Tropical cyclones, storm surges	A rapidly growing problem in both scenarios (see the very rapid rise in the number of disasters linked to these 1950-2004, most of which are due to inadequate or no infrastructure) but the BAU scenario likely to significantly increase the risks from these compared to the mitigation scenario and to expand the areas at risk	BAU scenario requires higher public investment and institutional capacity, including that in disaster preparedness and

Extreme rainfall, riverine floods	A very rapidly growing problem in both scenarios (see the twentyfold increase in the number of flood disasters by year, 1950-2004, most of which is due to inadequate or no infrastructure); BAU scenario likely to significantly increase their frequency and/or intensity in many locations compared to mitigation scenario?	emergency response but no costings available. With BAU, the gap between infrastructure adaptation costings and range of property and settlements that infrastructure cannot protect likely to grow exponentially if beyond 2030 is considered
Heat waves	Likely increase in heat waves of sufficient intensity and duration to cause serious health problems under both scenarios, especially for heat islands in cities; BAU scenario likely to significantly increase their frequency and/or intensity in many locations	
Changes in means		
Temperature	In most developing country locations, rising average temperatures which will bring increasing health costs and need for infrastructure-adaptation to deal with higher extreme temperatures and changing demands (for instance for water, electricity for air conditioning…..)	BAU scenario requires higher public investment and institutional capacity
Precipitation	Less precipitation in many locations, increasing need for infrastructure for increased water supplies; this often comes on top of poor water management and often adding to water stress that is already present. BAU increasing the speed and scale of needed investment and improvements in management	
Saline intrusion	In many low-lying coastal areas (where many major cities are located), this is already a problem because of over-use of groundwater. BAU increasing the need for better aquifer management and usually for developing alternative supplies.	
Sea level rise	Up to 2030, very little difference between the two scenarios – but in the longer term, likely to be a rapidly expanding difference in the scale of risks from sea level rise and in the infrastructure needed for adaptation (and in the extent to which infrastructure adaptation is able to protect people and places)	Taking a longer time perspective, BAU scenario's much greater risk levels up to 2100 and beyond implies need for much more progress by 2030 in building adaptive capacity – even if this is primarily to manage risks that come in later decades.

Up to 2030, projections suggest little difference between the two scenarios in the scale of mean sea-level rise (Nicholls 2007). So this could be taken to imply little difference in the funding needed for adapting infrastructure between them. But there is a very large difference between the two scenarios in terms of the likely impacts from sea-level rise in the decades beyond 2030 – and thus for nations with significant proportions of their population and economy (and thus infrastructure) in low-elevation coastal zones, there is a pressing need to build adaptive capacity to sea level rise between now and 2030 and to consider what changes are needed in the spatial locations of new investments. This also includes factoring in sea-level rise to current decisions and investments in infrastructure, given the long life of so much infrastructure (see Nicholls 2007). In virtually all low-income nations and many middle-income nations, it is likely to take several decades to build adaptive capacity within national and local governments – and even this may be impossible politically in fragile or failed states. Given the much larger sea-level rises likely under the BAU scenario by 2100, this scenario will require a much higher quality provision for climate-resilient infrastructure by 2030 and much greater capacity in the quality of the institutions responsible for planning, financing and managing these in 2030 to form the basis of adaptation beyond 2030.

Infrastructure adaptation costing

If we consider what is needed to infrastructure adaptation for climate change, there are really four components:

1: The cost of adapting (or if needed replacing) existing infrastructure

2: The cost of building infrastructure that is needed but not yet constructed, whether or not there is climate change
3: The additional costs of climate-proofing new infrastructure investments made in 2.
4: The cost of building the institutional/governance capacity to organize the tasks listed in 1-3.

The cost of 2 is the same for both scenarios; the cost of 4 is likely to be similar for the two scenarios, although the BAU scenario will need this capacity built more rapidly. At a risk of over-repetition, there are many nations where the political and economic circumstances make item 4 very difficult or even impossible to envisage – yet 1 to 3 depend on this being possible. Obviously the costs of 1 and 3 and the extent to which infrastructure adaptation can protect the infrastructure (or what the infrastructure is meant to protect) against climate-change related risks varies considerably between the two scenarios.

The review of literature to date found so little data on the costs of infrastructure adaptation in developing countries that it is not possible to discuss differences in adaptation costs in relation to different climate-change scenarios. In addition, the cost-estimates for remedying infrastructure-deficits and deficiencies independent of climate change (i.e. item 2) run into hundreds of billions of dollars over the next ten to fifteen years. Investments to limit the impact of extreme weather events independent of climate change – and so prevent tens of thousands of deaths, tens of millions of people affected and hundreds of billions of dollars of economic damage over the next ten years – would also require tens of billions of dollars.

The Stern report noted that even in high-income nations, only a handful of governments are moving towards implementing adaptation initiatives (Stern 2007). A partial review of what governments in low- and middle-income nations are doing on adaptation produced the following tentative conclusions:

- Many governments are initiating or sponsoring studies of the likely impacts of climate change but most are made by natural scientists who lack knowledge, capacity and often interest in engaging with impacts on infrastructure
- There is an urgent need for local studies because of how much local context shapes vulnerabilities and who is vulnerable and adaptation possibilities. The absence of a strong information base on what local changes climate change is likely to bring inhibits this (Satterthwaite, Huq, Pelling et al 2007).

Reviews on India, Chile and Argentina show that central government is beginning to consider adaptation but the big players in national and local governments are not engaged or interested. The Durban case study summarized above is interesting for showing the importance of a locally generated study of 'impacts' rooted in local contexts and possibilities for getting the attention of city governments; also the extent to which recent storm-damage in Durban helped sensitise local politicians/civil servants.[10]

Some studies suggest that the cost of adaptation to climate change at least in the next few decades is not very great in relation to nations' GDP but these are mostly from wealthy nations – where the infrastructure, services and good quality building stock 'to adapt' is in place and much greater investment and management capacities among local governments. For developing countries, if the cost of removing the backlog on basic infrastructure provision and in strengthening deficient buildings that will be needed for adaptation could be factored in, the costs would increase dramatically.

In regard to protection against sea-level rise, cost-estimates vary greatly from location to location. But many estimates have been made suggesting that coastal protection is able to reduce substantially the threat imposed by sea level rise at a relatively low cost (for a 1 metre sea level rise – and thus far beyond the sea-level rise likely by 2030). Studies showing that coastal adaptation could reduce the number of people at risk from flooding (i.e. the number of people living in risk areas times the probability of flooding) by almost 90 percent at an annual cost of around 0.06% of GDP. The IPCC's Fourth Assessment Report examined adaptation costs but was unable to come to an aggregate figure for costs of adaptation globally. The costs for coastal protection have been estimated at over US$ 1000 billion against a 1 metre sea level rise (IPCC, 2007; Tol 2002). But this estimate is acknowledged to be at best an informed guess.

[10] Debra Roberts, personal communication

There are some estimates for low- and middle-income nations – for instance one study suggested that the cost of coastal protection for a 1m sea level rise between 1990 and 2100 would range from a minimum of 0.01% of GDP per year in Latin America to a maximum of 0.2 percent of GDP per year for China and 0.25 for India (Deke, Hooss, Kasten et al 2001, page 54). Direct protection costs against a 0.13 m sea level rise are much smaller – 0.001% in Latin America to 0.035% in India (ibid). Other studies suggest "high levels of coastal protection" are possible (for instance more than 70 percent of the threatened coast) but the usefulness of such calculations might be in doubt if the 30 percent of the coast that is not easily protected included most of the major cities.

Another study looking at the direct cost of coastal protection – the cost of protection, of fixed capital lost and land lost – suggested that in a scenario of optimal protection against a sea-level rise of 50 cm by 2100 would represent 0.1 percent of total expenditures in 1990 for East Asia, 0.07 percent for South East Asia and 0.05 percent in 'the rest of the world' (Darwin and Tol 2001). However, some other studies suggest that the cost of protecting coastal settlements in low and middle income nations most at risk from sea level rise would be very high. For instance, one estimate suggested that protecting the populated coastline of Tanzania against a 1 metre sea level rise would cost US$12.7 billion (Smith and Lazo 2001) – and clearly this is far beyond any possible funding that Tanzania might receive. An analysis of benefit-cost ratios in terms of monetized avoided damage:cost of the intervention for sea level rises of 0.3, 0.5 and 1 metre was between 2.6 and 42.9 for protecting the coastlines of Poland and Uruguay and the Zhujian Delta in China (Smith and Lazo 2001). But for Venezuela, for full protection, for a 0.5 metre sea level rise, it was only 0.02. For Tallin and Parnu in Estonia, it was 0.9 and 2.3 for a 1 metre sea level rise (ibid).

Economic analyses may suggest that cities such as Dar-es-Salaam (or perhaps Alexandria in Egypt or Abidjan in Cote D'Ivoire) are not viable because of being on the coast and being very vulnerable to flooding/sea level rise where the investments needed to protect them from floods/storm surges that are likely in the next 50 years are beyond the likely investment capacity. But these cities are so central to the current and future development prospects of these nations and to the well-being of large sections of their population; they also contain most of the asset bases for large sections of the population. In addition, what appears as a relatively small cost in relation to a continent's GDP can hide very large adaptation costs for particular cities (Wilbanks, Romero-Lankao et al 2007).

Papers discussing the costs of adaptation can recommend that these should include not only the direct costs of implementing the adaptation but also the costs of enhancing adaptive capacity (for instance the managerial capacity and of services that need a greater capacity) and the transition costs (Bosello, Kuik, Tol and Watiss 2007). This is correct – but the difficulty is that in many nations, the political possibilities of this happening are very limited; this is not just an issue of 'costs'.

Two sources give rather general cost-estimates for adaptation for buildings and infrastructure. The first comes from high-income nations. The additional costs of making new infrastructure and buildings more resilient to climate change in OECD countries could range between $15 -$150 billion each year (.05-.5% of GDP) with higher costs possible with the prospect of higher temperatures in the future; this assumes that additional costs of 1-10% of the total amount invested in construction each year are required to make new buildings and infrastructure more resilient to climate change (Stern 2007). But this is not a methodology that can be applied in most low- and middle-income nations. To arrive at such an estimate, there is a need to know the total investments in construction. There is very little data on this in low- and middle-income nations. Even the estimates that exist are likely to be misleading for two reasons: first, there are the (often very large) deficiencies and backlogs in infrastructure investments and deficiencies in the building stock; how can an estimate be arrived at for 'adaptation' for all the infrastructure that does not exist. Secondly, official construction investment statistics rarely consider the investments made by households and community organizations, even when (as is often the case) these are responsible for most new housing and most housing improvement.

The second source for general cost estimates comes from the World Bank which has estimated the added costs for adaptation to climate change needed for aid flows ($1-4 billion a year), foreign direct investment ($1-4 billion a year) and for gross domestic investment ($2-30 billion a year). This means total adaptation finance per year of $4-37 billion (World Bank 2006b).[11] This only includes the cost of adapting new investments to protect them from climate change risks and there will be major impacts that will occur even with adaptation (Stern 2007). This also takes no account of the cost of providing infrastructure to the locations that have very deficient or no infrastructure. It also does not include reducing exposure to current climate change risks. Since this is only the cost to governments, donors and foreign investors of climate-proofing their new planned programmes and investments, it represents a fraction of the needed measures.

There are some estimates for the adaptation costs for certain cities in high-income nations. These are worth reviewing because they suggest that cost-estimates based on 'real adaptation plans' for particular cities and localities are going to produce very different estimates for adaptation costs than from the OECD and World Bank estimates.

New Orleans: in the early stages of rebuilding, state officials suggested that the cost of providing the city with protection from a category 5 hurricane was about $32 billion (Hallegatte 2006).
For **London**, the increased cost of maintaining flood defences over 100 years because of climate change was estimated at $3-6 billion to £3 billion (Environment Agency 2005).
Venice: A $2.6 billion scheme to protect the city from rising tides is being implemented but the current design is only able to cope with around 20 cm more of sea level rise (Nosengo 2003).

These three cities have basic infrastructure in place serving all households and businesses and a building stock subject to regulations on safety. If the adaptation costs for urban centres in low- and middle-income nations needs to include the costs of remedying their infrastructure deficiencies – for instance in water supply and sanitation systems, all weather roads and storm and surface drains – the costs are likely to be far higher than those implied by the World Bank. Two case studies of particular cities do give some idea of adaptation costs:

- Massawa (Mits'iwa) is the main port in Eritrea with a population of around 23,000 in 2002. It is vulnerable to a 0.5-1 metre sea level rise since most parts are of the city are less than 1 metre above sea level. A 0.5 m rise in sea level would submerge infrastructure and other economic installations to a total value of over US$250 million (State of Eritrea 2001)
- La Ceiba (Honduras) has a population of over 100,000 inhabitants. It is on the flood plain between the Caribbean sea and a mountain range; the Cangrejal river drains from the mountains and runs next to the city – and flooding is routine because of no storm water drainage system, Occasional major flooding occurs from heavy rainfall events and hurricanes. In considering the design of an urban drainage system, climate change could considerably flooding from more intense precipitation. The cost of an enhanced urban drainage system able to cope with the estimated increased risks from climate change over the next 50 years would be more than a third higher than the cost of a system to handle current climate (Stratus Consulting 2006).

Addressing infrastructure deficits

If a consideration of infrastructure adaptation for climate change in developing countries considers the cost of addressing the infrastructure deficiencies that have to be remedied to allow needed protection, this implies a much increased cost – of several hundred billion dollars. But before summarizing these estimates, some words of caution are needed. Estimates for the cost of needed infrastructure and building modification and for international finance to support this vary a lot. This is illustrated by the different costings attached to a programme to improve and upgrade sewers and storm drains in Karachi. One set of estimates, prepared by an international development bank (the Asian Development Bank) suggested a total cost of around US$100 million, with $80 million of this to be funded by a loan from this bank. A local NGO that had been working for 20 years in supporting community-based construction and management of sewers and drains came up with an alternative plan that they claimed was not only far more effective (it built on existing sewers and drainage systems constructed by households and communities rather than seeking to replace them) but also far cheaper. In the end, the local plan was chosen – and implemented, at a fifth of the cost of the original proposal and with no need for the

[11] These are quoted in Stern 2007; note some disparities between the figures in Stern and the figures in the original document.

international loan (Hasan 1999, Hasan 2006, Hasan 2007). In Karachi, the work of this local NGO (The Orangi-Pilot Project Research and Training Institute) and of the Urban Resource Centre has highlighted how other internationally funded infrastructure projects are generally far more expensive than those funded by local sources. In part, because banks have little interest in keeping down loan costs and their functioning depends on large loan portfolios. If the Asian Development Bank proposal for Karachi had been taken as an example of needed adaptation, it would imply the need for very large scale funding by international agencies. If the initiative finally implemented served as the example of needed adaptation, it needed no external funding – and no loan (and so no additional debt repayment burden for the Pakistan government). This is not an isolated example; there are many other examples of infrastructure investment, service improvement and upgrading the building stock that are increasing the resilience of cities to climate change in ways that serve poorer groups that are largely or entirely funded by local sources – typically a mix of individual and household contributions and government funding. One good example of this is the nation-wide slum and squatter upgrading programme in Thailand which is almost entirely funded by a combination of government and community and household resources (Boonyabancha 2005). Without doubt, this is providing a much stronger 'infrastructure' basis for adaptation although it would never figure in the conventional discussions of climate-change adaptation.

Three examples will be given here of estimates for addressing different aspects of the backlog in infrastructure provision. The first is the cost of remedying existing deficiencies in provision for water, sanitation and drainage in urban areas. Assuming that there are 30 million urban dwellings lacking provision for water and sanitation in Africa and Latin America and 150 million lacking such provision in Asia and that the average cost per household of providing water, sanitation and drainage is $200-$400 per household[12] with another $200-400 needed per household for the trunk infrastructure this needs, then US$42-84 billion would be needed. Obviously, the proportion of this that could be funded by local and national governments would differ greatly between these regions – and between nations. And obviously, this only deals with the water and sanitation infrastructure needed in urban areas and so does not consider the investment needed for the 55% of the population who live in rural areas.

The second set of estimates comes from the Millennium Assessment which estimated the investment needs per person for meeting the Millennium Development Goals in five nations (Sachs et al 2005). This included funds to address deficiencies in provision for roads ($103 - $217 per person) over this ten year period – so if we assume $100 per person would be needed for all low- and middle-income nations, this implies around $600 billion over ten years (covering rural and urban populations) – and another $600 billion needed for other large infrastructure projects.

A third set of estimates come from the Millennium Assessment's Taskforce on Improving the Lives of Slum Dwellers (UN Millennium Project 2005). This produced cost estimates for 'significantly improving the lives' of 'slum' dwellers and providing good quality housing with infrastructure and services for the likely growth in the low-income urban population up to 2020. (It is worth recalling that virtually all population growth in developing countries up to 2020 is likely to be in urban areas - United Nations 2006). These estimates are also unusual in that they consider the cost of the supporting infrastructure these would require. This report suggests that the average cost per person for significantly improving the lives of slum dwellers (upgrading) was U$665 – although this cost varied considerably by region. This estimate included funding for land purchase and transfer, housing improvement, network infrastructure, bulk infrastructure, schools and health clinics, community facilities, planning and oversight, and community capacity building. To achieve the Millennium Development Goal target of significantly improving the lives of 100 million slum dwellers would cost US$66.5 billion;[13] obviously, if this was to be more ambitious and significantly improved the lives of all slum dwellers, around ten times this amount would be needed. The 'infrastructure' component was 11 percent of the total costs in most of Asia but around a quarter of total costs for Arab States, Turkey and Iran and Latin America and the Caribbean and 36 percent of the costs in Latin America and 36 percent of the costs in Sub-Saharan Africa,

[12] It is impossible to estimate the real costs – in part because they will vary so much from place to place – and indeed within each place, depending on who designs and implements it. A 'high-income' nation solution with a 24 hour service of piped water supplies to drinkable standards and a flush toilet is generally much more than this; some innovative programmes that have provided good quality water and sanitation are less than this.

[13] This is in line with other estimates – for instance the estimate by the Cities Alliance that $50 billion was needed to upgrading housing for 100 million slum dwellers and the estimate of $74 billion for this by UN-Habitat; see Flood 2004

Egypt and the Sudan. So again, there is an estimate for remedying existing deficiencies in infrastructure that totals more than one hundred billion dollars – and this is only for urban areas.

For building good quality alternatives to ‘slums’ through assisted self-help housing, regional estimates were also prepared, taking into account regional differences in household size, dwelling size and costs of labour, construction, and building materials. Average per capita investment costs varied across regions from $285 for South Central Asia to $829 in North Africa and Western Asia. The total resources required to fund alternatives to slums for 570 million people through assisted self-help processes is about $227 billion. The proportion of this needed for infrastructure varies from 19 to 61 percent, by region. These estimates rely heavily on relatively few detailed costings of housing initiatives; these initiative also only apply to urban populations – which represent around two fifths of total populations in developing countries. However, they are valid in that they highlight the very large capital costs of addressing infrastructure and service deficiencies in urban areas; it does not really matter if the infrastructure costs for achieving this and for eliminating existing infrastructure deficiencies in urban areas are $200 billion or $300 billion; the point is that there are very large deficiencies. The net conclusion from the above is that several hundred billion dollars would be required to address current deficits in infrastructure in developing countries and upgrade the worst quality buildings. This is a cost that almost all estimates for adaptation costs have not considered.

7. Assessment of how current financing arrangements need to change to meet the requirements of the adaptation scenario

The issue here is not how current financing arrangements need to change but how international agencies can learn how to support local and national institutions that are capable of designing, implementing and managing adaptation. In discussing this, it is not possible to generalize for ‘developing countries’ because of the very large differences between nations in how far they are from this pre-condition.

For this paper, the key issue is how to build resilience to the many impacts of climate change in infrastructure in low- and middle-income nations:

1. That support and work with the reduction of risks for other environmental hazards, including disasters (there are strong complementarities between reducing risk from climate-change, non-climate change related disasters and most other environmental hazards);
2. that are strongly pro-poor (most of those most at risk from climate change and from other environmental hazards have low-incomes which limits their autonomous adaptive capacity);
3. that is based on and that builds a strong local knowledge base of climate variabilities and of the likely local impacts from climate change scenarios
4. that recognize that the core of the above is building the competence, capacity and accountability of local governments
5. that recognizes the key complimentary roles that are required by higher levels of government and international agencies
6. that is fully integrated into development (including national plans to meet the Millennium Development Goals and Poverty Reduction Strategy Papers).

As the IPCC Fourth Assessment notes, most forms of infrastructure can be adapted to the direct and indirect impacts of climate change (Wilbanks, Romero-Lankao et al 2007). All urban centres have an adaptation capacity because they already had to make large ‘adaptations’ to environmental conditions, site characteristics, natural resource availabilities and environmental hazards to be able to function as urban centres. In any well-governed locality, there is already a great range of measures in place to ensure that buildings and infrastructure can withstand extreme weather events and water supply systems can cope with variations in freshwater supplies. Good environmental health and public health services should also be able to cope with any increase in other health risks that climate change is likely to bring in the next few decades – whether this is through heat waves or reduced freshwater availability or greater risks from communicable diseases. It is easy to envisage a process by which adaptation is planned and managed. The tools and methods required to do this are well-known and their effectiveness has been demonstrated in many locations – for instance adjustments to building codes, land sub-division regulations and infrastructure standards combined with land-use planning and management that restricts buildings in high-risk areas and makes special provision to cope with extreme events including the use of insurance to spread risk. There are also (a few) examples of city-governments in developing countries moving in this direction.

Thus, when problems of infrastructure vulnerabilities are considered, independent of current conditions and institutional and political constraints, it is easy to map out a long-term process of support and funding for adaptation. At least in the next fifty years or so, assuming none of the high-impact but uncertain catastrophic changes take place, this seems able produce the needed adaptations in infrastructure without high costs in most locations. Certain cities and rural localities face far more serious risks than others, but it is possible to envisage an international funding system that gives special attention to helping them adapt. It is also possible to envisage national adaptation strategies that encourage and support development away from the areas most at risk from climate-change related impacts. Most governments and many international agencies have also officially endorsed recommendations to move in this direction.

It would be a mistake to assume that the above – a logical, justifiable, fundable process driven by good science - provides a viable roadmap for action. The large deficiencies in infrastructure provision described in this paper are as much related to inadequate institutional structures as they are to inadequate funding. There is not much point in discussing how local governments can invest in infrastructure to help protect the populations within their jurisdiction from risks arising from climate change when they have shown so little inclination or ability to protect them from other environmental hazards – including everyday hazards and disasters. If a local government refuses to extend infrastructure to half the inhabitants in their jurisdiction because they are in 'illegal settlements,' they are hardly likely to support adaptation for these settlements. There are really two separate issues here, although they often act together. The first is the incapacity of local governments in terms of their powers and the resources at their disposal. This in turn relates to the refusal of higher levels of governments to allow them the powers and resources they require to address local needs – and the long-established disinterest among most international agencies in supporting local development and local governance reforms (Satterthwaite 2001, Tannerfeldt and Ljung 2006). The second is the antagonistic relationship between many local governments and most low-income groups; this is particularly evident in urban areas in the antagonistic relations between urban governments and those who live in slums and informal settlements. The urban poor are so often not seen by politicians and civil servants as critical parts of the city economy but as holding back the city's success. Official urban policies so often increase their vulnerability to environmental hazards and climate shocks rather than reducing them (Hardoy, Mitlin and Satterthwaite 2001) – and so are best conceived as maladaptation.

The hope that private sector investments are likely to be important in infrastructure adaptation is misplaced. Current international financial flows on infrastructure from the private sector are heavily concentrated in particular forms of infrastructure (inevitably those that are most profitable – for instance telecommunications and electricity) and in better off nations or nations with economic success. Both now and in the future, it is difficult to see how private sector investments can have a major role in the poorest nations and in nations with poor economic performance (which include many that are most vulnerable to climate change) and in those kinds of infrastructure which are public goods and are particularly important for protecting the poorest and most vulnerable groups (for instance most roads/bridges and storm and surface water drainage).

There is also not much point in discussing how to adapt infrastructure standards and the regulatory framework within which these occur (which also regulate land use, land development and housing and building standards) to climate change when planning and regulation enforcement will only serve those with power and be used to evict and dispossess poorer groups, whenever it serves those in power to do so. Tens of millions of urban dwellers are forcibly evicted from their homes each year – mostly without compensation or with compensation that is inadequate or inappropriate (see for instance du Plessis 2005). It is very difficult to conceive of how the international support system can address this. The development of the institutions capable of providing and maintaining infrastructure, including competent, accountable local governments is a slow, difficult, contested process – as it was in high-income nations. It is opposed by many powerful vested interests – as it was in high-income nations. It is also particularly difficult to see how this can happen in nations with little economic prosperity – and for some little political stability.

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