TOPIC GUIDE :

Planning and Financing of the Effective Maintenance of Infrastructure

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Abbreviations and Acronyms

ADB	Asian Development Bank
AfDB	African Development Bank
DFID	Department for International Development
GDP	Gross domestic product
IDA	International Development Association (World Bank)
HIC	High income country
IPCC	Intergovernmental Panel on Climate Change
LIC	Low-income country
LMIC	Lower middle income country
MDGs	Millennium Development Goals
MIC	Middle income country
O&M	Operation and maintenance
OECD	Organisation for Economic Cooperation and Development
PBC	Performance-based contract
PBMC	Performance-based maintenance contract
PPP	Public–private partnership
PPPIRC	Public–Private Partnership in Infrastructure Resource Centre
SDG	Sustainable Development Goal
SOE	State-owned enterprise
SWAp	Sector-wide approach
UN	United Nations
UNCITRAL	United Nations Commission on International Trade Law
USO	Universal service obligation

Summary

The purpose of this Topic Guide is give DFID advisers and programme managers sufficient awareness and understanding of current key issues relating to the planning and financing for effective maintenance of infrastructure. The guide is brief and therefore only introduces each key issue. Further study can be made via the references at the back of the Topic Guide, but an annotated reading list directs the reader to selected relevant texts.

Section 1 highlights the importance of well-maintained infrastructure for economic growth, social development and poverty reduction. It introduces the notion of an 'infrastructure gap' between the demand and supply of adequate infrastructure. The infrastructure gap has arisen due to failure of governments to maintain existing assets, to replace worn-out assets in a timely manner, and to invest in additional infrastructure. Failure to design and implement suitable demand management measures has further exacerbated the infrastructure gap. **Well-managed infrastructure is characterised by well-structured maintenance planning and disbursement of maintenance funds in accordance with the maintenance plan. This is the important link between planning and financing to achieve effective maintenance.**

Section 2 provides two very important lessons. First, maintenance professionals have an important role to play in making politicians and the general public aware of the scale of the problem of under-funded infrastructure, in particular maintenance. Second, a lack of adequate infrastructure planning and lack of adequate maintenance means significant portions of national infrastructure stocks need replacing at the same time. This 'asset time bomb' will happen in the developing world if action is not taken now to investigate the scale of the problem on a country-by-country basis and make plans for addressing the infrastructure gap in each country. Despite the huge volume of literature on the benefits of well-planned and well-financed maintenance, there is widespread failure to implement what is necessary, including **rebalancing capital and recurrent budgets to give priority to preventative maintenance**.

Section 3 introduces current themes in infrastructure policy. These themes cut across all infrastructure sectors and include: the interdependence of infrastructures, the identification of critical infrastructures, the need for effective asset management, climate change and the increasing role of the private sector. While the involvement of the private sector can bring many benefits to infrastructure management, there needs to be greater awareness and greater preparedness for the additional responsibilities that this imposes on the public sector. The post-2015 Sustainable Development Goals will continue to promote gender equality. **There is insufficient information concerning how infrastructure maintenance policies can benefit women and girls. This area of policy research needs strengthening and carrying through to effective implementation.**

Section 4 makes the case that there is insufficient legislation that directly refers to, or supports, maintenance. There are few specific laws that require maintenance to be carried out, other than for reasons of safety. A pertinent piece of legislation would be to require sector ministries to employ asset management best practices and utilise whole-life costing approaches in determining the balance of budgets between capital and operating expenditure. **Improved legislation would support donor conditionalities related to strengthening maintenance funding and maintenance implementation.**

Strategic planning takes policies and commences the process of turning statements of intent into action, as outlined in **Section 5**. There are some major differences between strategic planning in the private and public sectors. Appendix A discusses the lack of a driver that would increase the effectiveness of public sector maintenance organisations. An important aspect of strategic planning is consideration of scenarios and associated risks. Asset management takes strategic planning a step further and brings professionals at all levels of a maintenance organisation together to examine the respective maintenance management systems and arrive at optimum maintenance strategies. A key feature of asset management is that it uses whole-life costing approaches to minimise the life-cycle costs of owning and operating infrastructure assets. **There must be a sense of proportion when developing asset management systems for developing countries, particularly in terms of the complexity and cost of implementation. The overall asset management regime should support rather than impede the attainment of strategic goals.**

Section 6 addresses the question of why so little money is available for maintenance in comparison to new capital works. A major problem with infrastructure management is that there is too little money assigned to maintenance. While existing infrastructure is deteriorating due to lack of maintenance, new projects are funded. The issue of too little money for maintenance is not an overall lack of funds, but more a question of obtaining the right balance between capital and operating budgets. **Not enough attention is given by governments to the adequacy and importance of maintenance budgets.** This is an overarching weakness of infrastructure planning. **Section 6** provides suggestions on sources for additional maintenance funding. It also points out that simply providing more money for maintenance will not address the maintenance problem. There is a shortage of suitably trained professionals in all areas of maintenance management, from planning and design, through to costing, procurement, contracting and works management. Appendix B provides first-order estimates of the amount of money required for optimum levels of infrastructure maintenance for each infrastructure sector.

Section 7 identifies the main features of maintenance management and briefly discusses each item, including: the maintenance organisation (see also Appendix C), maintenance standards, maintenance planning, maintenance costing, maintenance management information systems and risk management. Risk is best assigned to the party that is best able to manage it. Over the past twenty to thirty years, there has been an increase in contracts that place more risk on the contractor. The greater the role for contractors, the greater the risk they adopt. **There comes a point beyond which there is a premium for transferring risk from the public sector to the private sector and optimal value for money is no longer obtained.**

Section 8 considers modes of contract. Each type of contract apportions risk between the client and contractor to a different extent. Performance-based maintenance contracts (PBMCs) and public-private partnerships (PPPs) provide for increased participation of the private sector. PBMCs have changed specifications and methods of payment for maintenance works. PPPs have introduced commercial awareness and much-needed private sector monies into maintenance. **PPPs can provide a suitable means of improving the financing and delivery of maintenance, but only if the PPP model and financing structure are appropriate.** See also Appendix D.

Sections 9 and 10 provide key messages to DFID advisers and suggestions for further research.

A related Topic Guide is: *Infrastructure: Rapid Evidence Reviews*, PEAKS, 2012

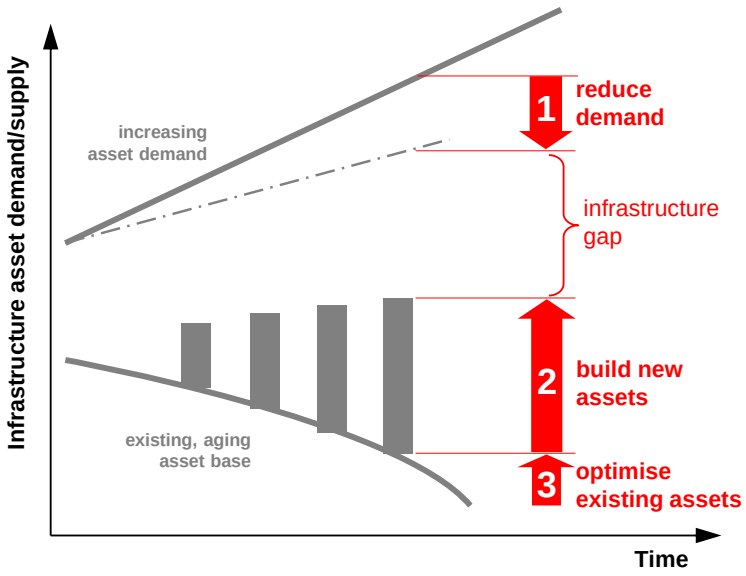
SECTION 1

The importance of well-maintained infrastructure

The World Economic Forum and others[1] have estimated that developed and developing countries need to spend around US$4 trillion per year to 2030, amounting to around US$57 trillion, to meet infrastructure demands that will ensure the required levels of economic growth to reduce poverty. To put this into context, about US$2.6 trillion was spent worldwide in 2013. The deficit of US$1.4 trillion is the scale of funding required to help close what is being called the **infrastructure gap**. Studies by the World Bank and national professional engineering institutions suggest that finding this level of funding will not be easy for any government and they will need to look to the private sector to invest in new large infrastructure projects.

The infrastructure gap, as illustrated in Figure 1, results from the lack of supply of adequate infrastructure compared to demand and failure to maintain existing infrastructure properly. The gap can be reduced via (1) innovative demand management measures, (2) providing new infrastructure and (3) optimising the use of existing assets (Figure 1). Managing existing infrastructure optimally will minimise the amount of funding required for new infrastructure and maximise the contribution of infrastructure to social development and economic growth.

Figure 1 Components of the infrastructure gap[2]



1 McKinsey Global Institute, McKinsey Infrastructure Practice (2013): http://www.mckinsey.com/insights/engineering_construction/infrastructure_productivity

2 Adapted from: World Economic Forum (2014), " Strategic Infrastructure: Steps to Operate and Maintain Infrastructure Efficiently and Effectively)"

There is no universal contribution of infrastructure to economic growth and social development. The required expenditure on infrastructure per country and sector priorities varies considerably. Chatterton and Puerto[3] estimated that around 7.5% of Gross Domestic Product (GDP) would need to be invested in South Asian economies to support GDP growth of 7.5%, including new investment and capital replacement. For Africa, it has been estimated that per annum growth of 5–7% is required to achieve substantial poverty reduction and attain the Millennium Development Goals (MDGs)[4]. Estimates of Africa's infrastructure requirement[5] to support this growth rate are a staggering 27% of GDP annually for fragile low-income countries (LICs), 16% for non-fragile LICs and 9–15% for the resource-rich, middle-income countries (MICs) and remaining Sub-Saharan countries, which is around twice what has been invested across Africa in recent years. Calderón and Servén[6] investigated more thoroughly the relationships between GDP growth and quantity and quality of infrastructure. They found that LICs needed to invest about 7% of their GDP on new or replacement infrastructure and 5.5% on maintenance if they are to achieve their GDP growth targets. Lower middle-income countries (LMICs) need to spend 4.9 and 3.3%, respectively, and upper middle-income countries 1.3 and 1.0%.

Estimates from recent studies combining industrial and developing countries suggest that a 1% increase in physical infrastructure stocks[7] temporarily raises GDP growth by as much as 1–2 percentage points, primarily from construction activity. Country-specific studies appear to support these estimates[8]. When government owns infrastructure there is a tendency to over-spend in the long run, but this spending does not result in larger quantities of infrastructure. Esfahani suggests this is due to ineffective maintenance and the lower quality of public services resulting in replacing poorly maintained infrastructure before the end of its intended design life. This clearly results in a lower impact on GDP and other development measures for every dollar spent on providing and maintaining infrastructure.

Generally, accumulation of well-managed infrastructure is shown to have a positive correlation with economic performance, but more is not always better. An increase in physical infrastructure has a considerably stronger impact on economic growth if the quantity of infrastructure is traditionally low. Since the economic circumstance of each country is different, the contribution to growth of each type of infrastructure will be different. As the economy, human capital and public institutions develop the contribution of infrastructure changes. Population density and urbanisation also influence the ratios of infrastructure assets to GDP growth[9] due to economies of scale. What matters is that countries have enough well-managed infrastructure in the right mix to address their individual economic growth and social development challenges.

In terms of the economic cost of inadequate maintenance, Iimi[10] found that the reliability of infrastructure services is important for business performance. Firms' operating costs increase significantly with more frequent and longer electricity outages, and increased hours

3 Chatterton, I. and Puerto, O. S. (2006) "Estimation Of Infrastructure Investment Needs In The South Asia Region, World Bank

4 Estache, E. (2006) "Africa's Infrastructure: challenges and opportunities", High-Level Seminar organised by the IMF Institute and the Joint Africa Institute

5 Foster, V. and Briceño-Garmendia, C. (2010), "Africa's Infrastructure: A Time for Transformation"

6 Calderón, C. and Servén, L. (2010) "Infrastructure in Latin America", Handbook of Latin American Economies

7 Bom, P. and J. Ligthart. (2009), "How productive is public capital? A meta-regression analysis". Andrew Young School International Studies Program Working Paper 09-12

8 Srinivasu, B and Srinivasa Rao P (2013), "Infrastructure Development and Economic Growth: Prospects and Perspective", *Journal of Business Management and Social Science Research*, ISSN No.2319-5614

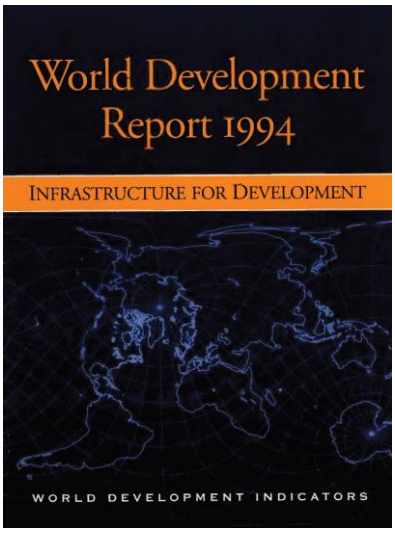
9 Esfahani, H. S. and Ramirez, M. T. (2003), "*Institutions, infrastructure and economic growth",* Journal of Development Economics

10 Iimi, A (2008), " Effects of Improving Infrastructure Quality on Business Costs", World Bank Policy Research Working Paper No.4581

of water supply interruptions reduce firms' competitiveness. He found that eliminating electricity outages could benefit economies in the range of 0.5–6% and eliminating water supply interruptions could produce a gain to the economy of 0.5–2%. But Iimi also found in his study across 26 countries in Europe and Central Asia that improving the quality of telecommunications services had no significant effect, presumably because telecommunications infrastructure is already in good supply.

In addition to raising society's overall level of income, an adequate quantity and quality of infrastructure can help the income of the poor more proportionately. Calderón and Servén[11] carried out an empirical evaluation of the impact of infrastructure development on growth and income distribution in 121 countries for the period 1960–2000, concluding, "…infrastructure development may be a win–win ingredient for poverty reduction". Poverty declines not only with increased infrastructure stocks, but also with improved quality of infrastructure services, which has significant implications for maintenance.

In terms of the role of infrastructure for achieving the MDGs, in his 2004 report to the UN General Assembly the Secretary-General highlighted "focussed investments in economic and social infrastructure" as one of the key areas in need of a "quantum leap in scale and ambition" if poverty is to be overcome. The assessment of the contribution of infrastructure to achieving the MDGs was based largely on rural areas, where the majority of poor people were located. Since then, there has been recognition of the urbanisation of poverty. Rapid urbanisation has created its own infrastructure challenges most particularly in terms of potable water and wastewater management, but also in terms of power supply and congested transport networks. Growth and prosperity are being achieved, but at the expense of the planet's life support systems and at the expense of greater equality[12]. A more joined-up approach is required and this is the basis for the post-2015 Agenda, which aims to integrate the three dimensions (economic, social and environmental) of sustainable development underpinning the Sustainable Development Goals (SDGs). While it is important to learn lessons from past policies, strategies and projects, it is also necessary to provide new reasoned thinking to arrive at inclusive solutions that meet the challenges of a rising population, increasing urbanisation, natural resource constraints and climate resiliency.



The World Bank's seminal World Development Report (1994) concluded that infrastructure could deliver major benefits in economic growth, poverty alleviation and environmental sustainability, but only when it provides services that respond to effective demand and does so efficiently. Another of its main conclusions was that inadequate maintenance had been an almost universal (and costly) failing, with many roads lasting only half their design life. Failings in maintenance were often compounded by ill-advised spending cuts. Misallocated project investments had created inappropriate infrastructures or provided services at the wrong standard. Demands of users for services of varying standards and affordability had gone unmet even when users were willing and able to pay for the services. The report identified the basic cause of poor past performance as inadequate institutional incentives for improving the provision and maintenance of infrastructure.

11 Calderón, C and Servén, L (2004), "The Effects of Infrastructure Development on Growth and Income Distribution", The World Bank

12 "Integrating the Three Dimensions of Sustainable Development", UNEP Post 2015, Note#1

In summary, the McKinsey study that identified the scale of the infrastructure gap has highlighted the magnitude of funding required to replace infrastructure that has not been well maintained. Effective maintenance optimises the use of existing assets while also protecting the huge amount of planned investments in infrastructure. Inadequate or deferred maintenance causes infrastructure to deteriorate faster, leading to expensive rehabilitation or replacement. This drains the pool of national financial resources that could otherwise be spent on supporting businesses and the poor, thereby strengthening economic growth and social development.

Well-managed infrastructure is characterised by well-structured maintenance planning and disbursement of maintenance funds in accordance with the maintenance plan. This is the important link between planning and financing to achieve effective maintenance.

SECTION 2

Lessons learned from developed countries

Section 1 discussed the importance of infrastructure to economic growth and social development. A lesson worth stressing is that **if infrastructure is important for development, it is also important to get the most out of it**, including maximising its economic life to achieve optimal value for money. For many years, the multilateral development banks and major donors have promoted the paradigm of preventative maintenance as being several times cheaper than rehabilitation or replacement of infrastructure, but have not adequately supported it. While this lesson may now seem obvious, the learning has been slow, even in countries whose economies developed as the result of extensive investments in infrastructure. It is worth reviewing the case of the USA to demonstrate lessons still being learned by the USA and other developed nations.

The USA is the world's largest economy and, despite incidences of relative poverty[13], has one of the highest GDP per capita in the world[14]. In the last 200 years, the USA has invested around US$1 trillion[15] in its physical infrastructure, including transport networks, power and water supply systems, flood and coastal protection, schools and other public buildings, and waste management systems. Much of the current infrastructure was built in the 1950s and 1960s when the USA was investing around 2.0–2.5% of GDP in its infrastructure, with a further 1.0–1.25% for operations and maintenance. But by the early 1980s, it was noted that the nation's infrastructure was not keeping pace with demand. Funding for maintenance, replacement and new infrastructure was inadequate. A bill was enacted in 1984 to establish a National Council on Public Works Improvement[16]. This led to the production of three annual reports on the state of the nation's infrastructure. In its 1988 report, the National Council stated that most major categories of infrastructure were performing at only passable levels, with many smaller systems facing acute difficulties. It noted that overall investment in infrastructure had slowed during the previous two decades[17] in relation to the demands of growth and environmental concerns and that the nation had "worn through the cushion of excess capacity built into earlier investments". The current generation was drawing down on past investments without making commensurate investments of its own. The Council noted that declining infrastructure would jeopardise the productivity of the economy and citizens' quality of life and further stated that failure to reverse the decline would exact a high price for the nation in terms of the cost of deferred investment and in reduced economic competitiveness.

The Council's primary recommendation was a doubling of the capital that the nation invested each year in new and existing public works. In 1985, the amount invested was US$45 billion[18]. The aim was to reverse the decline by the end of the century. The Council's final report, "*Fragile Foundations: A Report on America's Public Works*", provided America's first

13 http://en.wikipedia.org/wiki/Poverty_in_the_United_States

14 The USA is ranked tenth in the world on a GDP per capita basis by both the World Bank and the IMF; source: http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)_per_capita

15 http://babel.hathitrust.org/cgi/pt?id=uc1.32106011543615;view=2up;seq=4;skin=mobile (page 2)

16 https://www.govtrack.us/congress/bills/98/s1330#summary

17 In 1990 Aschauer and Munnell separately demonstrated that the decrease in productivity in the 1970s and 1980s compared to the 1950s and 1960s was due to the decrease in public capital stock, rather than a decline in technological progress.

18 In 2010, US$45 billion was the amount spent on infrastructure in the whole of Africa

national infrastructure report card. As shown in Table 1, the USA failed to reverse the deterioration of its infrastructure via adequate maintenance, even though spending on operation and maintenance (O&M) increased three-fold between 1960 and 1985. This is because in real terms, as a percentage of Gross National Product, O&M spending barely changed.

Category	1988	1998	2001	2005	2009	2013
Aviation	B-	C-	D	D+	D	D
Bridges	-	C-	C	C	C	C+
Dams	-	D	D	D+	D	D
Drinking Water	B-	D	D	D-	D-	D
Energy	-	-	D+	D	D+	D+
Hazardous Waste	D	D-	D+	D	D	D
Inland Waterways	B-	-	D+	D-	D-	D-
Levees	-	-	-	-	D-	D-
Public Parks and Recreation	-	-	-	C-	C-	C-
Rail	-	-	-	C-	C-	C+
Roads	C+	D-	D+	D	D-	D
Schools	D	F	D-	D	D	D
Solid Waste	C-	C-	C+	C+	C+	B-
Transit	C-	C-	C-	D+	D	D
Wastewater	C	D+	D	D-	D-	D
Ports	-	-	-	-	-	C
America's Infrastructure GPA	C	D	D+	D	D	D+
Cost to Improve	-	-	US$1.3 trillion	US$1.6 trillion	US$2.2 trillion	US$3.6 trillion

Table 1 America's infrastructure report cards (compiled by author from ASCE records)

Note: A = exceptional; B = good; C = mediocre; D = poor; F = failing

The National Council's final report included many quoted predictions from public officials regarding the consequences of failing to properly manage infrastructure at local, state and federal levels. Subsequent infrastructure report cards show that the warnings in 1988 have not been heeded. It is not simply a matter of preserving infrastructure in its intended condition. Engineers must constantly assess the components of infrastructure, not just the overall system, to ensure that they remain fit for purpose in changing circumstances. These changes, for example, may be due to loading increasing beyond that included in the design, or due to climate-related changes.

Box 1 The asset time bomb

Much of the existing infrastructure in developed countries was built in the mid- to late-20th century. Some items, such as sewers, are much older. All these infrastructures are aging, in many cases at a faster rate than designed due to lack of maintenance. But the longevity of assets is being pushed ('sweating the assets') due to a lack of funding for replacement infrastructure. There is an anticipated convergence of the lifespans of these infrastructures, what Thurlby [19] refers to as the "asset time bomb", when a large amount of infrastructure will need replacing at the same time.

Developing countries have built much of their infrastructures in just the past few decades and there is a push to increase the pace of provision to close their infrastructure gaps. A primary lesson to be learned from developed countries is the need to manage these infrastructures effectively to avoid an asset time bomb in future years in developing countries.

Perhaps learning from the American national infrastructure reports, or because they have for themselves realised that their major infrastructure is in need of attention, other developed nations have begun to take similar measures and their report cards reflect similar conditions. The World Economic Forum ranks the USA 19th out of 148 countries on the overall quality of its infrastructure, the UK 28th and Australia 34th. Switzerland is 1st and Germany 10th. There is now widespread realisation that it is not just the USA's infrastructure that is reaching the end of its economic life. The infrastructure report cards of many developed nations are showing that the infrastructures that enabled the economic growth of these countries are reaching the end of their physical and economic lives. And it is all happening at once. This is what Thurlby[19] calls the **asset time bomb**. **This is a hugely important lesson from developed countries that can be used to predict what could happen in future years in developing countries**.

Not enough has been done by way of optimising the use of existing assets via effective maintenance strategies. A lack of investment in preventative maintenance has accelerated the deterioration of these infrastructures, which has significantly reduced their economic lives. As a result, nations have to "sweat their infrastructure assets"; extract more years' service from existing infrastructure. This is not good practice, but it is postponing the asset time bomb while countries are gradually replacing these assets.

When commissioning new or replacement infrastructure there must be a simultaneous commitment to the ongoing annual maintenance costs as identified via proper asset management assessments. Spending appropriately on maintenance will extend the life of assets, thereby reducing the need for capital expenditures for replacement items. All governments must make better use of their existing assets and **rebalance capital and recurrent budgets to give priority to preventative maintenance**. Optimising this balance will result in the minimum envelope of capital and recurrent costs. This is the most cost-effective means of managing infrastructure assets. Staff must be trained to identify the most appropriate maintenance interventions, develop budgets, undertake cost-effective procurement and carry out good quality maintenance works. Although many developed and developing countries are aware of these lessons they still fail to implement them.

In terms of learning from other institutions, the International Development Association (IDA) issued a brief statement on its lessons learned[20] from its infrastructure projects. In summary:

- consider the respective roles of the public and private sectors
- infrastructure investments need to strike a balance between scale and responsiveness to local conditions on the ground
- from the outset, interventions need to be designed to safeguard people and nature
- the governance environment is key to development impact

Changes are also needed in the way projects are identified and approved, possibly by including conditionalities to ensure adequate maintenance funding. Projects can only be sustainable and infrastructure can only serve its intended purpose if maintenance funding is an integral part of the project's design and approval stages. Public sector management of infrastructure is rarely as efficient, innovative or cost-effective as that provided by the private sector, but the public sector does have an important role to play in regulation and in protecting the interest of the public.

19 Thurlby R., "Managing the asset time bomb: a system dynamics approach" (2013), ICE Proceedings

20 http://siteresources.worldbank.org/IDA/Resources/IDA15Infra-SectionIII.pdf

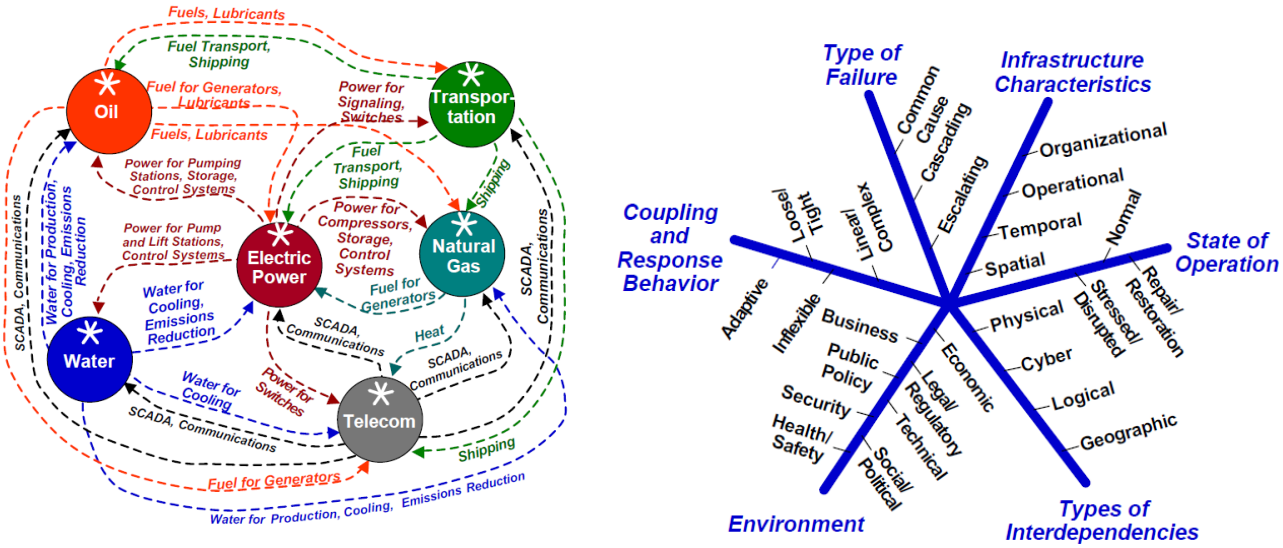
SECTION 3

Current trends in infrastructure policy and how these impact on maintenance planning

To date, infrastructure policies in the developing world have largely focussed on increasing the overall quantity of infrastructure. Research by the World Bank and others[21] has demonstrated that the quality (maintenance) of infrastructure is as important as the quantity of infrastructure and is vital for sustainable development. While the developing world is slowly responding to this lesson, developed countries are becoming aware of new infrastructure management challenges.

In addition to challenges posed by the infrastructure gap and the asset time bomb, infrastructure professionals are now acknowledging the challenges of **infrastructure interdependence**; i.e. recognition of the need to consider infrastructures across sectors (see). Typical examples quoted are the need for power to operate pumps for water supply and drainage, and the interconnectedness between utilities and transport. It is now recognised that a relatively minor and routine disturbance in one system can cascade into a larger outage in an interdependent system. Many of these systems play a crucial role in emergency response. This is a relatively new field, but more governments are establishing their own Geographical Information System Units as a means of bringing together information from different sectors and mapping the location and condition of infrastructures. Due to infrastructure interdependence, a low-cost outage in one infrastructure sector could ripple out into other sectors, infrastructure and non-infrastructure, possibly leading to huge economic and social costs. This aspect of the importance of maintenance has barely been researched. But some preliminary studies indicate startling results.

Figure 2 Illustrative infrastructure interdependencies



[21] For example: Fay, M and Toman, M (2010) “Infrastructure and Sustainable Development”

In 2013, the UK's Royal Academy of Engineering led an alliance of engineering institutions in preparing a paper to government on the need for policy-makers to utilise interdependency analysis to plot current and future policies and to align these policies in recognition of infrastructure interdependencies. They proposed improved communications between regulators and asset owners, but noted that further research and implementation of interdependency is required.

Measures to address the potentially adverse impacts of infrastructure interdependence are known as infrastructure resilience. This is an area of increasing research. The usefulness of integrated systems approaches[22] is still not yet widely recognised, even among infrastructure professionals. It should be expected that, as this new field of knowledge develops, it would find its way into the policies of developing countries and their development partners. This will help to focus on the infrastructure projects that matter most, to better identify the interdependency of infrastructure systems, and to optimise the cost-effectiveness of these projects.

America established a President's Commission on infrastructure interdependency in 1997. The subject quickly gained prominence following the September 2001 terrorist attacks. At the same time, the realisation grew that some infrastructure is more important than others are and this led to the identification of **critical infrastructure**.

Critical infrastructure may cross political boundaries and may be built, natural or virtual. Built critical infrastructure includes energy, water supply, wastewater, telecommunications and transportation. Natural critical infrastructure systems include lakes, watercourses, water sources, coastal wetlands and floodwater storage. Virtual critical infrastructure includes cyber, electronic and information systems. Critical infrastructure projects are often large in scope and size but, depending on their purpose and the population and businesses they serve, smaller infrastructure may also be critical. In its response to the challenges posed by critical infrastructure, the American Society of Civil Engineers proposed the following guidelines to policy-makers and infrastructure professionals:

- quantify, communicate and manage risk
- employ an integrated systems approach
- exercise sound leadership, management and stewardship in decision-making processes
- adapt critical infrastructure in response to dynamic conditions and practices

Effective maintenance is vital to keeping all critical infrastructure operational.

An approach to infrastructure management that has found its time[23] and is already becoming a common theme in infrastructure policies is **asset management**. This is a holistic approach to managing assets from their inception through to disposal, which involves balancing the needs of all stakeholders. Asset management comprises three interacting and mutually reinforcing components[24]:

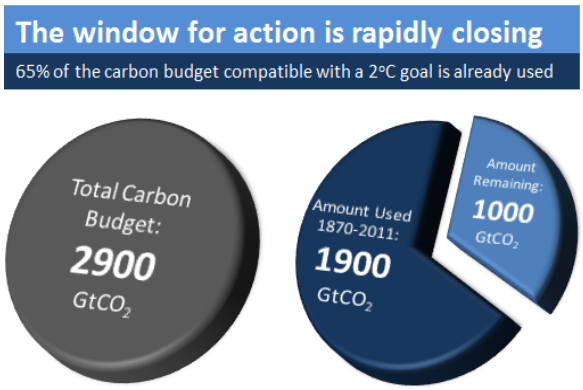
- a government policy component
- an organisational strategy component
- a technical component

22 for example: Warren. K, and Thurlby, R (2012), "Understanding and Managing the Threat of Disruptive Events to the Critical National Infrastructure"

23 Lloyd C. (2010), "Asset Management: Whole-life management of physical assets", Thomas Telford Ltd

24 Male, S., (2010), "The challenges facing public sector asset management", Thomas Telford Ltd

Asset management examines infrastructure from a whole-life perspective and therefore incorporates a range of government policies, including those concerning infrastructure interdependency and the recognition of critical infrastructure. It informs policy-makers of the optimal balance between capital investments, operating and maintenance costs, and disposal. By helping to get the most out of existing infrastructure and by informing appropriate decisions for new infrastructure, asset management is important for addressing the infrastructure gap. Asset management is discussed further in Section 5 of this Guide.



Climate change is a rapidly growing concern in most countries of the world, heightened by the economic and social shocks resulting from ever more prevalent floods, bush-fires and hurricanes. The Intergovernmental Panel on Climate Change (IPCC) has now produced its fifth assessment report (AR5)[25], which responds to the requests of world governments for a comprehensive, objective and policy neutral assessment of the current scientific knowledge on mitigating climate change. One thing now certain is that governments need to act to halve emissions before 2030, otherwise the measures to limit temperature rise from greenhouse gases to 2°C must double; almost two-thirds of the carbon budget to limit temperature rise to 2°C has already been used. This, in principle, is not unlike the need for governments to act quickly to address lack of maintenance before the costs rapidly rise. Climate change is expected to lead to increases in frequency and intensity of severe weather events and these will have serious implications for the design of new infrastructure as well as the maintenance of existing infrastructure.

2°C average rise in global temperatures does not seem much, but during the last Ice Age average temperatures were just 5°C-9°C lower than current temperatures. Without timely mitigation measures the IPCC projects that average global temperatures could rise by as much as 4°C this century.

Infrastructure adaptation can be reactive or proactive. For developing countries, good adaptation and good development policy are very strongly intertwined[26], and it is right that climate change should now become central to national planning processes and to development assistance. The IPCC is now talking in terms of an 'adaptation deficit' (akin to the infrastructure gap) between the current state of adaptation and an ideal state of adaptation. While countries are rushing to address high profile investment needs associated with headline items (e.g. the infrastructure gap and the adaptation deficit) there is a risk that attention could be turned even further away from the importance of maintenance.

Quoting from the Environmental Change Institute, "It is crucial that politicians recognise the need for well-developed city resilience policies, learning from other cities' successes and mistakes". Development partners are already supporting developing countries to review existing infrastructure and identify climate adaptation measures, but maintenance considerations must take a higher profile in these discussions.

Another trend in infrastructure policy is the increasing inclusion of the **private sector** in various roles. This is true in both developed and developing countries as governments realise they have neither the financial nor human resources to manage existing and new infrastructure to keep pace with demand. There is thus a drive to provide attractive

25 https://ipcc.ch/report/ar5/
26 http://www.global-greenhouse-warming.com/climate-mitigation-and-adaptation.html

investment conditions and to design infrastructure projects in a manner that attracts private sector investment. These themes are still evolving, but it is important that the reader of this guide be aware of these trends and the advantages they offer for the future provision and maintenance of infrastructure assets. The Asian Development Bank (ADB), for example, is supporting regional governments in a host of ways to attract private sector financing for infrastructure projects. These measures include:

- commercial principles
- political risk guarantees
- partial credit guarantees
- alignment with development impact policies

Bringing all these policy topics together – there is a growing trend in developed countries to establish central government **infrastructure units**, responsible for one or more of the following:

- development of the nation's annual infrastructure report card
- advising government on critical infrastructure and improving resilience and climate change adaptation
- working with the private sector, industry leaders and research institutions to develop new technologies and more effective ways of getting the best use from existing infrastructures, including demand management measures
- developing innovative financing and risk management methods

The aim is to identify and avoid the causes of past policy failures by bringing coherence and relevant experience to the planning and implementation of infrastructure projects in a manner that recognises infrastructure interdependencies as well as the need to incorporate lesson learning. But national infrastructure units must effectively incorporate input from regional and local levels in order that all stakeholder views are built into the policies and planning for new and existing infrastructures.

Regarding **poverty and pro-poor infrastructure**, DFID has commissioned its own research on the role of infrastructure in poverty reduction and its earlier publications remain relevant, for example the "Making Connections: Infrastructure for poverty reduction" first published in 2002 and updated in 2004. The documents are a good introduction to the key challenges of improving infrastructure in developing countries for the benefit of the poor. Section 2 of the Making Connections document focusses on learning from past mistakes and points out that "…even the challenge of increasing investment seems easy in comparison with the difficulties of ensuring that the investment is used in ways that avoid mistakes of the past … including lack of attention to maintaining infrastructure once it has been built, inadequate institutions and systems of accountability … to encourage efficient operation, and failure to assess the effects of investment in infrastructure on the environment, poverty and livelihoods". A good discussion on the current issues informing policies that link poverty reduction and maintenance of all types of infrastructure has been produced by the Organisation for Economic Cooperation and Development (OECD)[27].

With the convergence of many aid programmes due to the MDGs (and soon the SDGs), **gender equality** is now a primary cross-cutting policy theme in all development work. However, there is little guidance to be found on the Internet or in the grey literature, that specifically highlights gender, vulnerable groups and inclusion in relation to the maintenance of infrastructure. This is an area where further research is required. Meanwhile, the ADB-AusAid Toolkit on Gender Equality Results and Indicators[28] is a useful reference and starting

[27] "Promoting Pro-Poor Growth: Infrastructure" (2006), OECD
[28] "Toolkit on Gender Equality Results and Indicators" (2013), Asian Development Bank - AusAID

point when drafting infrastructure maintenance policies. Annex B of the OECD publication also tabulates the primary links between gender, infrastructure and the MDGs. See also Appendix E of this Topic Guide.

SECTION 4

Legislation and regulatory systems

The first step in implementing policy is the provision of appropriate legislation. However, notwithstanding ministerial mandates, there is relatively little by way of robust and clear legislation for maintaining infrastructure. Moreover, there is very little evidence of any legislation to ensure that sufficient monies are made available for adequate maintenance. This must change. Recognition of the costs to a nation of inadequate maintenance is probably a good starting point in making a case to protect the huge investments in a nation's infrastructure legally. Legislation, for example, could require an organisation to implement asset management practices in accordance with recognised international standards and this, in turn, would dictate a certain level of maintenance funding.

A study by the World Bank in 1988 of 85 countries that had received funding for roads found that allocations for road maintenance had been so low that 15% of the capital investment had been eroded, amounting to about 2% of GDP. Reconstruction costs amounted to US$45 billion because of a failure to provide around US$12 billion in maintenance. The taxpayer bore the brunt of paying four times what the road agencies/ministries avoided spending. This prompted the Bank to promote legislation that protects road maintenance monies by way of independent road funds.

A major difficulty in protecting maintenance funding is the way in which budgets are constructed: capital and recurrent allocations are determined separately and it is complete folly to defer maintenance to save money. If infrastructure budgets were compiled properly then the overall envelope of expenditure would be far less than when maintenance is deferred (or avoided completely) and subsequent rehabilitation or reconstruction is then required at several times the cost of preventative maintenance. ***Encouraging legislation that requires ministries responsible for infrastructure to minimise the 'total costs of ownership' via adopting whole-life cost approaches, leading to optimum balance between capital and recurrent budgets, would be a huge step in the right direction.***

In terms of infrastructure management, the most widespread feature of infrastructure reforms in developing countries and emerging economies over the past 15 years has been the establishment of new regulatory laws, institutions, contracts, regimes and processes[29]. Legislative action typically begins with the abolition of rules that have prohibited private participation and the removal of other legal barriers to competition that cannot be justified in terms of public (consumer) interest. This is often supported by the introduction of rules of competition; i.e. a regulatory system.

The aim of regulation is to encourage efficient, low-cost and reliable service provision while ensuring financial viability and new investment. These encourage utility companies and other infrastructure organisations to take steps toward greener practices and this has indirect implications for infrastructure maintenance. Some regulations, such as fire safety for buildings, provide standards at the time of construction or renovation but thereafter are procedural rather than maintenance related. Most other items of legislation or regulation

[29] Tremolet and Shah (2005) and Brown et al. (2006) estimate that about 200 regulators in some 130 countries are regulating infrastructure sectors such as electricity, water, and telecommunications (quoted from Eberhard, A. (2007), "Infrastructure Regulations in Developing Countries", PPIAF

have indirect implications for maintenance or asset preservation, such as axle-load regulation to prevent over-loaded trucks from accelerating the deterioration of roads.

The performance obligations of concession and maintenance agreements, and the technical standards contained therein have a similar effect to external regulation. They describe the standards to which the operator or maintenance contractor must perform and they are enforceable by law through the respective contract documentation. The United Nations Commission on International Trade Law (UNCITRAL) Legislative Guide[30] provides a good discussion on the legal and financial considerations of private finance in infrastructure projects. Model legislative provisions are provided in a follow-up document[31] published by the UN in 2004. A useful resource regarding all aspects of regulating infrastructure is provided by the Public–Private Infrastructure Advisory Facility-sponsored site "Body of Knowledge on Infrastructure Regulation[32]".

Regulation is not always desirable, or necessary, and as the customer will ultimately pay, the costs of regulatory enforcement must not be ignored. Over-regulation can stifle market forces where supplier–customer relations would otherwise achieve a satisfactory balance between quality and price. Regulation is therefore normally only required where the market fails to self-regulate. The World Bank has produced a handbook for evaluating regulatory systems[33] that describes the harm that can result from poor regulation. A key warning in the handbook is that in terms of regulation one size does not fit all. Regulatory systems from one nation should not simply be imported to another, especially in the early stages of introducing regulatory systems. The handbook proposes three meta-principles for all infrastructure regulatory systems, including transitional regulatory systems:

- Credibility: investors must have confidence that the regulatory system will honour its commitments.
- Legitimacy: consumers must be convinced that the regulatory system will protect them from the exercise of monopoly power, whether through high prices or poor service, or both.
- Transparency: the regulatory system must operate transparently, so that investors and consumers “know the terms of the deal.”

Once in place, regulatory systems tend to resist reform, but regular evaluations are necessary to ensure that the initial objectives continue to be served. It is vital to evaluate both the what (regulatory governance) and the how (regulatory substance) as it affects the infrastructure sector, and the customer and investors, while acknowledging that infrastructure services may be provided by the public sector, private sector or both. Changes in the composition of public and private services in a sector might call for changes to the regulatory regime.

The wide range of options for regulating the use of infrastructure can have a beneficial effect on limiting the stress on infrastructure, such as congestion charging that reduces the traffic on inner-city roads. But maintenance responsibilities are rarely regulated directly. There is a need for raising awareness among all members of society and politicians of the huge benefits to be obtained from effective maintenance. The need to repair potholes is obvious to ‘the man in the street’, but he would generally not know that action should have been taken long before the pothole grew to the size at which it became of concern to him.

30 "UNCITRAL Legislative Guide on Privately Financed Infrastructure Projects" (2001), prepared by the United Nations Commission on International Trade Law

31 "UNCITRAL Model Legislative Provisions on Privately Financed Infrastructure Projects" (2004)

32 http://regulationbodyofknowledge.org/

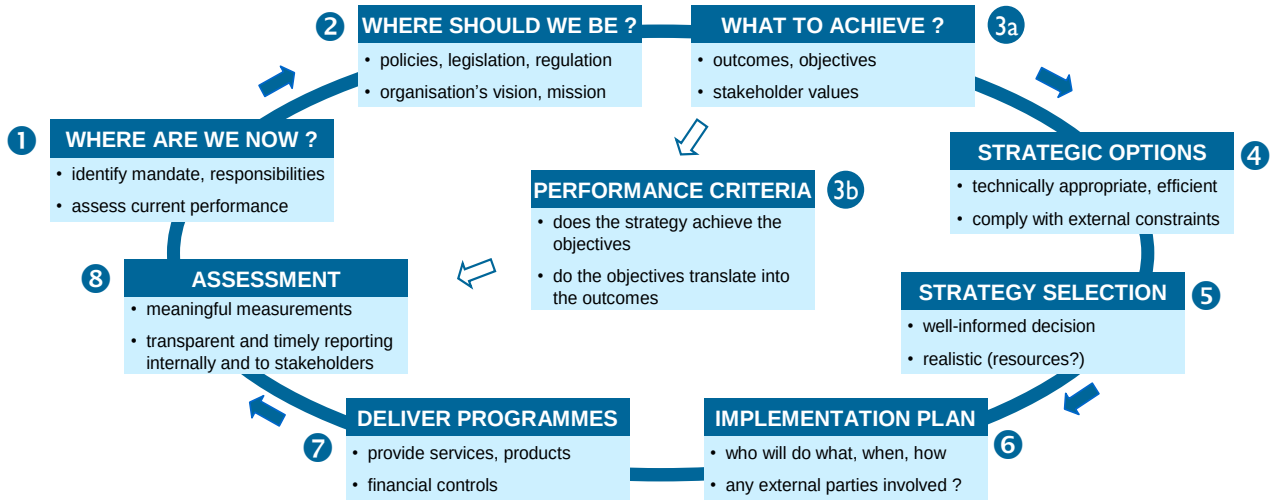
33 Brown, A. C, et al. (2006), "Handbook for Evaluating Infrastructure Regulatory Systems", The World Bank

SECTION 5

Strategic planning and asset management

Strategic planning[34] comprises a cycle of activities aimed at defining an organisation's strategic objectives, how to achieve them and how to measure progress toward them (Figure 4).

Figure 3 Strategic planning cycle



Source: Author

With respect to infrastructure management, the strategic objectives of both public and private sector organisations are guided by a common purpose: to manage infrastructure assets cost effectively. Public sector organisations need to achieve this because they typically have inadequate recurrent (O&M) budgets. Deferred maintenance rapidly accumulates and results in the need for either rehabilitation or replacement of assets, both of which are much more expensive than proper preventative maintenance and provide less return on investment in financial and economic terms. There has to be a paradigm shift from putting new projects first to ***prioritising optimisation of existing assets***. This should be a primary strategic objective for public infrastructure management organisations.

Private sector organisations have cost-effectiveness as a strategic objective because providing good quality infrastructure services at an affordable price is their main competitive advantage. When managing their own infrastructure assets they have to provide competitively priced levels of service to win and retain customers, or risk losing customers to rival service providers. When managing state-owned assets, failing to achieve the required service levels cost effectively would mean failing to meet the requirements of the contract, or being too expensive and not winning contracts. The duration and terms of contracts can have a significant impact on the cost-effectiveness of a contractor's investment strategies. While public sector organisations may have the same strategic objective, they do not have the same incentives. Without legislation to maintain infrastructure assets, there is no driver

[34] Further notes on strategic planning and asset management are provided in Appendix A

for a monopolistic organisation to achieve the same levels of performance as a private sector organisation.

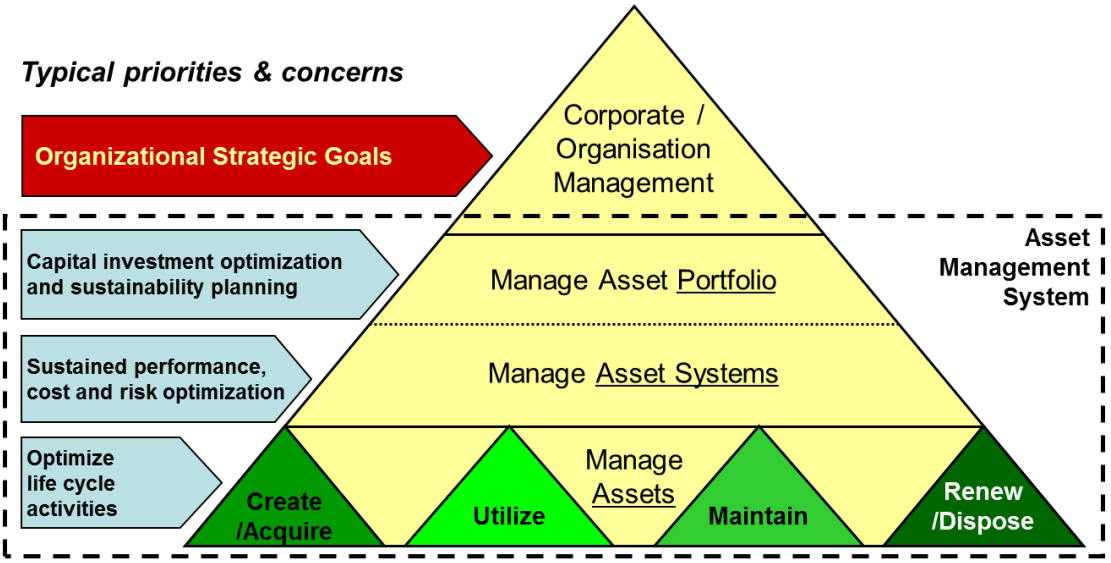
In examining strategic options for minimising costs, an organisation must consider the external factors of its business environment, from government policies and regulatory controls, to technical standards, and climatic and environmental effects. Strategic planning may identify a need to make changes to policy, legislation or organisational structures and staffing, which may be politically challenging for public sector organisations. Strategic planning must take into account the primary concerns of an organisation's stakeholders.

Developing strategic options involves predictions, including about the condition of assets and the associated operational and maintenance costs, levels of demand, the effects of climate change, and the prices of raw materials and other resources. Uncertainty increases as predictions extend further into the future. Some organisations develop strategic plans for just five or ten years, whereas others plan for 20 or even 50 years. Often, the life span of the key assets is used as the period for long-term strategic planning. This enables whole-life costing approaches to be employed and the most cost-effective strategy to be adopted. Increasing levels of uncertainty must also be considered when identifying the optimal balance between capital (capex) and operations and maintenance (opex) budgets. Strategic plans are a basis for developing shorter-term business or corporate plans that then determine the upcoming budgetary requirements.

Traditionally, companies have looked in detail at their maintenance options, but have failed to note that maintenance requirements are largely dictated at the planning and design stage. Of course, there will be unforeseen changes to operating environments during the lifetime of assets due, for example, to changes in demand, less-than-intended maintenance, increased loading and climate change. An organisation must have the flexibility to respond to these changes. Being able to predict many of these impacts, or to implement strategies that reduce the risk and shock of these impacts, makes it easier to budget for them and improves the ability of the organisation to respond to them. Organisations that just focus on their maintenance strategies are not seeing the ‘full picture’ and are failing to provide themselves with sufficient information upon which to make strategically optimal decisions.

Asset management improves the relevance of a strategic plan (Figure 5). Asset management involves making decisions about the interventions that need to be applied to physical assets to achieve an agreed level of service in a manner that optimises these decisions over the life of the asset. As such, asset management is a way to achieve one of the three levers for closing the infrastructure gap, by getting the most out of existing assets.

Figure 4 The relationship between asset management and strategic planning



Asset management goes beyond maintenance management. It brings together the infrastructure management organisation's key business functions:

- Strategic planning: including assessment of external and internal factors
- Whole-life cost analyses: to optimise the overall costs during an asset's life
- Organisational structure and staffing: including commitment and contributions from all levels to the asset management plan, and appropriate training for all staff, and
- Risk assessment and risk management: including political and strategic risks, operational risks, safety risks and financial risk.

In short, maintenance management differs from asset management in that maintenance management manages the resources and processes to carry out the maintenance strategy that has been determined via an asset management plan. Maintenance management involves technical staff at the works programming and operational levels, and procurement and financial staff. Asset management involves all levels and all disciplines in the organisation. Directors must be fully on-board with what asset management aims to achieve. The directors require information to be fed up to them from operational levels so that they can identify the available options and determine the optimal course of action given the external and internal operating constraints. For public infrastructure, the ministers must be equally on-board in terms of understanding the benefits to society that may be realised beyond the current political term in office.

Analysis of strategic options must consider the asset life-cycle costs[35]. Savings of, say, 10% in the initial costs may not be worth it if the 'cheaper' item results in, say, 2% more per year in maintenance and/or operating costs, unless other benefits are also gained. Thus, asset management is important in guiding the organisation's procurement strategies. For networks that comprise relatively few assets, such as road sub-networks, the condition and maintenance options can be considered for individual assets (individual roads, or even sections of roads). For utilities, such as water and power distribution networks, comprising thousands of similar assets (e.g. pipelines and valves), the assets are typically considered at a network level. Life-cycle cost analyses in both cases aim to examine the combined capex and opex in order to identify the optimal asset management strategy.

[35] "asset life cycle costs" are the combined costs associated with the planning, design, build, commissioning, operation, maintenance and recycling or disposal of an asset.

In addition to considering the physical interventions, development of an asset management plan must also consider the non-physical interventions; for example, the regulatory regime and demand management measures. Demand management can be achieved in many ways. Higher costs generally lead to less demand (due to what economists refer to as the ‘elasticity of demand’). Advertising can also help reduce demand, such as educating people to turn off unnecessary lights and water taps. Non-physical interventions are another way in which asset management supports one of the three levers for closing the infrastructure gap.

Finally, in implementing asset management there must be a sense of proportion. Collecting data on large networks can become a goal in itself. Many attempts at introducing computer-based maintenance management systems in developing countries have failed because of the cost of collecting data (e.g. staff, travel and equipment costs), and the costs of processing and interpreting the data. There is clearly a point reached when the money spent on collecting asset data could be better spent on implementing simple maintenance activities. A common-sense check on the complexity of the asset management system and the level of detail for collecting network data must prevail, such that the overall asset management regime supports rather than impedes the attainment of strategic goals.

SECTION 6

Financing considerations

A major problem with infrastructure management is that too little money is assigned to maintenance. While existing infrastructure is deteriorating due to lack of maintenance, new projects are being funded, so the maintenance issue is not an overall lack of funds, but more a question of obtaining the right balance between capex and opex budgets. This leads to two questions:

- How much is actually required for maintenance?
- Why is the required amount not readily provided?

How much money is needed for maintenance?
There is no universal answer to how much money is required for the maintenance of infrastructure as this must be determined on a per country and per sector basis. Each sector of infrastructure has its own specific requirements and, for each maintenance need, there is generally more than one available intervention option. For some infrastructure, there are also choices to be made on the method for carrying out maintenance, or the maintenance standards to be adopted. Labour-intensive methods are more cost-effective (or preferred in order to provide income to local communities) in some cases, while higher technology solutions are more appropriate in other cases. As assets age they generally require more repairs and maintenance to minimise breakdowns. In assessing financing requirements per sector, one must consider that for some infrastructure, the private sector is far more active and the maintenance funding contributions from the private sector must be considered alongside the public sector contributions. These broad considerations make it difficult to set clear benchmarks for how much maintenance funding is required in government budgets. Appendix B provides a high-level assessment of the amount of money required for the main infrastructure sectors. It draws on a range of sources, primarily studies carried out by the World Bank. It also considers why the required amounts of funding are not provided.

Why is the required amount not readily provided?
The absence of ‘a maintenance culture’ in many countries is a severe constraint on protecting investments in infrastructure. Achieving the optimum balance between capex and opex budgets begins with having the right policies in place to prioritise maintenance. Creating a maintenance culture must begin at the top with realisation by politicians of the need to protect previous infrastructure investments and to put in place adequate measures to protect current and future investments. One problem is that "maintenance does not win votes". The electorate needs to be made aware of the importance of maintenance. Engineers and their professional institutions have a distinct role to play in this respect. The production of annual infrastructure report cards has helped convert discussions on infrastructure management into action. New Zealand established its National Infrastructure Unit in 2009. The rationale for the unit was recognition that more money was required for infrastructure, but that it also had to be used better. In 2010, the unit produced its first 20-year infrastructure plan in which it noted the importance of maintenance for supporting businesses and economic growth, as well as protecting investments in infrastructure. Not all governments have yet fully understood the importance of maintenance. The UK Government, for example, has a unit within the treasury that is responsible for long-term infrastructure projects and securing private sector investment, but it does not give priority to securing funding to protect new or existing investments.

Securing sufficient maintenance financing
The typical sources of maintenance funding are:

- budgetary allocations
- budgetary support from development partners
- specific government borrowings
- user fees (e.g. utility charges, fuel surcharges, tolls, airport/port landing and berthing fees)
- private sector

Maintenance budget allocations are usually inadequate. When operations and maintenance are combined into a single budget head then operations generally have the first call on the available funds. The rigidity of budgetary allocations often prevents viring (shifting) of monies between budget heads. An example is where a maintenance department cannot use a vehicle because it does not have money for fuel or something as relatively small as a fuel filter, while it has under-spent in other budget heads. While restrictions on viring serve a purpose of governance and budgetary control, there should be mechanisms in place that permit a maintenance manager to maintain a higher authority to make an application to vire funds when a suitable case can be made. Better still, the manager should be given authority to vire up to a certain amount, or a certain percentage of his/her overall budget. This is particularly relevant when budgets are compiled based on needs and priorities identified many months prior to receiving budget allocations.

Properly compiled asset management plans will identify items of infrastructure that are still serviceable and should be maintained and items that should be replaced. This information should inform the balance between capex and opex budgets. In most cases, it is more economical to protect existing assets and this should result in more monies directed to maintenance. Cases where it does not make sense to maintain assets are when they have reached the end of their economic life and it is costing more per year to keep these assets operational (sweating the assets) than would be paid back in loans for replacement assets, or where a component has become unsafe for further use. A network-wide asset management plan will inform the manager of the appropriate actions to take and the associated budget requirements.

Ring-fencing or ear-marking maintenance funds has generally not been successful[36]. The first generation road funds were designed on this basis. One of the first lessons to emerge from the World Bank's Road Maintenance Initiative was that roads cannot be managed effectively as a social service; they should be managed like a utility on a user-pays basis. The second-generation road funds recognised these shortcomings and introduced the principle of commercialising roads, with road fund monies being managed independently of the state budget and protected by legislation. In most cases, second-generation road funds have still not resulted in sufficient monies for road maintenance but at least the revenues that are collected are protected by legislation in a fund separate from general revenues collected and managed by the treasury.

Budgetary support from development partners may be suitable for supplementing inadequate government allocations to maintenance budgets. But such support should be conditional on how these funds may be used and on having in place satisfactory mechanisms to report on and verify expenditures. Sector-wide approaches (SWAps) were introduced to overcome the often-uncoordinated modality of project-specific approaches. SWAps have been most successful when coordinated under a single policy that government

[36] Benmaamar, M (2006), "Financing of Road Maintenance in Sub-Saharan Africa", World Bank

and all donors sign up to[37]. The conditionalities may be performance-related, but this still results in unpredictable maintenance funding.

The availability of funding for new infrastructure from donors and development banks at low rates of interest supports the preference of politicians in developing countries to invest in new infrastructure. It would be more responsible and supportive of cost-effective development if donors based their support decisions on properly compiled infrastructure plans in which demand for infrastructure is to be met by balancing best use of existing infrastructure with replacement and new infrastructure. Aid dependency weakens accountability and risk management[38].

User fees for utilities can be linked directly to the level of service provided and are a means of achieving full cost recovery. But there are situations where the intended recipients cannot afford to connect to infrastructure networks. This is often the case for remote communities in Africa. Studies by Estache and others (see Appendix B) suggest that tariff structures can be used to increase accessibility by the poor to infrastructure. Tariff structures can also be designed such that they provide cross-subsidisation between those able to pay and those less able to pay for services. Care should be taken in setting tariffs as they are often political and can be short term. Easing payments for one group of users can adversely impact other groups, especially small businesses.

Privately funded infrastructure, such as telecommunications, is managed as a business. Owners of these infrastructures realise that they need to protect their investments. Their business plans are relatively long term and make suitable provision for maintenance, with users paying on a fee-for-service basis to achieve full cost recovery.

To secure sufficient funding for maintenance, governments need to adopt infrastructure management methods similar to those used by the private sector. They must undertake long-term planning that includes whole-life determination of the costs of owning and operating infrastructure. This long-term planning will identify the most cost-effective strategies and give maintenance a higher profile and suitable level of priority. This is what strategic planning and asset management aim to achieve. The long-term (whole-life) approach to managing assets must be supported by budget commitments, that allow for multi-year maintenance contracts to be put in place that match the level of funding determined from the asset management plan.

Identifying additional sources of maintenance funding

Innovative schemes need to be introduced to increase the range of sources and the overall magnitude of maintenance funding. The World Economic Forum[39] has proposed dedicating user fees to a maintenance fund, applying inclusive user charges where possible and capturing ancillary business opportunities. Airports already do this by offering retail space air-side and land-side, in addition to car-parking, hotels and other facilities outside the terminal building. Other infrastructure sectors need to think along the same lines. Offering ancillary business opportunities can support attempts to cover the full cost of providing, operating and maintaining infrastructure.

Additional funding can be raised from existing users by enhancing the service and cost-effectiveness in order to encourage optimum levels of utilisation. Under-utilised assets do not pay for themselves. Well-maintained assets whose availability is maximised also maximises the service time for which fees can be charged and collected.

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37 Brown A, et al. (2001), "The Status of Sector Wide Approaches", Overseas Development Institute

38 http:// www.devpolicy.org (2015) from the Australian Aid Development Policy Centre

39 World Economic Forum (2014), "Strategic Infrastructure: Steps to Operate and Maintain Infrastructure Efficiently and Effectively)"

Private sector involvement

Involving the private sector in managing infrastructure and providing infrastructure services generally has two goals: (1) to inject capital that the public sector does not have, (2) to introduce commercial discipline and efficiencies into the management of the assets and services, thereby increasing productivity and cost-efficiency in both operations and maintenance. The two goals are best achieved through long-term contracts where the contractor can achieve economies of scale, increase the efficiency of methods and where there are opportunities to invest in, and introduce, new technologies, all of which will reduce the unit costs of maintenance.

Public–private partnerships (PPPs) that cover the whole life cycle of assets provide more reliable maintenance financing than government recurrent budgets. Considerable untapped revenue can be sourced by ensuring that monies for billed services are actually collected from users. Effective revenue collection could typically stretch existing maintenance funds by the equivalent of 1–2% of GDP. Additionally, Foster and Briceño-Garmendia (2010) found that improving efficiency and reducing corruption in Sub-Saharan Africa could cut costs and enable subsidies to be cut by 8%. The work by Foster and Briceño-Garmendia, and others indicates many ways in which the infrastructure efficiency gap can be closed, or at least significantly reduced, in order to make maintenance monies go further:

- improve budget execution
- reallocate existing spending toward infrastructure most in need (therefore with the highest economic returns)
- introduce (where not already in place) and increase user charges to levels that recover costs where affordable (to provide more efficient price signals and capture lost revenues), and carefully design/manage subsidies
- reduce operational and maintenance inefficiencies of utilities and other service providers. including reducing distribution losses and illegal connections (to prevent wastage of resources, support healthier utilities, and improve service quality and value for money to the customers)
- reduce over-employment in state-run utilities
- increase revenue collection options and rates
- reduce corruption and poor procurement practices
- implement effective asset management to optimise financing decisions and asset life
- recycle old assets (including selling items no longer fit for purpose)
- recycle solid waste, water and construction materials (including selling to other users)

While the main components of maintenance costs for all infrastructure assets are labour, materials and equipment, many factors impact the magnitude of these costs:

- technical design of the infrastructure
- standard of construction or assembly
- current age and condition of the infrastructure assets
- size and scope of the infrastructure (i.e. economies of scale and the use of mechanised methods versus labour-based methods)
- service effectiveness (technical appropriateness and quality of previous repairs)
- timeliness and thoroughness/appropriateness of previous maintenance interventions

And these issues are affected by:

- institutional framework (ensure appropriate policies, legislation/regulation, etc.)
- availability and adequacy of maintenance monies
- costs and availability of materials and replacement parts

- location of the infrastructure (use remote sensing where appropriate to at least reduce inspection costs, while increasing the frequency of surveys)

Reducing the amount of funding needed for maintenance

Optimising maintenance regimes can reduce the amount of funding needed for maintenance. Following manufacturer's guidelines or implementing the findings from whole-life cost analyses can help reduce the life-cycle costs of maintenance. Foster and Brinceño[40] found that operational inefficiencies across Africa amount to US$17 billion annually. Addressing operational inefficiencies is an important policy priority that should form part of maintenance and institutional reform projects. Typically, the power and water sectors collect only 70–90% of billed revenues and distribution losses are up to twice industry best practices. Government ministries are often among the largest defaulters on utility bills.

Long-term concessions in the power, water and rail sectors have made a positive impact on operational performance[41] (although a significant number have had to be renegotiated or cancelled prematurely). Long-term performance-based contracts (PBCs) in the roads sector faced initial difficulties[39] as donors, consultants, contractors and recipient ministries struggled to find the best way of delivering these contracts in local contexts. But these contracts now show promise and their long-term nature means that roads ministries have had to find ways of funding multi-year recurrent works contracts. These contracts are now reducing the unit costs of maintenance as well as raising the standard and durability of repairs[39,42].

In small island states, it is difficult to benefit from economies of scale. The unit costs of maintenance are almost unavoidably high, particularly when materials have to be imported. Similarly, the cost of materials, replacement components and equipment are higher in landlocked countries. In fragile states, contractors factor in high margins to reflect the risks to equipment and labour. Many separate small contracts rather than a few larger contracts also suffer from lack of economy of scale.

Financial impact of climate change

Another issue that impacts maintenance costs and so far has not been fully researched is climate change. Initial studies[43] suggest that vulnerability to climate change arises mostly from a lack of infrastructure or poorly maintained assets and that the magnitude of the mitigation and adaptation gaps is relatively small compared to the overall infrastructure gap. This fails to recognise vulnerability where critical infrastructure is located in low-lying areas (coastal and inland flood plains), or where the options for locating critical infrastructure are limited (on islands). The likely impact of climate change on maintenance needs much further study, but Fay et al[41] provide an indication of the impact on annualised capital costs for the infrastructure-financing gap.

40 Foster V and Brinceño C (2010), "Africa's Infrastructure", The World Bank

41 For example (water sector PBMC projects): http://siteresources.worldbank.org/INTECAREGTOPWATSUPSAN/Overview/20618636/ABeck.pdf

42 For example: http://siteresources.worldbank.org/INTSARREGTOPTRANSPORT/3221770-1165232837016/21148058/19-PBMC-DELHINov1st2006latest-AP-Reddy.pdf

43 For example: Fay M, Iimi A and Baptiste-Perrissin F (2010), "Financing greener and climate resilient infrastructure in developing countries - challenges and opportunities", EIB Papers Vol.15 No.2

SECTION 7

Maintenance management

The main issues in maintenance management are:

- the nature of the maintenance organisation
- maintenance standards
- maintenance planning (including demand forecasting and performance standards)
- maintenance costing (including maintenance options and provision for emergencies)
- maintenance management information systems
- risk management

The maintenance organisation

Whether the infrastructure maintenance organisation should best be public or private sector is partly a government policy decision. The level of skills in the public sector and the flexibility of funding arrangements may influence policy, especially if the desire is to shift to multi-year maintenance contracts. Policy also depends on the capabilities of the domestic private sector and whether international firms are allowed to bid for maintenance contracts, or even for the privatisation of infrastructure. Private sector firms do not always perform better than the public sector. The aim of commercialising or privatising maintenance is to introduce corporate-style efficiencies in maintenance management, and to provide opportunities for innovative methods of management and new technologies for undertaking maintenance activities.

Decentralisation has been a popular theme over the past couple of decades. The intention is to put maintenance management decisions closer to infrastructure users. This is not applicable to all sectors of infrastructure. The roads sector has been particularly subjected to decentralisation. Decentralisation is fine in principle but decentralisation of responsibility for decision-making must be accompanied by appropriate mechanisms for funding the infrastructure. With the exception of well-managed utility companies, user fees rarely cover the full cost of providing and maintaining assets. Stakeholders must be consulted at local and central levels before proceeding with decentralisation. Appendix C discusses further options for maintenance management organisations.

Maintenance standards

The respective sector ministries provide the technical standards for the maintenance of infrastructure. Technical standards include design codes, testing procedures for materials and workmanship, and standards for equipment. When procuring new components, for example for power or water networks, these must be compatible with the existing network. Specific technical standards may be provided in contract documents, but these are informed by nationally approved technical standards from the respective sector ministry or a separate agency responsible for prescribing national standards.

Standardisation of technical specifications for equipment across networks is helpful to maintenance organisations as it means that they need to hold a smaller range of spare parts and that maintenance technicians need to be trained in fewer defect detection and repair methods.

With the increasing adoption of PBC, maintenance standards are being specified in a different way to traditional contracts. The standards in PBCs allow the contractor to choose maintenance methods and materials, so long as the infrastructure continues to provide the required level of service to users. The main difference is that maintenance standards in traditional contracts are 'reactive' (works are carried out to rectify defects) whereas maintenance standards in PBCs are 'proactive' (the contractor is required to take action to prevent defects progressing beyond a stage where they would adversely impact the specified level of service)[44].

Maintenance planning

For maintenance action plans, whether for utility or non-utility infrastructure, the following information is required:

- description of the maintenance activities
- frequency and timing of the maintenance activities based on relevant data
- Health & Safety actions and security arrangements (to protect workers and the public)
- resource requirements (manpower, materials, equipment)
- maintenance technical standards and approved maintenance methods
- performance measurements
- means of performance evaluation
- assessment of risks, consequences and corrective or remedial actions
- appropriate documentation to record asset condition before and after the maintenance actions, capturing costs, and time and resources used
- well-trained supervisors who understand the costs implications and legal constraints associated with each maintenance option

Outsourcing is an option to consider as part of a company's strategic planning. It involves delegating business functions partially or totally to another company, along with associated administrative and operational control. The main company and the company that takes on the outsourced maintenance responsibilities need to establish a contractual relationship. The decision to outsource is not straightforward. It is a strategic choice that impacts the entire company. Outsourcing is common in utility companies. Typical reasons for outsourcing include greater cost control, enabling the main utility company to focus on its core activities and customer management, improving service quality, accessing new technologies or skills, and reducing costs through competition. The same issues are relevant when a public sector maintenance organisation (public works department, water company, etc.) considers outsourcing part or all of its maintenance activities. Outsourcing may be a convenient option for developing countries but entails greater management oversight and usually requires capacity building.

Maintenance costing

There are four primary types of maintenance:

- corrective maintenance: necessary actions carried out on the network (or within the system) to repair or alleviate incidents that have occurred that have temporarily reduced the level of service
- preventative maintenance: a set of planned activities carried out on the network (or within a system) to keep them operating at the intended level of service and to reduce the likelihood of service-reducing incidents

[44] A useful comparison of traditional and performance-based contracts is provided at: http://www.balticroads.org/downloads/28BRC/3-2-1.pdf

- predictive maintenance, based on a set of analyses aimed at estimating the occurrence, nature and impact of an incident: actions required to prevent or immediately respond to these incidents
- perfective maintenance: aimed at continual improvement of the infrastructure, for example to improve operational efficiency

Maintenance costs can be considered in three groups:

Preventative maintenance costs:	These include the costs of quality and maintenance management, materials and other costs used in preventative works, health and safety, personnel training, certification and calibration of equipment and tools, preventative maintenance interventions, research and improvements, insurance
Appraisal costs:	These include the costs of surveillance (inspections) and of monitoring services and features, resources and tools for evaluations, measurement of customer satisfaction and market perception, evaluation of personnel motivation, etc.
Failure costs:	These include the costs of repairs, time costs associated with identifying the causes and consequences of failures, loss of productivity and income, supplier delays, inefficiencies in information systems and communications, contract or billing errors, debt, deductions, other incurred costs to resolve customer complaints, costs of penalties for regulation failings, loss of market reputation, etc.

Although the proportions vary between countries and sectors, the 40% to 60% ratio of prevention to failure costs is accepted worldwide. Types of equipment, size of networks, style of management and other factors affect this ratio, but the ratio tends to vary by no more than about 5%. The ratio provides a measure against which the maintenance contribution can be assessed, but there is insufficient research to date from an asset management and systems dynamics perspective to verify the extent to which the 40:60 rule of thumb is applicable across all infrastructure sectors.

Estimates of the residual life of infrastructure components is important for costing purposes, but also as a core part of asset management. The residual life of infrastructure components is important for calculating the current value of assets and for considering various maintenance interventions as part of the whole-life cost management of the assets. Changes in asset value are also a good measure of the effectiveness of the maintenance regime and a key performance indicator.

Maintenance management information systems

In the past two decades, computer maintenance management systems have incorporated algorithms. The algorithms help predict the condition of assets in the future based on various maintenance options and data on the rates of asset deterioration. Predictions help when assessing the whole-life costs of assets, but the information systems are typically only used for existing assets. Asset management goes further, ensuring appropriate infrastructure to optimally balance the costs of provision, O&M, and disposal; i.e. it ensures consideration of the total costs of ownership and network-wide optimisation *before* new assets are bought.

Maintenance management of infrastructure assets does not take place in an unchanging environment. The rate at which conditions change is increasing. External changes in conditions include:

- climate
- customer demands
- financial pressures from competing sectors of the economy
- changes in regulatory regimes, tariff structures, subsidy schemes
- increasing private sector involvement in infrastructure

Internal changes in conditions include:

- new component technologies
- new maintenance technologies and techniques
- changes to maintenance management schools of thought (asset management, etc.)
- changes in the skills of maintenance managers and maintenance operatives

To stay abreast of changing conditions, maintenance managers must be suitably empowered. This means that changes must take place at higher levels, including in:

- government policies, in order to recognise the importance and value of effective maintenance, and to put maintenance first (before new infrastructure)
- legislation, to address funding (especially multi-year funding) of maintenance programmes, including adequacy and timeliness
- strategies, to ensure that effective asset management is implemented and to hold maintenance managers accountable

There are clear difficulties in implementing the latter point, because maintenance managers may claim that they were not sufficiently empowered. Top-down institutional changes may be required to ensure that managers are adequately empowered through suitable delegation of authority. They can then be held accountable for poor performance.

Risk management

Risk management is an important part of asset management and project management. Whether considering risks as part of project design or as part of maintenance intervention options, an assessment of risks is vital to ensure that (a) the optimum decision is taken, (b) that measures are taken to mitigate risks associated with this decision, and (c) an appropriate back-up plan is in place if the risks are realised.

Levels of risk are determined by considering the likelihood of something adverse happening and the extent of the impact it would have. Risks that have the greatest likelihood of a large impact need to be addressed first. Risk assessments can be summarised in tables or charts, so long as the results are clear. Risks are usually more clearly illustrated in a graphical format but a tabular format enables more detailed descriptions to be included.

Experienced maintenance contractors and utility operators understand risk better than infrastructure owners. Over the past twenty to thirty years there has been an increase in contracts that place more risk on the contractor. As the range of activities within a contract increases and as the duration of a contract increases, so do the risks to the contractor. The greater the role of contractors, the greater the risk they assume. There comes a point beyond which there is a premium for transferring risk from the public sector to the private sector and optimal value for money is no longer obtained.

What risks should the public sector retain, to what extent, and how should it best manage these risks? Departments can benefit from retaining risk if they recognise the risk, learn how best to manage the risk, and then implement procedures to effectively mitigate the risk. The result should be improved maintenance performance. If performance improvement cannot be achieved (even after obtaining external assistance) then consideration should be given to outsourcing the activities that incur this risk.

The next section of this Topic Guide will consider forms of contract and the contractual transfer of risk.

SECTION 8

Modes of contract

Maintenance contracts can be as simple as one page; for example, a ***petty works contract*** that covers just labour, or labour, minor materials and equipment. In such contracts, given proper supervision, there is very low risk to the client. In these contracts the client assumes the risks associated with the choice of work (design), when it should be carried out, the materials to be used, and the standards to be achieved (quality of materials and workmanship), and the time for completion. In these simple contracts, the client pays for inputs of time (labour), materials and minor equipment.

Larger contracts give the contractor greater scope in scheduling works, which is why the contractor is required to submit a works programme to the client. The client retains the risk associated with the design of the works, including the choice of maintenance intervention and the technical standards (materials, workmanship, etc.), and these are the aspects the client particularly supervises. For contracts where the client determines the works and the contractor is paid for inputs (manpower, materials, plant, etc.) greater effort must be expended by the client on quality control, and cost and time overruns. Contracts are managed against specified technical standards and an agreed Bill of Quantities, so again the client is paying for inputs (labour, materials, equipment).

The client can transfer some of the risk associated with the type of work to be carried out by specifying works to be done but leaving the contractor to decide how to carry out the works. Such an arrangement can also make the contractor responsible for designing the works, provided that the output achieves the quality stated in the contract and is done within the agreed timeframe. Clients may get a consultant to manage these contracts or conduct the inspections themselves, but the client or consultant must identify what items need attention (i.e. maintenance interventions) and the period within which the defect must be rectified (i.e. the deadline for completing the maintenance intervention). These contracts are awarded for specified periods, which may be one or more years, hence they are called ***term maintenance contracts***.

There are two types of term contract. The type described here is a ***works instruction term contract***. An alternative to the works instruction contract is for the client, or an appointed consultant, to define the performance standard to which an asset must be maintained. These are ***performance standard term contracts*** or level of service term contracts. In both types of term contract, the client is paying for a desired standard of work and the contractor determines the most cost-effective manner to achieve this; i.e. the client is paying for outputs, not inputs. For works instruction (or works order) contracts the client is paying for the quality of works. For the performance standard (or level of service) contracts the client is paying for a standard of service.

In developed economies, contracts have evolved much further, into ***multi-year contracts*** that span 10 to 15 years. The multi-year contracts have evolved from traditional contracts through performance contracts, to contracts that allow co-management of the works and ultimately to partnering arrangements.

Performance-based contracts (PBCs) such as Performance-based Management and Maintenance of Roads, PBMCs and contracts under various other names, have grown in

popularity in recent years. The design of PBCs must suit the particular set of circumstances of a country, and take into account political and cultural issues and the state of the contracting and consulting sectors. Initially there were difficulties in introducing PBCs but this was usually due to lack of preparation. For example, for roads contracts, contractors did not receive appropriate training to enable them to understand the quantity and frequency of works to be carried out. The lack of clarity represented a large risk to the contractor and was reflected in the high prices of tenders. Learning from these difficulties, subsequent attempts to introduce PBCs have been more successful and, in many cases, have shown cost savings of at least 10–20%. PBCs can also provide a useful stepping-stone to introducing public–private partnerships. The World Bank and DFID have jointly developed a resource guide (http://www.worldbank.org/transport/roads/resource-guide/index.html) to assist governments, road agencies and others in identifying a practicable approach to PBCs that fits specific country conditions.

By contracting-out maintenance, infrastructure owners can focus on their core functions. This is the case for PBCs for roads and outsourced facilities management of buildings. Because a facilities management contract focusses on supporting the core business of an asset owner or operator, providers of facilities management services aim to provide added value. There is a clear and direct client-contractor relationship and the client as the owner of the facility and end-user holds the contractor accountable for achieving and maintaining an agreed level of service. In the case of roads, the end-user is the road user but the road user does not have a contractual relationship with the contractor. The agency that manages the road represents the road users and has the contractual relationship with the contractor.

While the scale of the infrastructure gap is only now appreciated, it has for a long time been recognised that governments alone, particularly in developing countries, cannot meet the total financing demand for providing and O&M of infrastructure. Until the early 1990s, the public sector provided and managed almost all infrastructure[45]. This has changed. Now the private sector provides and manages infrastructure in about half the countries of the world. Private sector entry into developing country markets is increasing in response to commercial opportunities and manageable risks, as because of fiscal crises in transition and developing economies in the 1980s and 1990s. Interest from the private sector creates new opportunities for financing infrastructure, including maintenance. In response, public–private partnerships (PPPs) are prominent in the policies of most developing countries. Currently, about 15–20% of total developing country infrastructure finance is provided in various PPP models.

In operations and maintenance, PPPs introduce commercial awareness as cost recovery is essential to the private investor. Private service providers emphasise eliminating unauthorised connections and system losses from power and water networks, and demand management. Commercial awareness also introduces other cost minimisation measures, such as ensuring that administrative overheads are as cost-efficient as possible. Commercial disciplines extend to customer charges. Water, sanitation, power and telecommunications charges are based on user-pays, involving a connection charge and charges for consumption. Setting tariffs for user fees can be politically fraught, calling for an independent regulator. Across Africa, the cost of providing infrastructure services is roughly twice that in other developing countries. One cause is the high profit margins due to a lack of competition; other causes are operational inefficiencies and over-staffing in certain areas.

Costs are also genuinely higher in African countries than in countries in most other regions because of the economic geography of Africa. Even relatively high tariffs can fail to fully

[45] Trujillo L., Perelman S. and Estache A (2005), "Infrastructure Performance and Reform in Developing Countries", World Bank Policy Research Working Paper 3514

recover the operational costs of the services. Estache[46] has estimated that for full cost recovery of just the new infrastructure required (to close the infrastructure gap; i.e. excluding O&M costs) would mean the poor and extremely poor would spend around 25–35% of their income to pay their share of total infrastructure costs. Foster's estimates of operation and maintenance costs for LICs suggest that spending by the poor to fully cover the costs of new infrastructure and O&M would be a staggering 35–50% of their income. Estache points out that the rule of thumb used by practitioners is that the poor should not have to spend more than 15% of their income on infrastructure.

The challenge of generating sufficient revenue to meet the costs of operations and maintenance is most acute in fragile, low-income states. In addition to the huge capital investment required to meet infrastructure gaps, fragile states do not make effective use of their current infrastructure revenues. Revenue collection is poor, in part because of the hazards in some areas of these countries, so the revenue that is collected needs to be used optimally. Even in non-fragile states, the inability of legal institutions to enforce payments to infrastructure service providers is a huge problem that impacts the service provider's ability to adequately fund maintenance. The inability of the poor and the limited ability of lower-middle income users to pay for infrastructure services has serious implications for the involvement of the private sector, regardless of which contractual model is used. Although unpopular among public financial management professionals, the suggestion from Foster that cross-sectoral subsidies can ease financing shortages needs to be further researched.

While PPPs have been largely successful in finding much needed capital to close the infrastructure gap, there are concerns about their cost-effectiveness. Separate studies by Andrés, Marin and others have found that user fees have typically risen following the introduction of private provision of utility services. In part this may be due to the pre-PPP position when public sector or state-owned enterprise (SOE) utilities under-priced the services and/or due to fee subsidies. Users have not always seen improvements in service. Some investigations have shown that PPPs have benefited from higher margins but have not increased investment in service quality or access to the poor. Foster suggests that subsidies should be targeted to assisting the poor to connect to networks rather than subsidising tariffs. Subsidised tariffs provide limited if any benefit to the very poor as they are either not connected or consume very little.

PPPs can be a suitable way to improve the financing and delivery of maintenance, but only if the appropriate PPP model is chosen and if the financing arrangements are appropriately structured.

More detailed advice can be obtained from the PPP advisory services provided by the main multilateral banks. The Public–Private Partnership in Infrastructure Resource Centre (PPPIRC) website provides suggestions on sources of finance for PPP projects.

[46] Estache A (2010), "Infrastructure Finance in Developing Countries: An Overview", EIB Papers Vol15, No.2

SECTION 9

Key messages for infrastructure advisers and decision-makers in project preparation

All countries, developed and developing, require an adequate quantity and quality of infrastructure to achieve economic growth and social development goals. The amount and mix of economic infrastructure and social infrastructure that each country needs depends on its stage of economic development and its economy. If infrastructure is important for development, it is also important to get the most out of it, including maximising its economic life to achieve optimal value for money. While infrastructure alone will not ensure elimination of poverty, a certain level of infrastructure (quantity and quality) is required to facilitate economic growth and poverty reduction. Effective maintenance will ensure that countries obtain optimal service from their existing infrastructure assets and will provide a degree of security against risks such as global financial crises, climate change, and so on. Well-managed infrastructure will ensure that donor value-for-money is maximised and that the recipient country obtains maximum benefit from the donor support. **For sustainable development, infrastructure quality is as important as infrastructure quantity. This underlines the importance of maintenance.**

Most governments mismanage the huge infrastructure investments made by previous generations. Many existing assets have reached the end of their useful economic lives prematurely due to a lack of adequate and timely maintenance. Asset lives can only be extended so far before becoming extremely uneconomical and possibly unsafe. The huge cost and the challenge of replacing so much infrastructure all at the same time is already being referred to as the ‘asset time bomb’. This is the single most important lesson to be learned from developed countries. Two immediate responses are required: (1) develop national report cards to determine the extent and severity of infrastructure problems across infrastructure sectors and the urgency of addressing critical items; (2) introduce proactive maintenance and repair programmes that safely and economically extend the lives of existing assets while suitable replacements are planned, designed and provided. The second step requires rebalancing capital and maintenance budgets and will be best informed by implementing effective asset management regimes. The maintenance problem is clearly multi-faceted. Hard decisions need to be made, in particular to improve maintenance funding and to improve the capabilities of infrastructure maintenance professionals.

Without adequate, well-maintained infrastructure, a country faces a huge constraint to economic growth and social development (including poverty reduction). Poor infrastructure management practices, including the failure to invest in timely capital and maintenance projects, have already opened up a huge infrastructure gap. The estimated levels of financing required to address this gap pose enormous challenges even for developed countries. For developing countries these challenges are so much larger, particularly those countries that are threatened by the effects of climate change and/or conflict situations. Greater involvement of the private sector in financing and managing infrastructure is necessary because governments simply do not have sufficient resources. Private sector involvement needs to be well designed and regulated to improve the standard and continuity of infrastructure services. PBCs and PPPs can be appropriate ways to boost private sector involvement, but are not without risk to the client. PBCs and PPPs must be properly planned and managed.

There will, however, still be cases where the risks and rewards do not attract private sector involvement. In these cases, the onus is on the government, supported by donors, to develop innovative financing systems and efficient ways of maximising the cost-effectiveness of infrastructure maintenance. Innovative financing systems may include subsidised tariff structures. Spatial or associated assets can provided additional sources of income (e.g. airports charge for car-parking, rent shops, rent space to restaurants and businesses). Including the private sector is best achieved by long-term contracts and by allocating risks between the infrastructure owner and the maintenance company based on the party that can best manage each risk. While the private sector is not perfect, there are lessons that the public sector can learn in terms of infrastructure management, including whole-life asset planning and effective financial management.

It is not just funding that will address the infrastructure gap and the asset time bomb. There is a huge shortage of infrastructure professionals, including planners, engineers/designers, procurement specialists, economists and financial management specialists, contract experts, and institutional reform specialists. Projects aimed at improving infrastructure maintenance should consider how best to draw on the capabilities and experiences of the private sector in developed countries (e.g. utility companies) where lessons have already been learned. This is not a simple matter. Full consideration has to be given to differences in the institutional and governance context in the home country of the private sector company and the institutional and governance context in the country where it would be providing technical assistance.

Maintenance has a central role to play in addressing the infrastructure gap. But attempts to improve maintenance management cannot work in isolation. There needs to be top-down support for improving maintenance, starting with institutional reforms to ensure full recognition of the need to maintain infrastructure at policy level. Policies need to be supported by appropriate legislation and regulations, and adequate budgets to enable maintenance to be carried out. Optimum use of maintenance budgets means identifying maintenance interventions on a whole-life cost basis, and that technical maintenance personnel use the most appropriate technologies, materials and methods. The process that integrates institutional, managerial and technical aspects to optimise use of existing infrastructure is asset management (Figure 6).

Alongside optimised maintenance, other institutional reforms can alleviate stress and extend the operational and economic lives of assets. These reforms include demand management, and direct and indirect regulation regarding the use of assets.

It is not easy to develop unit costs for maintenance. Many contributing factors make it difficult to compare costs across countries, even adjacent countries. Comparisons should fully investigate these contributory factors.

Financing maintenance is a huge challenge. There is clear evidence that the root cause of financing challenges in many cases is inappropriate policies. Priority must be given to maintenance by means of irrevocable commitments to funding for maintenance at the same time as commitments are made to investing in new infrastructure. Improving sector management, including fully collecting billed utility charges, would further alleviate the financing problem.

Finally, it is worth repeating the key message from Section 1:

Well-managed infrastructure is characterised by well-structured maintenance planning and disbursement of maintenance funds in accordance with the maintenance plan. This is the important link between planning and financing to achieve effective maintenance.

Figure 5 Effective asset management optimises infrastructure usage and asset life

SECTION 10

Gaps in the current body of knowledge

In addition to pulling together the most relevant material from the current body of knowledge, further areas of research are required:

- The World Economic Forum (in partnership with the Boston Consulting Group and the McKinsey Infrastructure Practice) assessed the infrastructure gap in an attempt to estimate the scale of the problem globally. A similar exercise for developing countries, adapted to local circumstances, would provide a better appreciation of the problem and should be supplemented with an assessment of realistic measures and timescales for addressing the infrastructure gaps in these countries. As already mentioned by Foster, estimates hitherto for the implementation of rehabilitation and replacement programmes have always been too optimistic. How can programmes be designed to incorporate realistic rates of implementation?
- Infrastructure is hugely expensive, takes time to plan, design and deliver, and if properly managed can last generations. But the beneficial impacts of infrastructure can be obliterated quickly in times of armed conflict. What lessons can be learned about planning and financing infrastructure maintenance in fragile and conflict-affected states?
- Infrastructure interdependencies have been identified as having potentially huge knock-on effects: a small defect in one system can lead to a large outage in an interdependent system. What are the consequences of this for infrastructure planning and maintenance management in developing countries? To what extent might interdependencies be less or worse in LICs, LMICs, MICs and fragile states compared to high income countries (HICs)?
- In addition to well-trained maintenance professionals, adequate and timely funding is vital for maintenance. How can legislation and regulation be strengthened across all infrastructure sectors to ensure adequacy, continuity and timeliness of maintenance funding?
- Donors and funding agencies are supporting initiatives to investigate climate change adaptation needs. Such investigations need to be done across all infrastructure in a concerted manner, and the scale and scope of the needs fed into studies of the infrastructure gaps in each country. What is the scale of the climate change problem and how should this be appropriately incorporated into maintenance planning and management? How should dealing with climate change be designed into future maintenance projects?
- Donor and funding agency practices with respect to the balance between opex and capex requires a thorough review. Can donors and funding agencies do more to help recipients and client countries meet maintenance needs? Australia's Development Policy Centre is already asking whether the ease with which new infrastructure can be funded encourages a laissez fair attitude toward maintenance.
- Greater emphasis is being put on reducing the costs and durations of construction projects. Are cost-cutting designs and construction methods resulting in higher downstream expenditures for O&M and shorter infrastructure service life? Are whole-life cost approaches being used to fully inform the planning and design of infrastructure projects?

- The lack of adequately trained and experienced maintenance professionals in developing countries contributes to poor standards of maintenance. How can infrastructure projects be designed to ensure that maintenance knowledge is fully imparted and that training leads to sustainable improvements in infrastructure management?
- Literature on the gender and inclusion aspects of infrastructure maintenance is scanty. Are there aspects of infrastructure maintenance that can better address the needs and opportunities for women, girls and other vulnerable groups?
- Can a system dynamics approach improve maintenance planning and management in developing countries and, if so, what are the conditions where and how it might work? Can a systems dynamics approach be used to better understand the longevity of infrastructure assets, to inform the ratios of prevention and failure costs, and to better design maintenance methods and budgets? How should a systems dynamics approach inform the design of donor-funded projects?
- Estache and Muñoz (2008)[47] used the IMF's financial programming tool to investigate the medium to long-term effects of investments in infrastructure, education and health. They found that the particularly important effects of O&M expenditures in infrastructure and current expenditures in social sectors, as well as the quality of stock proxied by O&M expenditures, are not fully taken into account by the standard IMF model when considering the impact of infrastructure investments on output growth and public debt levels. They conceded that even their improved model does not take account of types of investment, monetary issues, exchange rates and interest rates. How can this work be followed up to determine a better proxy for maintenance than O&M costs since O&M is often highly inefficient and poorly carried out? What lessons will this provide in terms of identifying the links between well-managed infrastructure and social and economic development?

[47] Estache, A and Muñoz, R (2008) "Building Sector Concerns into Macroeconomic Financial Programming: Lessons from Senegal and Uganda", Africa Infrastructure Country Diagnostic Working Paper 6

Annotated reading list

This reading list provides primary references for each section of the Topic Guide.

Section 1: The importance of well-maintained infrastructure

Vivien Foster and Cecilia Brinceño-Garmendia *Africa's Infrastructure: A Time for Transformation* World Bank, 2010	While the World Economic Forum has estimated the infrastructure gap for the whole world, Foster and Brinceño have estimated the funding gap for Africa's infrastructure in all sectors. Importantly, they have also estimated the opex funding gap. This is an excellent resource for infrastructure and social development professionals. It makes a strong case for improving infrastructure as the main catalyst for Africa's development. The document commences with an overview that provides 10 key findings from the study, followed by 10 recommendations. Part 1 of the document then discusses the funding gap, how more can be achieved with existing resources, issues of poverty and inequality, and facilitating urbanisation. Part 2 reviews each infrastructure sector and notes the major challenges to improving the sector.
Gregory K Ingram and others *World Development Report*, World Bank, 1994	This report makes clear the importance of infrastructure for developing countries. But it is also about lesson learning so it provides a good lead into Section 2 of the Topic Guide.

Section 2: Lessons learned

http://www.infrastructure.govt.nz/	The National Infrastructure Unit website provides informative material concerning the role of the National Infrastructure Unit within the Treasury, National Infrastructure Advisory Board, and preparing and implementing national infrastructure plans. The website also provides material related to asset management and PPPs.
http://www.nzcid.org.nz/Category?Action=View&Category_id=39	The New Zealand Council for Infrastructure Development (NZCID) website describes how the country began to develop annual national infrastructure plans but then realised the need to improve the evidence base by strengthening annual report cards.
Robert Thurlby *Managing the asset time bomb: a system dynamics approach*, ICE Proceedings, Paper 1200026	Dr Thurlby's paper highlights the challenge faced by asset managers when significant assets approach the end-of-life at the same time. Thurlby proposes an approach to help address this challenge. The approach is particularly appropriate for infrastructure networks.

Section 3: Current trends in infrastructure policy

IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, Cambridge Press, 2014	This is the Working Group WGII AR5's contribution to the IPPC's Fifth Assessment Report. The report includes work on: adaptation needs and options, adaptation planning and implementation, adaptation opportunities, constraints and limits, and economics of adaptation.
Aleksandra Kazmierczak and Jeremy Carter, *Adaptation to climate change using green and blue infrastructure: a database of case studies*, University of Manchester, 2010	This report provides case studies of innovative climate adaptation measures in fifteen cities around the world. The case studies are followed by discussions on adaptation planning and incorporating adaptation actions in policies and strategies.
Thomas Man, *Infrastructure Interdependencies Timelines*, Royal Academy of Engineering, 2013	The development of this report was led by the UK's Institution of Civil Engineers. It considers policy across five infrastructure sectors. It is a follow-up to an earlier report, which illustrates how timelines provide a framework in which interdependencies between policies can be examined.
Adam Rose, *Tracing infrastructure interdependence through economic interdependence*, CREATE Research Archive, 2005	The author first discusses economic interdependence and then provides a tabulated example of how major sectors of the economy could be impacted by failures in each category of infrastructure. The paper has an academic overtone, but it takes the theme of infrastructure interdependence beyond the typical example of a small power outage affecting other infrastructure. The paper illustrates how an economy is vulnerable to a chain of events that can be triggered through infrastructure interdependencies.
http://www.dhs.gov/critical-infrastructure-sectors	The USA has done a lot of research on critical infrastructure. This area of the Homeland Security website provides an introduction to the key issues of each category of critical infrastructure.
ASCE, *Guiding Principles for the Nation's Critical Infrastructure*, 2009	An interesting feature of this report is the mention of employing an integrated systems approach to the planning, funding, design, construction and operation of critical infrastructure and the adoption of a life-cycle systems management approach.

Section 4: Legislation and regulatory systems

https://www.gov.uk/government/news/infrastructure-bill	The UK Government website provides an overview of one of the few pieces of legislation proposed specifically for infrastructure. The bill would improve how the government plans, funds, manages and maintains national infrastructure.
http://regulationbodyofknowledge.org/	The website provides a wealth of knowledge on almost every aspect of infrastructure

	regulation, including application to utilities, market structures, financial analyses, price level regulation and tariff design.
Section 5: Strategic planning	
John Bryson, *Strategic Planning for Public and Nonprofit Organisations*, John Wiley & Sons, 2011	This book states why strategic planning is important to governments and public agencies. It emphasises the benefits of strategic planning and when it should and should not be used.
Asset management	
The Institute of Asset Management, *Asset Management - an anatomy*, 2014	The IAM publication provides a robust introduction to what asset management is and what it can achieve, including the fundamental concepts and philosophy.
Section 6: Financing considerations	
Antonio Estache, *Infrastructure: a survey of recent and upcoming issues*, World Bank, 2006	Professor Estache considers the current state of infrastructure, why it matters to growth, how the poor benefit, and fiscal and other financing options. He points out that an omission in the body of knowledge is how to improve the performance of public providers when privatisation is not an option.
Dobbs et al., McKinsey Infrastructure Practice, *Infrastructure productivity: how to save US$1 trillion a year*, 2013	This publication acknowledges the infrastructure gap and concerns about how to find enough capital financing, but points out that the focus on the huge amount of capital required could overshadow the equally compelling imperative of financing maintenance. It provides three main ways in which infrastructure productivity can be improved in order to deliver savings of 40%. Many of the recommendations are applicable to both economic infrastructure and social infrastructure.
Boston Consulting Group, *Strategic Infrastructure: Steps to operate and maintain infrastructure efficiently and effectively*, World Economic Forum, 2014	This is a very good publication that examines the O&M imperative, and advises on best practices and how to implement and enable them. It brings together a number of popular themes in many other references, including optimising asset utilisation, reducing O&M costs, extending asset life, reinvesting with a life-cycle approach, ensuring adequate funding and reforming governance.
Section 7: Maintenance management	
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Ken Gwilliam, *Africa's Transport Infrastructure*, World Bank, 2011	This publication is closely related to that by Foster and Brinceño. It examines a wide range of issues that impact on the effectiveness of maintenance policy, planning and

	implementation in Africa's transport sector.
Section 8: Modes of contracts	
http://ppp.worldbank.org/public-private-partnership/agreements/management-and-operating-contracts	The PPPIRC website provides a wealth of information related to O&M contracts. It provides examples of O&M contracts for each sector.
European Commission, *Guidelines for successful Public–Private Partnerships*, 2003	This publication addresses five PPP themes: • PPP structure, suitability and success factors • legal and regulatory structures • financial and economic implications of PPPs • integrating grant financing & PPP objectives • conception, planning and implementation

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Appendix A Further guidance on strategic planning and asset management

In planning for maintenance, infrastructure managers must ask themselves the following:

- Why is maintenance important?
- Does my infrastructure plan achieve an appropriate balance between maintenance and new or replacement items?
- What is the minimum level of maintenance I can "get away with"?
- What happens if I fail to achieve the minimum level of maintenance?
- What are the risks associated with "sweating my assets"?

Why is maintenance important?
High-level guidance on the first question is provided in Sections 1 and 2 of this Topic Guide and is also recognised in DFID's infrastructure policy framework (last updated January 2015). In short, maintenance management is part of asset management. Successful asset management will enable a country to optimise the use of its existing infrastructure in support of its economic and social development goals. The other questions need to be assessed separately for each country.

Does my infrastructure plan achieve an appropriate balance between maintenance and new or replacement items?
Asset management analyses, utilising whole-life costing approaches, will guide the decision on achieving a balance between new infrastructure and optimising the use of existing assets. Information provided by infrastructure managers to policy-makers will enable these high-level decisions to be based on suitable evidence such that decisions are appropriate not just for addressing the immediate infrastructure demands, but also for building the infrastructure asset base in a robust manner to support future generations. Policy decisions are then fed down in various ways to infrastructure managers. Increasingly, this is by way of strategic planning.

Strategic planning for infrastructure management involves both public sector and private sector organisations. Most of the tools and concepts of strategic planning were developed in the private sector and there are some differences to be considered when carrying out strategic planning for the public sector. Both public and private organisations are concerned with providing value for their stakeholders while meeting agreed service levels. Private organisations consider value in terms of *outputs*; i.e. products and services provided to their paying customers and return on investment to their investors. For public organisations, the stakeholders are generally the citizenry and value is measured in terms of *outcomes*; i.e. impacts on social groups or conditions.

With respect to infrastructure management, the strategic objectives of both public and private sector organisations are guided by a common purpose: to manage infrastructure assets cost-effectively. Public sector organisations need to achieve this because they typically have inadequate recurrent (O&M) budgets. Deferred maintenance rapidly accumulates and results in the need for either rehabilitation or replacement of assets, both of which are much more expensive than proper preventative maintenance and provide less return on investment in financial and economic terms. There has to be a paradigm shift from putting new projects first to ***prioritising optimisation of existing assets***.

Analyses of strategic options may find that more capital expenditure is required in the immediate future in order to lower subsequent maintenance costs. For example, analyses may determine that many current assets are no longer economically viable, that the costs of maintenance over the next few years would be higher than replacing these assets or that

new assets utilising new technologies or demand management measures would provide significant savings in operational costs, .

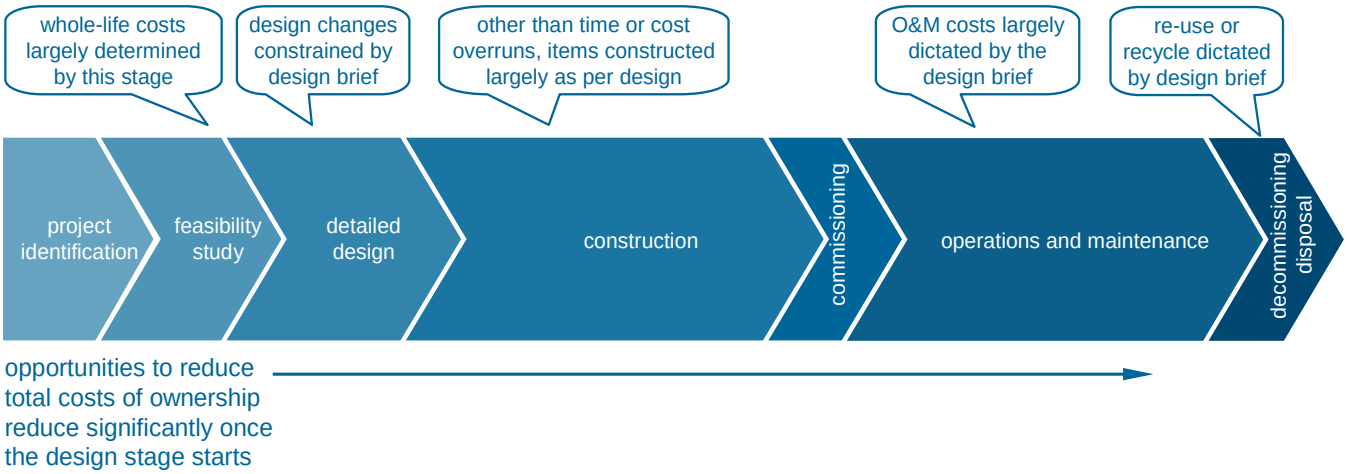


Figure A1 For civil works projects, whole life-cycle costs are determined early on

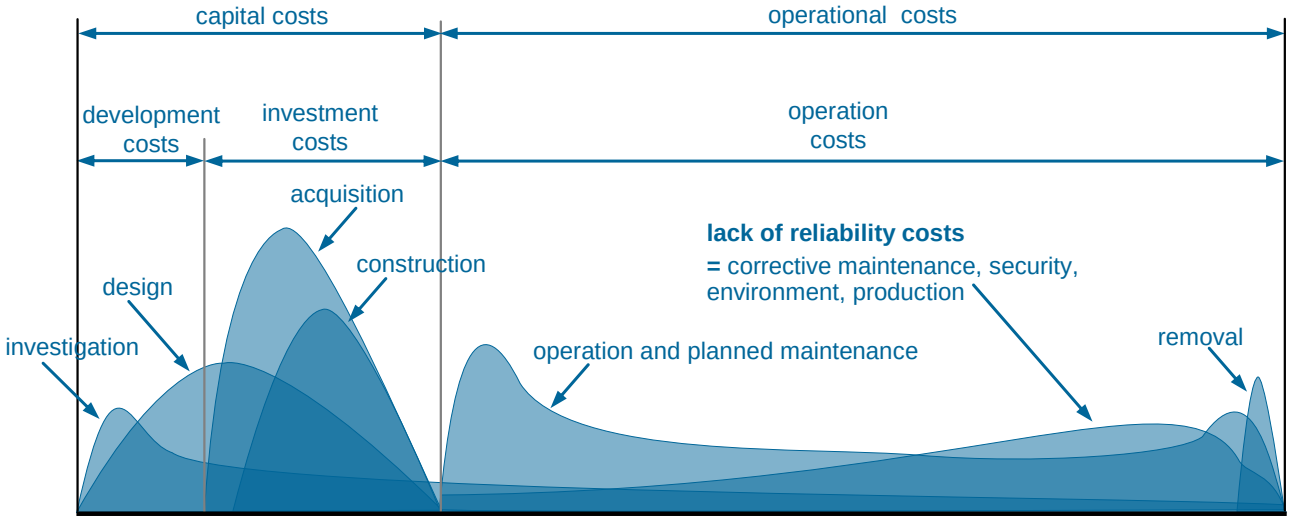


Figure A2 Life-cycle costs of equipment (typical for utility networks)
(adapted from Fernandez and Marquez, 2012)
(costs are not shown proportionally)

Asset management involves making decisions about the interventions that need to be applied to physical assets to achieve an agreed level of service in a manner that optimises these decisions over the life of the asset. As such, asset management is a way to achieve one of the three levers for closing the infrastructure gap, by getting the most out of existing assets. Asset management improves the relevance of the strategic plan.

What is the minimum level of maintenance I can "get away with"?
If the level of maintenance (amount and/or timeliness) provided is less than the optimal amount derived from a whole-life cost analysis (Figure A1) then the overall costs of owning and operating infrastructure will increase over the life of the asset. Providing less than optimum maintenance will reduce the life of the asset; it will deteriorate more quickly. The time at which a decision will have to be made regarding replacement or renewal will occur that much sooner. When insufficient funding is available for replacement of infrastructure

then the owner will typically try to "sweat the assets", meaning doing whatever can be done to keep the assets in service until funding for replacement can be found.

What happens if I fail to achieve the minimum level of maintenance?
Sweating infrastructure assets makes them unreliable. Service breakdowns occur more frequently. Loss of service affects the service provider because of lost income. For example, if the infrastructure is not producing power the owner cannot charge for it. Loss of service also affects households and businesses, health centres and schools, and other users. Overall, economic growth and social development suffer. The result of failing to achieve a minimum level of service in one small component of an infrastructure network can ripple out into much wider impacts in other sectors. The interdependencies between infrastructure were discussed in Section 3.

Appendix B How much money is required for maintaining infrastructure?

A major problem with infrastructure management is that too little money is assigned to maintenance. This leads to two questions:

- How much is actually required for maintenance?
- Why is the required amount not readily provided?

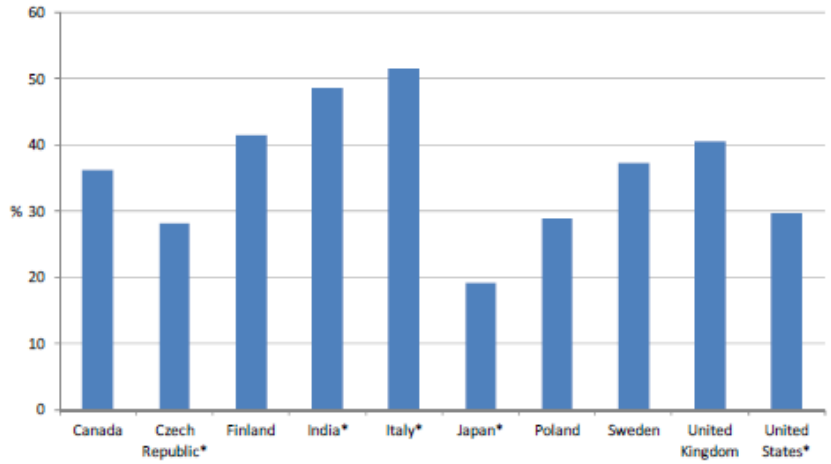
This appendix provides a high level of assessment of the amounts of money required for each infrastructure sector and attempts to address the question of why this amount is not provided.

Roads

How much money is required for maintenance?

A study by the World Bank (2011) stated that African countries have typically spent 1.8% of GDP on their road sector in recent years while achieving growth rates of around 4–6%. This level of expenditure is comparable to countries whose road sectors are already fairly well developed (spending 1–2%) that are achieving growth rates of 2–3%, but below the levels found in faster growing economies (spending 2–3%) with growth rates of 7% or more. To break down the African figures further, South Africa spends less than 1% on its roads and has had growth of 3–5%. The report states that for low-income African countries about around 70% of the investments are allocated to capital projects and the remainder to maintenance, whereas analysis of the roads sector shows that the split should be about 50-50. MICs allocate only around 25% to capital works. Figure B1 shows the range of maintenance share of total road sector expenditures in selected developed countries, which suggests that a share of 2/3 to capital projects is typical in MICs and HICs. But these figures do not take the difference in the actual costs of maintenance in each country into consideration.

Figure B1 Range of maintenance share of total road sector expenditure in HICs & MICs



Note: * 2009 data.

Foster and Briceño (2010) found that LICs spend about 50% more per kilometre than MICs, while countries with road funds and road agencies spend somewhat less than those without these institutions. The unit costs of road maintenance also fluctuate over time and are sensitive to the movement in all prices and costs of aggregate (as well as aggregate haulage distances). The African Development Bank (AfDB) commissioned a study in 2010/2011 to investigate the unit costs of road maintenance throughout the continent. The primary conclusion of this study is that there is no such thing as a "typical" unit cost. This is because (i) unit costs are calculated by standardising projects that are broadly similar but which differ in their design details and specific circumstances; and (ii) the size of the project invariably has an overriding effect on unit rates due to economies of scale.

Geography (terrain, arid vs wet, landlocked vs coastal, etc.) has a direct impact on the costs of road maintenance. The authors of the World Bank report analysed expenditure according to geography and found the following: coastal countries spend close to 50:50 on capital and maintenance works, whereas landlocked countries spend around 3/4 of the investments on capital projects. Similar proportions are spent by flat/dry countries and rolling/humid countries, respectively.

The overall monies required for maintenance can be reduced if unit costs are less. Performance-based maintenance contracts (PBMCs) are gradually being adopted and, where these are maturing, savings in unit maintenance costs of 10–20% are being achieved across developing countries (compared to 10–40% in industrialised countries). There is scope for a lot more improvement in the cost-effectiveness of road maintenance and this in itself would enable more maintenance works to be carried out within the allocated funds. PBMCs are being awarded for periods of between three to ten years. The longer contracts encourage contractors to carry out good quality (durable) preventative maintenance works. This means that, at best, percentages of GDP are only a rough guide to what should be spent on road maintenance.

A better rule of thumb is to take a percentage of the replacement value of the roads. This approach takes into account the geography, road design standards, local unit rates and institutions, since the same parameters apply to reconstruction and maintenance (albeit some differences in the type of works carried out). Studies by the World Bank in the Latin America and the Caribbean region suggest taking 2.5% of current replacement cost and sharing this as 1.5% for maintenance and 1% for rehabilitation. This of course depends on the current state of the network. The World Bank has a road maintenance cost database and the AfDB is developing one. Further research is required to determine suitable rules of thumb for Africa and Asia.

The best way to determine road maintenance costs is to calculate them via a bottom-up approach by calculating the cost of maintenance per kilometre for each category/type of road and then multiplying-up for the whole network. This also affords an opportunity to check the relationship between annual routine and periodic maintenance as a percentage of replacement costs for each road type, taking into account different conditions for highways, rural and urban roads. Having developed indicative figures for a selection of roads, these can then be extrapolated to provide network-wide estimates for maintenance budgets. But until such detailed calculations have been carried out, estimates using the percent GDP and percent replacement cost will provide a guide as to the costs withinan order of magnitude per country, which can be cross-checked against the studies by Foster, Briceño and others.

Why is the required amount not readily available?

The same 2011 World Bank study found that institutions play an important role in determining the proportion of road expenditures. Countries with road agencies, but no road fund, allocate about 86% of sector expenditures to capital projects compared to 64% in those with a road fund but no road agency. With both road fund and road agency the capital projects portion drops to 58%. The amount of fuel levy collected into road funds also influences the amount spent on capital vs maintenance works. High fuel levies result in 55% of the funds being spent on maintenance, whereas with low fuel levies only 28% goes to maintenance, compared to just 15% spent on maintenance in countries with no fuel levy. The lowest fuel levy collected is just US$0.03 per litre and the highest fuel levy is US$0.16 per litre; the latter covers most but not all road maintenance needs. The user-pays principle does work when road users are properly informed as to the benefits of good road maintenance and when they see that their fuel levy payments are actually achieving the promised results.

Various factors impede the collection of fuel levies, including evasion and severe delays in transferring monies from the collection agency to the road fund account. But World Bank analyses and studies by others demonstrate that having the right institutions in place for collecting road maintenance monies and efficiently procuring and managing well-designed road maintenance contracts make a huge difference to attracting adequate maintenance monies. One problem is political bias. Capital projects show almost immediate results, whereas maintenance works often show only a modest and short-lived improvement. Longer-term maintenance contracts have the potential to gradually improve the condition of a road over time, but then retaining the road in that condition with a total cost far less than would have been spent for rehabilitation of the road (after which it would have started to deteriorate again in the absence of adequate maintenance monies).

Some people ask why more roads are not tolled. There is little scope for increasing toll roads in Sub-Saharan Africa where only 10% of the roads carry more than 15,000 vehicles per day, the level at which the World Bank suggests that concessions become economically viable (taking into account the costs of collecting the tolls). On this basis, only a few roads in South Africa and perhaps in Nigeria would be viable for tolling.

In summary, for roads, developing countries need to spend at least 1.5% of GDP or 1.5% of road replacement cost on maintenance, and have effective institutions in place to ensure that user fees are collected via a road fund (rather than from general taxation) and actually transferred to and spent by a capable road agency. This includes having appropriate mechanisms for identifying and prioritising maintenance interventions, and efficient means of procuring and managing longer-term PBCs. Within this context, the establishment of road funds for a user-pays approach, and road agencies along with long-term PBMC contracts, is about as far as the roads sector can go for the foreseeable future in terms of managing the sector like a utility.

Railways

How much money is required for maintenance?

At the end of 2008 there were 52 railways operating in 33 countries across Africa. The network is mostly single-track. The network density, either on a spatial or population basis, is low compared to almost all developing countries. But investment in extending the rail network, or adding new sub-networks, depends on demand. A minimum level of traffic is required to make such investments viable. In 1976, the Union of African Railways had produced a master plan for 26,000 km of new network. That plan was never implemented and currently they are concentrating on ten corridors. Several proposals have been made for individual sections. Mining companies have proposed a number of dedicated lines. Some of these routes would compete with existing routes and Foster remarks that few of these are likely to be financially or economically viable.

Of the total Africa network of 69,000 km, only 55,000 (80%) is in operation; excluding South Africa the total network is 44,000 km of which 34,000 km is operational. Long-term neglect of maintenance has resulted in a huge backlog amounting to an estimated US$3 billion. Foster suggests addressing this over a ten-year period at a manageable rate of US$300 million per year.

From the overall levels of traffic for Sub-Saharan African railways, excluding South Africa, Foster calculated that the annual steady-state investment for facilities, maintenance, equipment and other costs is around US$20 million per year. Foster does not provide a breakdown of this figure for the maintenance portion, but US$20 million per year equates to about US$450 per km per year for recurrent costs.

Why is the required amount not readily available?
Excluding South Africa, reconstruction of railways would cost about US$350,000 per kilometre and would have a lifespan of 40–50 years due to the generally low traffic volumes, equating to an annualised cost of US$8,000 per kilometre. Foster remarks that few lines that carry less than 1 million net tons per year would warrant this level of rehabilitation. Lines would need to earn US$0.08 per ton-km to pay for the reconstruction works. Typical rail freight tariffs, however, are around US$0.05 per ton-km. Foster suggests that the cost of reconstruction could be reduced from US$0.08 to US$0.04 per ton-km or passenger-km by using second-hand items for rehabilitation. Lines with less than 250,000 tons per year probably could not justify anything more than routine maintenance.

The author has not located similar data for Asia and Latin America, but the situations are anticipated to be similar to Sub-Saharan Africa.

Ports

How much money is required for maintenance?
Data for the costs of port maintenance are hard to find, especially for making global comparisons. But some operating costs are available. Increased security demands (ISPS Code) have increased operating costs and can be expensive. The United Nations Conference on Trade and Development found that the cost of compliance is around US$3.60 per twenty-foot equivalent unit of container traffic and US$0.08 per ton of cargo, although separate studies for African ports suggest up to US$2.00 and US$0.05, respectively. Cargo and container-handling charges in Africa are higher than elsewhere. According to Gwilliam, this is largely due to technical and institutional deficiencies. Cargo handling per ton is US$6–15 versus US$6–9 elsewhere, and per container US$100–300 compared to US$80–100 elsewhere.

Foster reports that port usage is around 80% across Africa with no significant changes envisaged in the near future, but there are opportunities to improve productivity. Productivity could be increased by at least 50%, even in better-managed ports like Durban. Foster also reports that weak capacity, including maintenance capabilities, is a major constraint. Unfortunately, Foster and Briceño or Gwilliam provide no specific figures for port maintenance costs.

Why is the required amount not readily available?
For maintenance of African ports, the monopolies both in the public and private sector (and, for example, where there is just a single port in a country) mean that it should be possible for O&M costs to be covered from port revenues without the need for subsidies, especially if efficiencies are introduced. Port operations in South Africa are provided by an organisation that is responsible for rail and pipelines and operates a system of cross subsidising, but details are not known.

Power

How much money is required for maintenance?
Between 2001 and 2005, at least half of the economies in Sub-Saharan Africa grew at a rate of 4.5% per year. Their demand for energy grew at the same rate, but the energy sector increased capacity by just 1.2%. Operational inefficiencies and under-pricing results in revenue losses of US$3.3 billion and US$2.2 billion, respectively, per year. Foster reports that consumers could afford to pay prices that fully recover costs in countries with efficient large-scale hydropower or coal-based systems, but consumers in countries relying on small-scale oil-based plants could not. Foster and Briceño estimated the average O&M requirements in the power sector across Sub-Saharan to be 2.2% of GDP (US$14 billion); more precisely, 2.9% for MICs and 1.8–2.0% for LICs.

Why is the required amount not readily available?
Existing spending on the power sector in Sub-Saharan Africa amounts to US$11.6 billion, of which US$7 billion is for O&M. High-cost generation solutions mean that most of this is for operating costs. Even if all the inefficiencies were addressed and a further US$0.3 billion obtained from better spending of the capital budget, Foster estimates that the remaining spending gap for O&M is US$5.6 billion, representing 0.9% of regional GDP, ranging between 0.2% for LICs to 1.9% for MICs. These are not the current figures, however; they are the figures after addressing the capital-spending gap.

There are, however, some success stories. Kenya introduced a new power act in 1997, leading to unbundling of the sector the following year. The generation company is now 30% privately owned, and the transmission and distribution company 51%. Four independent power producers provide 12% of total power supply and three others are applying for licences. Losses on the transmission and distribution side have fallen from 1.4% of GDP in 2000 to about 0.1% in 2008 (including improvements in revenue collection from 81% to 100%). Power pricing tariffs rose in line with rising costs, from US$0.07 in 2000 to US$0.20 in 2008. The overall economy has benefited by over 1%.

Private sector involvement is not necessary for improvements in the power sector, as Botswana's state-owned power company shows. Formed in 1970 and responsible for generation and transmission, the state power company had extended access to power to 70% of the population by 2009 and aims to achieve 100% coverage by 2016. System losses are only around 10%, in line with the sector norm and less the half Africa's average of 23.3%. Part of Botswana's success is due to cheap imported power from South Africa, which power shortages in South Africa could threaten.

Power prices have risen substantially across Africa in recent years but have failed to keep pace with rising costs, especially when oil prices have been high. Foster's study showed that operating cost-recovery strongly drives power pricing. No mention is made of the maintenance component. But with the introduction of more cost-efficient technologies, and improvements in operational efficiencies and revenue collections, the unit costs of power should become more affordable and cost recovery more successful. But power company pricing and customer payments will be subject to effective tariff structuring. Customer power bills are closely linked to GDP per capita. With reliable, affordable power, businesses should be more competitive and customers should benefit. As the economy grows (due, of course, to many other inputs) customers' ability to pay power bills will improve but their demand for power will also rise. Provided that these increases are met appropriately, Foster suggests that monthly bills should fall from previous figures of around US$7–10 per month to a level where all but the poorest 25% of the population could afford subsistence power consumption levels. If regional trade in power is fully pursued to optimise production costs, then full cost recovery should be achievable.

Water

How much money is required for maintenance?
Currently, Sub-Saharan Africa spends just US$3.6 billion annually on water supply. This expenditure meets only one-quarter of requirements. Sector inefficiencies waste US$2.7 billion. Hutton and Haller (2004) reported that every dollar invested in water supply generates US$1.50 in economic benefits. Average water tariffs in the region are US$0.67 per cubic metre, which is below the full cost-recovery rate of US$1.00 (for comparison, the current cost in the UK is around US$1.90). Sub-Saharan Africa needs US$5.5 billion annually to address O&M needs, equal to 0.86% of GDP.

Why is the required amount not readily available?
Foster reports that the key to addressing inefficiencies in the water sector lies in institutional reforms of the legislative and regulatory frameworks. Public sector players are expected to continue to dominate the sector and governance reforms are required to improve their operational capacities in order to address expensive operational inefficiencies. But private sector participation could further improve sector performance. The institutional reforms must be from top to bottom, starting with policies and the roles and performance of the respective line ministries.

It is not just line ministries in the water sector that need to change. There must be a cross-sector response to the water supply challenge that addresses the rapid increase in demand due to urbanisation, the challenges of reaching the rural poor, and the needs of the agricultural sector.

Sanitation

How much money is required for maintenance?
The MDG goal for sanitation is to halve the number of households that were without improved sanitation in 1990. Eight percent of the urban population and 41% of the rural population in Sub-Saharan Africa still practice open defecation. To meet the MDG target will require about 0.9% of GDP annually, of which 0.7% is for improvements and 0.2% for O&M (about US$1.2 billion).

Why is the required amount not readily available?
Foster and Briceño found that the policy changes required to improve sanitation differed substantially between countries and between urban and rural areas. The ultimate objective should be to increase public education and to eliminate open defecation. This requires a top-down policy approach as well as a bottom-up community-demand approach. Extensive involvement at the community level and education about proper hygiene habits can produce dramatic results. Ethiopia is quoted as a good example, where between 2003 and 2005 latrine coverage increased from 13 to 78%.

Irrigation

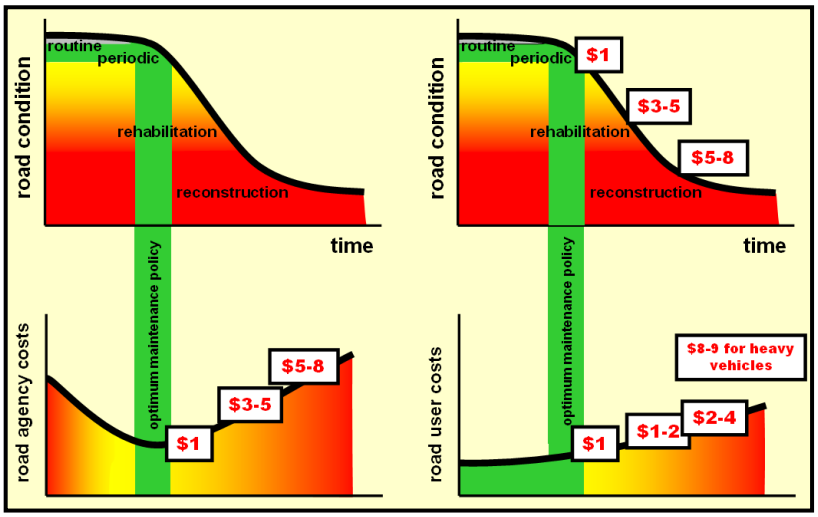
While power, water and sanitation are Africa's biggest challenges, the challenge of planning and financing maintenance of infrastructure for irrigation could be far more easily overcome, and could have a huge positive impact. The author could not find data to provide the same discussions as for the foregoing sectors, but some startling facts are available.

Over half of the unused arable land in the world is in Africa. Much of this is in need of irrigation. Increasing yields by 50% via irrigation, improved seeds and fertilisers, (and various institutional and cultural issues), could transform Africa from food deficit to food surplus. The additional incomes at household levels would relieve poverty, while taxes from food exports would provide revenue for subsidising the power, and water and sanitation sectors. While it may not remove entirely the need for subsidies for the very poor, along with addressing the infrastructure efficiency gap and reducing corruption, infrastructure costs would become more affordable. Climate change could actually help some areas that are currently arid and research projects are underway across Africa to locate so far unknown underground water reserves.

Appendix B2 Maintenance financing: further considerations

Financial benefits of preventative maintenance *(an example from the roads sector)*
Due to neglect of maintenance in past years, road rehabilitation costs are far higher than they should be. Failure to collect and properly spend US$500 million annually on road maintenance across Africa has resulted in around US$2 billion for rehabilitation per year; i.e. about US$4 for every dollar not spent on preventative maintenance (Figure B2). Periodic maintenance carried out too soon means the road agency is spending more than necessary without any great benefit to road users. Periodic maintenance carried out too late means that the amount of work needed and the costs to the road agency increase rapidly. At the same time, the damage to the road surface increases costs to road users.

Figure B2 Illustration of optimum timing for road maintenance interventions (Source: Author)



Making best use of the revenues that are collected is clearly a necessity. Road maintenance can be either equipment-based or labour-based. In cases where the pavement is not of a high technical specification, labour-based methods can provide a more cost-effective means of construction and maintenance and can directly benefit local communities in terms of providing income opportunities. The DFID-funded Rural Access Programme project in Nepal aims to provide almost 4 million employment days during a five-year period.

Making the best use of maintenance funding
The traditional sources of finance for maintenance of public works are public **taxes and user fees** (for utilities). In terms of additional sources of financing, Fay et al suggest that under certain circumstances (such as in Ethiopia) sources of **climate change finance** could provide additional funding for maintenance. But financing should not be left until after maintenance plans have been developed. To be realistic, maintenance plans must be developed using "constrained budget" scenarios that reflect the likely magnitude of maintenance financing and any interruptions that the flow of finance may experience, for example during the change from one fiscal year budget to the next.

Non-OECD finance has increased in recent years, particularly from China and India. China has proposed a new Asian Infrastructure Investment Bank, on similar lines to the ADB, but this is therefore unlikely to assist with developing countries' maintenance financing challenges. Another option is **direct budgetary support**, earmarked to support specific areas of infrastructure maintenance, but this should be conditional on the recipient government addressing its efficiency gaps.

For the roads sector, during the past two decades **road funds** have mirrored the user-pays principle of utilities to provide more reliable road maintenance funding. Results have not been as positive as hoped for, but the overall amount of monies collected via road funds that find their way into actual road maintenance works is somewhat greater than under the government recurrent budget situations. Earlier attempts at implementing (first generation)

road funds were based on earmarking or ring-fencing portions of the recurrent maintenance budget. As these monies were not protected by law they were easily dipped into and used for non-road purposes resulting in insufficient maintenance funding. The second generation road funds established off-budget accounts protected by legislation and managed by Road Fund Boards that comprised representatives of government's main sector ministries including the finance ministry, as well as representatives of road users (taxi and bus operators, agricultural co-ops and haulage contractors, tourism industry, etc.). Road user representation on road fund boards ensures that user concerns are included in discussions on maintenance priorities. It also helps the heavy-axle road users to understand the damage that their vehicles cause to a road pavement and engages their support in the demand management side of road pavement management.

Public–private partnerships (PPPs) that cover the whole life cycle of assets provide more reliable sources of maintenance financing than government recurrent budgets. But in all cases significant untapped revenue will come from addressing the **infrastructure efficiency gap**, which could typically stretch existing maintenance funds by the equivalent of 1–2% of GDP. Foster and Briceño-Garmendia (2010) found that improving efficiency and reducing corruption in Sub-Saharan Africa could cut costs and subsidies by 8%. Drawing further on their work and the work of others, there are many ways in which the infrastructure efficiency gap can be closed or at least significantly reduced in order to make maintenance monies go further:

- improve budget execution rates
- reallocate existing spending toward infrastructure most in need (therefore with the highest economic returns)
- increase user charges closer to cost recovery levels where affordable (to provide more efficient price signals and capture lost revenues) and carefully design/manage subsidies
- reduce operational and maintenance inefficiencies of utilities and other service providers including distribution losses and illegal connections (to prevent wastage of resources, support healthier utilities, improve service quality and value for money to the customers)
- reduce over-employment in state-run utilities
- increase revenue collection rates
- reduce corruption and poor procurement practices
- implement effective asset management to optimise financing decisions and asset life
- recycle old assets (including the sale of items no longer fit for purpose)
- recycle solid waste, water and construction materials (including selling to other users)

While the main components of maintenance costs for all infrastructure assets are labour, materials and equipment, there are many factors that impact the magnitude of these costs:

- technical design of the infrastructure components
- standard of construction or assembly
- current age and condition of the infrastructure assets
- size and scope of the infrastructure (i.e. economies of scale and the use of mechanised methods versus labour-based methods)
- service effectiveness (technical appropriateness and quality of previous repair works)
- timeliness and thoroughness/appropriateness of previous maintenance interventions

And these issues are affected by:

- institutional framework (ensure appropriate policies, legislation/regulation, etc.)
- availability and adequacy of maintenance monies
- costs and availability of materials and replacement parts

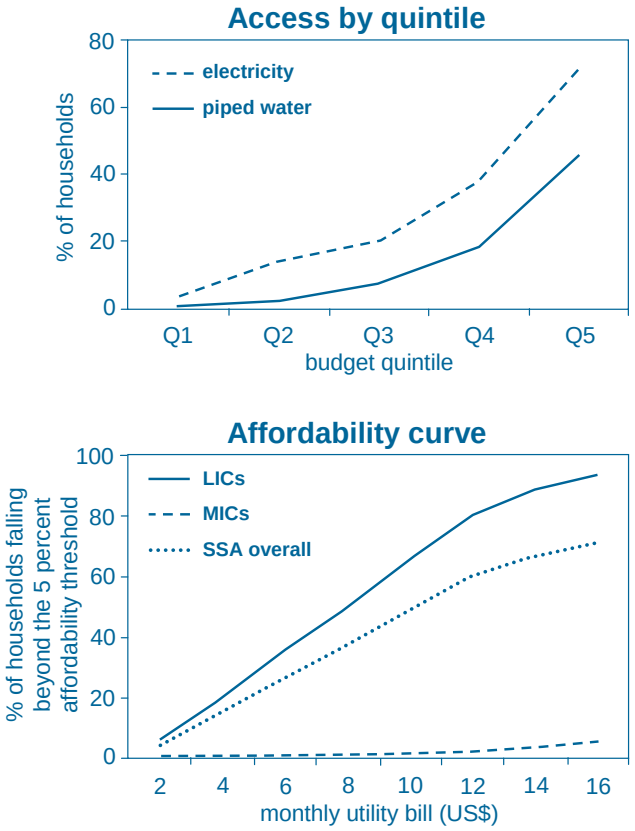
- location of the infrastructure (use remote sensing where appropriate to at least reduce inspection costs, while increasing frequency of surveys)

For small island states it is difficult to benefit from economies of scale and the unit costs of maintenance are almost unavoidably high, particularly when materials have to be imported. Similarly, the costs of materials, replacement components and equipment to landlocked countries are higher. In fragile states the location of infrastructure can cause contractors to place a high margin on work to reflect the risks to equipment and manpower. Many separate contracts rather than a few larger contracts also suffer from lack of economy of scale.

Assisting the poor via appropriate tariff setting

Africa's power and water utilities are characterised by high inefficiencies and distribution losses, over-staffing and under-collection of revenues. Foster, Briceño and Gwilliam found that utilities typically collect only 70–90% of billed revenues. State-owned telecommunication companies employ six times as many employees as privately-owned companies. For all countries in Africa, and other LICs, the revenues to be gained by addressing these inefficiencies are substantial.

Figure B3 Access to and affordability of household services (Adapted from Foster et al)



Tariffs are necessary to cover the costs of operations and maintenance, but there are occasions when subsidies are required to support the poor who do not have sufficient resources to pay for basic infrastructure services. The problem is in designing an effective subsidy system. A huge problem of rural poverty is that infrastructure does not reach the rural poor, and that which does is beyond their means to pay if full cost recovery is imposed. Across Africa, typically the upper three quintiles of the population connect to water and power services, so it is these households that benefit from subsidies, not the poorest quintiles who receive few services. Under-pricing of services in Africa costs US$4.7 billion per year. Although the issues need to be examined on a per country basis, simulations suggest that raising tariffs to full cost recovery would have only minimal effects on poverty rates[48]. Subsidies are important, but subsidy design needs major rethinking, with a sharper focus on subsidising connections, which can be more equitable and effective in expanding coverage. Chisari et al [49] studied access and consumption affordability in Latin America and found that the two are related. They found that residential users were more often exposed to increasing connection charges than commercial customers, particularly where this element had previously been subsidised. They looked at how subsidies and service obligations could be designed, imposed and financed to increase service coverage for water, power or telecommunications. Cheaper technologies and financing schemes can

48 Foster V., and Briceño-Garmendia C (2010), "Africa's Infrastructure: A Time for Transformation"

49 Chisari O, Estache A, and Price C W (2001), "Access by the Poor in Latin America's Utility Reform"

assist in increasing coverage but, once connected, penalties for arrears in consumption charges can be unbearable for the poor; how to protect them and the utility company from such delinquency? Four financing systems were proposed to assist the poor with connection payments to achieve Universal Service Obligation (USO):

- cross-subsidies among consumers and/or across products/services
- direct transfers either to consumers or through company disbursements
- setting up a specific fund, financed from suppliers or government
- extension of the concession

Chisari states that tailored programmes are required to achieve USO effectively.

Appendix C Options for maintenance management organisations

Public organisation (centralised vs decentralised)

Decentralisation is now widely present in developing countries. The objective is to localise decision-making and accountability, and to be more responsive to local needs and priorities. Local decision-makers are usually elected and accountable to the electorate whose taxes pay their salaries and pay for infrastructure provided by the local administration. In comparison, central decision-makers, appointed centrally, have less interest in the needs and priorities of local people.

The World Bank and others have investigated decentralisation[50] to examine the impact on the costs of providing and managing infrastructure. They found that decentralisation tends to increase both total and sub-national spending on infrastructure[51]. Decentralisation increases spending on infrastructure if sub-national governments place a higher priority on infrastructure than the national government, if they are less effective at delivering and managing the infrastructure services, or if they forego economies of scale to achieve greater autonomy. The spending on infrastructure reduces if the opposite effects exist. Bird (1995) concluded that a primary factor in effective decentralised infrastructure decision-making is that institutions must be in place to make the decision-makers fully accountable in both financial and political terms. In addition, the costs of the infrastructure and services must be borne by those who benefit from them by suitable local taxes, user charges (for non-resident beneficiaries) and other fees. The local budgeting, financial reporting, taxation, contracting, dispute resolution, rules for tariffs, etc., must all be founded on clear and enforceable legislation. Where decentralisation would result in the transfer of infrastructure maintenance responsibilities to small administrations then consideration must be given to providing adequate maintenance financing. Poor local communities may not be able to pay for water, power and road infrastructure on a user-pays basis based on full cost recovery. In these circumstances, consideration could be given to a mix of user-pays and indirect subsidising via general taxation.

Reforms to bring about decentralisation must be tailored to local circumstances. When considering decentralisation as a way to improve the management of infrastructure and infrastructure services, various scenarios should be assessed and subjected to risk analysis. These should include imbalances in expenditure decentralisation versus revenue decentralisation, the ability of decentralised organisations to raise additional revenues and their abilities to borrow (and pay back) and the ability to attract, retain and motivate suitable numbers of professional staff. Decentralisation cannot be fully successful unless there is change in both the local and central administrations. This may include budgetary changes so that appropriate levels and continuity of funding exist at the local levels.

A common problem of decentralised infrastructure management in the public sector is the lack of capacity to make technically effective and cost-efficient infrastructure procurement decisions (decisions are often based only on initial price, not whole life costs). While infrastructure management may be contracted out to consulting firms, there is sometimes not even the capabilities in the client public sector organisation to write appropriate terms of reference and contracts for procuring these services. This is where bilateral development partners can help, by providing support to get the right consultants and contractors in place.

50 "Decentralising Infrastructure: Advantages and Limitations" (1995), World Bank Discussion Paper 290, edited by Estache A

51 Estache A and Sinha S (1999), "Does Decentralisation increase spending on infrastructure?" World Bank Policy Research Paper 1457

When the private sector is contracted to manage and/or implement infrastructure maintenance, then the key issues to be overseen by the public sector client (centralised or decentralised departments) are the service level agreements, adherence to the regulatory framework, and meeting contractual obligations under any concession arrangement, including levels of investment, costs to consumers, and safety standards. To achieve this it must have the appropriate capacities in all technical, managerial and financial areas. These companies are answerable to their shareholders whose opinions may be stronger than even local taxpayers, making the company management even more accountable than locally elected officials.

Parastatals and SOEs

Parastatal organisations can introduce commercial management principles without fully privatising or using a public–private partnership arrangement. Government may establish a company under the Companies Act, which retains all or most of the shares in the hands of government. This is a way toward full privatisation if government decides later to sell its remaining shares. The company is financially responsible for reporting on its affairs just as any other registered company in the country. Alternatively, government may wish to pass legislation to establish the infrastructure organisation as a statutory authority. This bespoke legislation can be tailored to suit the needs of the sector and may be just for maintenance of infrastructure whose ownership remains with government (e.g. a road network), or for ownership and management of the assets (e.g. a utility authority for power supply or water supply). It is also possible to vest the infrastructure assets in the statutory authority. The authority has the option under its bespoke legislation to carry out the maintenance itself or to contract out.

State-owned enterprises (SOEs) should be avoided where there is a conflict of interest between the client and provider of maintenance services. SOEs typically remain under strong political influence. Experience shows that attempts to reform SOEs that fall short of privatisation tend to eventually slide back into the poor performance that characterised the SOEs pre-reform. In some countries that do not have a well-established maintenance contracting private sector, multilateral donors have tried to introduce improved governance by, for example, limiting tenders to SOEs from neighbouring provinces. This does not succeed where there is an insufficient number of SOEs (and/or private companies) to result in fair and transparent tender competition.

Commercialisation vs privatisation

Commercialisation means introducing commercial business principles to government agencies, for example ministerial departments or executive agencies. Privatisation means transferring the responsibility for infrastructure from an in-house department or agency to an external company; the company maybe government-owned, privately-owned or part-government and part-private owned.

Commercialisation without changes to staff means training existing staff in a very different way of planning, managing and operating infrastructure. It is hard to change a long-established public sector management culture and staff who have no experience of a corporate way of thinking. Since the early 1990s, the transition economies have been evolving from centrally planned systems to market-oriented systems. To facilitate and accelerate the process, institutional reforms have generally focussed on the separation of (1) policy formulation, ownership and administration of infrastructure sectors among government ministries, (2) the corporatised service providing entities (for O&M), and (3) the regulatory bodies (for tariffs and sector regulation).

Why privatise? Because ownership is a significant determinant of enterprise performance. In both developed and developing countries, good SOE performance has been very difficult to bring about and even harder to sustain. The same is true with respect to institutional strengthening of government departments responsible for infrastructure maintenance. When trying to develop government departments or SOEs one must consider the internal capabilities (strengths and weaknesses) and the external conditions that enable or constrain their performance (opportunities and threats). In undertaking institutional reviews these formal parameters are the relatively straightforward items to assess as they are easy to identify. The items that are more difficult to identify are the informal institutions, including cultural and societal norms, corruption, and so on. Corruption is not just actions that involve the transfer of money; it is anything that unduly influences a decision.

When the market is dominated by just a few private sector players then the forces of competition may not by themselves be sufficiently effective at ensuring service quality and value for money to customers, in which case government will need to regulate the services. In addition to regulating cost and quality, regulation can be employed to control the use of natural resources, ensure adequate levels of investment in infrastructure, the use or prohibition of certain technologies, impose employment and production norms, ensure universal access (within the network area assigned to the private sector), and to protect societal, heritage and/or environmental artefacts.

With increasing private sector involvement in the management of infrastructure and network utilities, maintenance has evolved from being considered as a necessary evil. Companies seeking operating margins, increased operational efficiency and competitive advantage take maintenance seriously. Within an asset management framework there is an attempt to increase preventative maintenance. One of the facts that underlines the importance of maintenance is its impact on GDP. In Spain, estimates indicate that effective maintenance contributes around 9.4% to GDP. Return on investment to investors, ranges typically 10–40% across all infrastructure. Murthy et al (2002) found that maintenance has a multiplying effect on business performance. A 1% improvement in infrastructure performance due to maintenance can result in 3% increase in business productivity. The maintenance department is no longer the 'poor cousin', saddled with huge challenges and meagre resources (including old equipment, grossly inadequate budgets and staff shortages). The commercial focus of utility companies and increasingly non-utility infrastructure organisations recognises that the huge benefits of pre-emptive maintenance in terms of return on investment compared to the very much lower returns from corrective maintenance and rehabilitation. The maintenance department now tends to be fully integrated into the core of the organisation with the following benefits:

- effective maintenance leadership and interaction with senior management
- support for increasing productivity and cost-efficiency
- reduction in overall equipment/machinery/plant emergencies
- accident reduction
- financial verification of the cost benefits of effective maintenance, as well as the reputational benefits that support competitive advantage and stakeholder satisfaction

Steps to reform (commercialisation and privatisation) have generally included:

(a) enacting legislation for reform;
(b) corporatising the service providing entities with their own legal identities under company law;
(c) commercialising their functions;
(d) unbundling monopolistic services by function, setting up corporate entities for each function and creation of commercial relations among them;

(e) creating independent regulatory bodies to set prices and carry out sector regulation;
(f) creating sector structures suitable for competition in those segments where competition is possible, and
(g) privatising the supply entities to strategic investors to secure investments, improve efficiency and enable competition within and across the borders.

Transition indicators have been developed to track progress along these transition paths. However, transition indicators imply equal expectations for transition end points. Each country needs to consider its system size, location in relation to relevant natural resources, technical skills, local and national government capacity for governance in designing the balance between public and private provision of the services, and for each the specific organisation and regulation. Larger systems have more scope for capturing gains from commercialised or private organisations. While all these reform steps are desirable, not all of them are considered critical (or the only alternative) to ensure that infrastructure sectors function effectively. Previous West European infrastructure sectors were able to operate at high levels of effectiveness and efficiency even as state-owned monopolies. The effectiveness and efficiency of their management systems were superior to those in the transition economies, so they had stronger foundations for progressing along the transition path through commercialisation to privatisation. They commenced with de-monopolisation and introduction of competition in search of further efficiency gains. There is no reason why transition economies should not leapfrog to current best-practice organisation structures and competitive provision of services. However, it may be more practical for reform efforts to focus initially on the critical factors which must be in place to ensure that the infrastructure service entities (whether owned and operated by public or private sector) function effectively on a financially sustainable basis.

The central objective to be achieved via commercialisation or privatisation is the sustained financial viability of the entities providing infrastructure services while providing quality services for fee-paying customers. World Bank experiences in the commercialisation and privatisation reforms in transition economies identify four critical success factors:

1. recognition of the existing key problems in the context of the internal and external operating environments
2. "ownership" of the commercialisation or privatisation programme (including payment discipline, tariff adjustments, and fair regulation) and commitment to its implementation
3. transparency in all transactions to enable meaningful accountability
4. strengthened governance, adequate to ensure effective sector management including the oversight of the agencies to ensure that they provide the services to their customers at acceptable levels of quality, reliability and value for money

These four factors are the basis on which all infrastructure service delivery systems must be developed (public, private, monopolistic, unbundled or competitive). They also include corporate governance and public enterprise reform in respect of entities remaining in the public sector.

Private vs public

The World Bank supports privatisation in over 60 countries. From their experiences, they consider the key factors for successful privatisation of government departments or SOEs are:

1. when privatisation is part of a larger program of reforms promoting efficiency
2. regulation is critical to the successful privatisation of monopolies

3. countries can benefit from privatising management without privatising the ownership of assets
4. the sale of large enterprises requires considerable preparation
5. transparency is critical for economic and political success
6. governments must pay special attention to developing a social safety net
7. the formerly socialist economies should privatise in all possible ways that encourage competition, and they should experiment with all available methods that go beyond a case-by-case approach to privatisation
8. in changing the public–private mix in any type of economy, privatisation will sometimes be less important than the emergence of new private businesses

It is possible for governments to mix public and private sector models. For example, government or a statutory authority might own infrastructure assets, such as a power station and distribution grid, while permitting private companies to provide sub-systems such as wind turbines that connect into the main grid. Special economic zones often have their own infrastructure of sufficient capacity and reliability to meet user needs in full. Stand-alone infrastructure is a way of attracting inward investment in industry, but services usually remain separate from the national networks.

This has been successfully challenged on several projects in Africa[52].

[52] Andreski A, (2014), "What's wrong with road construction in Africa?", Cardno IT Transport

Appendix D Further discussion on public–private partnership (PPP) contracts

PPPs cover the whole life cycle of an infrastructure asset and include O&M. PPPs are developing innovative approaches and already use a range of financial and risk management models. PPPs are often complex to design, implement and manage. The multilateral donors each have PPP advisory units and these have websites, for example, the PPPIRC at http://ppp.worldbank.org/public-private-partnership/. PPPs bring together (or "bundle") project managers, construction companies, maintenance companies and financiers to provide a public service or project, where the public sector does not have the finance and/or technical skills to carry out the project. Figure D1 provides summary guidance on issues to consider when determining a likely PPP candidate project.

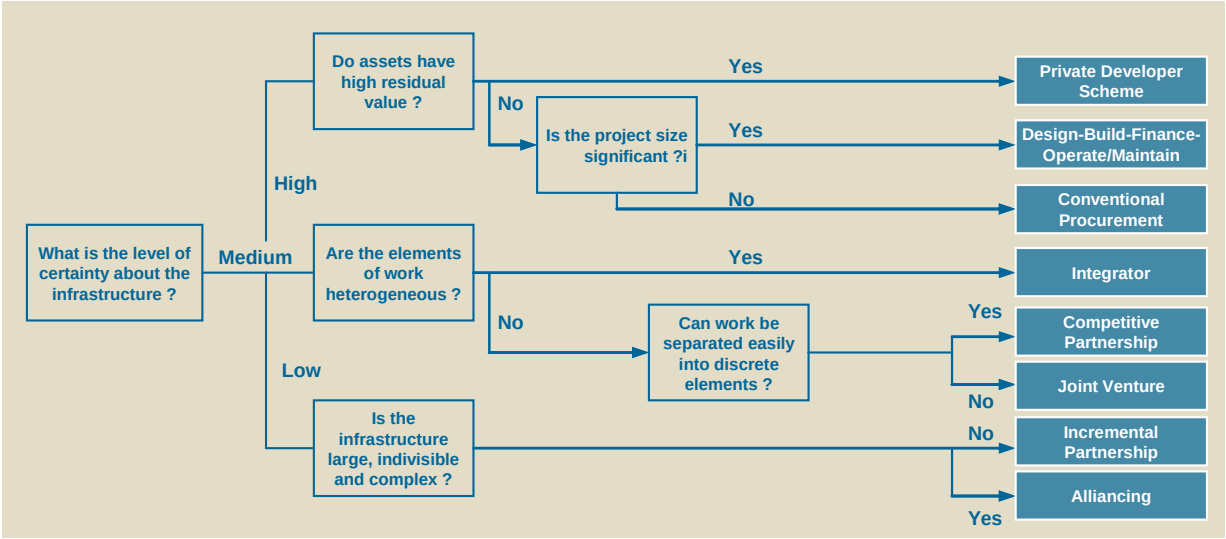


Figure D1 Selecting an appropriate PPP model

The extent of private sector involvement varies according to the model chosen (Figure D2). With each model, the proportion of risk varies between the public and private parties (Figure D3). Figure D4 summarises the key features of the more popular PPP models.

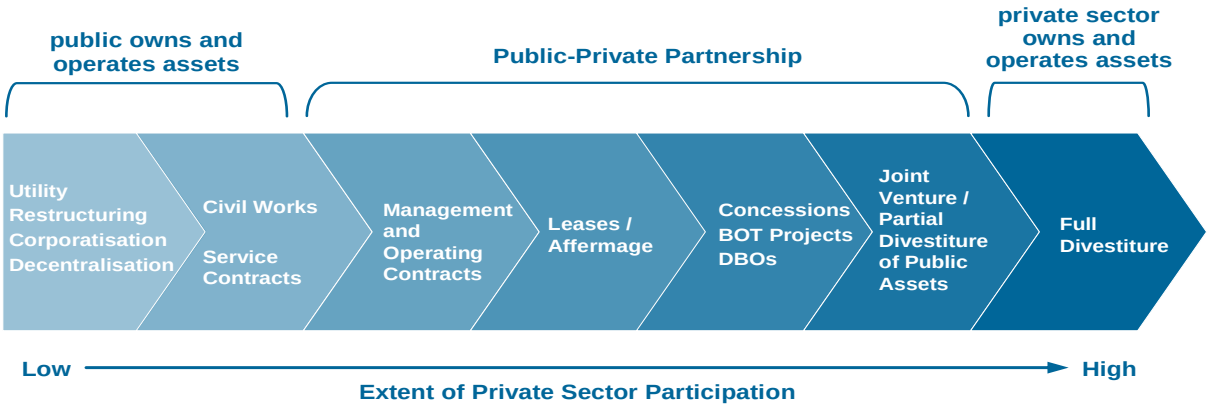
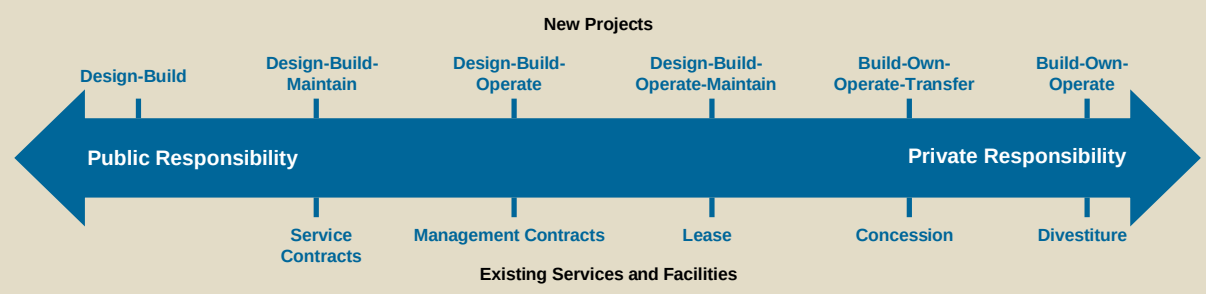


Figure D2: Extent of private sector participation in various PPP models

Figure D3 Distribution of public–private risk in various PPP models



PPPs are characterised by independent management, bundling of construction and operations, and the subcontracting of most of the production processes. A more detailed discussion of the options for public–private partnerships in infrastructure is provided by Delmon (2010)[53].

Figure D4 Examples of PPP models in use around the world

Public-Private Partnerships

A public-private partnership, or PPP, refers to a contractual agreement formed between a government agency and a private sector entity that allows for greater private sector participation in the delivery of public infrastructure projects. In some countries involvement of private financing is what makes a project a PPP. PPPs are used around the world to build new and upgrade existing public facilities such as schools, hospitals, roads, waste and water treatment plants and prisons, among other things. Compared with traditional procurement models, the private sector assumes a greater role in the planning, financing, design, construction, operation, and maintenance of public facilities. Risk associated with the project is transferred to the party best positioned to manage it. Some of the most common PPP models are described below.

Design-Build (DB): Under this model, the government contracts with a private partner to design and build a facility in accordance with the requirements set by the government. After completing the facility, the government assumes responsibility for operating and maintaining the facility. This method of procurement is also referred to as Build-Transfer (BT).

Design-Build-Maintain (DBM): This model is similar to Design-Build except that the private sector also maintains the facility. The public sector retains responsibility for operations.

Design-Build-Operate (DBO): Under this model, the private sector designs and builds a facility. Once the facility is completed, the title for the new facility is transferred to the public sector, while the private sector operates the facility for a specified period. This procurement model is also referred to as Build-Transfer-Operate (BTO).

Design-Build-Operate-Maintain (DBOM): This model combines the responsibilities of design-build procurements with the operations and maintenance of a facility for a specified period by a private sector partner. At the end of that period, the operation of the facility is transferred back to the public sector. This method of procurement is also referred to as Build-Operate-Transfer (BOT).

Build-Own-Operate-Transfer (BOOT): The government grants a franchise to a private partner to finance, design, build and operate a facility for a specific period of time. Ownership of the facility is transferred back to the public sector at the end of that period.

Build-Own-Operate (BOO): The government grants the right to finance, design, build, operate and maintain a project to a private entity, which retains ownership of the project. The private entity is not required to transfer the facility back to the government.

Design-Build-Finance-Operate/Maintain (DBFO, DBFM or DBFO/M): Under this model, the private sector designs, builds, finances, operates and/or maintains a new facility under a long-term lease. At the end of the lease term, the facility is transferred to the public sector. In some countries, DBFO/M covers both BOO and BOOT.

PPPs can also be used for existing services and facilities in addition to new ones. Some of these models are described below.

Service Contract: The government contracts with a private entity to provide services the government previously performed.

Management Contract: A management contract differs from a service contract in that the private entity is responsible for all aspects of operations and maintenance of the facility under contract.

Lease: The government grants a private entity a leasehold interest in an asset. The private partner operates and maintains the asset in accordance with the terms of the lease.

Concession: The government grants a private entity exclusive rights to provide operate and maintain an asset over a long period of time in accordance with performance requirements set forth by the government. The public sector retains ownership of the original asset, while the private operator retains ownership over any improvements made during the concession period.

Divestiture: The government transfers an asset, either in part or in full, to the private sector. Generally the government will include certain conditions with the sale of the asset to ensure that improvements are made and citizens continue to be served.

53 Delmon, J. (2010), "Understanding the Options for Public–Private Partnerships in Infrastructure", The World Bank Policy Research Working Paper 5173

A number of studies have researched the critical success factors for PPPs. Firstly, the procuring entity must bear in mind that PPP is not the only and perhaps not the optimum way of financing infrastructure. Secondly, studies show that while the two parties (private and public entities) to a PPP agreement have differing priorities, if both parties share a commitment to the overall objective then there can be agreement on the critical success factors. The four primary success factors are:

- ensuring open market access and fair competition
- protecting the public interest and maximising value-added
- defining the optimal level of grant financing both to realise a viable and sustainable project, but also avoid and opportunity for windfall profits from grants
- assessing the most effective type of PPP for a given project

The success of a PPP is not just about getting certain things right; it is also about avoiding the key factors that could lead to failure once a PPP is in place. These include:

- inappropriate PPP model
- poor or inappropriate legal agreement, including provisions for failure of projected revenues to materialise
- lack of clarity on the PPP objective
- too much focus on the transaction
- inadequate planning and consideration of scenarios that could otherwise lead to the need for renegotiations
- lack of internal capacity in the PPP operator and the client government department(s)
- failure to realise value for money

The public sector procuring entity must also be aware that the private sector is looking for return on investment. The greatest interest from potential PPP bidders will be for the most lucrative concessions. Before inviting interest from potential operators, the procuring entity must consider the "orphan" parts of the utility that would not be included in the concession agreement, including serving the poor not yet connected to the network. The PPP approach is not always the optimal solution.

The World Economic Forum provides guidance in its 2013 publication "Steps to Prepare and Accelerate Public–Private Partnerships", which also gives advice on challenges and reasons for past PPP failures. In a review of 181 PPPs in the energy, telecommunications and water sectors in Latin America, Andrés et al found that service quality rose cross all three sectors when compared to continued operations by public sector operators. While in most cases private sector PPP operators outperformed public sector operators, the best public sector operator outperformed the PPP operators when measured in terms of quality and reliability of service.

The surprising finding from studies of PPPs is that they rarely improve access to services. Extending infrastructure to remote communities is expensive regardless of who provides the infrastructure, although with commercial management it may often be somewhat cheaper when provided under a PPP arrangement than by a traditional public sector operator. Effective regulation and oversight is essential. A case in point is the rail operating concession awarded by the Zambia government in 2003. The concession was revoked in 2012 because the concessionaire failed to meet his commitments under the concession agreement, including failure to invest in new stock and adequate maintenance that led to an unacceptable number of derailments and poor safety record.

These lessons suggest that governments and their development partners need to consider carefully the case of each PPP through value-for-money analyses of suitable financing

options (of which, each may represent a different PPP model). The available literature is divided on whether there is a premium to be paid for including private investment compared to sole public provision of infrastructure and utility services. To some extent, it depends on the model and what is included in the agreement. But it is more expensive to provide debt on a project finance basis due to the guarantees and commitments that have to be provided. This can be optimised by government taking the demand risk. Some literature considers borrowing on a sovereign basis to be less expensive than private finance. Other studies point out that the costs of failed projects financed from the public purse are often unaccounted for because the taxpayer assumes the cost of this risk, whereas under a PPP risks are explicit and priced into the agreement as a proper incentive for carrying risk.

Appendix E Issues to consider in future research into the gender aspects of infrastructure maintenance

As mentioned in the main text (Section 4), there is little specific material on the Internet or in the grey literature on the links between the planning and financing of infrastructure maintenance and gender equality. The literature focusses on gender concerns during the planning for provision of infrastructure and on how existing infrastructure impacts unequally on females and males. Gender specialists can, of course, extrapolate these literature and their own experiences to link infrastructure maintenance and gender inequalities, but there is no specific guidance readily available, especially for non-gender specialists. In 2011, a Gender and Infrastructure Workshop for the Africa region aimed to mainstream gender equality in infrastructure policies and projects in Africa. The workshop focussed on the energy, irrigation, transport, and water and sanitation sectors. The word "maintenance" barely appears in the Concept Note[54].

Annex II of the workshop's Concept Note provides a framework for analysing gender and infrastructure issues. While this refers to the development, rather than the maintenance, of infrastructure, it does provide a take-off point from which to consider maintenance issues. The annex states: "Various studies have documented five major differences between men and women with respect to development, maintenance, access to and use of infrastructure:

- differences in needs for the type and location of physical infrastructure;
- differences in priorities for infrastructure services;
- unequal opportunities to participate in decision-making on the choice of infrastructure services, both within the households and within communities;
- unequal opportunities to participate in the design and implementation of infrastructure programmes and in the delivery of services; and
- significant disparities in access to infrastructure services.

Recognising that infrastructure is essential for poverty reduction, for private sector and business development, and for economic growth, the most compelling reasons for integrating gender into infrastructure programmes are to ensure that women and men both equally share the positive impact of economic and social transformation, including welfare and social empowerment, which infrastructure generates.

- Availability of infrastructure is highly correlated to poverty reduction.
- Disparities in health, education and incomes between women and men is associated with women's lack of access to infrastructure, and partly explains why women remain longer and at higher levels of poverty, particularly in rural areas.

Infrastructure and infrastructure services contribute to:

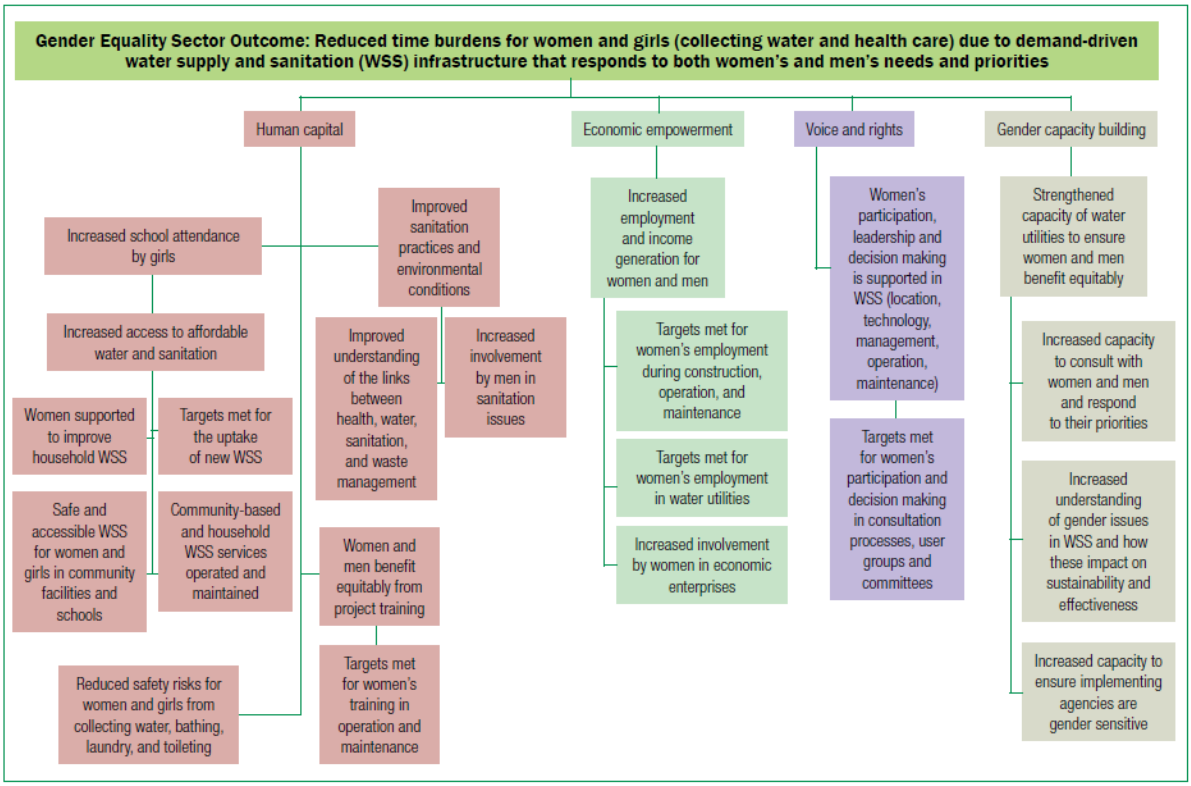
- increased productivity of urban and rural assets, labour and other factors of production, which are essential for economic growth and competitiveness;
- improved welfare of the urban and rural populations (reduced drudgery, mobility, dignity, leisure) by facilitating access to essential services for human capital development such as education/knowledge and health;
- social capital built-up of individuals, households, and communities, which is essential to ensure the effectiveness and efficiency in resource allocation, at all levels; and,
- risk mitigation from climate change to economic and social vulnerabilities.

[54] Gender and Infrastructure Workshop for the Africa Region, (2011), "A Collaborative Initiative of the Multilateral Development Banks: Gender Working Group" Concept Note

The ADB-AusAID Toolkit (2013) cautions that: “Transforming gender relations is a long-term process”, stating that demonstrating significant changes within a 4–5 year project can be a challenge. This is particularly true for initiatives and organisations aiming to bring about attitudinal and behavioural change. Moreover, efforts to promote the rights of women and girls may be seriously constrained when working in fragile states with conflict or political instability.

Setbacks and slow progress may mean that strategies, results and indicators need revision. Gender and social analysis is the key to making sense of the complex processes of change involved in empowering women. Moreover, the process of change is rarely linear; breakthroughs in one dimension may lead to setbacks in others. In this context, it is important to select gender equality outcomes that are realistic within the timeframe of programme and project cycles. It is also essential to identify immediate and intermediate results and indicators that are stepping-stones to transforming gender relations and achieving gender equality outcomes.”

The Toolkit also provides flowcharts (an example of which is shown below) summarising Gender Equality Results that may be useful when considering how well-managed infrastructure impacts women and girls, and hence the role of maintenance in increasing the availability of infrastructure and infrastructure services to women and girls.



Glossary

Asset management	Publicly Available Specification 55 defines asset management as the systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their lifecycles for the purposes of achieving its organisational strategic plan
Asset time bomb	A situation when a large amount of a country's national infrastructure assets are reaching a state when they must be renewed at the same time
Capex	Capital expenditures for new or replacement infrastructure, or rehabilitation works
Infrastructure (critical)	The assets, systems and networks that are vital to a nation's economic well-being, security, social development, public health or any combination thereof
Infrastructure (economic)	Engineers define economic infrastructure as physical assets that facilitate economic activity in a country, such as transport networks, power and water supply and sanitation systems, flood protection and coastal defences, telecommunications, and so on
Infrastructure (social)	Social infrastructure includes infrastructure that facilitates social services, such as government offices, schools and colleges, health centres and hospitals, community housing, civic and sports facilities, prisons, etc. There is some overlap with economic infrastructure; for example, bus stations which are transport-related may also be considered social infrastructure
Infrastructure adaptation	Measures to increase the resilience of infrastructure to the effects of climate change
Infrastructure gap	The difference between the demand for infrastructure and that which is provided; the gap arises from (1) a failure to implement appropriate demand management measures, (2) insufficient investment in replacement and additional infrastructure, and (3) a failure to properly protect earlier investments in infrastructure such that the infrastructure has deteriorated faster than planned
Infrastructure interdependence	Cause-and-effect relationships between different infrastructure sectors
Infrastructure report card	A summary report that records the current condition of each sector of infrastructure using the following grading system: A = exceptional; B = good; C = mediocre; D = poor; F = failing; infrastructure report cards are usually updated annually

Infrastructure unit	A department in state or national government responsible for infrastructure policy and planning
Opex	Operation and maintenance costs
Strategic planning	Although there are various definitions for “strategic planning”, this Topic Guide considers it to be *a systematic process that identifies how an organisation intends to fulfil its responsibilities to its stakeholders in the medium- to long-term, utilising the resources that are or could be made available to it, taking into account the challenges, opportunities and risks that dictate its operating environment … and how success will be measured*
SWAp	A sector-wide approach is a coordinated set of donor and government interventions led by a single comprehensive sector policy