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Strategic Infrastructure
Steps to Operate and Maintain Infrastructure Efficiently and Effectively

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Foreword

Foreword by the World Economic Forum

Today's global infrastructure demand is estimated at about US$ 4 trillion in annual expenditure with a gap – or missed opportunity – of at least US$ 1 trillion every year. One of the most important areas for investment globally is indeed infrastructure. This specific asset class should be put into perspective when addressing the needs of the fastest growing populations, namely, Africa and Asia. In spite of the growing gap in building new infrastructure it should be emphasized that the worldwide stock of existing infrastructure is worth about US$ 50 trillion, which is of the same order of magnitude as the global stock market capitalization (US$ 55 trillion) and comparable, to a certain extent, to the global GDP (US$ 72 trillion). This existing stock offers a tremendous opportunity to narrow the infrastructure gap if governments are capable and willing to optimize the operations and maintenance (O&M) of their infrastructure assets.

A country's competitive economic advantage clearly depends on a properly articulated infrastructure vision and long-term planning. Government leaders must inspect their project portfolios critically and decide which ones to accelerate first based on their strategic importance, independently of the restricted duration of a political cycle. However, vision and planning are not sufficient and it is fundamental that governments learn how to assess and select an appropriate infrastructure delivery model at the early stages of the project preparation process and are fully aware of the implementation consequences in terms of whole life-cycle cost. In addition, governments need to develop a holistic and long-term strategy for operating and maintaining their physical assets that may represent a considerable financial burden for future taxpayers.

The World Economic Forum's Strategic Infrastructure Initiative is a collaborative reflection of the steps required to efficiently and effectively deliver economic infrastructure projects. The Initiative, with its linkages to the B20 and G20, and its cumulative track-record of pan-regional engagement of the private sector, government and civil society, has identified the following key challenges to date: the prioritization of infrastructure projects in a robust and bankable project pipeline; the acceleration of the project preparation process; and the selection of the most adequate project delivery model. However, these challenges are often only the tip of the iceberg given that these infrastructure assets will be operated for 20, 30 or more years after initial construction. In fact, governments have to properly manage their stock of public infrastructure but are often much more interested in building new assets. This tempting choice may not be optimal given the opportunity of better managing the existing infrastructure stock by optimizing their utility and lifetime – at a reasonable cost. In reality, many governments struggle to achieve high O&M performance due to insufficient funding, weak capabilities and inadequate O&M governance.

This report assumes that infrastructure assets have already been built, after being selected and prioritized on the basis of a country's infrastructure vision and plan, and delivered with the most adequate procurement model – whether a public-private partnership or not. In this context, the four best-practice areas concerning O&M covered in this report are: (i) increase utility; (ii) decrease total cost; (iii) increase lifetime value; and (iv) policy enablers. For each of these best-practice areas the report identifies and illustrates three critical success factors that governments should be aware of and should seriously consider for their O&M strategies.

The Strategic Infrastructure Initiative – and its Knowledge Series Reports – has been providing a roadmap to steer governments and key stakeholders to comprehensive frameworks and actionable best practices that cover the whole infrastructure life-cycle, namely, origination, preparation and implementation of physical assets. This report is the last volume in this series and is focused on project implementation, namely the O&M of existing infrastructure assets – an often neglected and yet critical practice. The future of the World Economic Forum's work will fold into the broader umbrella of the Global Strategic Infrastructure Initiative, which will continue to carve out an exceptional space for a number of regional and national discussions in the years to come, including Latin America and Asia and also Europe and North America. These efforts will continue to substantiate the globally acquired body of knowledge and experience into concrete measures that contribute to boosting strategic infrastructure development.

This report is a direct result of a cooperative process with leaders from government, civil society and the private sector, particularly the engineering and construction, financial services and investors industries. In this regard, we would like to thank and acknowledge the World Economic Forum partner companies that served on the Strategic Infrastructure Initiative Steering Committee: ABB; Alcoa; AMEC; Arup; Bilfinger; CCC, CH2M HILL; CVC Capital Partners; Danfoss; Fluor Corporation; GE; Hindustan Construction Company; Kokusai Kogyo (Japan Asia Group); Leighton Holdings; Prudential; Punj Lloyd; The Rockefeller Foundation; Siemens; SNC-Lavalin Group; Toshiba and Welspun Corporation. We would like to give special acknowledgement to Hamish Tyrwhitt (Chief Executive Officer, Leighton Holdings 2011-2014) for his relentless interest and commitment to serve as chair of the Strategic Infrastructure Initiative from spring 2012 to spring 2014.

We would also like to thank the many experts who contributed to the report through their role on the Strategic Infrastructure Initiative Advisory Committee: Norman Anderson (CG/LA Infrastructure); Gordon Brown (Prime Minister of the United Kingdom 2007-2010); Victor Chen Chuan (University of Sichuan); Nathalie Delapalme (Mo Ibrahim Foundation); Angelo Dell'Atti (IFC); Clive Harris (World Bank Institute); Franziska Hasselmann (ETH Zurich); Rajiv Lall (IDFC); Yves Leterme (OECD); Clare Lockhart (Institute for State Effectiveness); Thomas Maier (EBRD); Mthuli Ncube (African Development Bank); Aris Pantelias (University College London); Mark Romoff (Canadian Council for Public- Private Partnerships); Douglas Stollery (Stollery Charitable Foundation); Shamsuddeen Usman (Minister of National Planning Commission of Nigeria 2011-2013) and James Zhan (UNCTAD).

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The experience, perspective and guidance of all the above people and organizations contributed substantially to a number of remarkable discussions with particular highlights at the World Economic Forum on Africa, Cape Town, May 2013, at the Summit on the Global Agenda, Abu Dhabi, November 2013, and the World Economic Forum Annual Meeting 2014 in Davos-Klosters.

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Foreword by the European Bank for Reconstruction and Development (EBRD)

Over the past several years, the discussion with respect to infrastructure investment has been punctuated by calls for more resources to be made available to close the “financial gap” between the current global levels of investment compared with the estimated global need. Systemic uplift in the levels of investment must happen to drive global economic growth, job creation and improved competitiveness. The work of the World Economic Forum, in close coordination with the Russian and Australian presidencies of G20 and B20, has helped to forge a new consensus on the drivers for the infrastructure gap and its underlying issues. While financing is, of course, essential, the infrastructure gap can mostly be explained by other overriding factors, namely insufficient numbers of projects that come to the market and which are based on adequate structures and optimal life-cycle costing, and are driven by a solid underlying economic case.

This report makes a valuable contribution to the debate by highlighting and explaining the importance of operations and maintenance (O&M) of existing infrastructure stocks. Given the sheer value of these sunken assets, the report rightly points out how countries and cities, particularly in the emerging markets, can extract high economic value by ensuing that the full asset value of these assets are extracted over the entire planned life-cycle of each asset. Indeed, if existing infrastructure is not well-maintained, countries often face a costly conundrum of political and social pressures to pursue much more costly greenfield projects, some of which may have been avoided (or at least postponed by several years) if rigorous approaches to O&M had been implemented from the outset. Given the general state of fiscal constraints prevailing in many countries today, the importance of O&M aspects is brought into stark relief.

Finally, it is crucial to remember that proper O&M is part and parcel of high-quality service orientation for users, and this user-based focus is what drives their willingness to pay for services and thus underpins funding sustainability. As such, effective O&M and asset management approaches for existing infrastructure provide a blueprint for sustainable greenfield investment of the future.

While the report recognizes that the set of answers towards improving the status quo is by nature complex and multifaceted – and touches on the need for example to deepen institutional strengthening and capacity across the board – it also makes a valuable contribution towards highlighting a host of tried and tested guiding principles and best practices that have been shown to produce good results. In that respect, it deserves wide dissemination both among the public and private sectors, and across the broad spectrum of investors in infrastructure.

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Context and Objectives of the Report

Infrastructure is essential for sustained economic growth, competitiveness and social progress. While building new infrastructure assets ranks high on the global agenda, governments in both developed and developing countries often neglect their existing infrastructure assets – witness the increasing congestion, unnecessary operational costs and inadequate maintenance. Against the backdrop of increasing user demand, constrained financing and an ageing asset base, it is imperative for governments to make the most of their existing infrastructure assets – specifically, to increase the assets' productivity and longevity. This report recommends ways of doing just that. It provides a structured and comprehensive framework for implementing operations and maintenance (O&M) best practices, as well as many real-life examples. In addition, it covers the enabling factors for O&M such as funding, capabilities and governance. Using the guidance provided in this report, governments and operators can systematically consider all possible optimization levers and so reap the full potential of their infrastructure assets.

Audience of the Report

This report is designed primarily for senior government leaders and for the officials responsible for managing infrastructure assets on the strategic and operational level. Other stakeholders would also benefit from the report – the private sector, multilateral development banks, the donor community and civil society – as it enables them to have a more productive engagement with governments. Finally, private infrastructure operators as well will value the report, as many of the best practices listed in it can be applied equally to privately operated infrastructure assets.

Scope of the Report

The report is intended to serve as a "roadmap" for directing governments and other stakeholders to the critical success factors in infrastructure O&M. It does so by providing a comprehensive framework, actionable lessons learned and more than 200 real-life examples and case studies. The framework and recommendations can be applied broadly in developed and developing economies, and across many sectors of economic and social infrastructure. The O&M best practices are collected from infrastructure assets that are delivered under public or private modes, or under public-private partnerships (PPP), and can likewise be applied to all kinds of delivery modes. The report is not a compendium of the whole infrastructure life cycle: it excludes initial design and construction, and takes those decisions as a given; and, its focus is exclusively on O&M and end-of-life-cycle decisions of existing assets (including rehabilitation, upgrade and replacement), as project origination and preparation have been covered in the initiative's previous reports.

In the context of this report, infrastructure is defined to include the following sectors:

– Economic infrastructure: assets that enable society and the economy to function, such as transport (airports, ports, roads and railroads), energy (gas and electricity), water and waste, and telecommunications facilities

– Social infrastructure: assets to support the provision of public services, such as government buildings, police and military facilities, social housing, health facilities, and educational and community establishments

This definition specifically excludes two other kinds of infrastructure: soft infrastructure (the public institutions required for maintaining society, notably the legal and judicial system, the education and health systems, and the financial system) and industrial infrastructure (such as mineworks, or the interconnected roads within a large factory complex).

Executive Summary

Around the world, many countries are experiencing severe infrastructure needs, owing to growing populations, economic growth, increasing urbanization and ageing legacy assets. While demands are skyrocketing, supply is impeded by various factors, resulting in a global investment gap of about US$ 1 trillion per year.

To bridge the gap, most governments emphasize constructing new assets, but this strategy is not a "silver-bullet" solution; after all, public-budget constraints exist, as do multiple difficulties in getting projects from idea to implementation in a reasonable time frame. A complementary and potentially more cost-effective approach is to improve the utilization, efficiency and longevity of the existing infrastructure stock – in short, to make the most of existing assets by means of optimal O&M.

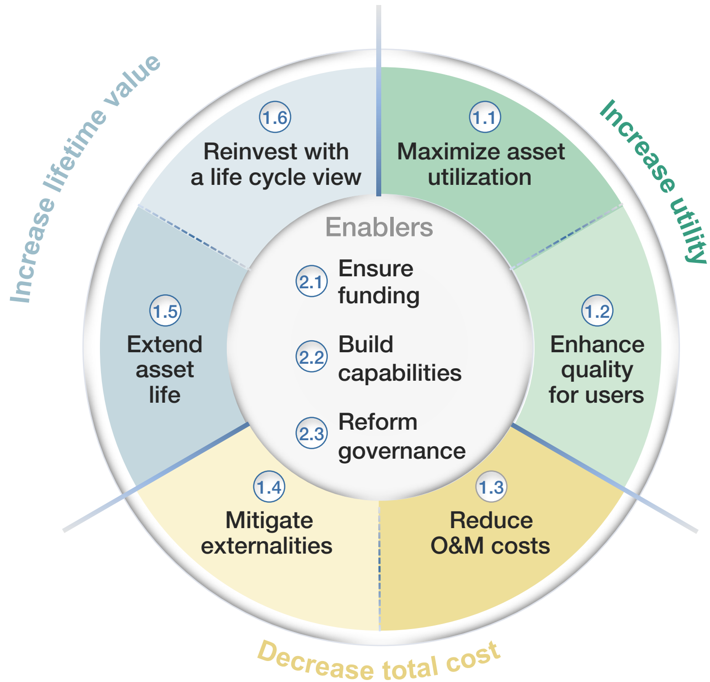
In reality, many governments in both developed and developing countries neglect their existing assets, and current O&M practices are often seriously deficient. In operations, they fail to maximize asset utilization and to meet adequate user quality standards, while incurring needlessly high costs as well as environmental and social externalities. Maintenance is all too often neglected, since political bias is towards funding new assets. Similarly, resilience to natural disasters tends to be ignored, although such hazards are becoming more common and more destructive because of climate change. As a result of the maintenance backlog and the lack of resilience measures, existing assets deteriorate much faster than necessary, shortening their useful life.

A proper solution will require a step change in infrastructure asset management. In fact, such a transformation is feasible. Many examples of O&M best practices exist from the various infrastructure sectors (e.g. airport, port, road, electricity) and other heavy industries around the world – they just need to be adopted more widely. And thanks to recent innovations in digital technologies, such as remote sensing, advanced analytics, autonomous operations, and integrated scheduling and control, traditional "bricks" infrastructure can now be used more effectively, and operated and maintained more efficiently. Most important of all, O&M solutions are affordable. They are highly cost-effective in an otherwise capital-intensive industry. Even small O&M improvements can make a remarkable impact, given the large size of the global asset base, where each per cent of improvement translates into billions of dollars saved. And in addition to generating financial savings, O&M improvements can also bring considerable social and environmental benefits, in line with governments' public-service mission.

This report, developed by the World Economic Forum's Strategic Infrastructure Initiative and its Partners, outlines government best practices for operating and maintaining existing infrastructure assets and is illustrated with more than 200 real-life examples. It follows the initiative's previous two reports, which outlined best practices for efficiently and effectively delivering new assets by identifying and prioritizing projects in an integrated infrastructure plan (Phase I) and preparing bankable public-private partnership (PPP) projects (Phase II).

This Phase III report examines two aspects of O&M best practice, summarized graphically in Figure 1: implementation strategies (represented in the outer circle) for asset operators to enhance O&M performance, and enablement strategies (represented

Figure 1: O&M Best Practice Framework



in the inner circle) for policy-makers to create the conditions that will enable sustainable O&M. The three implementation strategies that infrastructure operators should embrace are:

– Increasing the utility of infrastructure, by maximizing asset utilization and enhancing the quality for users
– Decreasing the total cost of infrastructure, by reducing O&M costs and mitigating environmental and social externalities
– Increasing infrastructure's value over its lifetime, by extending asset lifetime and reinvesting from the perspective of a whole life cycle

The report not only recommends specific actions for improving O&M, but also addresses the root causes of O&M underperformance, such as insufficient funding, immature capabilities and inappropriate governance structures.

Figure 2: Checklist of O&M Best Practices/Critical Success Factors

Increase utility	**1.1. Maximize asset utilization**	Enhance peak capacity and effective throughput	Apply demand management	Optimize availability/ reduce downtime
	1.2. Enhance quality for users	Adopt a customer-centric operating model	Enhance the end-to-end user experience	Use smart technologies to refine user performance
Decrease total cost	**1.3. Reduce O&M costs**	Implement lean and automated processes	Optimize procurement costs and outsourcing	Rightsize management and support functions
	1.4. Mitigate externalities	Arrange comprehensive sustainability/HSE plans	Embed sustainability/HSE into routine operations	Cooperate with relevant stakeholders
Increase lifetime value	**1.5. Extend asset life**	Invest in preventive and predictive maintenance	Control excessive asset consumption and stress	Enhance disaster resilience
	1.6. Reinvest with a life cycle view	Prioritize project options with whole life cycle CBA	Select contracting mode for best value for money	Prepare for efficient project delivery
Enable O&M best practice	**2.1. Ensure funding**	Dedicate user taxes via maintenance funds	Apply inclusive user charges	Capture ancillary business opportunities
	2.2. Build capabilities	Introduce asset management planning	Apply data, benchmarks and tools	Conduct training and develop talent
	2.3. Reform governance	Corporatize and profes-sionalize public agencies	Foster cooperation between agencies	Consider private-sector participation & competition

Note: HSE = Health Safety Environment; CBA = Cost-Benefit Analysis

To make high-performance O&M sustainable, policy-makers need to consider the three enablement strategies:

– Ensuring stable and sufficient funding
– Building institutional and individual capabilities
– Reforming governance

For each of the best practice areas, the report identifies the critical success factors that governments and operators should take into consideration (Figure 2). While many governments and operators already apply some of these levers, they often neglect to consider all the levers systematically, and so fail to reap the full optimization potential. By assessing their country's or asset's maturity in each critical success factor, and the relevance of that factor to the specific context, governments and operators can use this checklist to identify and prioritize the areas where change is required.

Implementation Best Practices

1.1 Maximize asset utilization. Given the challenge of congestion and public financial constraints (and sometimes space constraints) on building new assets, governments should aim to maximize the utilization of their existing assets. First, they can increase peak throughput by unlocking backup capacity (e.g. hard shoulder running, reversible lanes on highways), making targeted capacity enhancement at bottlenecks (e.g. adding lanes or introducing e-tolling) and encouraging users to utilize the full system capacity (e.g. introducing high-occupancy lanes). Even within the existing capacity, however, various measures are available to increase throughput. In transport, headways between vehicles can be reduced, for example, by advanced road traffic management and next-generation rail or air traffic control systems. For electricity and water, operators can reduce physical losses by harnessing leakage detection technology, properly maintaining and repairing networks, and investing in new equipment. Concerted action on all these levers can make a large impact. Manila Water of the Philippines, for example, drove its non-revenue water ratio down from 63% in 1997 to just 11% in 2010. Moreover, the water needs of 200 million people could be met if the 45 million cubic metres of water lost through physical leakage every day in the developing world could be retained.

To address the problem of congestion, operators should also pursue demand-side measures, and redistribute demand in time, space or mode. Demand-side measures are typically implemented via time-based user charges, which give users a powerful incentive to modify their behaviour. For example, Singapore's urban road pricing scheme reduced peak traffic by about 15%, and prompted a modal shift towards public transport. In addition, operators should educate the public and provide them with the information to enable wiser decisions on infrastructure usage.

Another important impediment to optimized asset utilization is downtime. In the United States (US), power outages cost the economy US$ 150 billion annually. Operators can address this problem through various strategies to optimize availability: refining maintenance and outage processes; improving incident management; and integrating operations planning with maintenance planning. Autostrade per l'Italia, for example, schedules short-duration maintenance tasks for off-peak hours, and has broadly re-engineered its maintenance processes for bridges and viaducts. As a result, the proportion of maintenance tasks causing medium or severe traffic interference has fallen from 50% to 10%.

1.2 Enhance quality for users. Historically, because infrastructure users have not been a high priority for many public operators, service levels have often been inadequate. To consistently improve quality for users, operators should adopt a customer-centric operating model: they could apply many of the techniques pioneered in consumer industries, including customer research, customer segmentation and willingness-to-pay analysis. The best operators not only address the basic user requirements, but also strive to create a positive end-to-end user experience. They excel in ancillary services by holistically addressing all customer needs. Singapore Changi Airport, for example, optimizes the passenger stopover experience through relaxation, entertainment and sightseeing offers. The best operators also make the best of the whole network's performance by partnering with infrastructure users, adjacent assets or government agencies to provide integrated and seamless services. Some port operators, for instance, cooperate with shipping lines to make optimal schedules and reduce waiting times; with adjacent rail operators to optimize hinterland connectivity; and with government agencies to speed the flow of trade-related documentation. Lastly, the best operators also adopt smart technologies, which now increasingly provide win-win solutions that simultaneously enhance user performance and reduce costs. For example, after a wide roll-out of smart electricity meters in Sweden, customer complaints about invoicing have dropped by 60%, while the costs of meter-reading have fallen by 70%.

1.3 Reduce O&M costs. Active cost management, often neglected in the past, is becoming increasingly important owing to public budget constraints. Operators can reduce waste using a broader application of lean principles to revamp existing O&M processes. In addition, they can greatly reduce operating expenditures by systemically using new technologies, in areas such as remote asset inspection, autonomous operations, and integrated scheduling and system control. Yorkshire Water, for example, integrated and digitized all previously paper-based data into a single, real-time information system to sharpen its work scheduling and routeing, enable dynamic task allocation and ensure availability of information to all field workers and external contractors; this resulted in a 50% reduction of unnecessary field jobs. Procurement costs can be reduced by 5-15% by applying technical levers such as standardization, in addition to the conventional commercial and process levers. In areas where the requisite technology is discouragingly expensive or where specialist skills would be needed, operators can opt to outsource maintenance works or information technology (IT) services, and thereby realize major cost savings. Performance-based outsourcing contracts (with financial rewards for contractors achieving the stipulated performance targets) have reduced the cost of service provision by 10-40%. Finally, many operators with legacy organizations need to adjust their overheads and organizational structures, for example by delayering, introducing shared services and optimizing the level of (de-)centralization.

1.4 Mitigate externalities. Infrastructure operators are increasingly subject to more regulation and public scrutiny regarding their environmental and social impact. To respond to these challenges, they should craft a comprehensive programme of sustainability measures, based on the theme "Reduce, Recycle, Replace". For example, modern wastewater treatment plants can change from being net energy consumers to net energy producers by using methane from waste-to-power generators. Ideally, sustainable practices should be deeply embedded in everyday operations by making sustainability a top-management responsibility; engaging the broader workforce and not just creating a sustainability department; and measuring and improving sustainability just as any other business process. In the US, the Metropolitan Transportation Authority (MTA) Metro-North Railroad made safety a line management priority, improved processes after analysing hazards, and increased communication and audits on safety – with the result that lost-time injuries declined by 60% within a few years. Operators should also take a multistakeholder engagement approach, actively communicating with communities in outreach campaigns and collaborating with fellow operators and users to generate a greater positive impact across the infrastructure system. Fully implementing next-generation air traffic management, which could reduce aviation carbon-dioxide (CO_2) emissions by 4% by 2020, requires enhanced cooperation between the various participants in the aviation value chain.

1.5 Extend asset life. Once a costly infrastructure asset has been built, every additional year of lifetime provides huge value, as the marginal costs of operations are relatively low. Clearly, operators should invest in preventive and predictive maintenance, which is increasingly facilitated by remote condition monitoring and advanced asset deterioration modelling. Some new bridges now have wireless sensors that continuously monitor and report the asset's condition, enabling predictions of the remaining useful life and optimizing maintenance routines. Any maintenance strategy will require close cooperation across different, often siloed departments, and will need to be customized to the specific

asset context and based on a proper assessment of the vulnerability and criticality of each piece of equipment. Developing such customized and innovative maintenance treatments can have a major impact; for example, the asphalt-preserving surface coating applied to the M25 motorway in the United Kingdom (UK) increased the pavement's life by a third.

Another crucial factor in extending lifetime is the adequate management of the asset, according to its specifications, to control excessive usage or consumption (e.g. regulating the use of heavy trucks on rural roads). A further major risk to infrastructure is natural disasters. The economic losses caused by storms, flooding and earthquakes worldwide over the past 30 years are estimated at US$ 3.5 trillion, and these hazards are becoming more common and more destructive because of climate change. To address this, governments must identify and assess those risks, develop cross-sectoral master plans and incorporate more resilience into existing assets. Their efforts should focus not only on structural measures, such as building protective barriers and retrofitting existing facilities, but also on cost-effective, non-structural measures, including the creation of natural buffer zones and the adaptation of more resilient design codes for future reconstructions and upgrades.

1.6 Reinvest with a life cycle view. Since most of the infrastructure in developed countries was constructed from the 1950s to 1970s, many assets are approaching the end of their life cycle and need to be rehabilitated or replaced. However, before committing to major capital expenditure, governments should first identify all possible project options and investigate more cost-effective solutions, such as throughput optimization, loss reduction, demand-side measures, systemwide capacity balancing and targeted investments to debottleneck existing sites. The project should then be selected on the basis of a rigorous cost-benefit analysis, taking the whole life cycle into account. In many cases, the life cycle analysis will reveal that the long-term costs of O&M are actually much greater than the initial costs of construction. The life cycle cost analysis thus needs to be performed early on and in the specific asset context, as the majority of life cycle costs can still be influenced through shrewd design and engineering decisions, such as whether to use concrete or asphalt for paving a road. After committing to the project, the most efficient delivery mode – public sector, PPP or private sector – should be chosen on the basis of a value-for-money assessment, taking into account the potential quality of service and level of risk to the government budget. For example, the new hospital in Tlalnepantla, Mexico was delivered as a PPP, realizing whole life-cycle savings of 30% relative to the projected costs of traditional public delivery, as well as producing a "greener" infrastructure facility with energy savings estimated at 20%.

Enablement Best Practices

In addition to implementing O&M best practices, governments also need to create the right conditions for optimizing O&M for the long term. They need to ensure funding, build capabilities and reform governance.

2.1 Ensure funding. A typical source of funding for O&M requirements is annual appropriations from the government budget. However, these are vulnerable to political expediency and so are often ill-suited to O&M, which requires a very predictable and sustainable source of funding. More suitable models include dedicated maintenance funds that earmark and ring-fence user taxes, user-charge models and revenues from ancillary businesses. As examples of dedicated maintenance funds, the Swiss and Austrian road funds provide reliable sources of funding that are decoupled from the annual public budget. But such funds face their own set of challenges in many countries: the increasing fuel efficiency of cars (and their future replacement by e-cars), as well as flat fuel tax rates, erode the funds' financial base. It is thus essential to link their revenues to inflation and actual traffic volumes. A broader adoption of user charges is also warranted, as they can more easily link funding to inflation and traffic volumes. User charge models not only ensure a dedicated funding contribution from each user, but also encourage customers to use the available capacity responsibly and sparingly. Introducing or increasing user charges requires a sophisticated stakeholder communication strategy, and a delicate balancing of financial and economic objectives as well as social considerations. Perhaps the best approach is to correlate new user charges with quality improvements on the one hand, and to provide targeted tariff reductions or alternative infrastructure on the other. Finally, ancillary business opportunities can generously supplement the funding of the core infrastructure business; for example, best practice airports can realize more than 50% of their revenues from retail, hotels, advertising and parking.

2.2 Build capabilities. In many countries, the key constraint to implementing all of these O&M best practices is the shortage of skilled staff. One priority is to increase formal O&M education and training in the various disciplines by academia, international financial institutions (IFIs), governments and the private sector, and to enhance other forms of knowledge exchange. Actually, the O&M phase itself is an excellent learning environment, as its stability and long-term orientation enable uninterrupted learning curves over a project's life cycle. While such skill education and training is essential, it is not sufficient. Governments need to do more to attract high-quality O&M managers and planners, and to develop and retain them for the long term. Sustainable O&M performance is compromised not just by the shortage of individual capabilities, but also by the common lack of institutional capabilities. When making their infrastructure plans, governments need to ensure that O&M projects are prioritized in an integrated cost-benefit framework, alongside greenfield projects; and, to ensure the continuity of the maintenance programme beyond election cycles. Governments should conduct regular assessments of the existing asset base, and create an infrastructure balance sheet to show how the stock of assets has evolved and to forecast the required maintenance funding. Governments should also introduce standardized infrastructure asset management processes and frameworks (such as ISO 55000), and make full use of data, benchmarking and modelling for optimizing O&M procedures and expenditures. The North-West Transit Way near Sydney, Australia provides a good example of what can be achieved by applying such data-driven decision-making. By using a sophisticated pavement-modelling tool based on highly granular data, the contractors were able to home in on an optimal whole life-cycle solution with cost savings of 15%, while still ensuring road availability of 99%.

2.3 Reform governance. Governments have to deal not only with legacy assets, but also with legacy organizations and cultures. The right governance model is a crucial factor in motivating agencies and their staff to optimize O&M. One approach is corporatization of public agencies; it often captures the advantages of a privately run company, including enhanced productivity, streamlined processes, commercial orientation and financial sustainability, while remaining accountable to the public and serving the public interest. When the Aqaba Water company in Jordan was corporatized, the outcome was a 30% sales increase, a renewal of 90% of the network, performance improvements, increased employee training and enhanced customer service. Improvements are needed not just to individual agencies, but also to coordination across sectors, government levels and even borders. Finally, additional private participation could enhance infrastructure O&M by tapping the private sector's skills in managing infrastructure assets. In water treatment, some major US cities have recorded savings of over 30% in operating costs. Given the current strong interest of private institutional investors in low-risk, long-term infrastructure investments, governments may consider granting concessions or selling some assets on favourable terms and recycling the proceeds into new projects – but only if such transactions provide value for money to society.

The Way Forward

While many governments and operators already apply some of these O&M best practices, many others fail to achieve anything near the full optimization potential. They should begin by systematically reviewing and benchmarking their O&M practices and policies against the complete best practice checklist (Figure 2). After identifying the most critical issues in a country's and sector's particular context, governments will need to establish a broad action plan. While inevitably some trade-offs will have to be made when crafting it, governments should always try to find win-win solutions; these are increasingly available now, thanks to new technologies and process innovations.

Many of the implementation best practices can provide quick fixes, and are essential for short-term efficiency improvements that can unlock funds for larger transformations. However, governments should treat O&M not only as an operational necessity aimed at reducing costs, but also as a strategic element that optimizes the value of an infrastructure asset for society – by increasing the asset's utilization, availability and service levels. In the long term, a sustainable O&M solution will inevitably require the right enablers in place, secured and stable funding, managerial and technical capabilities, and the right governance structure.

Excellence in infrastructure O&M is a key means of narrowing the global infrastructure gap – but it is no panacea. Most countries will still need to construct new assets and address vast infrastructure deficiencies. Still, by optimizing existing capacity utilization, O&M best practice can significantly reduce the amount of new construction and, by optimizing operating costs, can also make financial resources available for whatever new construction is truly needed. Of course, it can also ease current congestion far faster than new construction could.

Well-designed O&M strategies and policies, in conjunction with policies to improve the earlier phases of infrastructure projects (planning, preparation, procurement and construction), can benefit developed and developing countries immensely. They will thus have the opportunity to boost their infrastructure services, strengthen their competitiveness and foster socio-economic progress and prosperity.

Overview of the Strategic Infrastructure Initiative

The World Economic Forum's Strategic Infrastructure Initiative supports governments in their efforts to address three fundamental questions as they strive to maximize their returns on investment from strategic infrastructure projects. The questions are:

- How should they identify and prioritize infrastructure projects that make the greatest impact on economic growth, social uplift and sustainability?
- Once they have selected the investments, how should they prepare and procure these assets most efficiently and effectively?
- Once the assets have been built, how should they operate and maintain them to maximize their value for society?

The first phase of the initiative, in 2011-2012, explored the first question and produced the report *Strategic Infrastructure: Steps to Prioritize and Deliver Infrastructure Effectively and Efficiently* in September 2012. The second phase, in 2012-2013, addressed the second question, specifically looking at PPPs as exemplary modes of project delivery. The corresponding report, *Strategic Infrastructure: Steps to Prepare and Accelerate Public-Private Partnerships*, was published in May 2013. The third phase, in 2013-2014 and summarized in this report, addresses the third question and discusses in detail issues of operating and maintaining existing infrastructure assets. Figure 3 provides an overview of the initiative's three phases and their respective topics.

The initiative draws on Partners from the Forum's Infrastructure & Urban Development Industries and other relevant groups, including Mobility, Energy and Investor Industries. Other participants include experts from multilateral development banks, academia, governments and the wider infrastructure community.

Figure 3: Overview of the Strategic Infrastructure Initiative

Strategic Infrastructure Initiative addresses three key government issues

	Phase I	Phase II	Phase III
Project phase and title	**Project origination** **Prioritization and selection of infrastructure projects**	**Project preparation** **Preparation and acceleration of Public-Private Partnerships**	**Project implementation** **Operations and maintenance of existing infrastructure**
Topics addressed	— Project identification, prioritization & selection — Infrastructure master-planning — Delivery-mode choice	— Project preparation process — Feasibility study — Regulatory design — Enabling environment	— Asset-utilization maximization — Operating-cost reduction — Environ./social-impact mitigation — Lifetime extension and renewal
Delivery modes	— Public, PPP and private delivery	— PPP delivery as exemplary mode	— Public, PPP and private delivery
Outputs	 — Report published in Oct. 2012 — Strategic Infrastructure Planner Tool	 — Report published in May 2013 — PPP Maturity Assessment Tool	 — Report published in April 2014 — Operations & Maintenance Evaluation Tool

Introduction: The Operations and Maintenance (O&M) Imperative

A country's infrastructure endowment plays a major strategic role in its economic growth and global competitiveness. High-quality infrastructure facilities may be costly to build and maintain, but they provide many economic benefits, as they facilitate trade and production efficiencies for other industries. Consider how an unreliable electricity supply would add to the overall cost of doing business, as firms must either pause production during blackouts or pay for expensive back-up generators. Several studies have shown the positive effect of infrastructure on the national economy: depending on the current infrastructure stock, a 1% increase in infrastructure assets will boost gross domestic product (GDP) by 0.05% to 0.25% in the long term.[1]

Functioning infrastructure makes a positive impact not only on the economy, but also on the environment and society at large. Every family and community needs proper infrastructure to thrive and achieve social progress – for example, the electricity that enables children to read at night and the road that gives them speedy access to healthcare facilities. Yet in Africa, 40% of agricultural produce rots on the way to market because of bad roads, and half a billion people lack access to electricity.[2] In the absence of electricity, people continue using fuel sources such as charcoal and kerosene, with all the predictable social and environmental results: increased disease, deforestation and carbon emissions.

The Global Infrastructure Gap

The global infrastructure gap is a pressing issue

The global demand for infrastructure investment is huge and estimated at about US$ 3.7 trillion annually.[3] In developing countries, it is driven by growing population, economic growth, urbanization and industrialization. In the developed world, a particular concern is that so much legacy infrastructure needs maintenance and rehabilitation, owing to the ageing of assets, stricter environmental regulations and the globalization of supply chains.

The high demand is not being met, however, as only about US$ 2.7 trillion is invested each year.[4] The supply of new infrastructure cannot keep pace with demand because of various impediments; notably, the public sector's budget constraints following the global financial crisis, and the reluctance of private financiers to commit capital to long-term and risky projects. In addition, the delivery of infrastructure programmes is hampered by several issues in the project origination and preparation phase, including biased project identification and prioritization, low-quality master-planning, slow permit and procurement processes, and inadequate risk allocation and delivery models.

In short, the growth of the infrastructure asset base is failing to keep up with society's needs. The global road network, for example, has expanded by 88% since 1990, which might sound impressive, except that global road freight traffic has increased 218% over the same period.[5] Across all sectors of economic and social infrastructure, the global infrastructure investment gap amounts to at least US$ 1 trillion per year, which corresponds to about 1.4% of global GDP[6] (Figure 4). To make matters worse, much of the existing asset base is wearing out: many of the infrastructure assets in the European Union (EU) and North America were built in the 1950s-1970s, and many, approaching the end of their expected lifespans, are becoming structurally deficient or functionally obsolete. For example, the average age of the 607,380 bridges in the US is currently 42 years, and that of the 84,000 dams is 52 years.[7] And in Germany, about a third of rail bridges are over 100 years old.[8] In fact, most developed countries have neglected to modernize their infrastructure, as infrastructure spending has declined over recent decades, and priority has often been given to building new projects.

To narrow or close the infrastructure gap, governments can pull three levers

Governments can reduce infrastructure demand, build new assets or optimize existing infrastructure assets (Figure 4).

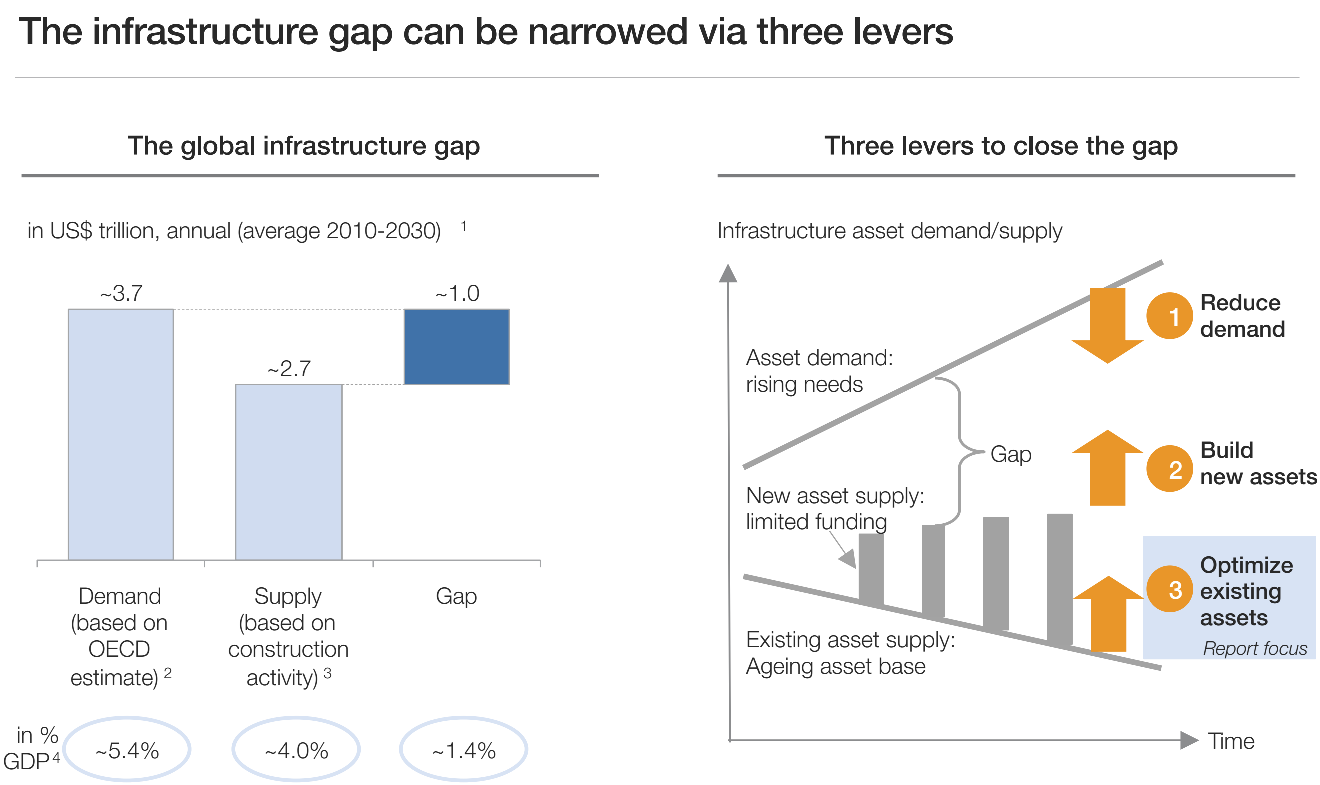
Reduce demand. Reducing demand for infrastructure services is sometimes a viable option, if user needs for these essential public services can be satisfied in other ways. Electricity consumption can be reduced through systematic promotion of energy-saving devices. However, many services, such as transport, cannot be feasibly reduced without jeopardizing economic and social development.

Build new assets. The most obvious and widely discussed solution is to build new infrastructure facilities. (The required actions were described in the Strategic Infrastructure Initiative's previous two reports.[9]) However, the solution is resource-intensive, complex and prone to delays – unappealing characteristics in a world of tight fiscal budgets and limited private long-term lending/investing.

Optimize existing infrastructure assets. An underexploited opportunity is to upgrade the existing asset base by optimizing the O&M of the infrastructure assets, i.e. making them more effective, cheaper or longer-lasting. While this lever has often been neglected by policy-makers in the past, it commands attention now in the current context of constrained finance, ageing facilities and rising demand. The Swiss transportation policy, for example, explicitly stipulates that optimal management of existing capacities has priority over capacity expansion.[10]

This report aims to examine the role that O&M best practice can play in narrowing the global infrastructure gap, while recognizing that a comprehensive and sustainable approach to closing the gap will require government action on all three levers.

Figure 4: The Global Infrastructure Gap and Levers to Close the Gap



1. Including economic and social infrastructure 2. *Infrastructure to 2030 (Volume 2): Mapping Policy for Electricity, Water and Transport*, June 2007. Paris: Organisation for Economic Cooperation and Development (OECD) 3. *IHS Global Insight Construction Database,* March 2012 4. Using $70T as global GDP, non-PPP adjusted (2011)

The O&M Opportunity

There is significant potential for improving O&M of existing infrastructure assets

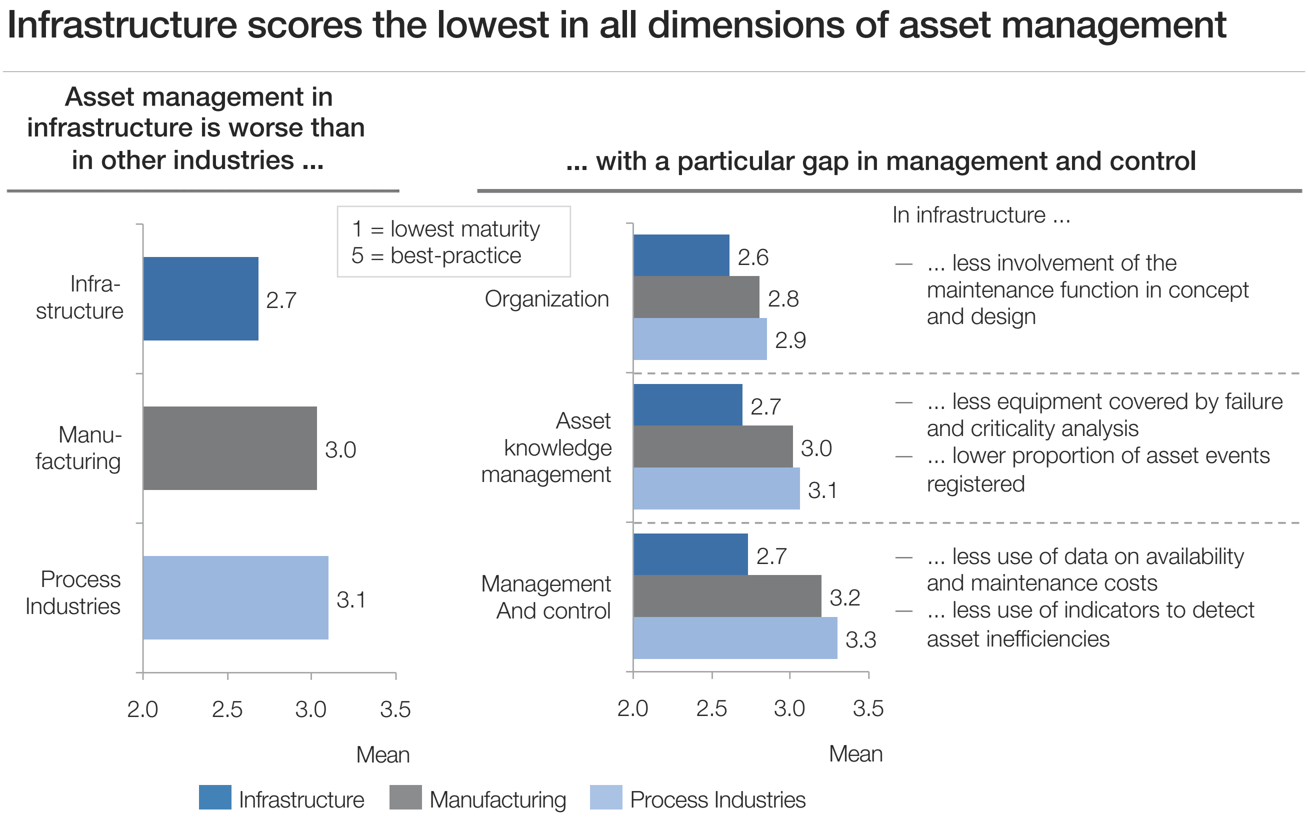
Current management of infrastructure assets is a cause for concern. According to a survey by the European Federation of National Maintenance Societies, asset management practices of the European infrastructure industry are rated below those of the manufacturing and process industries, not just in the overall ranking but in every one of the key subcategories (Figure 5).[11] Publicly owned infrastructure assets have been managed suboptimally in developed countries, and even more so in developing countries. In any country, O&M is often the victim of pressured public budgets and political priorities – O&M projects win few votes relative to greenfield projects.

Trillions of US dollars have been invested over the past decades to build the global infrastructure asset base, which includes 43,000 airports, 33 million kilometres (km) of roads and 1.2 billion fixed-line connections (Figure 6).

With worldwide infrastructure assets worth about US$ 50 trillion,[12] the value is roughly the same in magnitude as the global stock market capitalization (US$ 55 trillion)[13] and global GDP (US$ 72 trillion).[14]

Infrastructure, as one of the world's great capital stocks, cannot be neglected, and governments need to make a long-term effort to unlock this potential value. Pursuing the "power of one per cent" can make a dramatic impact, as each percentage point of O&M optimization brings substantial financial and economic rewards. But asset optimization yields more than

Figure 5: Comparison of Asset Management across Industries



Note: Asset management maturity measured on a scale between 1 (lowest maturity) and 5 (best-practice) based on 23 questions. 112 public and private entities from 24 European countries and 23 industry sectors contributed to the survey. "Process industries" includes extraction, mining and quarrying companies; "Manufacturing" includes food products, wood, paper and electronic equipment; "Infrastructure" includes production and distribution of electricity, water supply, roads and railways etc.

Source: *How organizations manage their physical assets in practice - EFNMS Asset Management Survey 2011, 2011*. European Asset Management Committee within EFNMS

cost savings; it can also provide social and environmental benefits, which makes it well aligned with governments' public service mission.

The O&M opportunity is realistic

The chances of successfully optimizing O&M are enhanced by three factors: existing role models of good practice, technological innovation and relatively modest implementation costs.

Role models. Many private as well as public infrastructure assets have already optimized their O&M, and thereby have set an industry benchmark and indicated various best practices. Infrastructure managers can emulate their counterparts' work in their own sector, or adapt the work of those in other sectors. They can also learn lessons from other capital-intensive industries, such as oil and gas or heavy industry. The potential for laggards to improve is clear.

Technological innovation. Infrastructure, with its long innovation cycles, has generally not been a front-runner in innovation, but it could soon experience an impressive productivity gain from innovative technologies promising new O&M solutions. The technology revolution in remote sensing, advanced analytics, integrated scheduling and control, and autonomous operations will also have a transformative effect on the infrastructure industry. As they say, "the Bits will become just as important as the Bricks". Just consider the differences made by applications such as smart meters, dynamic traffic management and e-tolling, and next-generation air traffic control systems. These technologies are increasingly moving beyond the pilot phase and becoming more affordable, with cost-effective roll-outs at scale either a prospect or already a reality.

Relatively modest implementation costs. In the otherwise capital-intensive infrastructure industry, O&M solutions usually carry a very reasonable price tag; payback is quick, and economic benefit-to-cost ratios are high. Regarding the costs of supplying water: estimates are that building new dams and rainwater harvesting facilities, for example, would cost US$ 0.04-0.06 per cubic metre (m^3), whereas rehabilitation of existing infrastructure would only cost about US$ 0.02/m^3, and demand-side measures far less than that.[15]

The O&M Challenges

The O&M reality is a sobering one

Many issues with existing infrastructure illustrate the lack of O&M best practice. The following statistics indicate the extent of the problem:

Congestion and unproductive use of capacity

– Despite the slowdown of shipping activity in the aftermath of the global financial crisis, about 5-10% of the global vessel fleet was kept idle by port congestion in 2009-2012.[16]
– In the US, airport congestion and delays cost its economy US$ 22 billion in 2012,[17] and unless matters

Figure 6: Overview of the Global Infrastructure Asset Base

Given the world's huge infrastructure stock, substantial value can be unlocked through proper O&M

Note: Data describes the global infrastructure stock.
Source: CIA World Factbook, https://www.cia.gov/library/publications/the-world-factbook/, 2012

improve, 20 US airports will find that traffic exceeds capacity by 2015.[18] At China's largest airports, in Beijing and Shanghai, three-quarters of all flights are delayed, with each minute of delay costing airlines wasted fuel, passenger compensations and interruptions to luggage handling.[19]

– In the developing world, 45 million cubic metres of water are lost daily because of leakage, enough to provide for the needs of 200 million people.[20]

Poor quality for users

– A large-scale power outage in India left approximately 700 million people without electricity in July 2012.[21] The north-eastern US experiences on average 214 minutes of power outage per year, compared to just six minutes in Japan.[22]

– More than 20% of the 54,700 US tap water systems supplying 49 million people are regularly in violation of the Safe Drinking Water Act.[23]

– One-third of US highways and one-quarter of major urban roads are considered to be in poor or mediocre condition, and are increasingly subject to failure.[24] Furthermore, 25% of bridges are structurally deficient or functionally obsolete.[25] Overall, ageing and unreliable infrastructure will lead to job cutbacks and declining business productivity, costing the average US family an estimated US$ 3,000 in disposable household income annually through 2020.[26]

– Barges on the US inland waterways system, where more than half of the locks are over 50 years old, are regularly held up for hours each day by service interruptions that delay goods from getting to market.[27]

Cost inefficiencies

– If an additional US$ 12 billion had been spent on road repairs across Africa during the 1990s, the US$ 45 billion spent on reconstruction could have been pre-empted.[28] And, the cost of keeping the US transportation system in a state of good repair is just one-third of the cost of replacing it.[29]

– More than US$ 250 million[30] was spent to rehabilitate the Longfellow Bridge in Boston (US); had regular maintenance been performed on it, the total historical cost would have been only about US$ 81 million.[31]

– Crane productivity at many ports is only half of the over 40 moves per hour that world-class ports can achieve, suggesting that a large number of ports are operating at seriously inefficient levels.

Environmental and social externalities

– More than 25 million metric tons of CO_2 are produced in US traffic jams each year,[32] corresponding to the CO_2 emitted from electricity used by 3.4 million homes per year, or the annual greenhouse gas emissions of 5.2 million cars.[33]

– Every year, traffic accidents kill more than 1.2 million people around the world and injure up to 50 million.[34]

In India alone, about 15,000 people die each year crossing rail tracks.[35]

– Unsafe drinking water is one of the main causes of the 1.5 million diarrhoea-related deaths of children in developing countries each year.[36]

These O&M issues affect both developing and developed countries, although the type of problem does vary (Box 1).

O&M underperforms for a variety of reasons

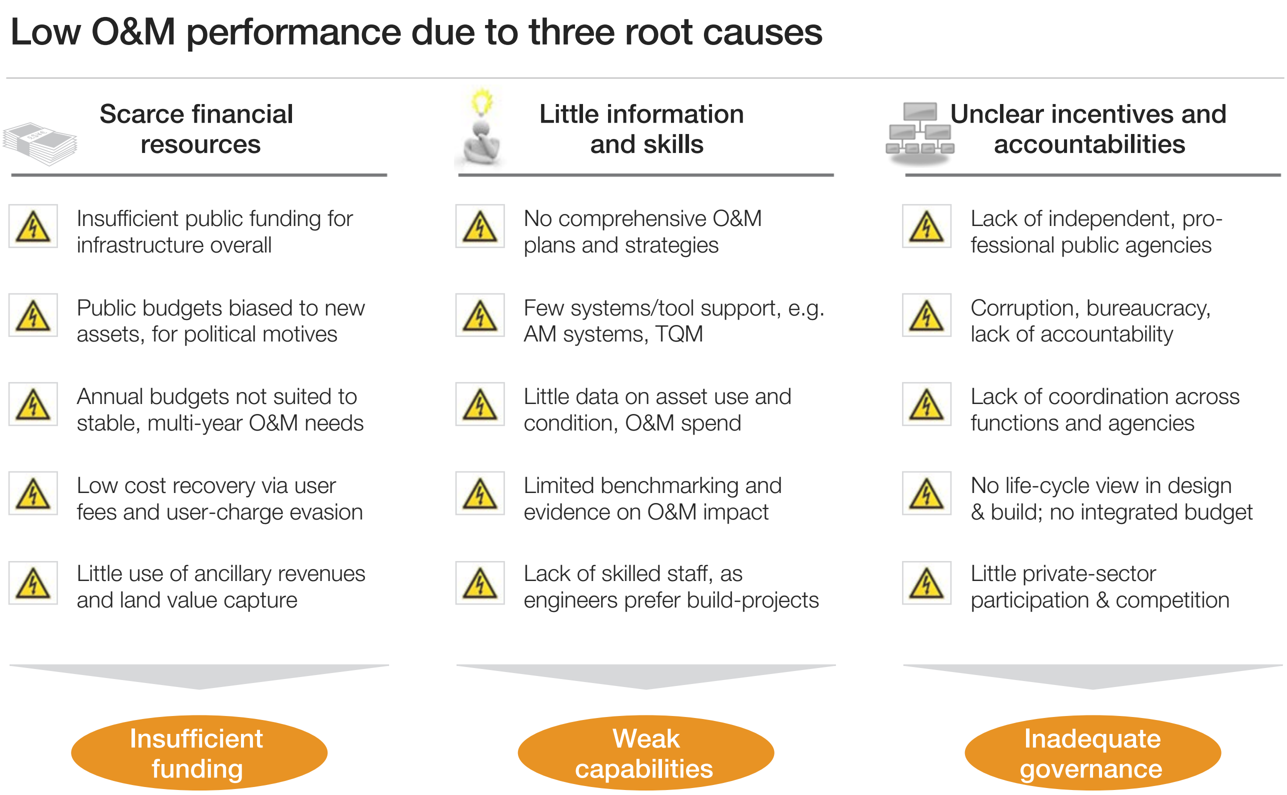
There are three broad causes of the shortage of high-quality and sustainable O&M (Figure 7).

Insufficient funding. Overall public funding for infrastructure is inadequate, and the amount of available funds for O&M specifically is even worse. The O&M shortfall is partly due to politicians' built-in bias in favour of greenfield projects, which have vote-catching potential. By contrast, O&M projects have low political visibility, and long-term maintenance requirements do not make a good fit with the short political cycle. So it is hardly a surprise that decision-makers generally do not participate in ribbon-cutting ceremonies for a maintenance project. In addition, the public budgeting processes, where O&M and capital expenditure (capex) budgets are typically separated and where budgets are set annually, do not match well with the multiyear requirements of O&M programmes. In addition, O&M costs cannot always be easily recovered from user charges: the requisite price increases tend to provoke stakeholder opposition, and in developing countries, they are often subject to payment evasion.

Weak capabilities. O&M decision-making is often hampered by poor asset management processes and frameworks, and substandard systems, tools and data. Without abundant and accurate data on the asset's condition and performance, and without reliable benchmarks and best practices for guidance, O&M managers are bound to struggle. Even when best practices are known, they might be insufficiently exploited because of understaffed or underskilled engineering and management departments, as O&M has a less-appealing image for professionals than construction. And even though a great opportunity exists to reskill staff using the learning curve derived from stable O&M tasks, that opportunity often gets neglected.

Inadequate governance. The institutions governing infrastructure assets are often weak and bureaucratic, which hinders professional and independent O&M. Because of the absence of private-sector involvement and competition, little pressure to reduce costs or to optimize the existing facilities exists, and inefficiency can flourish.

Figure 7: Root Causes of O&M Issues



Notes: AM = Asset Management; TQM = Total Quality Management

Box 1: O&M – A Global Issue Affecting Different Countries or Regions in Different Ways

Infrastructure O&M is a perennial challenge in both developed and developing countries. In developed countries, the large and ageing infrastructure stock creates greater pressure to pursue O&M. However, even in developing countries, with their great need to build new infrastructure assets, O&M is still an important issue. In Africa, where infrastructure needs amount to US$ 93 billion per year, one-third of that total is for maintenance.[37] And in South Asia, the proportions are, or should be, 45% for new investments and 55% for O&M (jointly accounting for about 7% of GDP).[38]

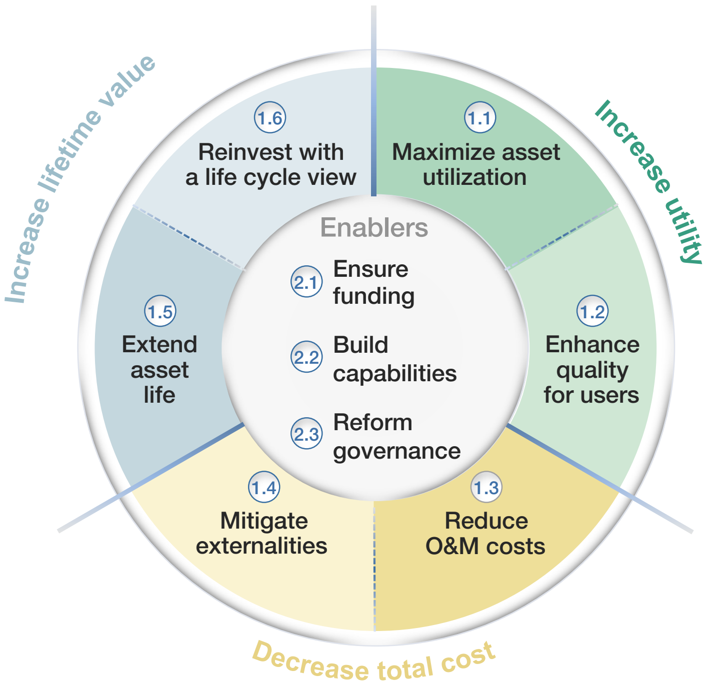
While the main concern in developed countries is optimizing legacy assets to cater for rising user demand without running up huge bills, an additional factor exists: the public desire for a greener, safer, more reliable and more efficient infrastructure operation. The O&M priorities for developed countries thus include the following:

– Introducing new technologies into existing infrastructure systems
– Making smart capacity extensions, or making better use of existing capacity to avoid congestion
– Pursuing environmental sustainability and making existing infrastructure more resilient
– Ensuring optimal maintenance of ageing assets, and developing optimal replacement and upgrade strategies for functionally obsolete or structurally deficient assets
– Overcoming stakeholder opposition to newly introduced or increased user charges
– Reforming legacy agencies, and making processes more efficient

For developing countries, by contrast, the main concern is often just to fulfil basic O&M requirements and service standards. As a country's infrastructure network expands, so does its O&M workload. In China, for example, the road network increased from 1.7 million km in 2001 to 4.1 million in 2011;[39] such increases are set to continue, and the maintenance costs and thus the funding requirements will go up accordingly. If O&M is neglected, China will stumble in its efforts to catch up with the efficiency and capacity of developed countries; today, transporting freight by road is still half as fast and twice as expensive in China as in the developed world. The O&M policy priorities for many developing countries are the following:

– Overcoming the preference for and focus on new asset construction as opposed to O&M
– Introducing O&M deliberations (including resilience strategies) based on life cycle analysis into greenfield projects from the outset
– Enhancing O&M funding: combating charge evasion (due to corruption and insufficient metering/billing) and the use of excessive and untargeted subsidies
– Addressing local capabilities gaps; for example, fly-in, fly-out infrastructure construction can leave a shortage of O&M skills, as with some of the facilities built in Africa and fragile states
– Setting up institutional, legal and regulatory frameworks to support long-term O&M

Figure 8: O&M Best Practice Framework



A Framework for O&M Best Practices

Governments should aim to make the most of existing assets

A basic government responsibility is to secure maximum value for money from the O&M of a country's existing infrastructure assets. Governments can adopt various strategies to optimize the socio-economic returns generated from those assets; the framework in Figure 8 offers a structured overview of management strategies (represented by the outer circle) and enablement strategies (represented by the inner circle).

Three broad strategies are available to governments for managing their infrastructure assets and maximizing the return on those past investments:

– Increase the utility of the existing infrastructure asset, by maximizing its utilization and enhancing its quality for each user.

– Decrease the total costs of providing the infrastructure service – not just by reducing internalized O&M costs but also by mitigating the environmental and social externality costs.

– Increase the lifetime value, either by extending the asset's life to maintain the benefits over an extended period, or by organizing a rehabilitation, replacement or upgrade plan that takes whole life-cycle considerations properly into account.

Some of those levers can be interdependent. While in certain situations trade-offs will be required between the different strategies (for example, reducing operating costs may reduce service quality), governments should seek win-win solutions that assure a simultaneous realization of those strategies (for example, e-tolling reduces both operating costs and the environmental footprint, while increasing quality for users).

Figure 9: Checklist of O&M Best Practices/Critical Success Factors

Increase utility	**1.1. Maximize asset utilization**	Enhance peak capacity and effective throughput	Apply demand management	Optimize availability/ reduce downtime
	1.2. Enhance quality for users	Adopt a customer-centric operating model	Enhance the end-to-end user experience	Use smart technologies to refine user performance
Decrease total cost	**1.3. Reduce O&M costs**	Implement lean and automated processes	Optimize procurement costs and outsourcing	Rightsize management and support functions
	1.4. Mitigate externalities	Arrange comprehensive sustainability/HSE plans	Embed sustainability/HSE into routine operations	Cooperate with relevant stakeholders
Increase lifetime value	**1.5. Extend asset life**	Invest in preventive and predictive maintenance	Control excessive asset consumption and stress	Enhance disaster resilience
	1.6. Reinvest with a life cycle view	Prioritize project options with whole life cycle CBA	Select contracting mode for best value for money	Prepare for efficient project delivery
Enable O&M best practice	**2.1. Ensure funding**	Dedicate user taxes via maintenance funds	Apply inclusive user charges	Capture ancillary business opportunities
	2.2. Build capabilities	Introduce asset management planning	Apply data, benchmarks and tools	Conduct training and develop talent
	2.3. Reform governance	Corporatize and profes-sionalize public agencies	Foster cooperation between agencies	Consider private-sector participation & competition

Note: HSE = Health Safety Environment; CBA = Cost-Benefit Analysis

In addition to the management strategies, governments also need to establish the right enabling conditions to address the root causes of substandard O&M performance (as discussed earlier) and to sustain the implementation of O&M best practice. The enablement strategies are:

– Ensure sufficient funding for continuous O&M

– Build sufficient capabilities to execute O&M successfully

– Reform governance to incentivize optimal O&M

Above all, it concerns the political will to implement those best practices. The issue is not about a lack of best practices or too little technological innovation; it really has to do with the structure and the will to adopt the lessons learned and apply them on a broader scale.

Based on extensive consultations with the multistakeholder constituencies of the World Economic Forum's Strategic Infrastructure Initiative, this report identifies and discusses 27 actionable best practices and critical success factors that are essential when undertaking the O&M implementation and enablement strategies (Figure 9).

Figure 9's checklist represents a holistic or ideal agenda for optimizing O&M. Although it shows how complex and broad O&M can be and needs to be, it certainly does not imply that successful O&M is unachievable; many countries and sectors have accomplished much by simply concentrating on those aspects most relevant to their particular context. While many governments and operators are already well advanced in some of these levers, they often fail to consider all the levers systematically, and so fail to reap the full potential of optimizing their existing infrastructure assets.

Many of the implementation best practices can provide quick fixes and are essential for short-term improvements, as they can be implemented relatively quickly if the right engineering and operational know-how is in place. For many countries, however, the greater long-term issues are about securing continuous O&M funding and establishing the right governance structure – factors that are of paramount importance for any sustainable O&M solution.

The rest of this report is organized according to the O&M critical success factors/best practices. Part 1 of the report, intended particularly for managers of public infrastructure assets, discusses the management best practices for optimizing existing infrastructure assets; it is subdivided into six chapters (1.1 to 1.6) with a total of 18 best practices. Part 2, intended primarily for policy-makers, provides guidelines and recommendations for creating the right enabling conditions so that O&M can be optimized in a holistic and sustainable way; it consists of three chapters (2.1 to 2.3) with nine best practices overall.

The report aims to explain the basic principles of a comprehensive asset management (Box 2) capable of optimizing existing infrastructure assets and making them fit-for-purpose for societal needs. However, the report is not meant to provide detailed technical guidance on implementing such O&M best practices in any specific infrastructure sector. Given the report's cross-sector scope, the best practices listed will apply to all infrastructure sectors.

Box 2: The Framework Proposes a Comprehensive Asset Management Approach

Advanced asset management is a holistic endeavour; its aims go well beyond considering just a single outcome (such as reducing an asset's total cost of ownership). Instead, it seeks to optimize the asset over its life cycle, across functions and tasks, in social, economic and environmental dimensions, and across the entire infrastructure system/network. Distinctive characteristics of sound and comprehensive asset management, in contrast to some of the narrower, traditional approaches, include for following:[40]

- *Value perspective*. In some traditional approaches to asset management, the emphasis is on minimizing the total cost of owning and operating fixed capital assets (while providing the desired level of service).[41] The framework in this report implies a wider agenda; a well-configured infrastructure asset should not only minimize cost but also provide the greatest possible life cycle revenues, user benefits and, hence, aggregate socio-economic returns. In this comprehensive version of asset management, governments should transition their view of O&M as a "cost burden" to O&M as a "value creator".
- *Triple bottom line objectives*. Comprehensive asset management not only attends to operational and financial goals (internalized costs and benefits), but also explicitly considers environmental and social dimensions (externalized costs and benefits).
- *Whole life-cycle horizon*. The proposed approach does not limit itself to annual cycles, but engages in whole life-cycle analysis and decision-making.
- *Risk recognition*. As in financial asset management, infrastructure asset management needs to optimize risk-adjusted returns – securing a maximum return (e.g. throughput, user quality) at a given acceptable level of risk (e.g. downtime, congestion, resilience).
- *Systemic scope*. Good asset management is concerned with system-level performance, not just with performance at asset level.
- *Integrated activities*. Good asset management involves more than effective maintenance; it is not just a traditional maintenance programme "on steroids", but a means of operating, managing and optimizing infrastructure assets centrally, and in a smart way.
- *Comprehensive measures*. While this report recognizes the central importance of funding for O&M, it also encourages stakeholders to put some effort into other essentials, such as getting more out of the provided funds through operational excellence, which in turn reduces costs. Advanced asset management not only involves operational levers to improve efficiency, but also addresses other strategic business objectives of the asset owner to improve effectiveness. Rather than just focusing on short-term fixes, stakeholders should also concentrate on measures that "enable" O&M for the long term, i.e. developing appropriate funding, capabilities and governance for the asset.
- *Organizational integration*. Good asset management avoids creating silos for maintenance management and budgets. Instead, it conscientiously integrates and interconnects maintenance with design, engineering and construction, and integrates maintenance planning with operations planning.
- *Proactive attitude*. Asset management needs to be proactive and innovative, instead of reactive and taking a formal approach. It should drive fact-based reviews of the asset base, suggest innovations and dynamically adjust its processes and organization to new issues.

Figure 10: Panama Canal O&M Measures

O&M strategy of the Panama Canal illustrates the O&M framework

Increase utility	1.1. Maximize asset utilization	— Increased throughput by reducing transit from 27 hours to 24 hours — Optimized availability by redundant lock valves enabling "hot" replacement — Mix of rule-based and price-based demand management
	1.2. Enhance quality for users	— Customer segmentation (e.g. by vessel type) and monitoring of competitors — New just-in-time service that allows vessels to avoid waiting
Decrease total cost	1.3. Reduce O&M costs	— Detailed overhaul planning 1 year ahead, enabling maintenance "in one go" — Procurement with life-cycle evaluation and performance specifications
	1.4. Mitigate externalities	— Integrated water resource mgmt and operation of hydro power plants — Well-resourced environmental division with external audits and clear KPIs
Increase lifetime value	1.5. Extend asset life	— Mix of preventive and corrective maintenance depending on equipment — Significant investment in regular maintenance
	1.6. Reinvest with a life cycle view	— Maintenance function involved in planning, procurement and reconstruction — Contractor has to maintain new locks for 3 years with failure mode analysis
Enable O&M best practice	2.1. Ensure funding	— Tolls optimized to different cargoes and tolls kept in ACP to cover opex — >20% ancillary revenues and exploring e.g. container and Ro-Ro terminals
	2.2. Build capabilities	— >8,000 employees trained p.a.; maintenance circle among employees — Centralized balanced scorecard system; modern maintenance software
	2.3. Reform governance	— ACP not privatized but corporatized: independence keeps out politics — CEO selected based on experience and not a political nominee

Note: KPI = Key Performance Indicator; ACP = Panama Canal Authority; LNG = Liquefied Natural Gas; Ro-Ro = Roll-on Roll-off

This report illustrates the best practices with support from over 200 examples and case studies to give the reader a real-life impression of successful implementations. The examples are drawn from different sectors of economic and social infrastructure, and from both developing and developed countries. Part 4 contains a comprehensive case study of the Panama Canal O&M, which holistically exemplifies the full array of both implementation and enablement best practices. Figure 10 provides an overview of the O&M measures taken at the Panama Canal along the dimensions of the O&M framework.

1. Implementing O&M Best Practices

This section of the report discusses O&M management best practices. It provides selected approaches to optimizing existing infrastructure assets, without any attempt to cover each sector comprehensively, and addresses six broad strategies:

- Maximize asset utilization (chapter 1.1)
- Enhance quality for users (chapter 1.2)
- Reduce O&M costs (chapter 1.3)
- Mitigate externalities (chapter 1.4)
- Extend asset life (chapter 1.5)
- Reinvest with a life cycle view (chapter 1.6)

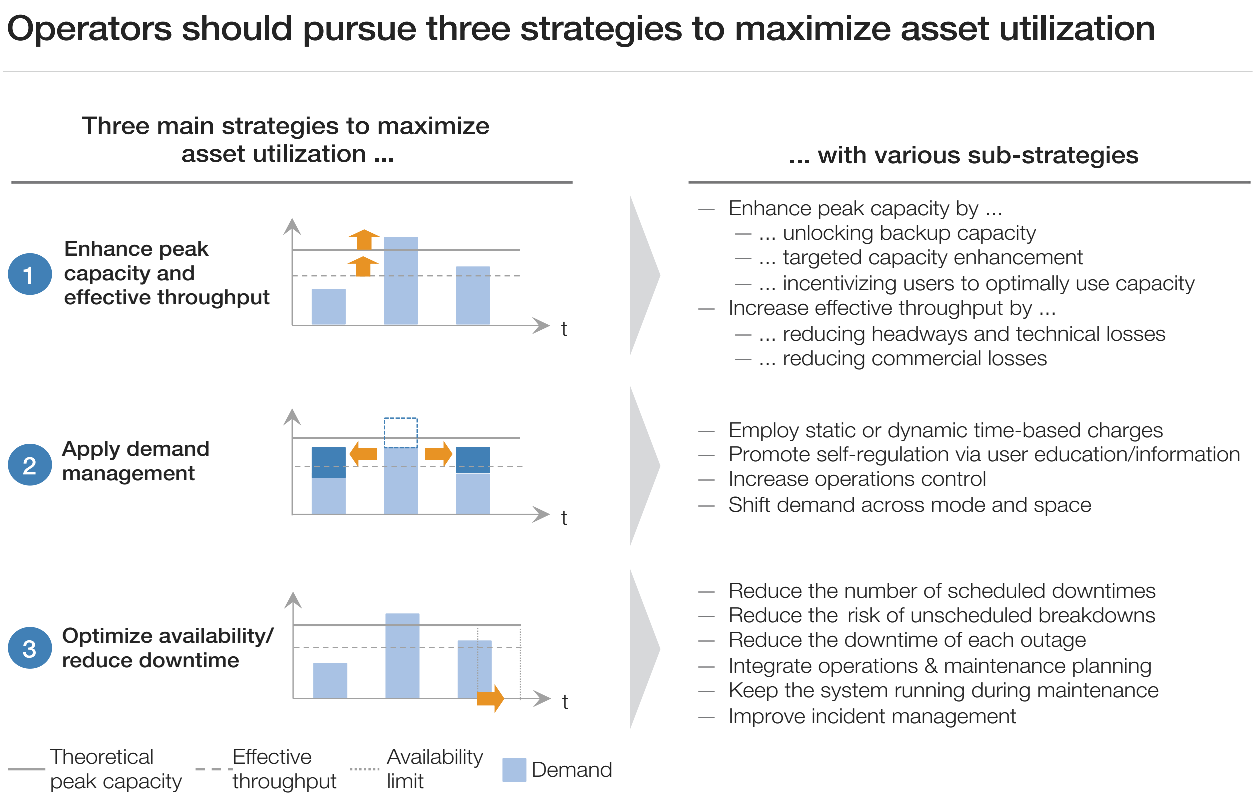
1.1 Maximize asset utilization

Many existing infrastructure assets suffer from congestion because demand has risen well beyond the level forecasted. Since their capacity is limited, and it might not be feasible to build new assets, it is essential for governments to make the most of their installed asset capacity. Even a slight increase in effective throughput can make a large difference, since congestion is a strongly non-linear phenomenon.

Increasing throughput of existing assets has enormous societal value. Once the large, upfront sunk investments for building an infrastructure asset have been made, each additional user will incur only low marginal costs, but that usage will translate into greater user benefits and/or revenues – and thus contribute to pay off the initial investment.

To alleviate congestion and maximize asset utilization, operators should pursue a three-part best practice strategy: enhance peak capacity and effective throughput; apply demand management to reduce peak demand by shifting some of it off-peak; and optimize availability and reduce downtime (Figure 11).

Figure 11: Overview of Asset Utilization Strategies



Enhance peak capacity and effective throughput

Enhance peak capacity by unlocking backup capacity.

Infrastructure assets often have embedded additional or reserve capacity that is not being used. Once made available, it can ease bottlenecks dramatically. Some examples:

– The hard shoulder or emergency lane on highways: by opening these to traffic during rush hours, or in dynamic response to heavy traffic, authorities can greatly reduce traffic jams. Using this approach, the Italian highway system at Bologna has cut total user time lost by almost 75%, while also reducing accidents by 18% and injuries and deaths by about 35%.[42]

– Reversible lanes on highways: when necessary, certain stretches of a highway can be designated for traffic going in either direction. Hong Kong's busy Route 8 highway, for instance, applies a real-time mix of lane assignment management.[43]

– Underexploited power transmission lines: real-time ratings, based on a continuous monitoring of mechanical tension and temperature, tend to yield higher capacity than static ratings (which are based on conservative assumptions such as high ambient temperature and high solar radiation). This allows operators to harness existing, untapped transmission capacity and thus resolve line congestion problems. The McCarney-to-Big Lake line in Texas, for instance, was able to increase its capacity by 10-15% through real-time ratings, thereby accommodating the increase in wind farms and cancelling a planned US$ 20 million line upgrade.[44]

Obviously, such backup capacity techniques have their risks (safety lapses, increased stress, wear on the system), which need to be carefully managed.

Enhance peak capacity by targeted capacity enhancement.

A system operates only as effectively as its weakest component. So a cost-effective approach to enhancing capacity is to conduct a systemwide analysis to identify bottlenecks, and then make targeted and incremental investments using existing infrastructure and/or rights-of-way, rather than undertaking major construction work. Some examples:

– Airports: London City Airport (UK) took a coordinated, capacity-boosting initiative across the system, from landside (four additional security lines, a larger departure lounge, self-service kiosks) to apron (four new aircraft stands for larger aircraft, a new runway link and connecting pier) and airside (closer cooperation with air traffic control to optimize slot availability). The result was an increase in capacity from 32 to 38 air traffic movements per hour.[45]

– Roads: various debottlenecking techniques have been used, such as adding extra lanes in upslopes in hilly terrain, and free flow tolling to maximize capacity at typical choke points.

– Water treatment: for example, the As-Samra plant in Jordan, when overloaded owing to pollution, made a limited but targeted investment in additional centrifuge presses and gravity belt thickeners to remove the bottleneck in the treatment process.

A related approach is to dynamically adjust resources to prevent congestion at bottlenecks. Frankfurt Airport, for instance, introduced an integrated system of real-time, passenger flow forecasting and resource planning. The system simulates passenger flows, identifies upcoming bottlenecks, provides continuous updates to the Terminal Operations Centre and dynamically adjusts the required staff. The system increased peak terminal capacity from 150,000 to 200,000 passengers per day, reducing passenger waiting times by 20%, and also reduced resource planning from five days to only a few hours.[46]

Enhance peak capacity by enabling and encouraging users to optimally use capacity.

A system's capacity is determined not only by the infrastructure asset's design and operation, but also by the users (e.g. cars, aircraft, ships). While infrastructure operators have no direct influence over that aspect of capacity, they can enable and encourage users to use the system capacity to the fullest extent possible.

– Enable high-capacity usage via structural measures: many airports, for example, have constructed new gates to accommodate larger aircraft such as the Airbus A380. To encourage carpooling, Vinci Autoroutes in France created 1,000 dedicated parking places near toll gates,[47] and many US highways have introduced special managed or high-occupancy vehicle lanes.

– Encourage high-capacity usage through pricing: For instance, Heathrow Airport (UK), limited to two runways while other major European airports with similar passenger numbers have three to four, charges small aircraft relatively higher fees to motivate carriers to use larger, high-capacity aircraft. And on US highways, high-occupancy toll (HOT) lanes create incentives for carpooling by waiving charges for multi-passenger cars.

In addition to increasing peak capacity, asset utilization can be boosted by increasing effective throughput.

Increase effective throughput by reducing headways and technical losses.

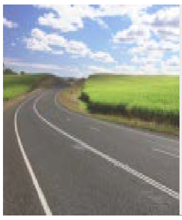
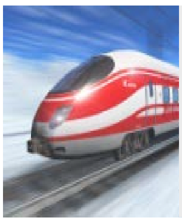
An asset's theoretical peak capacity seldom translates into actual realized capacity, owing to the system's complexity and dynamics. User interactions are too unpredictable, and system interfaces can never be perfectly managed. Such losses are unavoidable; for example, water tends to drain away through cracks in the piping, and traffic flow is interrupted by erratic driving behaviour. The search for parking places can account for as much as 30% of inner-city traffic,[48] and suboptimal timing of traffic lights on US roads accounts for an estimated 10% of delays.[49] The two broad measures for increasing throughput are to reduce headways (in transportation) and to reduce technical losses (in utility operations).

– Reduce headways: A system that requires large headways (intervals or distances between units) can accommodate and process fewer vehicles, passengers or items of cargo. To reduce the headways, operators need to introduce a coordinated and sophisticated form of system management with enhanced user information and control, without compromising user safety. Some examples are provided in Figure 12, along with various innovations expected in this area.

– Reduce technical losses: Physical leakage is a major issue in water

Figure 12: Examples of Headway Reduction Strategies

Headway reduction in transport leads to higher throughput

		Many existing options to reduce headways ...	... and more innovations will become available in the future
	Road	– A dynamic traffic-management system, with lane-specific signals, driver info panels, and hard-shoulder running on the UK's M42 reduced the journey time during the afternoon peak by 24%, reduced accidents with injuries by 64%, reduced fuel consumption by 4%, and reduced noise. – The Traffic Light Synchronization programme in Texas reduced stops by 14% and delays by 25%.	– Autonomous cars could double or even treble road capacity as they allow smaller distances between cars, as they react faster and brake more effectively than human drivers can. – The "SAfe Road TRrains for the Environment" (SARTRE) initiative, currently tested in the EU, allows shorter headways: cars join in a road platoon and automatically follow the lead car.
	Airport	– Systems to ensure that pilots use the right exits and speed while taxiing and a continuous climb and descent mode can increase runway capacity. – Improved gate allocation and faster ground-handling enable shorter minimum connecting times and thus better connectivity.	– Next-generation air-traffic control can lift EU airport capacity by 15 million by reducing the minimum distance between planes taking off and landing. – The German Aerospace Centre DLR patented a technology that inhibits the air turbulence behind aircrafts, and could decrease aircraft separation and thus increase runway capacity by 10%.
	Rail	– The New York City Transit Authority introduced platform floor markings to show commuters where to stand, and departure clocks for drivers to standardize dwell time; this increased throughput on one of New York's busiest lines by 4.5%. – The European Train Control System allows more throughput, as train frequency and speed can be increased thanks to automatic emergency braking.	– The implementation of the European Rail Traffic Management System (ERTMS) Level 3 under a moving-block system (instead of traditional fixed-block operations) has the potential to reduce headways between trains by 10%-20% compared to ERTMS Level 2 – and thus increase line capacity accordingly.

Sources: "Active Traffic Management. Monitoring and Evaluation Project Results and future work". UK Highways Agency, http://www.easyway-its.eu/download/392/1172/, 2009; "Weniger Wirbel an Flughäfen: DLR testet neues Verfahren zur Entschärfung von Wirbelschleppen". Deutsches Zentrum für Luft- und Raumfahrttechnik, http://www.dlr.de/dlr/desktopdefault.aspx/tabid-10081/151_read-6937/year-all/#gallery/9611, 2013. "Intelligent Transportation Systems For Traffic Signal Control". U.S. Department for Transportation, http://ntl.bts.gov/lib/jpodocs/brochure/14321_files/a1019-tsc_digital_n3.pdf.

and electricity transmission and distribution systems, owing to low-quality design and construction, insufficient maintenance and ageing components. About 45 million cubic metres of water is lost daily in the developing world as a result of physical leakage – enough to meet the water needs of 200 million people.[50] And the loss of potential water revenues in some parts of Africa is often as high as 40-50%. To reduce the losses of water or electricity, the following steps are indicated:

– *Use technology and analytics to detect leakages*. For example, in Malaysia's Selangor state, the installation of pressure control in the water distribution network reduced leakage by more than a quarter.[51] Similarly in the UK, an advanced pressure management system with software, sensors and controllers is used to detect leakages early on, and has reduced water loss by 1.5 million litres per day.[52]

– *Conscientiously and promptly repair leakages*. In Bangkok, more than 150,000 leaks were repaired and 551 km of mains were replaced between 1997 and 2004, by using performance-based service contracts that incentivized the private contractor on actual leakage reduction, effectively reducing the non-revenue water ratio from 42% to 30%.[53]

– *Invest in new equipment*. For example, replacing old, high-loss distribution transformers by modern high-efficiency transformers, as done in large programmes in India and China, can reduce losses by up to 80%. Globally, this approach could reduce energy consumption by 200 terawatt-hours per year, which is equivalent to the Benelux countries' entire electricity consumption.[54]

Increase effective throughput by reducing commercial losses.

Effective throughput is impeded not only by technical issues, but also by commercial losses. For example, "commercial leakage" in the developing world accounts for 30 million cubic metres of water that are consumed daily but not paid for.[55] The causes include operational issues such as poor metering, billing and debt collection, employee corruption, and illegal connections and theft. Commercial leakage is not confined to water and electricity utilities, but also occurs in the transport sector (although it is less pronounced there), through toll evasion on highways and fare-dodging on public transport. Several measures can be taken to reduce commercial leakage:

– Install improved or smart meters, making customer metering more reliable, and use anti-corruption measures to enforce correct readings. Phnom Penh's Water Supply Authority, for example, increased meter coverage from 12% in 1993 to 100% in 2008, and introduced an incentive-based payment scheme for meter-reading staff, correlated to their collected bills. The result was an increase in the debt-collection ratio from 50% to 99%, and only a 6% non-revenue water ratio (down from more than 50%).[56]

– Improve debt collection. In São Paulo, contractors were offered incentives to collect on outstanding bills; the initiative raised US$ 43 million, equivalent to 78% of the bad debt, within two years.[57]

– Prevent theft and improve enforcement. Closed-circuit television and system protection devices can be used to prevent theft, and enforcement can be improved by pressing for revised laws and collaborating with the police.

– Combat illegal connections by means of marketing campaigns and public participation. For example, in South Africa, a national campaign was conducted via the Internet, posters and media to curb illegal connections, including the option of reporting electricity thieves anonymously. This campaign led to the discovery and disconnection of about 80,000 illegal connections and tampered meters.[58] In Delhi, India, authorities have reduced theft by using a "social audit" and information campaigns on the dangers of tapping electricity from live wires.[59]

In combination, these measures can make a particularly strong impact. The State Electricity Board in Andhra Pradesh, India launched a comprehensive drive to regularize its finances. It backed a new law that punishes electricity theft, and introduced IT-supported metering (protective boxes on transformers) as well as new tools to analyse customers' monthly consumption and to trigger alerts. The board also embarked on an anti-corruption fight: inspectors have to issue a numbered report and receipt to customers, and users are given a one-time opportunity to obtain an authorized connection after paying a fine. The cumulative impact of those measures was a reduction of electricity losses from 38% to less than 20%, and a regularization of 2.25 million unauthorized connections.[60] In the water sector, Manila Water of the Philippines provides a good example of what can be achieved by applying similarly broad measures; it drove down its non-revenue water ratio from 63% in 1997 to just 11% in 2010.[61]

Apply demand management

Demand-side strategies, aimed at redistributing demand in time, space or mode, are equally important in making the most of existing capacity. They often present a cost-effective alternative to increasing capacity, and also have the potential to deliver better environmental outcomes, improved public health and more prosperous and liveable cities.

As Tony Blair declared during his time as British Prime Minister, "We cannot simply build our way out of the problems we face. It would be environmentally irresponsible – and would not work."[62] Far preferable would be a comprehensive application of demand management techniques; this could, for instance, reduce peak-period car travel in British urban areas by over 20%.[63] The opportunities for applying demand management have increased greatly, thanks to technological progress in metering, billing and payment, such as e tolling and smart meters.

Four broad approaches are available: time-based user charges; self-regulation through improved information; increased operations control; and a shift of demand across mode and space.

Employ static or dynamic time-based user charges.

Introducing time-based peak pricing provides users with powerful incentives to adjust their behaviours and shift their usage patterns (Figure 13). This approach is more relevant for infrastructure assets serving individual consumers (whose usage patterns show peaks in time) rather than industrial users (who tend to be more stable throughout the day).

– Use time-based price segmentation wherever appropriate: Such segmentation is suited to almost all sectors of infrastructure. For example, many airport tariffs are adjusted by time of the day. Many electricity contracts in Italy and Sweden include time-of-use tariffs, enabled by a broad smart meter roll-out. Singapore has led the way on congestion pricing for urban roads; in 1998, it introduced its Electronic Road Pricing system, where rates are adjusted based on a three-monthly review of actual congestion to achieve the targeted optimal speed range. The system has led to increased use of public transport, and has reduced traffic by 10-15%, particularly during the morning rush hour.[64]

– Consider dynamic pricing: Although this technique has been little used up to now, it looks very promising. Prices are not preset in line with assumed peak times, but are dynamically adjusted in line with the actual congestion in the network. For example, State Route 167 in the US state of Washington introduced HOT lanes with dynamic prices for single-occupant vehicles, with a range of US$ 0.50 to US$ 9.00 depending on real-time traffic levels updated every five minutes. As a result, the regular lanes also benefited during peak hours: speeds have increased by over 20%, collisions are down by 2% and the number of vehicles has decreased by 5%.[65]

– Maintain a clear customer focus and take social mitigation measures: Peak pricing does tend to arouse criticism and public discontent; users complain about the extra cost burden, and some policy-makers and social activists criticize the tariffs as being inequitable. However, while time-dependent pricing is often used for optimizing yield, it can be implemented as revenue-neutral ("zero-sum pricing"). In that way, it becomes more socially and politically acceptable. Operators can also take other steps to soften the blow, for example:

  – Dynamic toll lanes in Puerto Rico allow access for the local Bus Rapid Transit (BRT) system (assuring transport for all social classes) as well as car drivers at certain times if they pay a toll (assuring financial sustainability of the operator). The rate varies according to actual traffic density, and the system is updated every five minutes to avert congestion and ensure the free flow of general traffic and the BRT.

  – In the US, Baltimore Gas & Electricity first piloted time-of-use pricing and carefully monitored customer reactions. For the roll-out, a high level of customer service was assured by providing

Figure 13: Overview of Time-based User Charges

Demand management can be realized with static or dynamic peak pricing

Static peak pricing | **Dynamic peak pricing**

Prices depend on time: peak vs off-peak | **Prices depend on real-time congestion**

Static peak pricing:
- Predictable revenues for the operator
- Preventive congestion avoidance
- Transparent charges for users
- Lower technology costs

Dynamic peak pricing:
- Optimized revenue management for the operator
- Real-time congestion avoidance
- Charges difficult to predict for users
- Higher technology costs

Baltimore, US: Electricity & Gas
— Time-of-use pricing

Santiago, Chile: Highway
— Three price tiers based on time

Puerto Rico: Dynamic Toll Lanes on Highway 22
— BRT lanes, sometimes accessible to cars, at variable rates according to traffic level

Washington State Route 167
— Prices for single-occupant vehicles (US$ 0.50 to US$ 9.00) depending on real-time traffic

energy reports, investing in advanced meters and retaining optionality for users. The result was a high customer-satisfaction rate, while achieving the goal of reducing peak demand by 18-33%.[66]

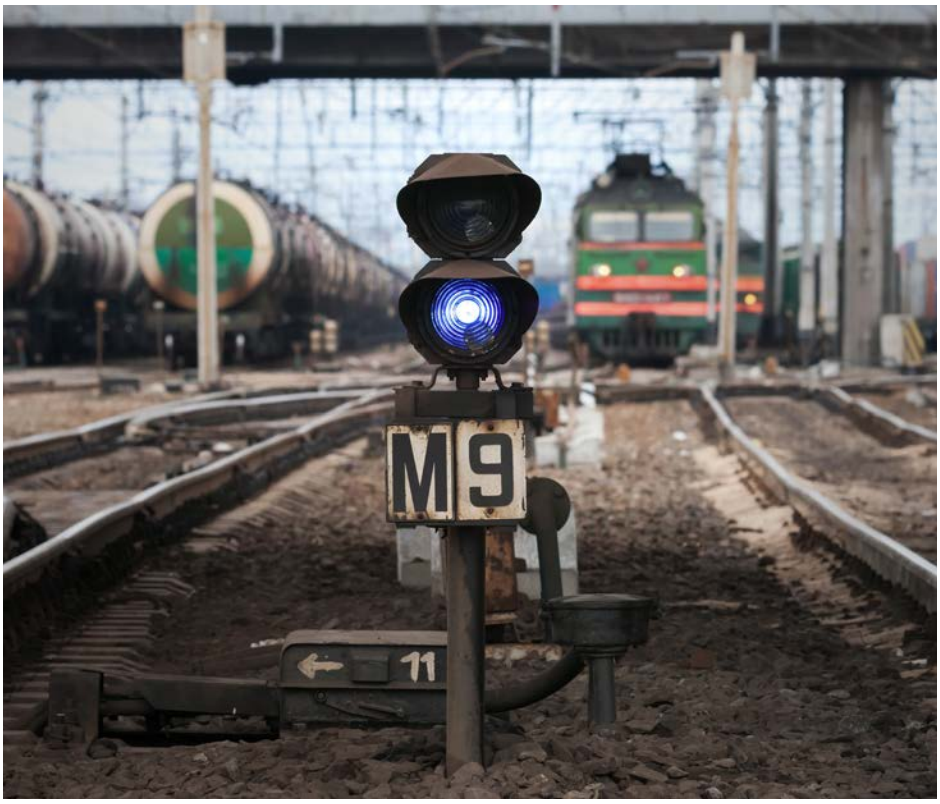
Promote self-regulation through user education and information.

Customer behaviour is driven by more than just financial incentives. In fact, if users perceive the value of shifting their demand patterns – value such as less time lost or better environmental outcomes – they might intrinsically adapt their behaviour. In some settings, however, additional consumer education is needed on the potential of savings and appropriate measures, as in the São Paulo Slum Electrification and Loss Reduction Programme in Brazil. If customers are educated about the potential impact, all they need is the relevant information to act. Technology is making such information increasingly available. Smart meters, for example, enable customers to "see" their usage profile in real time and take appropriate action. A survey in North America found that 71% of consumers believe that detailed water usage data would encourage them to save water.[67] The various technologies employed in the transport sector can be considered, ranging from asset-heavy solutions on the infrastructure side to asset-light IT on the user side:

- Asset-heavy: Hong Kong's Route 8 highway, for instance, has traffic displays providing real-time congestion information with warnings, and also implements passive and active diversion.[68]
- Asset-light: Traffic and navigation apps such as Waze (community-based and crowd-sourced) are now available. Drivers passively contribute real-time traffic data, or actively report accidents and any other hazards; the app then provides other road users with an up-to-the-minute account of road conditions and suggests an optimized route.

Increase operations control.

In many cases, promoting self-regulation may not be sufficient; explicit usage limitations may be required, which can usefully complement the pricing approaches while avoiding the social-exclusion effects of user charges. Administrative slot allocation at airports is one example, and many cities, from Athens, Greece to Quito, Ecuador, impose road space rationing based on licence plate numbers.



Shift demand across mode and space.

The various techniques just discussed – static and dynamic peak pricing, self-regulation and operations control – can facilitate demand management not just by reducing demand or by redistributing it more evenly across time, but also by spreading it across space and mode. Examples include:

- Shifts in space: In France, to discourage diversions of truck drivers from tolled highways to free regional roads, authorities are planning a satellite-based tolling system to charge trucks even when they are on these non-toll regional roads.
- Shifts in mode: To encourage cargo companies to use rail rather than road transport, Switzerland introduced a heavy traffic toll, based on distance, weight and emissions. As a result, heavy-truck traffic across the Alps has slightly declined over the last ten years despite increasing cross-border trade. Canada's Central Okanagan region, formerly the most car-dependent region of British Columbia with 85% of suburban commuters driving to work in single-occupant vehicles, set about to redress the balance. It raised parking prices above the cost of a public transport pass; launched a carpooling initiative; introduced a school-based, green transport educational programme; and expanded infrastructure for bicycles and public transport. The result was a surge in bicycle commuting, with one in seven residents bicycling to work in 2004, and the region's highest growth rate in public transport usage.[69]

To succeed in shifting usage in mode or space, the best strategy is not only to impose punitive pricing on the traditional, unfavoured option, but also to ensure that the new, favoured option offers greater convenience and efficiency. In the Swiss case mentioned, the railway option became more competitive because the government invested in modernizing the rail infrastructure, and introduced reforms that gave rail companies greater flexibility and entrepreneurial freedom.

The work of the World Economic Forum in Tianjin, People's Republic of China, reflects another wide-ranging concerted initiative, involving systemwide throughput optimization and demand management measures (Box 3).

Box 3: The Future of Urban Development Initiative and Its Work in Tianjin, People's Republic of China

The Future of Urban Development Initiative,[70] led by the World Economic Forum, aims to serve as a partner in transformation for cities around the world as they address major urban challenges. Tianjin, its inaugural "champion city", is a growing metropolis of 13 million people, with the world's sixth-largest seaport and an important special economic zone for manufacturing. Not surprisingly, it suffers from heavy traffic congestion, and the initiative has developed a holistic city strategy to address the issue.

While car ownership in the city has recently increased 10-15% per year, road infrastructure has increased by only 3%. With the number of cars forecast to double between 2010 and 2015, the solution will have to involve more than constructing new roads and public transport systems; it will also require optimizing the operations of the existing transport network. The initiative's recommendations include the following:

Expand intelligent transport systems.

- Introduce dynamic traffic control and parking guidance systems
- Improve driver information on traffic conditions using dynamic signboards, highway radio and on-board navigation systems
- Install transponders for electronic toll collection and congestion pricing

Optimize public transport operations.

- Improve last-mile access by coordinating bus and metro schedules
- Introduce digital payment cards valid for all transport modes within the system
- Eliminate left turns on bus routes, and introduce express and local bus services
- Establish a BRT system with its own right of way

Integrate land use and transport planning.

- Establish a process for all government departments to work together on land use and transport planning
- Promote transit-oriented development
- Create a safer and more pleasant environment for bicycling and walking

Optimize availability and reduce downtime

Asset availability may be constrained by legal issues, for instance with night-time restrictions on port and airport operations. In such cases, the unused capacity can only be released through regulatory changes. For other types of downtime, however, resolution lies within the power of the infrastructure operators themselves.

Asset downtime certainly represents a challenge for operators, and reduces reliability for users. Eight out of 10 ports suffer from unscheduled downtime, and of those, almost half are down at least 10% of the time.[71] These challenges are increasing as the stock of infrastructure assets ages. For example, Germany's Kiel Canal, the most travelled artificial waterway in the world, had to close for several days in 2013 for repairs to its inadequately maintained locks. This downtime required detours of 250 nautical miles (463 km), costing about € 70,000 on average per vessel.[72]

To increase availability, operators should take the following measures when appropriate and feasible:

- *Reduce the number of scheduled downtimes* by adapting the maintenance cycle and by bundling maintenance tasks into a one-time intervention.
- *Minimize the risk and number of unscheduled breakdowns* by

undertaking regular and reliable preventive maintenance and by adhering to strict construction standards.

– *Reduce the downtime of each outage* by optimizing the repair and maintenance processes. For example, Skanska used rapid-strength concrete for road paving bay replacements on the UK's M25 motorway to minimize lane closures and increase road availability for drivers. Autostrade per l'Italia has broadly re-engineered its maintenance processes for bridges and viaducts, reducing the share of maintenance tasks with medium-to-severe traffic interference from 50% to 10%. Shift work can keep construction sites active, and thereby also speed completion of repairs: in Germany, for instance, highway works currently use only two-thirds of the maximum possible daylight working hours.[73]

– *Consider operations requirements in maintenance planning*. Autostrade per l'Italia schedules short-duration maintenance tasks for off-peak hours, minimizing the inconvenience to drivers if congestion could be expected during daytime works.

– *Keep the systems running during maintenance works* by properly planning deviations and providing temporary alternatives. For example, Skanska, while replacing the movement joints underneath the Queen Elizabeth II Bridge on the M25 motorway, installed an innovative ramp to reduce the duration of lane closures and increase bridge availability for drivers. The Panama Canal duplicates key components to ensure 365-day, 24-hour service; two pairs of canal locks and two pairs of valves for the lock chambers exist, so replacements can be made without interrupting normal operations.

– *Improve incident management*. Accidents, other incidents and construction work jointly account for up to 25% of road congestion,[74] so efficient incident management is crucial, including accident prevention measures, a quick-response rescue service, rapid clearance of accident sites and localized weather forecasting to alert snow removal teams. London is improving the management of utility construction sites with a web-based utility management plan, a system piloted in Birmingham: if proposed water and electricity utility works are likely to interrupt traffic, the operator is assigned a specific time slot for carrying them out, and has to pay a penalty if the deadline passes before completion.

As all the measures come at a price, the objective is not to maximize availability but to find the optimal operating range – to balance the costs of implementing the various measures against the benefits, such as saved user time and revenues. Aircraft operators and manufacturers serve as good examples; their sophisticated quantitative models determine optimal O&M schedules for reducing downtime.

1.2 Enhance quality for users

Historically, the users of infrastructure assets have not been a priority consideration for many operators. Infrastructure facilities tend to enjoy a natural monopoly, so there is little competitive pressure to provide outstanding customer service. Instead, a "public service mentality" tends to prevail – the dutiful provision of predefined, uniform service for customers rather than an engaged effort to monitor their changing needs and satisfy their wishes. The customers, on their side, might grumble, but their options are limited, especially if the service is subsidized or provided for free, and usually no alternative provision exists anyway.

Service quality, a constant issue in many countries, is becoming more acute because of ageing assets. Low-quality service is not only annoying for users, but is also expensive for society. The US Department of Energy reports, for example, that power outages cost the national economy US$ 150 billion annually.[75]

On the users' side, expectations are rising not only because of the increasingly applied "user pays" principle, and increased competition and privatization, but also because customers increasingly compare their local service to international benchmarks, such as the Skytrax rating of airports.[76] As some user groups consolidate – through airline and shipping mergers or alliances, for example – so their clout increases.

Against this background, infrastructure operators need to take steps to advance their service levels. Three broad strategies are indicated: adopting a customer-centric operating model; enhancing the end-to-end user experience; and launching smart technologies to refine performance.

Adopt a customer-centric operating model

Infrastructure has traditionally been an engineering-driven endeavour, which puts greater emphasis on the asset than on the user. By custom, the operators adhere to predefined performance standards derived from stable, well-defined and standardized regulatory requirements and/or technical handbooks, and pay little attention to customers' ambiguous and diverse needs. The providers might put great effort into optimizing the asset's technical features (e.g. the speed of trains), while disregarding what is really important to the customer (e.g. access to and frequency of the trains, and the comfort and general experience of the journey).

In view of these challenges, however, some operators are beginning to see the virtues of a more customer-centric mindset, and are trying out the standard marketing tools routinely applied in consumer industries. To embrace customer orientation, they should seek to improve customer insight, and then adopt an operating model that enables continuous client focus and service.

Improve customer insight.

– Identify the customers and segment the customer base. Infrastructure operators do not necessarily have a direct relationship with end users, and so might not have a good understanding of their needs. Both direct and indirect customers exist: at airports, the airline companies as well as passengers; and at ports, the shipping lines, third-party logistics providers, railways and trucking companies, all with their distinct needs. Some airports have duly developed an in-depth understanding of their various customer segments, even targeting non-travellers (e.g. sightseers and pick-up people), and increased their appeal to them through, for example, airport events, visitor tours and improved landside shopping outlets.

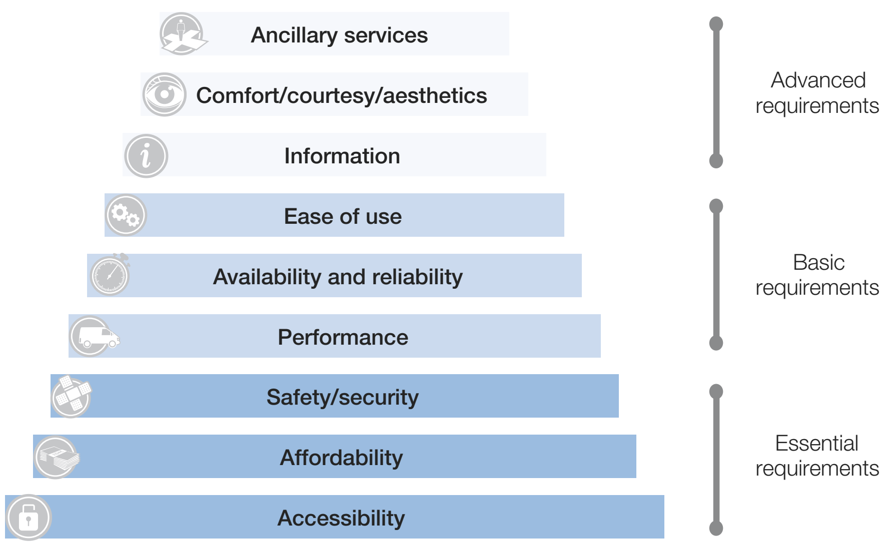
- Understand what the customers need. Conducting market analysis and research to provide a thorough understanding of the drivers, trends and economics of the corporate customer's business and the end user's personal needs can help create a compelling customer experience for infrastructure assets and related services.
  - Conduct customer surveys: While standard procedure in consumer industries, surveys are still underutilized by infrastructure providers. A survey of 10,000 airport users on their most-wanted amenities revealed that 49% want a cinema, 36% would appreciate sleeping options and, perhaps surprisingly in the age of e-readers and smartphones, about 32% would like a library; yet, only a few airports offer these services.[77] Without proper market research, operators often give priority to "hard" characteristics such as speed, rather than to "soft" characteristics (e.g. convenience, reliability), even though users might also demand the latter.
  - Assess user needs according to various categories: These cover essential requirements such as accessibility, affordability and safety; basic requirements including performance, reliability and ease of use; and advanced requirements such as information, comfort and ancillary services (Figure 14). While the basic requirements are "hygiene factors", the higher-level requirements can provide a differentiated user experience.
- Establish what the customer values in order to prioritize spending among the quality categories. Use advanced analytical tools including conjoint or discrete choice analysis, based on revealed or stated preferences data or big data analytics, to clarify customers' willingness to pay. Also, consider upgrading to two-way user engagement through social networks to receive lively feedback.

The overall objective is not to maximize quality, but to deliver the appropriate level of quality in line with the users' quality-cost trade-off. In other words, operators need to strike a trade-off between service improvements and increased costs. Such an approach will help to accomplish two aims: first, to challenge over-engineered technical specifications with no tangible benefit to the end user; and second, to ensure that hidden customer requirements do get fulfilled.

Enable and institute customer orientation in the operating model.

- Define a customer value proposition, differentiated by customer group. For example, some ports are specializing in a particular user segment, such as shippers seeking to minimize port and service fees, or shippers whose priorities are quick turnaround times and streamlined procedures. In fact, a single infrastructure facility can provide for more than one customer segment. Kuala Lumpur International Airport in Malaysia opened a special terminal to serve low-cost airlines that value quick aircraft turnarounds and low airport fees, while the main terminal caters to full-service carriers by providing short connecting times and high-quality services.
- Evaluate the competitive advantage and the uniqueness of the value proposition relative to competition (which is often indirect). For example, the Panama Canal monitors the alternative routes, such as the US intermodal land bridge or the Suez Canal, segmented by type of goods.
- Develop and implement a comprehensive marketing plan. The benefits can be remarkable: even toll roads, where demand is largely exogenous, have increased revenues by about 10% using the full marketing mix – product and process improvements such as e-tolling, special promotions, price optimization by time and user group, and loyalty programmes.
- Measure and track customer performance and satisfaction. Set up an outcome-oriented internal management system based on key performance indicators (KPIs) with specific quality targets. Incentivize the organization through performance standards and service-level agreements (for example, some airports have entered into KPI-based quality-performance agreements with airlines). In addition, communicate the quality results to stakeholders to keep them informed. However, care should be taken to manage expectations; for instance, rail customers might expect 100% punctuality, but for most operators a realistic target is about 80%, and they should engage customers accordingly.
- Shift to a customer-oriented organizational set-up. Leighton Contractors in Australia uses a 24 hours a day, 7 days a week (24/7) help desk at the South East Queensland Schools PPP to serve as a single point of contact for teachers to discuss any concerns about security, cleaning, maintenance, groundkeeping and janitorial services. The helpdesk resolves 97% of issues at first contact, thereby freeing teachers to devote their energies to educational outcomes. And the Dutch oil and gas terminal company Royal Vopak uses a key account management system as a one-stop shop for customers, contributing to its consistently high occupancy rate.
- Engage the workforce. To ensure high-quality customer service, a committed workforce is just as important as well-defined processes and advanced technology.
  The high punctuality levels on Japanese railways, for example, are attributable not only to excellent maintenance, availability of reserve carriages and careful timetable planning, but also to the training of new drivers on punctuality, and to the governance model that enables communication and coordination across drivers, and allows departments to excel in incident management.
- Train staff in customer service as well as operational processes. Paris-Orly Airport in France runs courses for staff on how to treat customers from different cultures (e.g. India, China) to meet their specific expectations.[78]

Figure 14: Types of Requirements for Infrastructure Users



Enhance the end-to-end user experience

The best operators not only address the basic requirements of users, but also strive to create a positive end-to-end user experience in two respects: the operators excel in ancillary services by holistically addressing all customer needs (Figure 14), and they optimize the whole network performance by partnering with adjacent assets and other stakeholders.

Address customer needs holistically.

To maximize the value that the customer will derive from using the infrastructure, operators should consider all end-to-end service features that may be relevant from the customer's perspective. Some examples:

- The Panama Canal Authority (ACP), or Autoridad del Canal de Panamá, has launched a just-in-time scheme that notifies vessels of their required arrival time and their provisional transit time 96 hours prior to their scheduled transit. This information enables them to arrive much closer to their scheduled transit, and thereby reduces anchorage time and saves fuel because they can slow-steam to the canal entrance.[79]
- Vinci Autoroutes strives to provide road users not only with a high-standard, on-road experience, but also with an impressive end-to-end experience by "reinventing the break". It introduced 33 themed rest stations, including a vineyard station close to Bordeaux and a "Catalan Village" close to the Spanish border. During the summer high season, it organizes events (sports and games, and family-centred and kids' activities including a petting zoo) which attract nearly 500,000 participants.[80]
- In the airport sector, Singapore Changi Airport is a world leader in customer quality, with the accolade of 5-Star status in the Skytrax ratings. Its high rating is due at least in part to the abundance and quality of ancillary services it offers in the effort to satisfy various customer needs. Figure 15 provides an overview of these services. (Some of them can actually be charged for, and contribute to the funding of O&M activities, as elaborated in chapter 2.1.)

Optimize the quality of the full system, in partnership with other stakeholders.

Infrastructure assets operate in networks, and an individual operator is unlikely to have full control over the whole system's performance. No matter how impressively any one operator performs, the user experience could be dented by any poor performance on the part of adjacent assets or carriers using the infrastructure. Accordingly, to optimize full system performance and the end-to-end customer experience, partnering is crucial.

- Partner with main users. Enter into strategic partnerships with the main clients, as they play a key role in delivering quality to the end user. Frankfurt Airport cooperates closely with its main airline by integrating information, logistics processes and IT systems, to keep connecting times to a minimum and avoid delays and lost baggage.
- Partner with adjacent assets. Port operators, for instance, need to cooperate with adjacent supply chain operators (e.g. railways) to optimize hinterland connectivity and intermodal processes, and thereby enhance the full supply chain's competitiveness.
- Partner with relevant national authorities. Khalifa Port in Abu Dhabi joined forces with the Customs Administration and the Food Control Authority to introduce a one-stop-shop system for customers. With their backing, Khalifa Port is able to integrate and accelerate the flow of trade-related documentation in a centralized electronic system.[81]

Use smart technologies to refine user performance

As digitization is affecting all businesses, it is also becoming a key driving force in infrastructure. Currently no pressing need for additional innovation exists, as many smart technologies are already available and have been tested. Better and wider application, however, is needed. By harnessing the new technologies aptly, infrastructure providers can ease many of the traditional quality-cost trade-offs and achieve win-win solutions (Figure 16; and chapter 1.3 on automation.)

Consider the example of e-tolling on highways and its effects: for customers, it speeds up the journey and reduces congestion; for the operator, it reduces the cost of collecting payments; and for the environment, it lowers emissions and fuel consumption by reducing stops and waits at tollbooths.

Smart technologies can be employed to produce three types of improvement in quality for users: better customer information and interaction; improved system performance and safety; and faster billing and payment. Operators need to take advantage of using smart technologies in each case.

Increase and refine customer information and interaction.

Real-time and mobile applications enable new ways of informing and interacting with users at relatively low cost:

– Many municipal transport agencies have established portals or apps with maps, real-time traffic information and intermodal journey planners. For example, the Singapore Land Transport Authority developed “MyTransport.SG”, a one-stop app for travellers to plan a seamless trip, and to get real-time information on parking availability, train delays and road congestion.

– When Ottawa, Canada introduced a real-time passenger information system, bus ridership rose as commuters no longer had the traditional disincentive of unpredictable waiting times.

– In the UK, Red Funnel Ferries’ call centre reduced its customer abandon rate from 50% to less than 10% by using innovative processes and updating its technology.[82]

Improve system performance and safety for customers.

– New York City has implemented the first phase of its congestion management system, “Midtown in Motion”. Traffic conditions are monitored in real time by 100 microwave sensors, 32 video cameras and e-tolling readers at 23 intersections. In response to the data, traffic signals are adjusted to clear traffic choke points, resulting in a 10% improvement in travel speeds.[83]

– Puerto Valparaíso in Chile introduced an in-house information system to monitor cargo and enhance communications among all stakeholders in its new logistics extension zone. The result was a 70% reduction in the average time that trucks spend inside the port system.[84]

– Autostrade per l’Italia installed the Safety Tutor, an automatic system that measures the average speed over a stretch of dozens of kilometres, in contrast to conventional speed-enforcement devices which monitor vehicle speed at one point only. This new system shifted the perspective from repression to education and prevention, with dramatic results on driving behaviour: accidents decreased by 19% and deaths by 51% in the first year.[85]

Provide fast and reliable billing and payment services to customers.

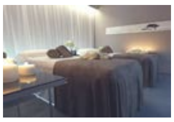
Electronic payment systems are making revenue collection more efficient for operators, and are providing a faster and safer payment method for customers:

– In Sweden, where smart electricity meters have been rolled out widely, customer complaints about invoices have dropped by 60%, and the cost of meter-reading has fallen by 70%.[86]

– In the US, the Oklahoma Turnpike’s e-toll system Pikepass has benefited commuters in two ways: journeys are smoother and quicker, and paying by e-toll costs 5% less than paying by cash. For the operator, it has reduced transaction costs by more than half, resulting in first-year savings of US$ 2 million.

Figure 15: Case Study on Singapore Changi Airport

Singapore Changi Airport addresses customer needs holistically

Customer needs	Services offered at the airport	
Relaxation & calmness		**Themed gardens** — Five gardens with ponds and seating: butterfly, orchid, fern, cactus and sunflower gardens
Recreation & indulgence		**Facilities for recharging** — Rooftop swimming pool and Jacuzzi; showers, fitness and spa — Rest areas and snooze chairs
Entertainment & amusement		**Entertainment areas** — Playgrounds for children — Movie theatre, game consoles and music
Experience & sightseeing		**Recommended transit schedules** — Transit schedule tips based on time available — Free guided city tours if transit time >5 hours
Personalized service		**Luxury terminal “JetQuay”** — Personalized service during departure and arrival — Business and leisure facilities in the lounge

Sources: Changi Airport, http://www.changiairport.com/our-business/about-changi-airport; *Service Innovation by a World-Class Airport: The Case of Singapore’s Changi Airport,* September 2008. Singapore: EGL Singapore.

– The Octopus payment card in Hong Kong, used by 95% of the 16-65 year-old population, allows users to make seamless payments across all modes of transport (bus, rail and boat), as well as at parking garages. The card also provides users with discounts, and is accepted at 12,000 retail outlets.[87]

Such smart systems can generate further value for operators; by collecting and analysing data, they can gain deeper insight into user behaviour and thereby optimize capacities, enable time-based pricing and provide additional information to customers.

Smart solutions are not a panacea, of course, and sometimes they are inappropriate. They can be difficult to integrate into legacy systems, and the investment required for acquiring and installing them might not be worth it. Some smart meter projects, for instance, have failed to provide a positive business case. Moreover, the technology landscape is still evolving, with asset-heavy solutions implemented by infrastructure operators competing against asset-light and smart-phone-based solutions. Despite this uncertainty, many technologies that appear too expensive today will increasingly become cost-effective when implemented at scale, and will further enhance the effectiveness and efficiency of infrastructure assets.

Figure 16: Examples of Smart Technologies in Infrastructure Sectors

Smart technologies are emerging in all infrastructure sectors

Smart Transport

- **Intelligent transport systems** — **Hong Kong:** Large-scale traffic management system
- **Congestion charging** — **Singapore:** Time-based urban road pricing
- **Smart parking** — **San Francisco:** Sensors report free parking spaces and prices are adjusted based on demand
- **Public transport information-sharing** — **Singapore:** Inter-modal journey planners and real-time information systems

Smart Energy

- **Smart electricity meters** — **California:** Roll-out of smart meters since 2006, with >90% of households accepting
- **Electric vehicle infrastructure** — **France:** Staged introduction of obligatory charging stations in new-builds and offices
- **Demand-response** — **Ontario:** "Peaksaver" programme to switch off home devices during peak hours
- **Distributed generation integration** — **Lower Saxony:** Piloting of dynamic distribution transformers

Smart Water, Waste and Social

- **Smart water meters** — **Toronto:** Large roll-out of smart water meters improving metering accuracy and billing efficiency
- **Distribution network control** — **São Paulo:** Digital water management, real-time system control, automatic leaks warning
- **Remote social infrastructure** — **Boston:** Telepresence robots, observing out-patient recovery after discharge from hospital
- **City safety & security** — **Rio de Janeiro:** Real-time city monitoring and control of municipal services

1.3 Reduce O&M costs

While operational efficiency is currently a watchword in most infrastructure sectors, it received far less attention in the past. In the public sector particularly, management rules and culture offered few incentives for cost optimization because of the often-used "cost-plus" approach to allocating funds. The issue is still particularly acute in developing countries, where the priority is on building new assets rather than on operating existing assets efficiently. Africa's maritime ports, for example, operate at a productivity that is only 30% of the international norm.[88]

Pressure is growing to reduce costs, however. Public budgets are constrained, and customers increasingly demand lower prices. Operators had better respond to the challenge. Three broad strategies are recommended: making processes more efficient by implementing lean and automated processes; reducing unit costs by optimizing procurement costs and outsourcing; and optimizing overheads by rightsizing management and support functions.

Implement lean and automated processes

This strategy consists of two main strands: adjusting processes in line with lean principles, and leveraging automation.

Redesign and optimize processes according to lean principles.

The starting point for process optimization is a full and thorough review of business processes. Such an analysis needs to take a holistic approach rather than focusing on narrow functions, and comprehensively investigate all critical processes throughout the value chain. Transparency needs to be created on all the activities and costs of current processes. For example, the maintenance processes should be traced along the full chain of events – from the initial identifying and reporting of the failure, through failure registration and works planning, to works implementation, billing, monitoring and evaluation. Guided by process-mapping, analysts can identify opportunities for reducing O&M costs. Costs are often unnecessarily high, owing to typical sources of "waste" such as unnecessary and non-value-added activities, lack of standardization, insufficient coordination, low workforce effectiveness and lack of workload planning. Given these sources of costs, efforts to reduce them include:

– Reduce unnecessary activities

  – Check and if possible extend the maintenance cycles for time-based maintenance of non-critical equipment. Currently, the intervals are often based on conservative risk and warranty practices, whereas they should be based on a factual review of the actual vulnerability and criticality of specific components.

  – Direct the bulk of spending and maintenance effort at those pieces of equipment that are most likely to fail and whose failures would have the most damaging impact.

  - Implement condition-based maintenance to avoid needless replacements and thereby save on costs.
  - Consider start-from-home initiatives rather than summoning depot-based maintenance teams, to reduce travel in company cars and trucks.

- Standardize O&M processes
  - Develop standard operating procedures, including the "who, what, where, when, why and how". For example, London Underground developed a generic concept describing the likely O&M of stations, depots, railways and passenger services up to 2020, in order to reduce the variety of operating standards and equipment used in future upgrades and to achieve high reliability at minimum cost.[89] Remain alert to changing system requirements, however, and remain flexible enough to forgo some standardization.
- Improve work scheduling and coordination
  - Strengthen field force effectiveness by refining coordination between supervisors and the field force, as well as contractors. Yorkshire Water (UK) integrated and digitized all previously paper-based data into a single, real-time information system to sharpen its work scheduling, enable dynamic task allocation and allow access for both the internal field force and external service partners. Better routeing and information on repair jobs led to a 50% reduction in unnecessary field jobs, and customer performance improved.[90]
- Enhance workforce effectiveness
  - Optimize team size, being guided by internal or external benchmarking.
  - Consider centralizing teams and adopting flexible team set-ups.
  - Consider staff specialization. At the Barranquilla water supplier in Colombia, for example, specialized teams were established to deal with different tasks – customer-complaint handling, maintenance work and inspection. In conjunction with other initiatives, this specialization has reduced the time taken to repair pipe leaks by 50%.[91]
  - Optimize staff allocation and shift work. By reorganizing its shifts, Singapore's public transport operator SMRT improved driver productivity by 10%.[92]
- Plan well ahead to streamline processes
  - Integrate maintenance planning with operations planning to enable anti-cyclical scheduling of maintenance tasks during times of low system load.
  - Plan holistically to reduce workload variability and to average out workloads over the course of the year.
  - Plan individual work processes in a detailed way to avoid, for instance, insufficient stocks of inventory and hence delays and additional logistics costs.

With its strong maintenance planning philosophy, the ACP, for example, is able to pre-order or pre-build components and equipment, and thereby avoid waiting times during the actual maintenance works. Using Gantt charts, it plans maintenance activities down to the minute. Thanks to such detailed planning, it optimizes the sequence of maintenance steps, and has succeeded in reducing major gate outages from an average 14 days in the past to just 4.5 days now. It has also successfully shifted to an all-in-one-go model of maintenance work, rather than multiple sequential work packages, to avoid repeating some of the fixed costs (e.g. sending out staff, building scaffolding).

In some cases, however, economies of scale can be achieved by bundling similar maintenance tasks from various sites, rather than by conducting all-in-one-go maintenance at a single site. For example, the MTA New York City Transit found that its one-station-at-a-time rehabilitation approach was proving too costly and time-consuming, so it shifted to a component-based programme. This involved assessing certain items of equipment and structures across all stations, such as platform edgings or escalators, and then carrying out repairs where indicated. In this way, resources were concentrated on the most needed upgrades.[93]

Leverage automation technologies.

Process optimization often requires difficult trade-offs between quality and costs. The need for these traditional trade-offs can be increasingly reduced or even dispersed by automation.

Opportunities for automation abound – from driverless underground trains in metros and unmanned stacking cranes in ports, to the inspection of assets using wireless sensors and to automated repair scheduling (see Figure 17 and Box 4 for examples). Skanska's use of Building Information Modelling provides a good example of automation leading to improved value. Instead of traditional survey methods, Skanska used laser scanning to store design and construction information from structures and road surfaces, and to optimize and plan maintenance and rehabilitation works – providing a return on investment of 10 to 1 relative to the old methods.

Automation is not limited to single operation processes, but is now being applied to whole systems. Control and monitoring take place in integrated and sometimes remote operations centres, which provide real-time, end-to-end visibility on all of a system's processes, and enhance efficiency without compromising quality or safety. The high-tech Rio Operations Center in Brazil is a case in point; opened in 2010, it integrates the data and monitoring functions of 30 agencies and utilities under one roof.[94]

Figure 17: Examples of Automation in Infrastructure

Many opportunities for automation in infrastructure

Automation in operations processes	— Driverless trains, as in Dubai, the world´s longest driverless metro network, with 76km in total and 47 stations. — Automated border control scheme at Paris-Orly, utilizing biometric fingerprint checks and taking only seconds, thereby saving passengers time and reducing staff requirements. — Advanced electricity meters in Nashville, allowing remote and accurate reading, and enabling staff reductions of up to 63%. — Unmanned stacking cranes at Abu Dhabi Khalifa Port – 30 cranes fitted with lasers and partially remotely operated, to optimize detection and positioning of containers. — Smart street-lighting in four Dutch municipalities, switching off or dimming when no one is walking in the street.
Automation in asset-condition monitoring	— Automated ultrasonic testing system on Seto-Ohashi Bridge, with a total length of 13km, to detect welding defects. — Wireless monitoring on Jindo Bridge, with 663 wireless sensors constantly analysing vibration, wind and humidity, and reporting anomalies to the central computer. — Drones at Autostrade, for inspection of assets and surveillance of highways, particularly in difficult-to-access locations such as bridges in mountainous areas. — GE’s Cage system, active at 130 sites, measuring sound and electrical signals of sub-sea equipment as early warning for leaks and defect isolation, with 10,000x higher accuracy.
Automation in systems command and control	— Rio Operations Centre, which monitors and integrates data from 30 municipal and state agencies and utilities 24/7 under one roof. It monitors everything from weather, traffic, electricity and water to disease outbreaks and emergencies; e.g. enabling the local waste firm to better sequence rubbish collection and reduce fuel use, and enabling the transit agency to redirect traffic promptly to alternative routes to avoid congestion. — GE’s remote monitoring system of its Jenbacher gas engines. More than 3,400 engines around the world send operating data every 30 seconds to the system, which monitors, diagnoses and predicts their performance. As a result, more than 50% of issues are solved remotely without a service engineer on-site, reducing downtime (which would cost users up to US$ 16,000 a day).

Box 4: GE’s Centralized Asset Management Operating Model for Healthcare Facilities[95]

While health systems nowadays are challenged to reduce costs to match financial realities, the opportunity to reduce the cost burden associated with managing assets remains relatively neglected. About 95% of a hospital’s clinical asset base consists of ventilators, infusion pumps, telemetry units and other mobile workhorse devices. The amount of such equipment per hospital bed has jumped 62% over the past 15 years, but average utilization is only about 42%; a modern hospital’s asset inventory is now both pricier than ever and often underutilized.

GE’s Centralized Asset Management Operating Model for healthcare facilities can help reduce those costs. The model optimizes the asset workflows at each hospital through better tracking and monitoring of the mobile assets at all hospitals within a healthcare system. In addition to *facility-level* optimization, the model can enable healthcare systems to leverage their operations’ scale on the *system-level* by centralizing and coordinating distribution of the devices for three or more hospitals within a 50-mile (80-km) radius. In this comprehensive approach, all processes associated with clinical asset management (procurement, utilization, infection control and equipment maintenance) are controlled and supported centrally. A central distribution unit maintains appropriate stocks at each facility, moving the devices as needed from one hospital to another to meet fluctuating demand.

By adopting the model, healthcare systems can reduce the costs associated with asset management by 15-25%, and can save on future capital spending.

Optimize procurement costs and outsourcing

Optimize procurement costs.

Despite high spending, the purchasing practices of infrastructure operators are often underdeveloped. Many procurement departments tend to concentrate on the initial purchase rather than on whole life-cycle cost, and regularly base their purchase decision on single product attributes, such as brand, performance, durability or after-sales service. A wiser policy is to apply a total-cost-of-ownership analysis, incorporating a whole life-cycle review of any high-value system, equipment and component being purchased.

A comprehensive procurement strategy needs to apply the various commercial procurement levers such as supplier management, bundling and best-cost country sourcing. In addition, however, it should seek to enhance procurement processes and apply technical procurement levers such as standardization and make-or-buy where possible. The checklist in Figure 18 provides an overview of the various procurement levers, and the case study on the As-Samra wastewater treatment plant (Box 5) illustrates an example of select technical procurement levers.

Figure 18: Checklist of Procurement Opportunities

Procurement should address commercial, process and technical levers

Examples [1]

	Lever	Typical actions	
Commercial	1 Supplier management	❑ Review and develop supplier base ❑ Facilitate supplier switch / Qualify new suppliers ❑ Renegotiate contracts and terms/conditions	❑ Develop framework agreements ❑ Adjust frequency of negotiation ❑ Optimize negotiations: multi-round, e-auctions
Commercial	2 Bundling	❑ Centralize purchases for scale economies ❑ Use global tenders and master agreements ❑ Coordinate purchases across departments	❑ Compare prices and terms with benchmarks ❑ Optimize orders over time and consolidate orders ❑ Optimize single-order quantity and quality
Commercial	3 Best-cost country sourcing	❑ Purchase products from best-cost countries ❑ Ask suppliers to purchase/manufacture in BCC ❑ Buffer cost uncertainty via indexing/hedging	❑ Leverage global economic price trends ❑ Introduce global procurement organization ❑ Optimize taxation
Process	4 Demand management	❑ Assess buying needs regularly ❑ Plan volume by purchasing department ❑ Control unplanned maverick buying	❑ Check compliance with supplier agreements ❑ Simplify order process and streamline logistics ❑ Coordinate and balance workload of contractors
Process	5 Process optimization	❑ Simplify bidding process ❑ Standardize bidding process/documents ❑ Use e-tools in bidding and negotiation	❑ Implement standard terms and conditions ❑ Transmit orders and invoices electronically ❑ Optimize supplier stocks to share risk
Technical	6 Standardization/ redesign	❑ Standardize specs to reduce variants in use ❑ Modularize or use market standard products ❑ Simplify specs via design-to-cost	❑ Get supplier input for specifications ❑ Redesign services without compromising quality ❑ Enforce stability of specifications/limit changes
Technical	7 Make-or-buy	❑ Assess make-or-buy opportunities regularly ❑ Optimize ratio of own vs external production ❑ Enforce transparency on cost/margin structure	❑ Purchase inputs for suppliers ❑ Understand "should" cost and cost-drivers ❑ Assess supplier performance permanently

1. Not a comprehensive list of all available actions.
Source: BCG

Box 5: Case Study – The As-Samra Wastewater Treatment Plant

The cost of electricity has almost doubled in Jordan over the past five years, and further increases have already been scheduled. The As-Samra Wastewater Treatment Plant, with its sponsors Suez Environnement and Consolidated Contractors Company, has adopted several measures to reduce its energy bill. Because few commercial levers are available to pull when purchasing commodities such as energy, the company has taken advantage of the wide range of existing technical levers, notably:

– *Reducing electricity consumption*. The company has implemented an energy management system as per ISO 50001 to evaluate and control its energy consumption. The project involves reviewing the efficiency of each energy source, defining KPIs and targets, and taking appropriate, subsequent action. An example is the air blowers used for aeration, which consume the most electricity in the plant. One aeration tank is currently undergoing modification to enable each zone to control its air injection independently, leading to potential electricity savings of 2-3%.

– *Maximizing electricity production.* The company also produces electricity through its hydro turbines and biogas generators. It has implemented several measures to maximize the availability of its biogas generators at over 95%. These include: planning preventive overhauls, reducing the maintenance cycle and negotiating a supplier service agreement with incentives to reduce downtime.

Consider outsourcing of activities.

Increasingly, infrastructure operators need to "do more with less". Outsourcing can help, with its high potential for reducing costs. Without outsourcing, operators would have to acquire advanced technology and other expensive resources themselves, invest in the necessary process know-how and take on specialist employees. Outsourcing can spare the operators those costs, while maintaining or even improving their service levels.

The two main applications for outsourcing are:

– Maintenance works. While construction and design works in most countries have already been mostly outsourced over the past decades, maintenance is still largely performed in-house. Yet in the UK, for instance, the public sector has been contracting out for many years a great deal of routine maintenance and reactive work for urban and local roads.

– IT services and call centres. While many agencies still rely on legacy IT systems, technological progress often allows for more efficient solutions.

Some precautions are necessary, as outsourcing is not always beneficial:

– Run a whole life-cycle analysis and establish the strategic relevance of each activity that is a candidate for outsourcing. Each make-or-buy decision should balance the operator’s own know-how, cost and scale against those of third-party providers.

– Use performance-based contracts. Such contracts have worked successfully in many countries (e.g. Brazil and Argentina) in the roads sector, as they incentivize the private-sector partner to operate efficiently over an extended contract period of 5-7 years with clear outcome-based performance metrics. Typically, they achieve savings of 10 40%, while also improving road quality and safety.[96]

– Decide carefully on the contracted outsourcing period. It should be long enough for the contractor to justify investment in advanced equipment, research and development, training and new systems, but short enough to benefit from a competitive market and to get the best price through regular re-tendering.

– Select the right package size or take a portfolio approach, where multiple small projects are packaged and managed by a single contractor. Such a method will realize synergies and enable economies of scale, reduce transaction costs, diversify financial risks for the private contractor, integrate the management of all the projects and provide comparable standards. A good example is the trend towards regional contracts for O&M outsourcing. In Alberta, Canada for instance, outsourcing contracts has led to 25% savings in road maintenance.[97]

– Assess and amend the procurement processes and foreign direct investment framework to assure that both domestic and foreign outsourcing providers will be able to participate in the bids. This will maximize competitiveness and get the best deal for the government based on world-class skills and knowledge.

– Build a strong relationship with the provider organization. While contracts are obviously important, they often are not sufficient, as outsourced services may entail hard-to-measure outcomes and unpredictable needs and costs, and hence, a reliance on the provider’s cooperative attitude.[98]

  – Retain an appropriate level of control. A fair degree of direct operational control may be necessary when many contractors are involved and in need of coordination.

  – Keep some of the outsourced activity in-house, to preserve an “echo” or benchmark of the service.

  – Secure organizational know-how. Even when outsourcing is used abundantly, the agency will still need staff with engineering and commercial skills, to manage risks and to challenge the contractors’ performance.

– Assess the alternatives to outsourcing. For example, in Denmark, a fairly common approach to maintenance is through partnering. In Italy, Autostrade per I’Italia, in repaving its highway network with porous asphalt, opted to assign the project to its subsidiary construction company. This approach provided the flexibility and incentives of external contracting, but also reaped the benefits of scale across the network. The two associated organizations supported each other in optimizing the asphalt recipe and the works processes, and succeeded in reducing the price of the innovative asphalt by 30% to the same level as regular asphalt.

Rightsize management and support functions

In addition to improving operational processes and costs, infrastructure operators also need to make structural improvements to overheads. Many organizations have grown organically over time, changing their regional footprint and functional requirements but retaining legacy structures that are now ill-suited to current demands. In this regard, the operator needs to conduct a regular strategic review of its organization, and in particular its management and support functions such as finance, human resources and technology/IT. (See chapter 2.3 for more comprehensive governance reforms to be initiated by policy-makers.)

Transform into a lean organization.

Many infrastructure operators apparently regard themselves as "oversized", and perceive their support functions as being of low quality. The following remedies are indicated:

– Redesign the organization. A high-performance organization requires the right structure, clearly defined individual roles and accountabilities, as well as collaboration guidelines and joint budgets to align incentives and coordinate and facilitate information exchange across departments.

– Undertake delayering. Delayering will optimize the number of direct reports (span of control). By making the organization leaner, operators can avoid micromanagement and excessive bureaucracy, cut duplication and reduce the distance between top management and the customer.

– Investigate and perhaps adopt shared services. Such one-stop service centres can centralize, standardize and automate support functions, and reduce their costs by up to 40%.[99]

Any of these initiatives will only be successful if accompanied by a rigorous, organization-wide change management effort, supported by strong commitment and strategic direction from key executives.

Embed a cooperative and high-performance culture.

Given a lack of spontaneous cooperation among employees, O&M decisions in many infrastructure organizations are taken in silos. But to optimize total costs of ownership, it is essential to have joint decisions and active communication involving the engineering, construction, purchasing, maintenance and operations functions. To realize such a cooperative culture requires adaptation not just of the organizational design, but also of the organizational context. Fostering teamwork and cooperation involves the following essentials: shared values and vision, an open and performance-oriented culture, proper career paths, long-term incentives, strong leadership capabilities, and high-quality IT systems and tools. Two examples illustrate this:

– The Tennessee Valley Authority in the US introduced a Balanced Scorecard with clear financial, customer, process and learning targets, and cascaded and communicated this to all employees, with bonuses and non-monetary rewards linked to the targets. The initiative resulted in office-space savings worth US$ 20 million, and a US$ 6 million reduction in system losses.[100]

– The ACP transformed from a "process control" culture to one of entrepreneurial decision-making, by abolishing the "instructions for everything" and installing a continuous improvement process, where staff can propose ideas through the intranet. The new culture inspired a team of about 70 professionals to set up a "maintenance circle" and get together even after work hours to discuss issues and best practices.

Balance centralization and decentralization within the organization.

This balance is of particular importance to network infrastructure such as roads and railways, as well as to water and electricity distribution and transmission networks with an extensive regional structure. While the role of the centre can vary, successful infrastructure operations typically balance local asset management responsibility with central knowledge sharing and scale efficiency gains. Infrastructure assets are real assets, which require distributed visual inspection and asset management interventions by teams with local responsibility for O&M. However, to enable economies of scale, some degree of coordination, monitoring and exchange of know-how should be provided by central units or regional operations centres.

1.4 Mitigate externalities

Infrastructure is a public good, with great economic and social advantages for a variety of stakeholders. The advantages come at a cost, of course, and often not just financial costs but also environmental and social externalities.

The environmental impact includes contributions to climate change, air pollution, loss of biodiversity, and soil and water pollution. For example, total external transport costs in the EU (excluding congestion) amount to more than € 500 billion or 4% of total GDP, and more than half is attributable to environmental impacts.[101]

The social impact includes adverse health effects and the annoyance of noise and congestion. Traffic accidents kill more than 1.2 million people worldwide each year, and injure up to 50 million.[102] See Figure 19 for an overview of the environmental and social externalities of different transport modes and electricity-generation technologies.

Increasingly, infrastructure operators are being scrutinized for their environmental and social sustainability. Against a background of resource constraints – scarcity of water, energy and raw materials – and the problems of waste management and climate change, infrastructure operators not only have to meet the tighter environmental regulations set by policy-makers, but also have to pre-empt public criticism from consumers, societal groups and the media.

Three broad approaches can be taken: planning a comprehensive programme of sustainability/health, safety and environment (HSE) interventions; embedding sustainable practices into everyday operations; and cooperating with other relevant stakeholders.

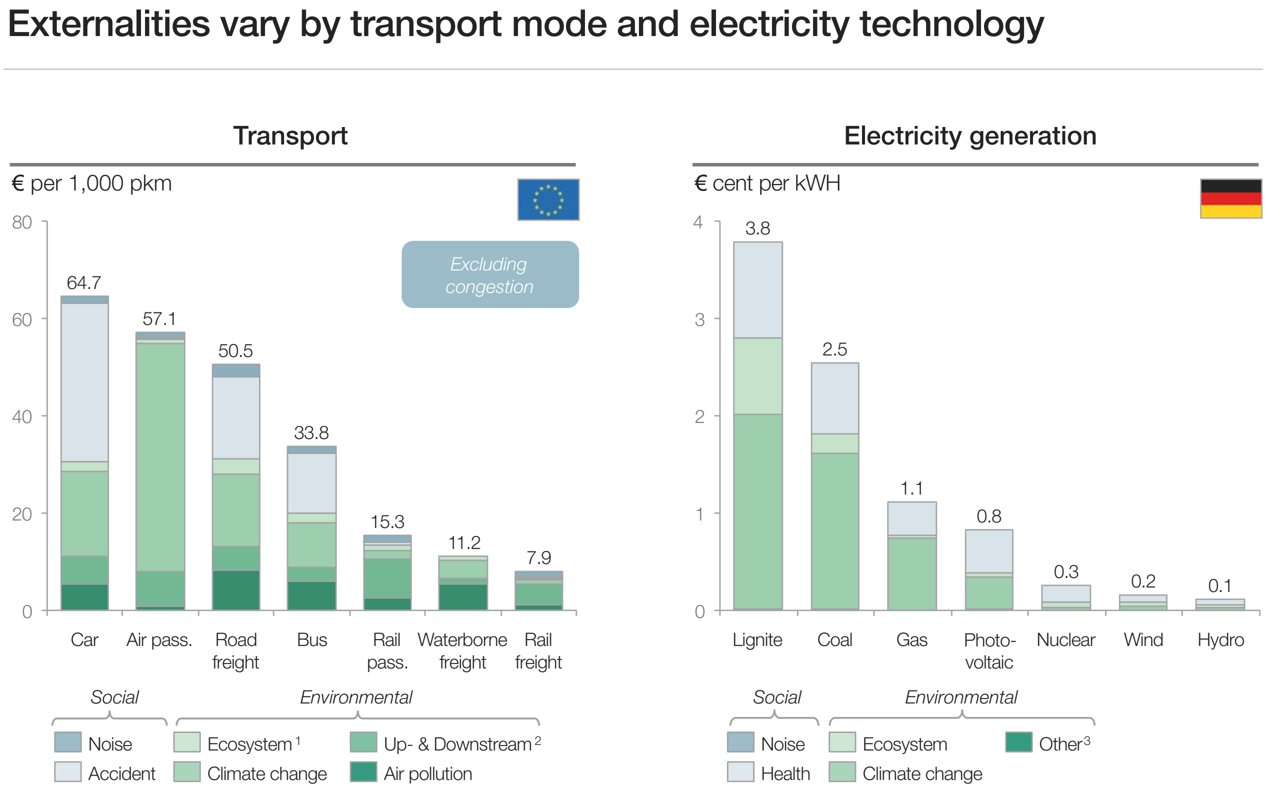
Arrange comprehensive sustainability/HSE plans

Develop a holistic sustainability/HSE strategy and plan.

Sustainability is a wide domain, so no single measure will suffice. Operators need to take action, and set clear KPIs, on a number of fronts to tackle environmental and social issues. In particular:

– Improve resource efficiency to use materials, energy and water in a thoughtful and eco-friendly way, and to minimize waste.

Figure 19: Overview of Externalities in Transport and Electricity



1. Including landscape and biodiversity losses, soil and water pollution, and urban impacts 2. Vehicle and fuel production, and infrastructure provision 3. Including material usage and impact on crops

Note: The data displayed for transport refers to the "high scenario" in the source.

Source: *External Costs. Research results on socio-environmental damages due to electricity and transport,* 2003. Brussels: European Commission

– Minimize the impact on biodiversity and the ecosystem.

– Minimize noise, dust and emissions to mitigate the adverse health impact on local residents.

– Commit to responsible business conduct by, for example, respecting labour rights, preventing corruption and preserving cultural and historical monuments.

One comprehensive model of concerted action is the "Paquet Vert Autoroutier" that Vinci Autoroutes signed with the French government, which addresses several aspects of sustainability (Figure 20).

Adopt a comprehensive set of sustainability measures: "Reduce, Recycle, Replace" – and Rethink.

– Reduce input materials, waste and emissions. London Underground is using regenerative braking to save up to 25% of used electricity. Modern water treatment facilities can reduce sludge production by 35% and energy use by 30%, while emitting little bad smell.[103] And, the UK's National Grid has reduced greenhouse gas emissions by 58% from the 1990 baseline.[104]

– Recycle waste, as a resource for other products. The East Bay Municipal Utilities District in California uses methane from waste to power generators, thereby making it one of the first wastewater treatment facilities in the US to be a net-energy producer.[105] And in Singapore, the advanced treatment facilities produce 30% of the country's water supply, thus reducing reliance on imports from Malaysia.[106]

– Replace equipment, and leverage innovative technologies. Examples of this are Tokyo's Toei subway, which has replaced most of its trains with energy-efficient rolling stock; and efficient coal plants that emit about one-third less CO_2 than most of the plants currently installed.[107]

– Rethink the conventional ways of operating infrastructure. For

Figure 20: Case Study on French Highways

Green Pact on French highways addresses key sustainability issues

	Emissions reduction	**Carbon footprint reduction of traffic** — Encouragement of car-sharing via park-and-ride schemes — Electronic toll collection, avoiding stops at toll booths — Dynamic traffic control systems and speed regulations
	Noise protection	**Improvement to residents' quality of life through noise protection** — Noise reflection/absorption barriers and facade isolation on 271km — Noise reduced by 2-10 decibels (equivalent to 35% less traffic)
	Waste reduction	**Environmentally friendly renovation of 311 stations** — Standardization of waste separation and installation of sewage treatment — Energy-efficiency measures, e.g. energy-saving lamps
	Biodiversity protection	**Preservation of flora and fauna in 120 projects** — Construction of 686 wildlife crossings and ponds, insect hotels, fish ladders — Installation of biotopes and ornithological observatories with walk-throughs
	Water protection	**Prevention of water pollution** — Water retention via basins and drainage; treatment facilities — Use of hydraulic construction and rainwater disposal on >115 sites

Source: *Nos actions concrètes: Le paquet vert autoroutier,* November 2012. Rueil-Malmaison Cedex: Vinci Autoroutes.

example, the US city of Charlotte conscientiously set about transforming the city from being traditionally automobile-oriented (e.g. 75% of streets had no sidewalks) to having more liveable urban space.[108] The effect is expected to halve the death rate among pedestrians and bicyclists.

Evaluate sustainability measures by taking a long-term, whole life-cycle and strategic perspective.

– Consider the project's whole life-cycle impact to justify the upfront investment. Environmental compliance is likely to involve higher costs initially, but could well yield efficiencies in the long term. The switch to greener alternatives might serve to offset the soaring prices of scarce resources, which should be modelled in different business case scenarios.

– In conducting the project evaluation, take into account the additional strategic "soft" benefits that would derive from sustainability, including improved reputation and increased employee motivation.

– If the sustainability measures appear unlikely to pay for themselves, seek additional finance methods, such as the Clean Development Mechanism (CDM), a Kyoto Protocol mechanism whereby developed countries finance low-emission infrastructure projects in some developing countries. Both the Delhi metro and the Bogotá, Colombia BRT system received funding via the CDM.[109] In addition, leverage grants for pilot initiatives. Norway's Transnova programme, for example, provides grants for environmentally friendly transport technology, better utilization of capacity, and demand-side solutions.

Unfortunately, environmental and social goals are not always compatible with each other, let alone with financial constraints, and difficult trade-offs will sometimes be needed. Operators will have to find the sweet-spot between financial, environmental and social performance, and select from a range of competing strategic priorities.

Embed sustainability/HSE into routine operations

For a sustainability strategy to last, it needs to become a fully incorporated element of the operator's daily processes and organization. While sustainability has been on the radar of many public and private organizations, only a few have really made it a strategic issue embedded in the operating model beyond public relations or corporate social responsibility activities.

– Start by defining a bold and clear sustainability vision. Increasingly, operators are looking beyond mere compliance with environmental regulations, and are seeking a lasting competitive advantage and reputation by achieving a neutral or even positive environmental status. For example, the ACP, by reforesting 20,000 hectares near the canal, aims to offset its greenhouse gas emissions to the point of becoming carbon-neutral in 2014.[110]

– Ensure dedicated leadership of any sustainability initiative, and incorporate sustainability activities into the senior management agenda. For example, Hong Kong's Mass Transit Railway (MTR) established a board-level corporate responsibility committee; developed a sustainable competitive advantage model to guide its actions; adopted a corporate responsibility policy;

and, in 2001, was the first Chinese company to publish an annual sustainability report.[111]

– Engage the broader workforce, and build a sustainability culture within the whole organization. In particular, arrange an internal communication programme and training courses for all staff members, not just for those responsible for HSE. For example, Manila Water runs extensive employee training, convenes monthly meetings to discuss environmental issues and raise awareness, monitors energy use and greenhouse gas emissions, and conducts energy audits.[112]

– Adjust governance structure. Ideally, create a sustainability department with appropriate authority and accountability; however, also assign responsibilities for sustainability to the key units of the organization, not just to the central team.

– Amend business processes. For example, to reduce work-related injuries, the MTA Metro-North Railroad made safety a line management priority, improved safety processes after analysing hazards and increased communication and audits on safety. As a result, lost-time injuries decreased by 60% and lost work days by 81% between 2002 and 2006.[113] By taking similar measures, the Los Angeles County Metropolitan Transportation Authority (US), which received 2,700 injury claims in 2001 at an estimated cost of US$ 68 million, managed to reduce the number of claims and lost work days by about 50%.[114]

Cooperate with relevant stakeholders

Successful operators in the sustainability field take a multistakeholder approach. They have an active programme of communicating with stakeholders, as well as collaborating with fellow operators and other stakeholders for higher impact across the infrastructure system.

Communicate promptly and proactively with stakeholders.

– Develop an information campaign to raise the awareness and interest of employees, suppliers, customers and other stakeholders. The ACP proactively engages with its surrounding communities through an outreach programme; its water governance approach is based on six regional advisory councils and 30 local committees.

– Ensure transparency. Manila Water, for example, became the first Philippine company to publish a climate change policy and a sustainability report. It also offers tours of its water and wastewater treatment plants to public- and private-sector visitors and schools.[115]

– Make sure the information provided to stakeholders is understandable and concise, and not in the form of a full technical analysis/report.

– Ensure that communication is two-way. Solicit reports on sustainability attainments or shortfalls, and invite suggestions on remedies.

Collaborate on systemwide sustainability measures.

Adverse social and environmental effects are often due more to the users than to the infrastructure operators. No single operator can remedy the problem on its own; sustainability efforts have to be made across the system and value chain, and should be addressed in collaboration with customers, adjacent operators, suppliers and other stakeholders.

– Evaluate measures from a system perspective. For example, innovative road surfacing not only benefits the operator financially by saving on maintenance, but also benefits drivers and the public at large by reducing car fuel consumption. The refurbishing of Missouri's Interstate 70 (US) with smoother surfacing improved fuel efficiency by 2.5%, reduced emissions and enabled annual savings of US$ 8 million for the 9,000 large trucks that use the road every day.[116]

– Incentivize users to improve their environmental performance. For example, Zurich airport was the first in the world to charge differentiated landing fees according to the aircraft's emissions, a policy that has contributed to the marked increase in efficient, emission-class 4 and 5 aircraft at the airport – from about 55% of movements to above 85%.[117]

– Support customers to operate sustainably by providing them with the necessary facilities. For example, the Port of Los Angeles runs an air quality programme to reduce emissions from ships: as a result of its "Alternative Maritime Power", vessels at berth can now run on mains electricity rather than on heavy-diesel-fuel combustion engines.[118]

– Require and help suppliers and contractors to adhere to environmental standards; implement a system of compliance checks or certification. Manila Water, for example, conducts training courses and audits for suppliers to help improve their environmental performance.

– Coordinate with other agencies. The South African National Roads Agency runs a comprehensive road safety programme that not only focuses on costly engineering measures but also cooperates cost-effectively with other authorities on user education (e.g. road safety lessons at schools) and on enforcement (e.g. overload control).

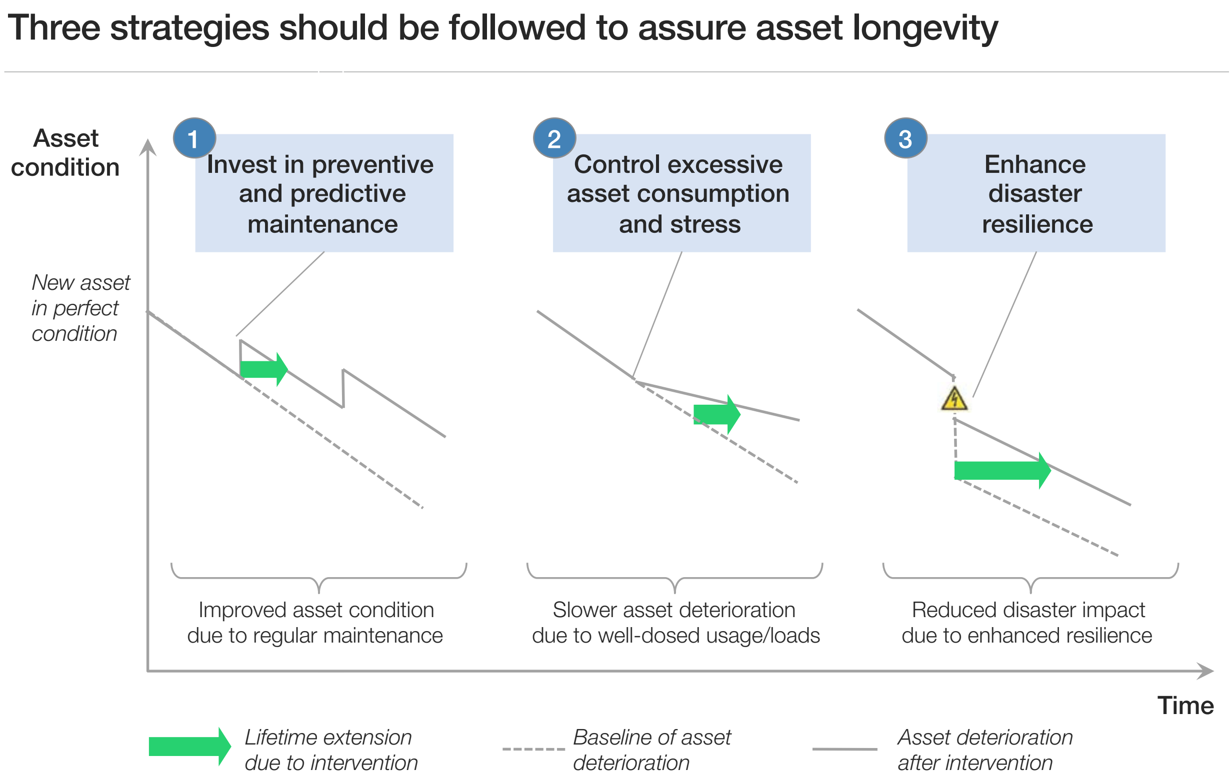
– Cooperate across the value chain. Improvements to air traffic management, for instance, require the cooperation of aircraft manufacturers, airports, airlines, regulators and air traffic controllers. Backed by such cooperation, a full implementation of next-generation air traffic management could lead to a 4% reduction in aviation CO_2 emissions by 2020.[119]

– Cooperate across sectors. For example, mining infrastructure could generate more social value if the various stakeholders, including mining firms, transport operators and government agencies, were to work together to create a multipurpose transport system where mine cargo and passenger traffic can interoperate.

1.5 Extend asset life

Using existing infrastructure assets as long as possible provides clear benefits. As most of the cost of providing the infrastructure consists of fixed past investments, and given relatively low current operating costs, each additional

Figure 21: Overview of Lifetime Extension Strategies



year of service will produce high value as the asset is amortized. The problems also are clear: the condition of the infrastructure keeps deteriorating as a result of ageing, usage and various external factors. Eventually, the asset may lose its ability to function cost-effectively or even to function at all.

To extend the asset's life, operators should pursue three broad strategies (Figure 21):

- Invest in preventive and predictive maintenance, thereby keeping the asset in operational shape and preventing breakdowns.
- Avoid and control excessive asset consumption and stress, and thereby slow down the deterioration process.
- Enhance the asset's resilience against disaster; in that way, extreme events should not produce a devastating effect.

Unfortunately, these approaches tend to get neglected. For politically-minded decision-makers, little incentive exists to invest in preventive maintenance and resilience; the immediate benefits are hardly visible, and the long-term positive impact is difficult to measure and verify. In fact, in the UK, an 11-year backlog in highway maintenance has accumulated.[120]

The impact of such neglect can be severe, both for users and the cost of later repair. The Rhine bridge in Leverkusen, Germany, for example, had to be closed to trucks for four months in 2012-2013 while overdue repairs were made. And in Norway, an undermaintained bridge, at first denied a waterproof membrane costing about US$ 600,000, had to be replaced entirely at a cost of US$ 15 million (excluding the cost of detours for users).[121]

Invest in preventive and predictive maintenance

Preventive maintenance is applied to infrastructure assets suffering light to moderate distress. It involves planned treatments that are carefully timed and cost-effective. Its aim is to forestall costly corrective action and to improve the condition of a system before a failure occurs.

The case for preventive maintenance is a strong one:

- Preventive maintenance slows deterioration and increases the lifespan of an asset; for example, it can add 5-10 years to the service life of a road surface.[122]
- Preventive maintenance reduces life cycle costs. If maintenance is neglected, more drastic repairs might be required in the future, often with dramatically higher costs. Therefore, preventive maintenance can postpone or replace costlier rehabilitation. An analysis of US highways revealed that deferred maintenance led to 29% higher costs overall: the total life cycle cost of a well-maintained road is US$ 2.82 million per lane mile, vs US$ 3.64 million per lane mile for an undermaintained road.[123]
- Preventive maintenance enhances performance; it improves the quality, functioning and availability of a system for users. By preventing breakdowns, it saves the costs and inconvenience that users suffer as a result of blackouts or detours.

A preventive maintenance strategy is clearly indicated, but it is not so easy to formulate, implement and adhere to. A structured approach is needed – evaluating the likelihood and impact of asset failures, customizing a maintenance strategy, assessing the asset's current condition and creating a formal intervention plan.

Monitor assets to determine their vulnerability and criticality.

Only with a fact base of asset failures and their impact can operators define evidence-based maintenance approaches and justify their investments in preventive maintenance. The various steps required are as follows:

- Record all past failures and the corresponding maintenance work for all structures, equipment and components. On a malfunction-cause-and-treatment sheet, note the downtime and the type of maintenance work undertaken. Record the types of failures, including the manner of failure, the circumstances and the failure-event sequence. Establish and analyse the root cause of the failure, and identify the components whose deterioration led to the failure.
- Calculate the frequency and impact of the failures to assess the vulnerability and criticality of the asset:
  - Assess the failure rate (taking into account the condition of the asset). If empirical data is limited, establish a risk measure through expert judgements and laboratory tests.
  - To establish the criticality of each asset, estimate the impact of such failures in terms of lost revenues, increased costs and dissatisfied users. In addition, assess the level of service expectations and requirements of the users and regulators.
- Prioritize the assets in a risk classification matrix along two dimensions: failure frequency and failure impact (or vulnerability and criticality).

Customize the maintenance strategy for each asset.

On the basis of the asset's vulnerability and criticality, choose an appropriate maintenance strategy. There are four broad types to consider – one is essentially reactive, the other three are preventive (Figure 22):

- *Corrective/reactive or failure-based maintenance* is a strategy that activates repair work in the event of a breakdown, and is designed to bring a failed system back to its operational condition. It should be the strategy of choice only if the risk of failure is very low and if the consequences of failure are fairly mild; or, where preventive maintenance measures are not available.
- *Scheduled maintenance* is performed at defined intervals, either after a certain period of use (time-based) or after a certain amount of usage (use-based). This is the strategy of choice when failures are costly or safety is critical, and when the failure rate is fairly low but tends to increase over time. The specific time intervals for inspections and maintenance can be based either on the manufacturers' recommendations or on the operator's experience.
- *Condition-based or predictive maintenance* is a strategy that triggers maintenance activity when the asset's condition (as measured by machine diagnostic techniques or by continuous or occasional monitoring) falls below a certain threshold. The aim is to time the maintenance work optimally, so that it is not performed more often – and hence more expensively – than necessary, and so that it can be undertaken at a convenient time, when the service will be least disrupted.
- *Risk-based or reliability-centred maintenance* considers not only the asset's current condition, but also the likely consequences of failure, including the impact on network performance. The main aim of this strategy is to reduce the overall risk and impact of unexpected failures, i.e. to ensure high reliability. The strategy involves inspecting and monitoring the high-risk components of a system very frequently and thoroughly, while paying less attention to evaluating the low-risk components.

Two examples highlight the benefits of preventive maintenance. In the UK, Skanska applied an asphalt preservation surface coating on the M25 motorway that reduced water ingress and extended the life of the road surface by one-third, thereby reducing costs by one-fifth. And in the US, the Georgia Department of Transportation developed a new maintenance strategy for each airport in the state, prioritizing preventive measures such as crack sealing, surface treatments and thin overlays. The policy effectively delayed the need for rehabilitation work, and thereby reduced the funding required for runway resurfacing each year from 75% of the state programme budget to just 37%, and improved the condition of the assets.[124]

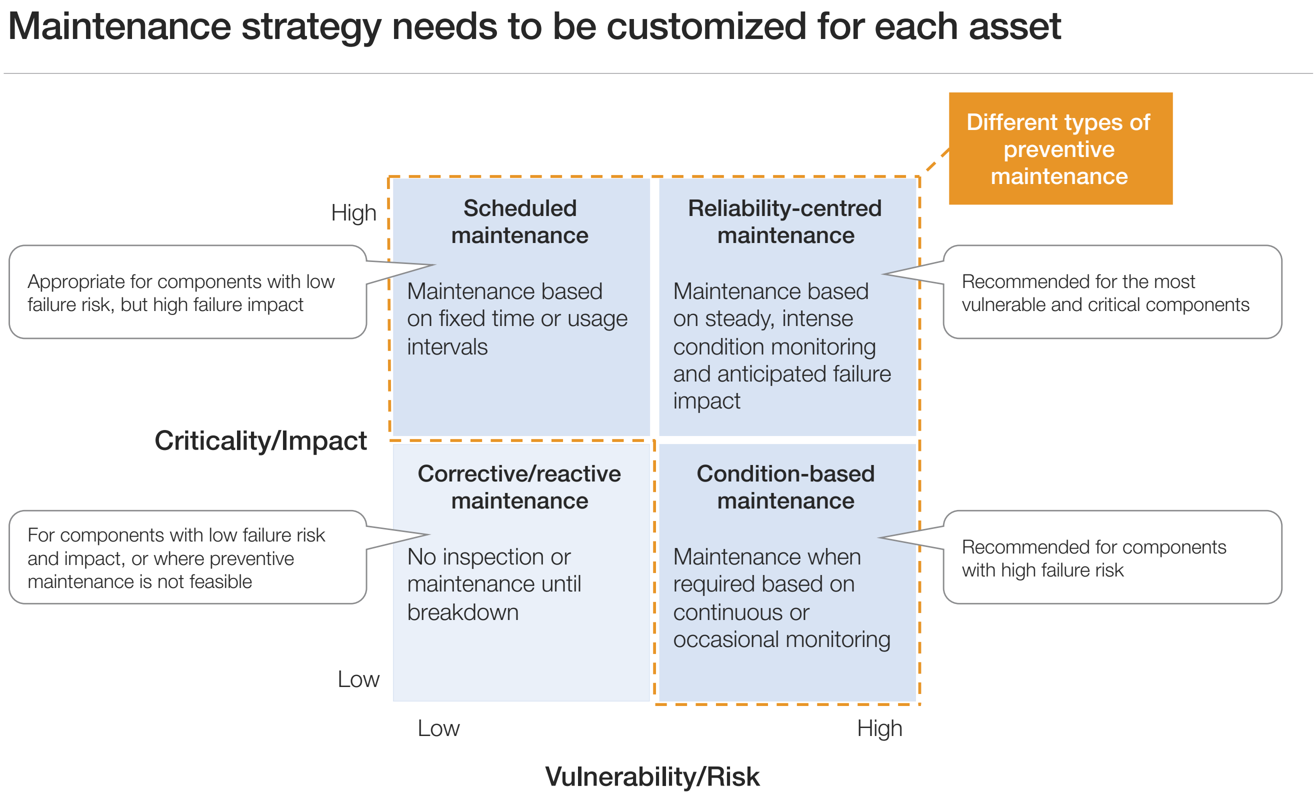
The trend is increasingly away from fixed-interval scheduled maintenance and towards predictive, data-enabled maintenance; the effect is to reduce waste, as equipment and parts are now exchanged only when they clearly need to be. The Massachusetts Water Resources Authority (US), for example, developed a predictive maintenance strategy based on condition monitoring and the probability and consequences of failure of each component. The programme increased equipment availability to 99%, and achieved cost savings by eliminating unneeded and low-value preventive maintenance work and shifting the freed-up resources to predictive tasks and actual maintenance work.[125] To enable such predictive maintenance strategies, repeated assessments of the asset condition are paramount.

Assess the asset's current condition.

For predictive maintenance, the choice and timing of treatments need to be based on the asset's starting or current condition; establishing its condition as accurately as possible is thus crucial and can be done in the following ways:

- Introduce a system of continuous assessment. New technologies can improve equipment checks; for example, laser technology can be used to detect road damage, and sensors, which are becoming much cheaper, can embed intelligence into previously "dumb" objects. Fluxys, a natural-gas infrastructure company, installed 39 sensors to monitor any possible damage to two pipelines crossing the Dutch-French border.[126] Another new approach is urban crowdsourcing, used for collecting asset-condition data at much lower costs and with faster response times than the traditional inspector approach. In the US, Boston's pothole-finding app, Street Bump, records every judder and jolt

Figure 22: Overview of Maintenance Strategies



when a mobile phone with a built-in accelerometer is running the app. If a bump triggers three separate reports within four days, it is declared an issue and the problem will be fixed once located via the Global Positioning System (GPS) coordinates.[127]

- Model the asset's degradation process. For example, many UK water utilities use advanced decision support systems for asset deterioration curve modelling, based on statistical methods such as regression and Markov models.
- Develop a standardized metric for each asset's condition, including a warning level that is typically set close to the fatal limit minus a buffer, which correlates with the processing time needed for implementing repairs. Network Rail in the UK uses a health index for its asset condition assessments.

The Seto-Ohasi bridge in Japan, which has an intended lifespan of 200 years, is a case in point. The inspection routine includes daily visual checks, biannual structural checks and extraordinary inspections after natural disasters. The data is fed into the "Inspection Management System" and the "Repair History System". One output is a deterioration curve for the top coat of paint: it enables the maintenance team to make early plans for repainting (a task which takes years), thereby helping to forestall any damage to the expensive and less accessible undercoat.[128]

Draw up a tailored maintenance intervention plan for each asset.

Operators need to establish both long-term and short-term plans, indicating the required maintenance interventions at varying levels of detail. To do so, they need to consider and evaluate different treatments; for roads, this could include improved drainage, sealing of joints and cracks, and resurfacing to protect against progressive erosion, based on a whole life-cycle evaluation. Aspects that operators need to consider in crafting those plans include the following:

- Select a specific strategy for each piece of equipment (sometimes even for each component), as each of them has its own distinctive failure rate, maintenance cost, serviceability and criticality. Infrastructure assets typically consist of different structures and pieces of equipment, so a one-size-fits-all approach is hardly appropriate.
- Contextualize the chosen treatment to the specific circumstances. For roads, the choice and timing of preventive maintenance treatments depend on such factors as climate, type of traffic and volume of traffic. In addition, consider the asset's historical design and construction features, as well as the previous maintenance routines. Ideally, all data is recorded in an integrated asset management system (chapter 2.2).
- Determine an optimal monitoring and maintenance cycle. All too often, preventive maintenance cycles/intervals are based on conservative risk and warranty practices. Conduct a thorough review of risk and warranty, based on the asset's vulnerability, criticality and components. Academic research can provide much guidance in this regard.
- Adopt a system perspective, not just an asset perspective. Take into account the components' interdependencies within the complex system, and design an appropriate group maintenance strategy that maximizes overall reliability and availability, and takes advantage of cost synergies.
- Even the most conscientious preventive maintenance is no guarantee against failure, so all maintenance policies should include

procedures for ad-hoc corrective/reactive maintenance.

– While prioritizing preventive maintenance, take care not to overmaintain. The best strategy is not the one that maximizes the asset's lifespan, but the one that enables an optimally economical life and optimal availability. Preventive maintenance can be uneconomical if conducted to excess. The optimal level will balance the preventive maintenance costs against the costs of breakdown and repair (Figure 23).

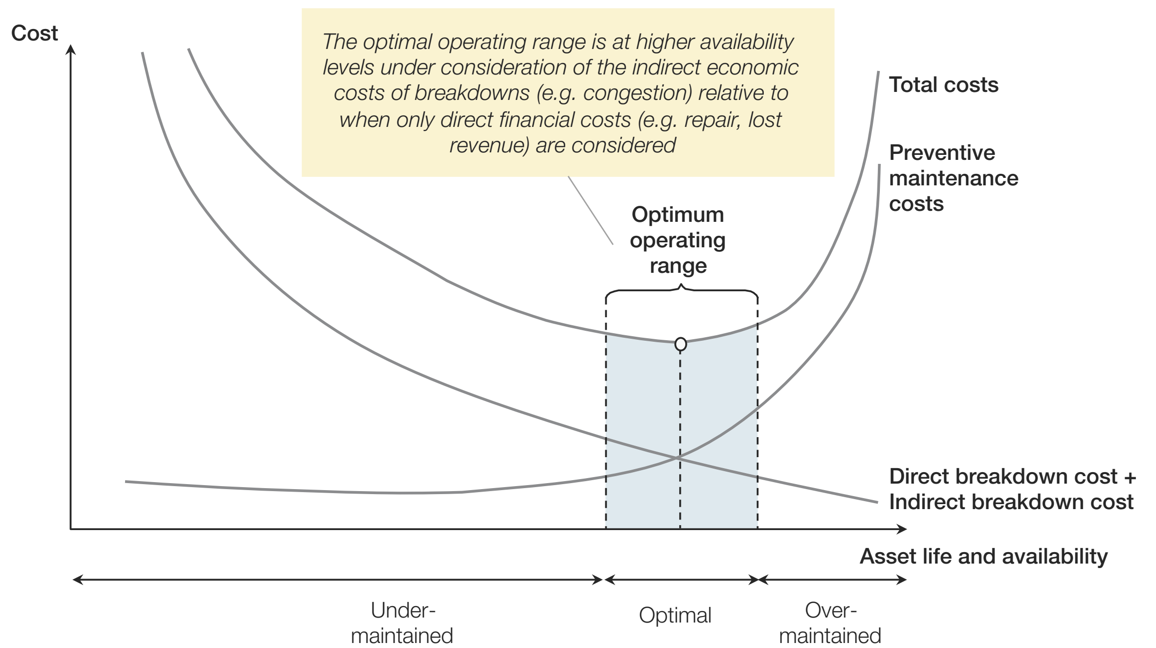
Control excessive asset consumption and stress

Infrastructure assets suffer when subjected to inappropriate usage volumes and/or excessive loads. The resulting wear and tear from such uncontrolled practices can drastically degrade the asset's condition and shorten its lifespan.

Typically, an infrastructure asset is designed to accommodate a level of service within a defined range. For example, a road is constructed to a given degree of robustness, based on the anticipated number of vehicles and weight of the loads per vehicle. Usage requirements change, of course, so the original design parameters are sometimes exceeded. In the US, the majority of local roads were designed for far lower volumes of traffic than they now accommodate; since 1990, heavy-truck traffic has increased at a rate 50% greater than that of car traffic.

Figure 23: Optimization of Maintenance Spending

Maintenance strategy involves trade-offs between preventive maintenance costs and total breakdown costs



To protect their infrastructure against uncontrolled or excessive asset consumption and stress, operators should consider the following measures:

Study and assess the empirical relationship between asset use and degradation.

Consider, for example, the current proposal in Germany to introduce megatrucks ("gigaliners") of up to 60 tons. Prior to authorization, the proposal is being studied in trials on specified roads in several federal states; this is to assess the impact that the vehicles will make on the service life and safety of roads and bridges.

Enact rules and regulations, and develop operations manuals and restrictions that conform with the evidence.

Local traffic laws, for instance, could be enacted to control the issuing of overweight vehicle permits, to designate truck routes or to restrict vehicle weight, length and height. Besides enacting those rules, however, it is essential to collaborate with authorities to ensure enforcement. For example, the concessionaire for the N4 route in Mozambique and South Africa assisted both governments in establishing axle-load controls, which reduced the proportion of overloaded vehicles from 23% in 2001 to 9% in 2004.[129]

Leverage technology for usage monitoring.

NedTrain, Dutch Railway's maintenance company, uses a wayside monitoring system that can measure axle load and detect wheel defects while trains are in motion, and report them promptly. The defective wheels can then be repaired directly before causing any further damage to tracks. One particularly important feature is that of linking the wheel quality measurements to information from the maintenance database. In this way, NedTrain optimized the wheel profile and introduced an alternative maintenance regime, leading to a 30% increase in wheel life and life cycle cost savings of up to 50%.[130]

Embed incentives in user agreements or user charges.

Adopt segmented and incremental user charges, according to the amount of asset consumption and stress caused to the system. So that road pricing varies in line with the costs incurred by each vehicle, truck owners – depending on the truck's mass and the distance – would pay much higher road tolls or licence fees than car owners, as a single, fully-loaded 80,000-pound (36-ton) truck degrades the road surface as severely as 750 cars do.[131]

Enhance disaster resilience

Infrastructure assets repeatedly face natural hazards, and can suffer major devastation – as shown by the broken telephone and electricity lines after Hurricane Sandy (Caribbean, US), the interrupted water supply after the earthquake in Chile, and the breached levees after Hurricane Katrina in Louisiana (US). The economic losses caused by such disasters over the past 30 years are estimated at US$ 3.5 trillion worldwide. Major disasters can cost about 5% of GDP, such as the 2011 tsunami in Japan, and more than 100% of GDP in low-income and small-island states.[132] While these catastrophes dominate the media, equal or even greater losses can be caused by less dramatic but recurrent misfortunes.

Although disasters are infrequent, infrastructure assets, with lifetimes of several decades, remain at risk. Moreover, natural hazards are becoming more common and more destructive; evidence suggests that their frequency and severity, and hence their damaging impact, are increasing.[133] In the future, climate change could intensify storms, droughts, flooding, landslides, extreme temperatures and forest fires, particularly in coastal and arid areas, with dire effects on any infrastructure assets that were not built to withstand such forces. The Organisation for Economic Co-operation and Development (OECD) predicts a rise in sea level of half a metre by 2070; that would put 150 million people and US$ 35 trillion of assets at risk from coastal flooding.[134] In addition to these hydrometeorological or geophysical threats, infrastructure assets are also increasingly under threat from terrorist attacks and even cyberattacks.

Greater disaster resilience is crucial. Fortunately it is attainable, and is generally far less costly than fixing the damage. For instance, the flooding of New Orleans during Hurricane Katrina in 2005 caused US$ 81 billion in damage,[135] whereas the hurricane protection system that was built afterwards cost only US$ 14 billion.[136]

Resilience measures tend to be neglected, however. The perception is that resilience-building generates low net returns on investment, in view of the long-term nature of resilience investments and the low likelihood of occurrence.

A new approach and a new mindset will be required to remedy those shortcomings. Governments need to mainstream disaster risk management into all stages of the infrastructure life cycle – from planning and construction to O&M – particularly for critical infrastructure assets. To strengthen the infrastructure system's ability to resist, cope with and recover from extreme events, a comprehensive set of resilience strategies is required (as follows, and Figure 24).

Figure 24: Overview of Disaster Resilience Measures

Develop a master plan for resilience.

Only a broad and holistic set of measures will ensure resilience. They need to be coordinated and integrated in a master plan.

– Conduct a scenario analysis (given the high unpredictability of extreme events) and a thorough socio-economic cost-benefit analysis to identify the optimal resilience measures. Prioritize the most effective interventions and filter out those least beneficial. In some cases, it might be so expensive to adapt to the new challenges that policy-makers might opt instead to relocate an entire infrastructure asset.

– Consider both “preparedness” and “responsiveness” measures in the master plan.

– Take a cross-sector perspective. For example, when evaluating energy production and water supply facilities, consider their linkage to agriculture, coastlines and the local ecosystem.

– Involve all the various operators and departments in a collaborative approach.

For example, New York City has drawn up a US$ 19.5 billion plan to defend itself against rising sea levels. The plan involves a balanced set of about 250 measures, including a construction programme for levees, storm surge barriers, sand dunes and oyster reefs.[137]

Enhance the identification, assessment and communication of risks.

The foundation of any disaster risk management strategy is a thorough understanding of the different hazards and their impacts, and of the exposure and vulnerability of assets to those hazards. Accordingly:

– Make a comprehensive assessment of vulnerability and disaster impact to quantify the risks and anticipate the potential damage, by geography and hazard type.

– Use such information for producing hazard maps and zones to enable governments and communities to make better-informed prevention decisions and to set priorities for developing, maintaining and adapting at-risk facilities.

One such assessment is the World Bank’s recent collaboration with the Africa Climate Policy Centre to conduct a study on what it would take to “climate-proof” Africa’s infrastructure. The study models various climate scenarios and, for each of them, assesses the potential impact of climate change and the cost of adaptation.[138]

Combine structural with non-structural measures to reduce risk.

– Build protective infrastructure assets such as dykes, spillways, storm drainage, sewers and canals. In the Netherlands, the Delta Works dyke and barrier system was built to withstand a 1 in 10,000-year storm, the strictest standard in the world (the US uses a 1 in 100 standard).[139]

– Retrofit existing infrastructure facilities. Ensure compliance with updated construction codes and technical specifications, or relocate critical components. In Switzerland, for instance, the Les Toules dam was strengthened and modified in shape to enhance its resilience to seismic activity.

– Apply non-structural measures. Adapt policies and regulations on zoning and land use, for example by introducing risk-based territorial planning. Consider creating natural buffers; in Vietnam, eight provinces organized the planting of mangroves to prevent flooding of coastal roads or railway tracks. Relative to dyke maintenance, this natural, non-structural approach yielded an exceptionally high benefit-to-cost ratio of 55.[140] A related approach suitable for urban environments is to create green areas that serve as "sponges"; many cities have encouraged the creation of parks and lake systems to retain and absorb overflows.

Make appropriate preparations for managing residual risk.

Even the most thorough preventive measures will sometimes prove insufficient, and reactive measures will be indicated. Clear plans should be in place for implementing them if the need ever arises.

– Develop improved models for predicting natural disasters, whether earthquakes or storms. Install early warning systems and enhance monitoring.

– Enhance disaster preparedness and refine emergency response plans; identify and improve evacuation routes, and conduct emergency drills. In the Netherlands, community water boards use volunteer dyke-watchers to check on the dykes, and train the watchers to contain breaches.

– Prepare recovery plans for the aftermath of a disaster, and plan for rapid mobilization of resources for recovery. For example, the World Economic Forum's Disaster Resource Partnership, an international alliance of engineering and construction companies, provides fast, professional and scalable response to disasters in public-private collaboration.[141]

(Re-)construct and rehabilitate for resilience.

– Adapt design codes to cope with new challenges. In cold regions, oil pipelines now tend to use more robust and structurally flexible designs to reduce damage from melting permafrost. Peru adapted its design and construction codes to improve resilience to earthquakes.[142] The US Army Corps of Engineers issued guidance that infrastructure planners should consider three scenarios, ranging from a 0.5- to a 1.5-metre rise in sea level by 2100.[143]

– Strive for greater robustness when reconstructing or refurbishing assets. For example, Rotterdam (Netherlands) has built an underground parking garage designed to hold 10,000 cubic metres of rainwater.[144] Opportunities to leapfrog infrastructure resilience standards particularly exist in post-disaster and post-conflict countries where significant rebuilding is taking place.

Make financial and institutional arrangements that can support resilience.

– Earmark some budgeted routine maintenance funds for smaller-scale repairs that might be needed in the wake of natural hazard events.

– Arrange appropriate budget and financing instruments. Mexico's Fund for Natural Disasters (FONDEN) provides funds not only for the reconstruction of public infrastructure assets, but also for advance efforts to reduce disaster risks. It leverages its budgetary authority and deals with uncertainties by using parametric reinsurance and a catastrophe bond.[145]

– Create a central body for disaster risk management that coordinates plans nationwide and across ministries and sectors (transportation, utilities and water/ environmental management). The Republic of Kiribati, one of the nations most vulnerable to rises in sea level, has coordinated coastal protection by assigning the responsibility for the various initiatives, such as building sea walls, planting mangroves and improving water management, to a single high-level ministry.

– Promote PPP opportunities for delivering resilience initiatives most efficiently. A model for this is the dual-purpose tunnel in the centre of Kuala Lumpur, which operates either as a stormwater channel or a road tunnel (depending on weather conditions), preventing US$ 1.6 billion of flood damage and saving US$ 1.3 billion by avoidance of traffic-congestion over the concession period.[146]

– Engage in the campaign launched by the United Nations Office for Disaster Risk Reduction, which already involves more than 1,000 cities globally in sharing experiences and lessons learned.[147]

1.6 Reinvest with a life cycle view

Many infrastructure assets are approaching the end of their useful life. About half of the main water pipes in London are more than 100 years old, and one-third could be even older than 150 years.[148] In the United States, the equipment in electricity substations is on average 42 years old, with an estimated original lifespan of 45-55 years. Social infrastructure facilities as well are ageing: the education system in many Western countries was greatly expanded in the 1960s and 1970s, and many school and university buildings are now in a state of decay. In Germany, every second school is considered to be in bad condition, and the cost of a thorough rehabilitation programme has been estimated at € 75 billion.[149]

Faced with an ageing asset, governments should pursue a three-part reinvestment strategy: prioritizing the project options using a whole life-cycle cost-benefit analysis; selecting the contracting mode that offers best value-for-money; and making thorough preparations for the efficient delivery of the project. (In short, they should apply the same diligence for reinvestments as has been recommended for new construction projects; this was discussed in detail in the previous two Strategic Infrastructure Initiative reports.)

Prioritize project options using a whole life-cycle cost-benefit analysis

Start by assessing the future needs of users and forecasting demand. Then, identify and evaluate the different project options, using a whole life-cycle analysis. Finally, prioritize and select the option that offers the best socio-economic benefit-to-cost ratio.

Conduct diligent baselining.

This assessment will establish exactly how the infrastructure asset, in its current form, falls short of users' present and future needs.

- Start planning early, well before a replacement becomes necessary. Project origination and preparation can take many years, and the project itself could take several years more. For example, the lead times for planning, permitting and constructing a new airport terminal in the United States is five to eight years, and more than 10 years for a runway.[150]
- Analyse diligently the asset's current performance and capacity in order to identify the problems and constraints – before committing to across-the-board measures.
- Conduct a user survey to clarify the future requirements, and avoid assuming that needs are already clear in advance.
- Take a rigorous demand forecasting approach, using high-quality data, a sophisticated forecasting methodology, robustness checks, and stakeholder reviews and validations. Bear in mind that demand forecasts, particularly in transport, tend to be inflated, owing to strategic misrepresentation and optimism bias.[151]

Identify all potential solutions.

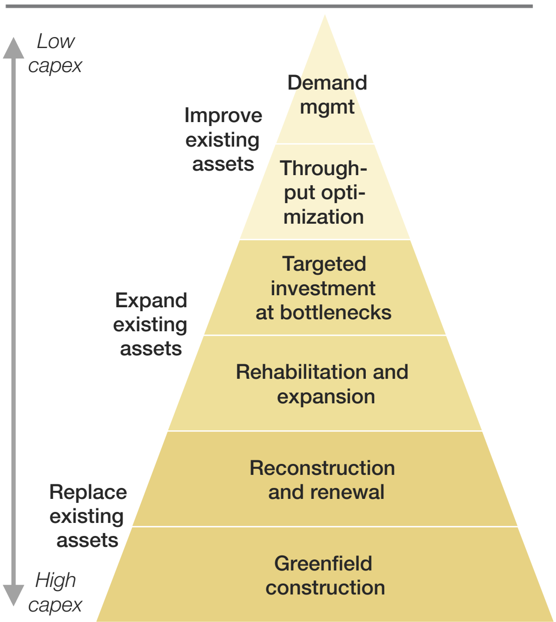
Assess the various options – specifically, improving, expanding or replacing the existing system – as outlined in the following order and as illustrated in Figure 25.

- Manage demand through new pricing models, such as the peak pricing used in many electricity markets or the congestion charges applied in various cities around the world. Consider as well other idle system capacity in space or mode.

Figure 25: Overview of Options for Expansion and Renewal Projects

Different project options need to be identified and assessed

Hierarchy of quick infrastructure wins



Examples

Kamloops used a system-wide approach to identify under-used routes, increase transit frequency, and promote car-pooling and biking, and reduced up-grade costs from US$ 120 million to US$ 14 million.

Munich transit uses new express buses and buses with 130 passengers to enhance corridor capacity, rather than investing in a costly tram system.

Autostrade, by adding a fourth lane on the congested A4 in Italy, reduced lost time by 75%, incidents by 30% and deaths by 45%.

Nairobi Commuter Rail project aims to rehabilitate 160 km of existing rail lines within the congested city – at a relatively modest capex of US$ 200 million.

PennDOT, via its Rapid Replacement Bridge Project, aims to reconstruct 200 to 1,000 structurally deficient bridges across Pennsylvania.

Abu Dhabi Ports built the deepwater Khalifa Port as its old port, Mina Zayed, was plagued by delays and size constraints.

- Increase throughput by means of new technologies, such as automated highway tolling or next-generation air traffic control systems. Alternatively, reduce losses in the case of utilities; for example, water systems can be optimized economically by reducing leakage and theft rather than by building new supply lines or treatment plants.
- Make a targeted investment to debottleneck the system. This applies to port terminals, for example, that require systemwide coordination, from sea-side (berth allocation for vessels) to yard-side (yard space allocation) and land-side (truck gate management).
- If new construction is needed, opt for expanding a current facility if possible (e.g. a new runway at an existing airport), rather than creating a new facility on a greenfield site. The former option will enable economies of scale in operations and better connectivity, whereas the latter option could result in fragmentation.
- Undertake greenfield development as a last resort. Before taking the decision, ensure that the following criteria are met: current system capacity is fully and efficiently used; rehabilitation of the current facility would be too costly because of serious structural deficiencies; an expansion of the current facility, owing to design or space constraints, is unable to meet the expected demand or changing requirements of users; and cheaper alternative modes or system designs are unfeasible.

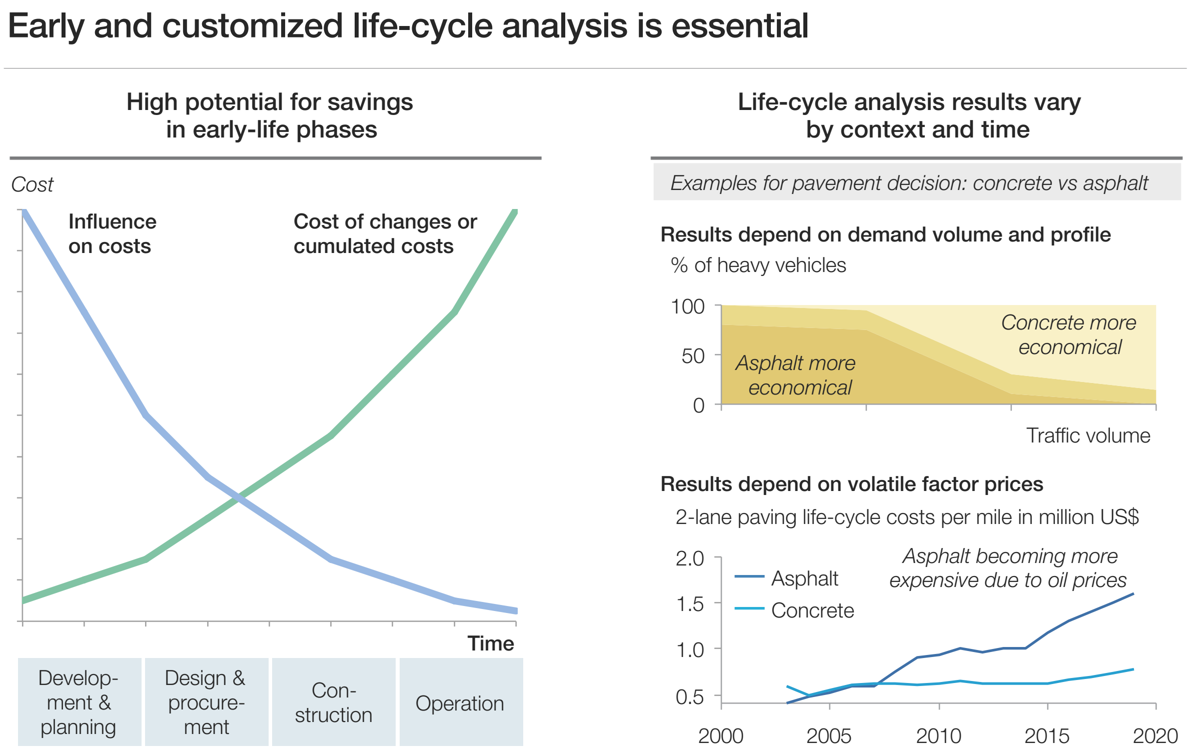
Conduct a whole life-cycle cost-benefit analysis for each alternative.

Once the different project alternatives have been identified, evaluate each by conducting a whole life-cycle cost-benefit analysis, which should consider: all associated costs from cradle to grave, as well as the various benefits including direct user benefits; the environmental impacts (air, water and noise pollution, climate change, resource depletion, land and forest degradation); social effects (e.g. on education, health, safety, cultural diversity); and economic effects (e.g. on GDP, employment, property values, taxes).

In many cases, the life cycle analysis will reveal that the long-term costs of O&M are actually much greater than the initial costs of construction. The life cycle cost analysis thus needs to be performed early on, as the majority of life cycle costs can still be influenced at that time through shrewd design and engineering decisions. Later on, that influence diminishes, and the cost of changes increases (Figure 26). In the life cycle analysis, the trade-off between opex and capex should be explicitly modelled, and any smart solutions that might reduce whole life-cycle costs should be considered.

Previous designs and construction techniques were not always conducive to O&M. Thus, for rehabilitation and reconstruction projects (as for new construction projects), adopt a life cycle orientation when making decisions on design and procurement – "purchasing not the cheapest but the best in the long run". In addition, leverage the results of the life cycle analysis to plan and secure the budget for later O&M expenses.

Figure 26: Benefits of Life Cycle Analysis



Sources: Prieto, B.: Application of Life Cycle Analysis in the Capital Assets Industry. In *PM World Today, 2012; Long-Life Concrete Pavements in Europe and Canada, 2007.* US Federal Highway Administration. The *New Paving Realities: The Impact of Asphalt Cost Escalator Clauses on State Finances, 2012. Portland*: Portland Cement Association.

Prioritize and rank the projects within the portfolio, and develop the project pipeline.

– Rank projects according to their socio-economic benefit-to-cost ratio, and screen out any that do not add value.
– Identify and highlight trade-offs that are inherently difficult to quantify – for example, environmental impact versus financial costs.
– Embed projects in the context of the broader strategic infrastructure plan.
– Across projects, assess both cost-side synergies (enabled by the synchronizing of procurement and construction schedules) and demand-side synergies (based on interdependencies of a network's assets).
– Decide on ideal timing, not just for the start of the project but also for the build-out – specifically, whether to follow a steady, incremental development or to take a "batch" approach.

Select the contracting mode that offers best value for money

Consider the full array of procurement and contracting options.

The options range from traditional civil works contracts (e.g. Design-Bid-Build, Design-Build) to PPPs (e.g. Build-Operate-Transfer [BOT], Design-Build-Operate). But there are also less common and more innovative forms of contracting; for example, Sweden is increasingly moving towards Design-Build contracts with O&M periods.[152]

PPPs are often particularly well suited to upgrades, replacements and rehabilitation. By tapping private-sector know-how in designing, constructing, operating and maintaining infrastructure, the asset can maximize quality and minimize total life cycle costs. The following are two examples:

– The BOT concession for expanding the terminal at the Colombo, Sri Lanka port enabled investment in a new quay and berths; an increased alongside-depth; a modern container-handling system; and a "hot seat handover" system that allows three shifts per day. These measures reduced congestion and vessel waiting times, improved productivity by 33% and yielded an overall 40% reduction in transportation costs for imports and exports.[153]
– In Romania, the upgrade of Bucharest municipality's water and sanitation system was assigned to a concessionaire, which invested US$ 210 million in modernizing services and built a new water treatment plant. Water losses declined by 44% after leaks were fixed and a new metering system was introduced, and customer satisfaction has increased dramatically.[154] The case study on the hospital PPP in Tlalnepantla, Mexico provides another example (Box 6).

Conduct a rigorous value-for-money analysis.

PPPs will not always provide best value for money (VfM). To choose the most promising delivery and financing mode, governments should create a public-sector comparator (PSC) that estimates the whole life cost of carrying out the project under the traditional standard government delivery model. Then, they should estimate the whole life costs of the alternative PPP approach, and compare them against the PSC. A PPP is considered VfM only if it entails a net positive economic gain relative to the PSC.

In doing the VfM analysis, the analysts should take into account the following advice:[155]

– Consider both costs and benefits of all the rival delivery modes. Include all types of costs, not only the evident costs for investment, O&M and financing, but also those related to the transaction and oversight of the contract. Make sure to compare "like with like" when assessing the non-financial benefits of various modes, such as the potential of a PPP for accelerated and higher-quality project delivery.
– Analyse and evaluate the risks, which will help to correct distortions; risks are typically not budgeted under public procurement. To place a value on each risk, multiply the projected cost of resolving the problem (in the event that the risk is realized) by its estimated likelihood.
– Make any other adjustments that might be necessary for competitive neutrality; for example, factor in the different tax treatments that the various options would be subject to.
– Adopt clear guidelines to improve quality and consistency. For instance, UK policy is to use standardized Excel tools and guidelines, specify discount-rate assumptions, and estimate risk values on the basis of past projects.
– To check the robustness of the base-case analysis, use sensitivity testing and scenario analysis to challenge the underlying assumptions and their impact on the VfM results.
– Supplement the quantitative analysis with qualitative expert assessments on whether it is in the public interest to deliver core services by the private sector. For example, in the UK, qualitative reviews are conducted on three aspects: viability, desirability and achievability.
– Take a multistage approach, and repeat it at various times. For example, Australian policy is to conduct a VfM analysis before issuing the request for proposals, but then to reassess the alternative delivery modes at later stages of the project, such as after submission of the bids.

The result of the VfM analysis will depend on a number of factors. Private-sector delivery stands a better chance of providing a net benefit to society when more of the following characteristics apply:

– Large size of the project relative to transaction costs
– Opportunities for reducing life cycle costs via innovative design and engineering solutions
– Opportunities for revenue optimization and innovation
– Superior design expertise and/or implementation expertise within the private sector
– Feasibility of risk identification and allocation
– Specification of service needs as outputs and outcomes
– Possibility of estimating the asset's long-term costs and demand
– Stability of technological aspects
– Low complexity in intra-government coordination

Box 6: Case Study – Hospital PPP in Tlalnepantla, Mexico, Led by Grupo Marhnos[156]

In 2010, a new hospital was commissioned in Tlalnepantla to replace the old hospital, which was no longer able to satisfy the medical needs of the local population. The new hospital was delivered as a 25-year PPP, with a consortium led by Grupo Marhnos, responsible for design, financing, construction and maintenance, as well as different services including cleaning, logistics, waste disposal and diagnostics.

The contract has a pay-for-performance structure: the government stipulates outcome-based quality metrics and targets (which are checked by a government supervisor), and the contractor's payment is adjusted according to its results. This enables the contractor to retain the entrepreneurial freedom to make innovative decisions incorporating whole life-cycle assessments. For example, after making a calculated trade-off of capex and opex in the design and engineering phase, the contractors opted for a mainly metallic rather than concrete structure, as it entails lower maintenance costs over the hospital's lifespan. They also have a strategic framework agreement with key suppliers of medical equipment, yielding lower prices based on the volume across multiple hospital sites.

Overall, the PPP has accomplished whole life-cycle savings of 30% relative to the projected costs of traditional public delivery. It has also produced a "greener" social infrastructure, with energy savings estimated at 20%. Above all, the new hospital is providing the local patient population – 6,000 inpatients and 20,000 outpatients annually – with enhanced medical outcomes.

Prepare for efficient project delivery

The success of any project, whether a new construction or rehabilitation project, relies crucially on efficient and high-quality project preparation, including feasibility studies on the technical, financial, legal and environmental aspects. For projects that are implemented as PPPs, the best practices have been detailed in the previous Phase II report, and are summarized in Figure 27.[157]

Figure 27: Project Preparation Best Practices

Rigorous preparation is need for both traditional and PPP projects

General

Rigorous project-preparation process	Team and leadership	**1.1.** Assemble an experienced, cross-functional team	**1.2.** Secure buy-in and leadership of high-level political champions and public servants
	Governance, project mgmt	**1.3.** Set up a governance structure with clear roles/responsibilities and a coordinator	**1.4.** Pursue rigorous project management and devise multi-stage planning
	Preparation funding	**1.5.** Secure sufficient preparation funding, and minimize costs through standardization	**1.6.** Leverage project-preparation facilities (with cost recovery, advisory and monitoring)
Bankable feasibility study	Technical scope	**2.1.** Conduct robust and sophisticated demand forecasting	**2.2.** Fix contractible, innovation-friendly output specification cross-checked by cost forecast
	Commercial attractiveness	**2.3.** Apply user charges, ancillary revenues, land-value capture and government payments	**2.4.** Test bankability continuously and conduct market sounding early
	Prerequisites	**2.5.** Pursue proactive, inclusive and professional stakeholder engagement	**2.6.** Complete holistic legal feasibility check and expedite permits and land acquisition
Balanced risk allocation and regulation	Incentives	**3.1.** Adopt a life-cycle-oriented contract model aligned with the policy objectives	**3.2.** Apply incentive-based price regulation and evaluate competition options
	Risk mitigation	**3.3.** Identify all risks, allocate them to the best-suited party and apply risk-sharing/ mitigation	**3.4.** Adopt regulation that is adaptive to exogenous changes and volatility
	Safeguards	**3.5.** Fulfil social objectives via enforced quality regulation and efficient monitoring	**3.6.** Provide for government intervention options in a predictable and fair way

PPP-specific

Source: *Strategic Infrastructure: Steps to prepare and accelerate Public-Private Partnerships*. May, 2013. Geneva: World Economic

For projects implemented under the traditional government delivery, the same best practices as listed in the upper part of Figure 27 apply, but some additional engineering and design levers are advisable.[158]

Apply value engineering.

- Avoid over-engineering in design. Specifically, be frugal and adapt to (and perhaps adapt) customer needs; question the performance specifications, and deliver only what the customer really wants. For example, for the Tyrrhenian toll-road project, Autostrade per l'Italia managed to reduce the projected capital expenditure from € 3.6 billion to just € 2.0 billion by lowering the maximum speed and thereby saving on expensive tunnels and bridges. A railway project might similarly achieve huge savings by opting for a medium-speed rather than a high-speed rail line: that would be particularly feasible for short-distance lines, where reliable and economical travel may be more important than slightly shorter journey times.
- Develop systems that fulfil customer needs at the lowest possible life cycle cost – for example, by developing and adopting modular or standardized designs that can be repeated across projects; homogenizing processes, equipment and material; and leveraging learning and scale effects.
- Design for longevity. The private concessionaire of the world's tallest bridge, the Millau Viaduct in France, has guaranteed that it will remain operational for at least 120 years.
- Design for flexibility. User needs evolve; ports, for instance, might need to accommodate larger container ships. So ideally, the asset should have built-in, long-term adaptability from the outset. Heathrow Airport's Terminal 5, for example, employed modular designs so the gates could be equally usable for both low-cost and hub carriers. Leighton Contractors, for its South East Queensland Schools PPP, made the school facilities future-proof for the 30-year concession by planning three stages of construction, with progression to the next stage based on increasing student numbers. When school enrolments accelerated beyond the original forecast, one facility was redesigned to accommodate 30% more students than planned.
- Consider innovative designs. For example, the proposed eco-friendly "sponge-like" water system in Philadelphia (US), involving new forms of drainage, repaving with porous materials, green roofs and wetlands, would be less than half the cost of a conventional upgrade of the current system of pipes and basins.[159]

Optimize construction management and monitoring.

- Set up a project management office for systematically monitoring and supporting project teams and contractors in their efforts to avoid slippages in cost and schedule. Define clear roles and interfaces to improve coordination of the different parties involved.
- Define and implement lean methodology in construction and the supply chain to avoid waste, such as waiting times for materials and equipment, unnecessary movements and rework.
- Establish a rigorous and forward-looking system of cost-, risk- and time management.
- Use innovative technologies. For rebuilding roads, for instance, this could involve modern and specialized asphalt systems or concretes, prefabricated components and recycled materials.

Optimize procurement.

- Procure any equipment and components based on the best VfM, taking a whole life-cycle perspective and considering both cost and quality.
- Consider innovation-friendly output/outcome specifications; use input specifications sparingly: every additional input specification limits design options, and so could increase costs.
- Scope procurement documents diligently, and freeze the project specifications before putting the project out for tender, to avoid costly changes later.
- Design contracts with clear liability rules and bonus-malus incentives.

2. Enabling O&M Best Practices

This section of the report discusses and illustrates the best practices related to enabling sustainable O&M. It is structured along the dimensions of funding, capabilities and governance. It does not deal with the broader enabling environment, that is, best practices related to the legal and institutional framework, and development of the local industry and the financial market.

2.1 Ensure funding

The funding (or revenues) for operating and maintaining infrastructure assets needs to come from somewhere.[160] Traditionally, the funding would come mainly or entirely from the government, through tax revenues, and would act as a full or partial subsidy, in that the services were provided to users for free or at prices below cost. With public budgets often depleted nowadays, however, that model is unsustainable, and more diversified funding sources are needed.

One particular problem with traditional public budget funding is that it makes maintenance budgets vulnerable to political expediency: when politicians need to make overall budget cuts, O&M funding suffers. Even without these rival claims on funding, however, politicians have little incentive to make provision for O&M, given the low profile of O&M projects relative to those for new construction. In addition, the oft-employed pay-as-you-go funding might defer maintenance work, or even stop it midway, and thereby create additional inefficiencies as well as an undue focus on achieving the lowest-possible initial costs.

What O&M needs is long-term planning certainty and continuity of funding across multiple government cycles. To ensure sufficient and stable funding for O&M, governments can earmark a proportion of user taxes, apply user charges or capture ancillary business opportunities. (The following discussion mainly relates to publicly operated infrastructure. In a PPP model, the same funding sources are available, but the government automatically enters a long-term O&M funding commitment through the contract with the private party.)

Dedicate user taxes to a maintenance fund

User taxes, such as a fuel tax, are often channelled into a nation's general budget; the relevant agency receives discretionary allocations from that general budget, and in turn allocates them to O&M, which is often subject to political expediency. A sounder system would ring-fence all or some of the user taxes for the O&M of the infrastructure asset – whose users actually pay those taxes, after all. One approach is to set up a dedicated maintenance fund, which receives the user taxes and disburses the money to the agencies implementing O&M. The road sector, for instance, benefits from a "road fund" in many countries.

This closed monetary cycle will enable a reliable source of maintenance funding, and prevent alternative uses of the user taxes. The ring-fenced maintenance fund means that maintenance can now take place when needed, rather than when current liquidity allows. The fund effectively provides long-term predictability and a multiyear funding guarantee by decoupling funding from the annual logic of public budgets.

The benefits go further than that. The fund enhances transparency on spending levels and resource allocation. If the fund is able to issue debt to raise liquidity for investments, enhanced public budget control and better financial planning result, as the fund needs to repay those loans using its dedicated future income streams.

The gain in predictability has a downside: less fiscal flexibility for the government. The current government loses its allocation rights over a part of the tax revenues and so has less room to manoeuvre in its overall budgeting.

A dedicated fund can create a more stable funding base for O&M, but it is no panacea and does not guarantee efficient use of the acquired funds. Many first-generation road funds in the 1960s and 1970s in Africa, Asia and Latin America were characterized by insufficient revenues and poor governance, resulting in poor allocation of funds and low operational efficiency.[161] Governments should consider the following lessons when designing O&M funds:

Secure a sufficient and diversified revenue base.

- Consider the various user taxes (for roads, these include fuel tax, vehicle licence fee and vehicle purchase tax), as well as user charges (such as tolls, vignettes, overweight charges and fines) as potential funding sources besides regular government appropriations from the general budget.
- Evaluate the performance of each revenue source in terms of economic efficiency, user incentives, social fairness, collection cost,

susceptibility to evasion and adaptability over time.

- Strive for a diversified and robust funding mix. For example, the Swiss national road fund receives 50% of the fuel tax, 100% of the fuel surtax, and 100% of the income from vignettes.[162]
- If appropriate, raise the level of user taxes to top up funds. For example, in Ukraine, the excise tax for fuel had to be increased threefold over a few years to ensure sustainable funding for the road sector.[163]
- Implement mechanisms to protect against inflation. When maintenance is partly funded from a user tax, politicians are often unwilling to index those taxes to inflation, so revenues erode over time. The dangers are shown by the US Highway Trust Fund: fuel tax rates have remained flat since 1993, but as cars have become more fuel-efficient, so the fund's income base has declined while its expenses have grown owing to inflation. In the end, the only way to rescue it was through transfers from the general budget. By contrast, the Austrian road fund ASFiNAG avoids such underfunding because toll pricing is adjusted annually through a formula based on the consumer price index.

Design an appropriate governance structure.

- Separate control over funding from implementation responsibilities. For instance, when policy-makers establish a road fund, they might simultaneously set up a road agency – an autonomous and independent entity charged with efficiently implementing road maintenance and rehabilitation works.
- Review and if necessary improve the various aspects of the fund to ensure that its legal basis is sound, its governance is independent, the eligible expenditures are clearly defined and the allocation mechanisms are transparent (Figure 28).

If appropriate, supplement the perpetual maintenance fund with time-limited funds for large new construction projects or previously missed/neglected rehabilitation. Switzerland, for example, has established a specific fund for financing four large-scale rail expansion projects.

An important role can be taken here by IFIs in urging countries to establish such fund structures or similar accounts. The European Bank for Reconstruction and Development (EBRD) established Maintenance, Replacement and Development (MRD) accounts for Romania, by which dividends, taxes and concession fees from local water utilities are dedicated to servicing debt and funding future MRD works.[164]

Figure 28: Lessons Learned for O&M Fund Design

O&M funds should be designed following established principles

Principles of fund design

Sound legal basis
- Act plus supporting regulations
- Independent financial and technical audits

Independent governance
- Executive board mixed with public and private representatives
- Strong, independent chairperson

Earmarked and diversified funding
- Earmarking assures funding certainty
- Diversification assures stability over economic cycles

Transparent and independent fund allocation
- Separation of funding control and implementation
- Clear criteria for allocation between agencies

Spending procedures fostering efficiency
- Competition in awarding O&M contracts
- Implementation of efficiency measures
- Reviews and benchmarking of spending

Examples of second-generation road funds

Ghana

Defined processes and solid legal base
- Established in 1997 by legal act
- Systematically carried out independent technical audits
- Well-defined disbursement and accounting procedures

Japan

Public and private interests are balanced
- Board members include representatives of the motor industry, business community, unions, academia and local government

New Zealand

Diversified sources of revenues
- Fuel excise added to the price of petrol
- Weight-distance charges paid by diesel vehicles
- Motor vehicle registration fees
- Revenues earned from sale of surplus property

Tanzania

Funds are collected, distributed and disbursed by different agencies
- Tanzania Revenue Authority collects fuel levy
- Ministry of Finance distributes money to Ministry of Works for main roads and to local governments for other roads
- Road Fund disburses amounts to executing agencies

Zambia

Structured budget allocation increased efficiency and quality
- Share of maintenance works contracted out: ~ 90%
- Reduction in road maintenance cost per km by 10%-20%
- Share of "good" roads increased from 21% (1997) to 30% (1999)

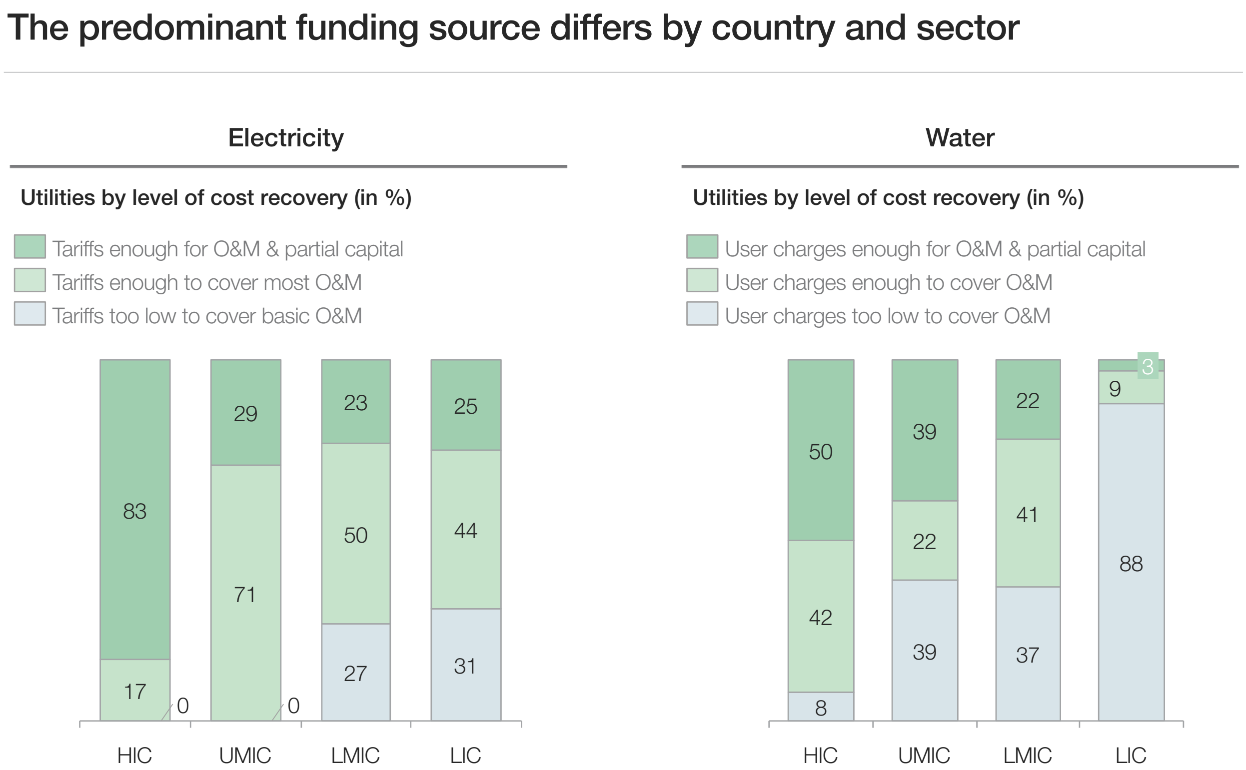
Source: *Road Funds Revisited: A Preliminary Appraisal of the Effectiveness of "Second Generation" Road Funds*, January 2012. Washington D.C.: World Bank

Apply inclusive user charges where possible

In many infrastructure sectors in many countries, user prices have traditionally been artificially low. As a result, users have had little incentive for efficient use of scarce infrastructure capacity, and operators have been left underfunded and struggling to provide adequate services and attract investment. Low water prices, for example, have led to over-extraction in China and underinvestment in India. Similarly, low road charges lead to inefficient capacity use: in most European countries, 20-30% of truck movements are empty backhauls[165], a waste that could be partially avoided with a state-of-the-art logistics model – but those models often only pay off if charges are levied on each kilometre of drive.

In reality, the use of user charges varies greatly by sector and country (Figure 29). Around the world, most major airports and ports are funded mainly by user charges, whereas roads and railways are more reliant on tax funding. For electricity and water utilities, the predominant funding depends on the region: in developed countries, user charges cover most of the funding, but that is typically not the case in developing nations.

Figure 29: Overview of Infrastructure Funding Sources



Note: HIC = High Income Countries; UMIC = Upper Medium Income Countries; LMIC = Lower Medium Income Countries; LIC = Lower Income Countries
Source: *Managing Water for All.* An OECD Perspective on Pricing and Financing, 2009. OECD.

Introducing user charges could bring many benefits:

– They are beneficial from an economic point of view, as they motivate consumers to use the capacity responsibly and sparingly, and thus reduce congestion and increase asset utilization ("demand management").

– They can contribute directly to funding the infrastructure asset's O&M and can thus ensure the operator's financial sustainability, as they provide a steady source of funding over the life cycle ("cost recovery principle").

– They potentially internalize environmental and social externalities into prices, and thus encourage responsible consumer decision-making ("polluter pays principle").

– They give a performance incentive to the infrastructure operator, which leads to higher quality for the user.

– They can be viewed as financially fair, as only users pay, and the debt burden on future generations will be minimized.

However, user charges also have certain disadvantages or limitations:

– They impose a financial burden on users, and raise the risk of social exclusion. For social reasons, some essential public services, notably water, should be affordable for everyone.

– User charges could give rise to unintended second-order effects.

For instance, a toll road could lead to rat-run congestion on a parallel uncharged road; and, the imposition of congestion charges to reduce traffic levels could result in lower revenues for shops within that zone.

– They involve transaction costs for the operator, and can mean time costs for the user (e.g. queues that form at some highway tollbooths). The issue is receding, however, in step with technological progress; e-tolling, for example, eliminates such delays.

– User charges are by no means applicable for all assets. Only in some sectors, such as airports or ports, or in particular parts of a network, such as expressways, is there enough demand to support charging users. For other infrastructure assets, particularly in rural areas, additional government funding arrangements need to be in place.

Once again, IFIs can play an important role in introducing user charges. For example, the EBRD's Municipal Environmental Loan Facility provides loans to commercialized utilities in Romania, on condition that cost recovery user charges are levied and effectively collected.[166]

The following is a list of measures for policy-makers to consider when introducing user charges:

Forestall or at least defuse the likely resistance from users.

Upon initial introduction, user charges tend to arouse opposition. They typically gain acceptance, however, if any of the following measures are applied:

– If initiating user charges, correlate them with significant quality improvements, as when an upgraded toll road saves motorists valuable time commuting to work each morning. If appropriate, actively communicate this added value in a publicity campaign. In the long run, people tend to moderate their opposition or modify their behaviour. For example, when the congestion charge was introduced in Stockholm, Sweden in 2006, more than half of the population was against tolls, but in 2011, 70% supported the charge, given the 20% reduction in rush-hour traffic.[167]

– Offer user-friendly, efficient and accessible payment options. Highway 6 in Israel bills its users automatically, using an in-vehicle transponder unit. Alternatively, non-registered users are billed through licence plate recognition, allowing the highway to operate as a normal freeway with interchanges and without tollbooths, while achieving a toll collection rate of 97%.[168]

– Educate the public on the advantages of the new system and the anticipated payments. For the Barranquilla water PPP, a publicity campaign explained how the new water supply line greatly reduces the cost of water in comparison with the traditional supply from water trucks.[169] Education initiatives can also help users to reduce their consumption, and hence their bills. In the case of the São Paulo (Brazil) Slum Electrification and Loss Reduction Programme, user consumption fell by 40% partly as a result of an information campaign and various energy efficiency measures.[170]

Set user charges by balancing financial sustainability, user incentives and affordability objectives.

Various objectives need delicate balancing, as in ensuring that the asset is financially sustainable, encouraging users to deliberately use the asset and making the service affordable for all potential users.

– Ensure the operator's financial stability, within limits.

  – Determine the user charge based on the investment and operating costs, so that a risk-adequate return can be generated; alternatively, consider subsidies to fill the funding gap.

  – Establish mechanisms to adapt the user charge over time to adjust for inflation.

  – Set a cap on the user charge to avoid an abuse of monopoly power by the operator.

– Embed incentives into user charges to manage demand (see chapter 1.1).

– Ensure that user charges are affordable to all user groups, based on an analysis of willingness and ability to pay. According to an international rule of thumb, an affordability problem arises when households spend more than 3-5% of their income on a particular infrastructure service, such as water or public transport.[171]

Design "inclusive user charges" to mitigate the adverse social consequences.

– Consider reduced tariffs for at-risk groups, or design socially inclusive tariff structures. Several countries have used a tiered water pricing system: for instance, a certain amount of water a day is provided at a low price to satisfy basic needs, and thereafter, as water consumption increases, so does the price. Some public transport systems apply flat pricing, which effectively subsidizes the daily commute of poor working people who live in distant suburbs.

– Provide different service levels to address affordability concerns. Manila Water's "Water for the Poor" programme, for example, offers relatively modestly priced community connections.[172]

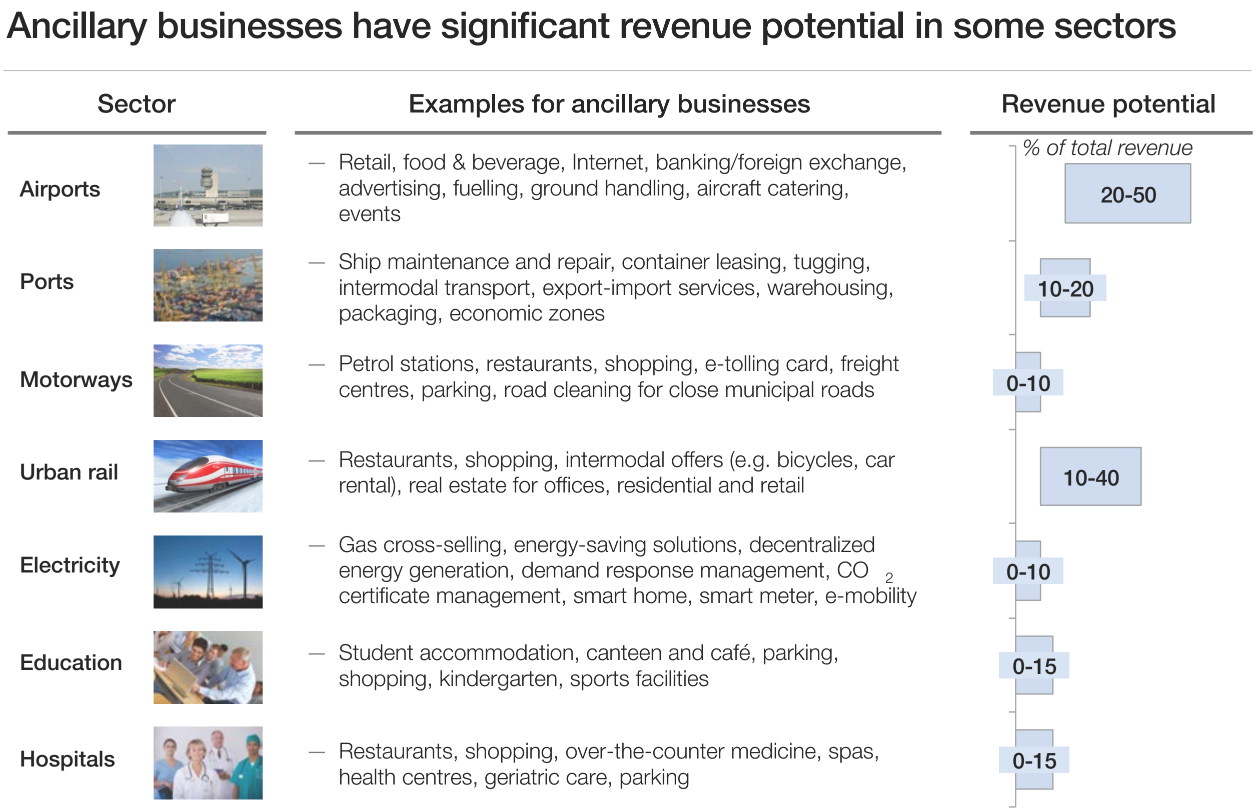
– Improve alternative infrastructure. When the inner London cordon toll was introduced in 2004, the social exclusion effect was offset by simultaneous improvements to the public transport system. The combined intervention reduced car traffic by 15% and congestion by 30%, while increasing bus ridership and bus reliability.[173]

– Seek subsidies where appropriate. When an asset receives a subsidy (or viability gap funding), user payments can be reduced, and ideally that will make the service affordable for all users. For example, most public transport systems in the world cannot recover their expenses through fares alone; they regularly receive supply-side subsidies for the sake of positive externalities, such as increased frequency of service, reduced congestion and less adverse environmental impact. An alternative approach is that of direct demand-side subsidies targeting specific users, but it is often difficult to implement in practice.

Capture ancillary business opportunities

Operators of infrastructure assets often have many opportunities to generate additional revenues from ancillary businesses, such as retail outlets, advertising, accommodation and cross-selling. The type of ancillary business is sector-specific, but various possibilities exist in each sector. Some sectors have explored the possibilities systematically and vigorously – notably, best practice airports generate 50% or more of their revenues from so-called non-aviation business (Figure 30). (In addition, refer to chapter 1.2 on enhancing quality for users, and the Phase II report of the Strategic Infrastructure Initiative.)

Figure 30: Revenue Potential of Ancillary Businesses



Source: *Strategic Infrastructure: Steps to prepare and accelerate Public-Private Partnerships.* May, 2013. Geneva: World Economic Forum

Build a strategy and skills specifically for ancillary business, or leverage specialist firms.

The required skills in ancillary businesses are quite different from those for the core infrastructure business. Airport retail activities, for instance, require a deep understanding of customer demands and shopping behaviours, whereas conventional airport operations are more about operations processes and capital asset management.

– Devise a comprehensive and long-term strategy and plan. For example, the ACP, already generating more than 20% of revenues from the sale of electricity, water- and transit-related services, is studying many other ancillary business opportunities, including a container terminal, a ship repair yard and logistics parks.

– Build a skilled team to implement the strategy holistically. Executing an airport retail master plan, for instance, requires more than installing new shops: the team needs to optimize the shop mix to have the right products on offer; find the right balance between high-margin and high-turnover business; and optimize passenger flows and the aircraft gate allocation (e.g. guiding Russian and Chinese travellers through luxury goods areas can double per-passenger spending).

– Constantly seek innovative business opportunities. In China, Shanghai Metro introduced virtual supermarkets in 70 stations; large LED screens advertise the goods, which are then scanned by shoppers and delivered to their homes within two days.[174]

– Contract external partners if the required skills are not available in-house. For example, most airports award concessions for individual shops or even for the entire airport retail operation. When Pittsburgh International Airport (US) awarded the concession for its retail business to an external specialist in the 1990s, the retail revenues per passenger tripled over the next decade. More recently in the US, Virginia's Office of Transportation posted a request for information for a pilot project on the development of mixed-use facilities at two metro stations, in order to get private-sector feedback on an area of business having little in common with its roadway-centric heritage.[175]

Leverage scale and all assets for ancillary business.

Leverage the project's scale, its tangible assets or even its intangible assets. An example of each:

- *Scale*: a motorway PPP might offer road cleaning services to nearby villages.
- *Tangible assets*: a highway operator might rent space for fibre-optic cables, or charge for right-of-way to solar and wind power generators.
- *Intangible assets*: a public transport network could make its electronic payment scheme available to other businesses to accept payments or conduct promotion activities. As an actual example, New York City secured a US$ 41 million deal from a bank, giving the latter the naming rights to the city's bike-sharing programme.[176]

Capture land value.

Land value capture is mainly applicable in greenfield settings, but not exclusively so. Operators of existing infrastructure assets can benefit as well:

- Make the most of existing land. In Hong Kong, MTR derives more than 30% of its operating profits from property development, ownership and management.[177]
- Increase the space efficiency of existing operations, and thereby free up land or increase capacity. Dusseldorf Airport in Germany is introducing an automated parking system that enables cars to park closer to each other, thus increasing space productivity by 40%.[178]
- For expansion projects, pursue further opportunities to apply land value capture. During the brief window of opportunity between planning and publicizing the project, buy up the land and then either sell it to independent real estate developers or make it part of the development package. For example, the new metro lines in Brasilia (Brazil) and Copenhagen (Denmark) raised 85% and 50%, respectively, of their required funding through land sales.[179]

2.2 Build capabilities

To implement O&M best practice, governments first need to build the right capabilities. These are of three broad types:

- Asset management planning on the country-wide institutional level
- Data, benchmarks and tools on the agency-specific institutional level
- Training and talent development on the individual level

This section offers detailed recommendations for developing each of the three capabilities.

Introduce asset management planning

To introduce sound asset management planning, governments need to embed O&M into national infrastructure plans, reform the principles of infrastructure accounting and adopt a common asset management framework across the various agencies.

Embed O&M into national infrastructure plans.

- Make O&M a priority in the national infrastructure policy. Develop policies to foster and enable the efficient management of existing infrastructure, in addition to the conventional focus on policies for new asset construction, as in Switzerland.
- For each infrastructure sector, commission occasional reports on network condition and performance, and aggregate and consolidate agency-level maintenance plans into a nationwide plan. While no clear process for identifying maintenance and rehabilitation needs exists in many countries, this reporting and planning will produce an integrated perspective across regions and operators – a crucial resource, given how fragmented the management responsibilities tend to be across regions and municipalities, as well as across agencies, state-owned enterprises and private operators (refer also to the discussion of public agency cooperation in chapter 2.3). On the basis of this assessment of current condition and future demand, draw up long-term maintenance plans and forward-looking O&M budgets.
- Develop a truly integrated national infrastructure plan. Integrate maintenance and rehabilitation projects into the national infrastructure programme/plans, alongside greenfield projects, and prioritize all projects according to the highest cost-benefit ratio based on economic, environmental and social factors. This will counter the common temptation to over-favour high-profile greenfield projects, and discourage a pure "fix it first" policy.
- Ensure the durability and continuity of these O&M plans across government cycles, either by legislating standards or by assigning the planning to quasi-independent, technocrat-led agencies.

Reform the principles of public infrastructure accounting.

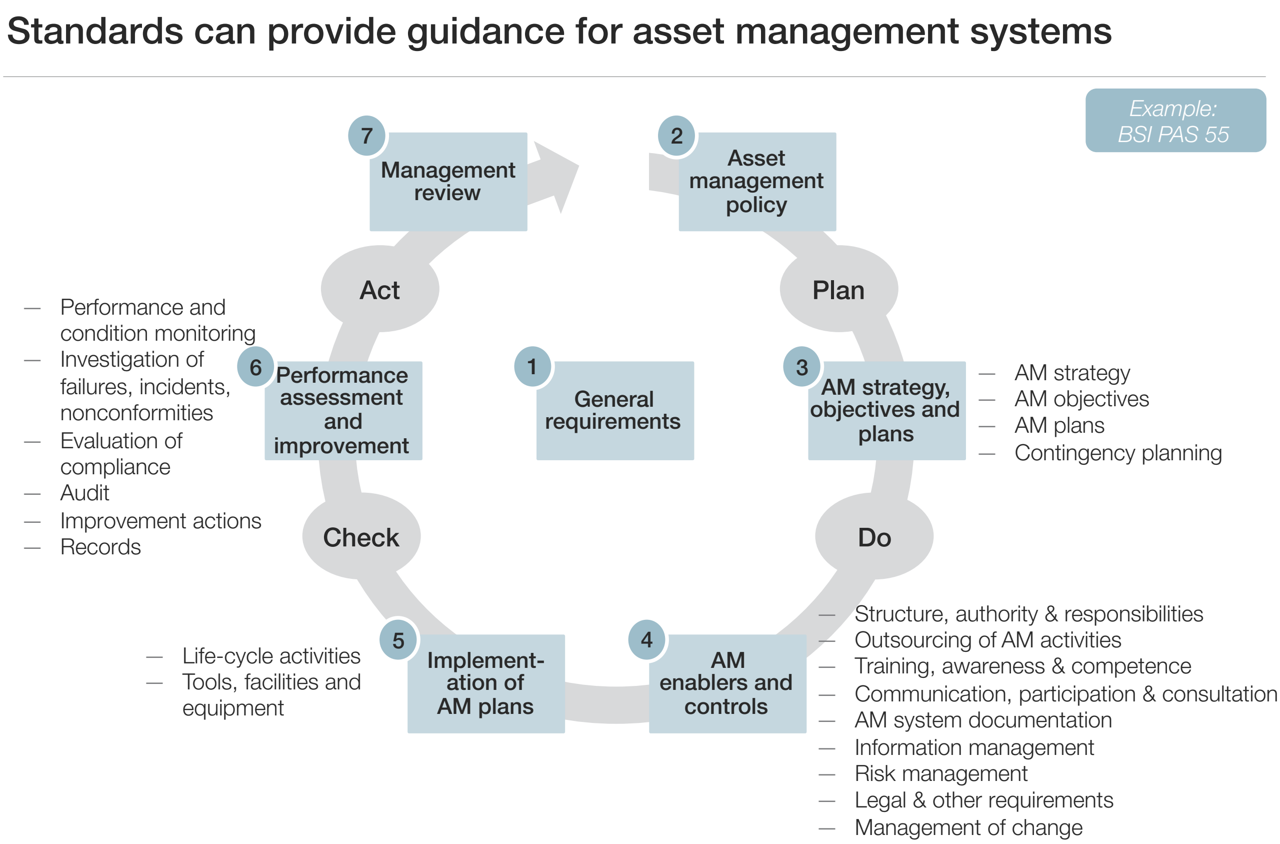
- One key requisite for robust O&M budgets and plans is an appropriate system of public accounting. Under the traditional, single-entry cameralistic systems of fiscal accounting, which concentrate simply on cash inflows and outflows, decision-makers have little incentive to maintain the existing asset base: after all, maintenance appears to involve cash outflows but no inflows, as the increase in value of the asset stock is not recorded. In contrast, a proper, modern accrual-based double-entry system of accounting can rebalance the incentives. Assets can now be recorded on the balance sheet, with their value being depreciated and regularly reassessed. For instance, a road's value depreciates with each additional pothole, and that information can be used to improve decisions and report to stakeholders to reveal the maintenance backlog, helping to justify maintenance spending. The US introduced the Governmental Accounting Standards Board Statement 34 in 1999 to help local and state governments profile their infrastructure in a proper way; and, many countries now aim to abide by accrual-based International Public Sector Accounting Standards, which are based on the private-sector International Financial Reporting Standards (IFRS).[180]

Adopt a common asset management framework.

– Develop a country-wide, standardized asset management framework for adoption by the different agencies to guide managers and workers in executing their O&M tasks. Such a framework should cover all aspects of a sound asset management system, ranging from asset management policy and strategy to enablers and controls, and to performance assessments and management reviews. For each agency, these system capabilities need to be developed in a customized approach based on their respective human resource, knowledge management and organizational learning challenges and opportunities.

– Structure the asset management framework in keeping with international standards, such as the British Standards Institution's (BSI) Publicly Available Specification (PAS 55) and International Standards Organisation 55000 (ISO 55000) (Figure 31). The PAS 55, published by the BSI under the supervision of the Institute of Asset Management, provides a 28-point requirements checklist of good practices in physical asset management. Its guidance is widely applicable, for instance to gas, electricity and water utilities, and to road, air and rail transport. It also provides a toolkit for self-assessment. In fact, PAS 55/ISO 55000 certification was ranked second among the top 10 investment priorities for asset management practitioners in 2013.[181]

Figure 31: Example of an Asset Management Framework



Note: BSI = British Standards Institution; PAS = Publicly Available Specification; AM = Asset Management
Source: PAS 55-1: Asset Management in The Institute of Asset Management:, 2008.

Apply data, benchmarks and tools

The main O&M-relevant capabilities that each individual government agency needs to develop are those for collecting relevant data and benchmarks, acquiring the appropriate IT systems and other tools, and using them in conjunction as a way to improve decision-making.

Traditionally, the O&M of infrastructure assets has been subjected to insufficient scrutiny and measurement. Operators often have only a very sketchy overview of a facility and its equipment. The history of an asset's construction and repairs is often lost, and information on the current asset condition is frequently not available. Operators also tend to have too little data on the asset's usage and performance levels, and hence on its cost effectiveness. Even when they have abundant data, they may struggle to use it because of its varied relevance and inconsistency.

Without the right hard data for analytics, benchmarking, modelling and impact evaluation, operators are hampered in their decision-making and setting of stretch targets. Governments and operators should ideally know the state of each asset, piece of equipment and component, and how each of them performs, both over time and relative to others. That will involve a structured approach to capturing, sifting and aggregating the relevant information in a comprehensive IT system. The better the monitoring and measuring, the sharper the O&M decisions will be, and the greater their eventual impact.

Collect comprehensive O&M data.

– Assess and understand the data requirements that are necessary to optimize O&M. A prioritized list of the key data requirements will assure that costly data collection is focused on the areas where most value can be created.

– Set up an asset register and collect data on the asset's history, the current condition, O&M measures, performance, usage and context.

– To supplement that effort, put adequate systems, processes and resources in place for regularly updating the data. Early data repositories may lack the comprehensiveness needed for full life cycle analysis, but the models should improve as more data becomes available over time.

– Exploit the big data opportunity (Box 7), which will complement the traditional structured database and data management systems.

Box 7: The Big Data Opportunity

Today's world produces a vast amount of digital data. The volume is currently increasing by 2.5 billion gigabytes every day. The proliferation of low-cost sensor technology has opened a treasure trove of new information sources, including transactions, social media, radio frequency identification sensors, cameras and GPS, which can be harnessed by infrastructure operators.[182]

New opportunities arise not just from the soaring volume of data, but also from the data's increasing variety (which can now be mined even from unstructured data sources) and velocity (i.e. the speed at which data is collected, processed and used for decision-making and automatic system responses). With this mass of data and rapid advances in processing power, storage density and connection speed, big data applications are becoming increasingly economical. They present a major opportunity for improving productivity and efficiency in infrastructure. Operators will find it easier than ever to improve market research, enhance O&M decision-making and boost customer relationships and satisfaction.

One obvious benefit is that of making infrastructure operations more efficient. They might, for instance, leverage big data to improve intelligent transportation systems and enable dynamic peak pricing, and in that way avoid having to invest in expensive new capacity. The Stockholm road authorities, for instance, collect real-time traffic data from a variety of sources, including vehicle GPS, radar sensors, congestion charging and weather reports, and process it via algorithms to advise motorists on optimal travel routes.[183]

To take full advantage of big data, infrastructure operators need to define open and interoperable interfaces and industry standards to enable data interchange. They can publish data through application programming interfaces and thereby enable entrepreneurs to unlock the value of the data; connect to other data; and develop new user solutions. New York City's "Midtown in Motion" congestion management system provides such an interface for app developers. Despite this openness, operators need to be cautious and manage data responsibly in the public interest to earn the trust of stakeholders on data privacy and cybersecurity.[184]

In addition, the infrastructure industry needs to embrace new forms of multistakeholder collaboration. In the Netherlands, for example, the Amsterdam Smart City project has 70 partners from business, government, academia and the local population working together to identify, test and eventually scale up different smart city initiatives, such as car sharing, home energy management and electricity-powered ships.[185]

Organize benchmarking.

Infrastructure operators should benchmark themselves against other operators to identify potential ways of improving the system. Comparisons are seldom straightforward, of course, and no two situations are identical. To ensure meaningful results, the analysts have to delicately choose which data to analyse, decide on the best level of granularity for the KPIs, and take into account contextual factors such as demand, location and the asset's age. And, they need to use a consistent and standardized methodology when collecting data. One challenge they face is that infrastructure data is seldom available publicly; the rules on record-keeping and on disclosing data vary from country to country. A global infrastructure benchmarking initiative, as suggested by the Multilateral Development Banks (MDB) Working Group on Infrastructure and supported by the latest Business 20 (B20), would be beneficial in this regard.

– In benchmarking, cover all aspects of O&M in a sector-specific approach; combine qualitative and quantitative data, and also exchange ideas on cost reduction, quality upgrades and other improvements. The Community of Metros (CoMET), a consortium of 30 metro systems from around the world that is facilitated by a research centre at Imperial College London, is an interesting example. It tracks more than 30 KPIs of its members, provides quantitative benchmarks and establishes qualitative best practices in case studies. Partly on the basis of its indications, the New York City Transit Authority introduced floor markings to show commuters where to stand on platforms, and departure clocks for drivers to standardize their "dwell time". As a result, capacity on one of New York's busiest transit lines increased by 4.5%, with 17% considered achievable.[186]

– Actively seek appropriate peers, and then conscientiously conduct external benchmarking. For example, in the US, the Phoenix Water Services Department undertook a review of its O&M practices and benchmarked them against other well-run utilities, both public and private. The quality of customer service rose, while costs fell by US$ 10 million annually.[187]

– Benchmark data can also be provided by national governments to consolidate data from the many local and regional agencies. The US Department of Transportation operates an online database of detailed capital and O&M cost estimates for Intelligent Transportation System deployments, ranging from roadside information to toll plazas and parking management.[188]

– Conduct internal benchmarking as well, if possible. London Underground has introduced a benchmark report comparing the different areas of its network.[189] And Royal Vopak of the Netherlands uses its terminal maturity model to assess and compare its oil and gas storage terminals throughout the world, and improve their performance.[190]

Implement asset management systems and tools.

There is no point in collecting data for data's sake; the point is to transform data into useful information that aids and improves decision-making. For that to happen, operators need to put in place the right information management systems and mechanisms.[191] They need to implement an IT-based asset management system to integrate the different datasets, plan and time interventions, trigger actions, and monitor and evaluate performance. Such an asset management system serves three purposes (see Figure 32 for examples):

– *Real-time and transparent status reports*. A coherent dashboard of maintenance needs should support funding calls, ease the budgeting process, build consensus across siloed departments and facilitate communication with external stakeholders.

– *Ex-ante modelling*. The system should help analysts to model and predict the costs and impacts of different planned O&M interventions, and thereby help to refine decision-making.

– *Ex-post analytics*. The system should provide evidence-based assessments of O&M interventions, which can help to optimize quality and expenditures over time.

Some considerations to bear in mind:

– The asset management system should integrate a variety of modules, including fixed-asset accounting, inventory management, condition assessment, financial forecasts, work management, quality management and regulatory compliance. Many systems also include a geographic information system (GIS) component, which can help with maintenance scheduling and staff deployment for dispersed assets. For example, Swiss Federal Railways has complemented its fixed asset database with a geographical information system, and the asset records of Rand Water, a water utility in South Africa, are all linked to GIS data.

– One key challenge for asset management systems today is to manage different standards across an infrastructure system, as over time, assets have been built according to changing norms and codes. Not only do these assets need different operating standards and maintenance routines, but also the user perception regarding those different service levels needs to be managed.

– Any asset management system will only be as good as the information it contains; hence, the need for adequate asset surveys and maintenance records, data entry protocols and interfaces to other databases, such as the accounting system. When the Massachusetts Water Resources Authority introduced a computerized maintenance management system, an initial audit concluded that the data quality needed improvements, and recommended new procedures and links to other software.

One case in point is Jordan's As-Samra wastewater treatment plant, which uses a computerized maintenance management system and exemplifies several of the benefits. It integrates and shares information across different functions, including maintenance activities, spare-parts inventory and procurement. In addition, it makes predictive maintenance possible by monitoring the asset's condition, sets KPIs for major equipment and compares the actual availability and condition against targets.

Figure 32: Functionality of Asset Management Systems

Asset data can be leveraged for many purposes

Many data types to be collected ...

Examples

Asset register	— Asset inventory and organization — Assets with physical attributes
History	— Used design codes — Used equipment and components
Asset condition	— Regular or event-driven inspections — Remote condition-monitoring
O&M measures	— Recording of maintenance activities — Costs per activity for each asset
Asset performance	— Technical: reliability, throughput ... — Commercial: customer, accounting ...
Asset use	— Level and type of use — System stress
Context	— Weather — Geo-location

... and used in integrated information systems

Real-time and shared information

The South Carolina DoT in 1997 began putting online 1.9 million scanned images of road construction plans for use by employees and also external surveyors, engineers and government offices. By replacing the slow and cumbersome old card-catalogue system, the scheme greatly improved efficiency and reduced costs.

Ex-ante modelling of O&M interventions

The St Michael's Hospital in Toronto used a Facility Condition Assessment – based on an independent review of all infrastructure and consolidating data from all sites into a singe database – to create building-development scenarios, prioritize facility plans and automate funding projections.

Ex-post analytics and impact evaluation of O&M

The Metropolitan Atlanta Rapid Transit Authority tracks its 1,520 vehicles and fixed assets in a single enterprise asset-management system. Thereby it tracks defects, repair and maintenance in real-time, measures productivity, and uses analytics to improve decision-making and efficiency.

Note: DoT = Department of Transport

Source: "Best of the Best: Americas Transportation Awards". US Department of Transportation: Federal Department of Highway Administration, http://www.fhwa.dot.gov/publications/publicroads/12marapr/03.cfm, 2012.

In addition to information management systems, operators should also develop guidance and tools for improving O&M decision-making (e.g. operations manuals and maintenance guidelines; methodological guidelines for life cycle cost analysis and demand forecasting; virtualization, simulation and modelling tools such as the road management software HDM-4). (See the case study in Box 8.)

Box 8: Case Study – Leighton Contractors, North-West Transit Way, Australia[192]

In the north-west of Sydney, with its rapidly growing population, commuters needed a new public transport system for rapid and reliable access to the city centre. Leighton Contractors won a 10-year concession to design, build, operate and maintain the bus-only, 21-km route with 30 bus stations. The contract specifies strict performance and maintenance standards, and the road has to be in good condition when transferred at the end of the contract.

To fulfil those requirements and manage the concession efficiently, the contractor analysed historical data (based on monitoring the roadway's condition at one-metre intervals), identified and excluded from the analysis all irrelevant external factors, established a performance model and deterioration rates for the paving, and applied the Highway Development and Management (HDM4) system, a decision-making tool for optimal whole life-cycle management. The HDM4 tool was beneficial, as it can predict road network and paving performance, road-user effects, and can produce a schedule of optimum roadway maintenance as well as plan overall funding requirements.

Leighton Contractors was then in a position to predict the performance and condition of the paving, and draw up a life cycle plan that struck a balance between capex and opex, and optimized the maintenance strategies. As a result, overall cost savings of 15% were achieved.
The company also undertook scenario analysis to evaluate different levels of service and the associated cost implications. A whole-of-life solution emerged that provides a higher level of service (the road is now 99% available) while still complying with the contracted maintenance requirements.

Conduct training and develop talent

For high-quality O&M, operators need more than institutional knowledge in the form of plans, frameworks, data and decision-making tools; they also need individuals capable of exploiting these resources. All too often, the critical deficiency in an infrastructure asset is that of local human capital. In developing countries in particular, international companies commonly construct the infrastructure and then move on, leaving behind an insufficiently qualified workforce to handle future O&M tasks. Even in developed countries, staffing can be difficult: technicians sometimes cannot keep pace with the increasing sophistication of the technology, and for skilled engineers, O&M projects have a lower status than design and build projects.

Excellence in infrastructure O&M planning and execution requires a broad set of skills. Operators need to make serious investments in training, and to formulate a consistent human resources (HR) strategy to recruit, develop and retain O&M professionals.

Organize regular and targeted training for employees.

The first training opportunity occurs during the asset's construction. The problem is that O&M staff is not typically involved in the design and build stages, and may not even be hired until construction is completed (except for PPPs). For the Enguri dam in Georgia, the Russian contractors undertook very little knowledge transfer, so Georgia's own O&M of the dam proved far from competent at first. To conduct training and develop talent, several measures are indicated:

- Hire and involve O&M staff early on, and arrange knowledge transfer from the external engineering and construction firms through on-the-job and off-the-job training.
- Include a training component in engineering and construction contracts, so that designers and contractors are obliged to provide local staff with continuous training and thereby create local competence, for several years after project completion.
- Reskill the O&M workforce continuously, during the later life cycle stages, as system operations and technologies evolve and staff fluctuates. The O&M phase itself can be a great learning environment, as its stability and long-term orientation can facilitate strong learning curves over the project's life cycle. To achieve these skill upgrades, adopt as appropriate any of the agency-specific and sector-wide training approaches outlined in Figure 33.
- Pursue broad capacity-building policies. For example, urge a shift in university engineering curricula; currently, they tend to emphasize the design and construction aspects of infrastructure assets, even though most infrastructure-related engineering work in the next few decades will be in facility maintenance and rehabilitation. Infrastructure O&M knowledge will be required in other domains, such as operations management and finance. Especially in developing and fragile countries, a local academic strategy for building infrastructure skills in general, and O&M skills in particular, is essential.
- Engage with IFIs and urge them to expand their involvement in on-the-job training, as provided by the EBRD for some of its transport projects in Romania. The traditional approach of many IFIs and donors, to simply bring in international

Figure 33: Examples of Capacity-Building

Agency-specific training to be complemented by sector-wide initiatives

Agency-specific training

Combine project delivery with local training
— For a gravel road upgrade in the Lusikisiki municipality in South Africa,148 local young people were trained and employed for the works. The result: a new road and a set of newly skilled people.

Combine classroom training with hands-on experience
— The Port of Salalah in Oman trains crane operators in a simulator that emulates all real-world challenges but without interrupting regular operations or putting staff or property at risk.

Use a train-the-trainer approach
— For the Jamaican water sector, the Japan International Cooperation Agency used 19 master trainers to refine the skills of local staff, leading to a 35% reduction in water loss.

Cross-train and exchange staff across departments and agencies
— Phoenix Water Services Department encouraged staff to develop multiple skills via on-the-job training and cross-training, thereby reducing the need to hire additional staff.

Sector-wide capacity-building

Leverage academic programmes
— The South African National Road Agency provides scholarships to employees and students, co-operates with local universities, and sponsors chairs of pavement engineering and transport planning.

Institutionalize training programmes
— The Singapore Land Transport Authority and MoT set up an Academy, serving as knowledge hub for best-practice exchange, research, training, and cooperation with international and local universities.

Exchange best-practices and innovations via sector associations
— The Romanian Water Association ARA runs an annual competition for pipe-leakage detection for its members, thereby enhancing performance and effectively diffusing knowledge.

Leverage knowledge platforms in the international community
— ADB's Transport Community of Practice provides training on road asset management to staff and officials, conducts peer reviews on maintenance in project proposals, and disseminates information.

Note: MoT = Ministry of Transport; ADB = Asian Development Bank experts to provide technical assistance, can have a distorting effect by demoralizing agency staff.

Actively engage in talent management and development.

When building capabilities, operators should look beyond training, and take a longer-term, strategic approach through talent management and development. They need to adopt vigorous policies in three key areas: HR planning, recruitment and retention, and people development. Details for each include the following:

– *HR planning*. As a result of the demographic shift in developed countries, many utilities face the prospect of a dearth of engineers and other skilled labour. In response, several operators have initiated strategic workforce planning by splitting their labour force into different skill categories, calculating the potential shortfall in each one, and developing pre-emptive measures such as new recruiting and retention strategies. The Department of Transport in Victoria, Australia, compiled a core-capabilities report identifying required skills; established a list of 146 vacancy-sensitive jobs with the current job occupants and potential successors; introduced a career planning and development tool; launched a two-year programme to advance high-potential employees into leadership positions; and increased the use of mentoring, coaching and mobility schemes.[193]

– *Recruitment and retention*. Infrastructure operators will increasingly have to draw from a limited number of engineering graduates and unfamiliar recruiting pools. In what is traditionally a bricks-and-mortar industry, they now have to recruit IT and technology specialists as well. Some operators are engaging the challenge head-on. The Hamburg Port Authority in Germany now has a dedicated chief information officer with a 60-member IT team to facilitate its transition to a smart port and realize its ambition to treble container numbers by 2025 – and all within its current, confined port area. More broadly, Chile has taken a long-term approach to increasing the appeal of public service jobs in general by sending talented recruits on university courses abroad, and by offering them competitive salaries.

– *People development*. Singapore's public services lay out generalist or specialist career paths for future leaders, offer customized training and university scholarships to develop their skills, and provide attractive performance-based compensation packages.[194]

2.3 Reform governance

Many public infrastructure agencies have outmoded governance structures and procedures. They are still subject to political influence and weighed down by bureaucracy – characteristics that militate against institutional independence, efficiency and accountability. In fact, many public agencies assume both policy and implementation roles, a process that conflicts with the good governance principle, namely the separation of control and management.

Corporatize and professionalize public agencies

In such cases, institutional public-sector reform is strongly advisable, either through corporatization or professionalization of the agencies managing infrastructure assets. Corporatization is the process by which a public-sector department is transformed into a distinct legal entity (with the government as owner), whose assets, finances, and functions are segregated from other government operations. Corporatization aims to capture the advantages of a privately run company, including productivity, streamlined processes, commercial orientation and financial sustainability, while remaining accountable to the public and serving the public interest. Professionalization likewise involves adopting many aspects of private companies, but without changing the agency's legal status.

Corporatization achieves its goals by giving the former agency the following:

– Clear incentives and targets for improved performance

– Greater organizational autonomy for decision-making, compared with its limited independence as part of a government department

– A more rigorous system of oversight, by clarifying the role of the government as owner and controller, and defining priorities for the board

– External accountability for achieving its targets

Corporatization also enables a more flexible system of shared ownership between different government levels and departments, and allows for easier transfer of ownership in the future, including privatization.

When pursuing corporatization, governments should consider the following actions:

Establish a separate legal entity and sound corporate governance.

– Specify strategic direction and clear objectives, as well as clarify roles and responsibilities. Spell out the limited, arm's-length nature of departmental control over the newly corporatized entity. And, avoid duplication of activity between the new organization and the department sponsoring it.

– Ensure the organization's managerial independence by granting it considerable freedom of action. The entity will be successful to the extent that it keeps politics out of its policies, and maintains sound corporate decision and planning horizons of more than one election cycle.

– Retain some control. The new entity has to stay externally accountable (to the government, or rather to the electorate); it needs incentives and targets to reinforce its performance goals, while at the same time not being micromanaged. The best way to bring that about is by contract – whether through a licence, performance agreement, service-delivery agreement or shareholders' agreement. The contract should contain the agreed obligations of each party (in particular, specific financial and operational targets set by the government departments); the reporting and monitoring requirements; and any incentives, penalties, ministerial intervention and approval rights, such as for the business and financial plan. For example, the Sydney Water

Act allows the regulator to demand remedial action, impose monetary sanctions and even terminate the licence for the corporatized entity.

- Establish an independent board. It should be sufficiently qualified, and should act independently of the controlling shareholder or department to ensure the entity's long-term financial sustainability. In South Africa, Johannesburg Water's board members cannot be members of the City Council. And for PUB, Singapore's national water agency, members of the board are deliberately selected to represent a broad spectrum of stakeholders.[195]

Introduce modern financial management and accounting practices.

- Set clear financial targets and policies related to cost recovery, profitability, dividends and subsidies.
- Give the new entity full control of financial matters, including investment, financing and pricing (within the regulatory limits), to ensure financial sustainability. In contrast to a government department, which often is managed as a cost centre and so has little incentive for superior performance, a corporatized entity is managed as a profit centre with its own revenue streams. For such an entity, the key source of funding is no longer government transfers but customer revenues generated through services, meaning it will have strong cost, revenue, investment and service-quality incentives, and will treat consumers accordingly.
- Implement dual-entry corporate accounting, and decision-making frameworks based on net present value, to ensure an unbiased budget allocation for construction and maintenance based on a whole life-cycle view.
- Set up an adequate and transparent financial reporting system to enable internal controls through the board, external independent audits and easily accessible information for the general public.

Institute customer and commercial orientation.

- Commit to the customer via a customer charter or a formal customer contract. The National Water & Sewerage Corporation of Uganda has a customer charter that specifies service standards. Another example is the operating licence for Sydney Water, which includes schedules for customer service that set out the rights and obligations of both the corporation and the customer.
- Monitor and report on customer satisfaction targets. Sydney Water is required by the terms of its licence to accurately measure, record and annually report its performance against specified customer service indicators to the regulator.

Establish data-driven management, and nominate capable leadership.

- Establish a transparent framework for setting targets, monitoring performance and prioritizing measures. For example, the Municipal Finance Management Act of South Africa requires production of a Balanced Scorecard for Johannesburg Water.
- Motivate staff through a remuneration scheme, career progression and personal performance assessments. In 2004, Singapore's PUB moved from tenure-based fixed incremental pay increases to a system of performance-based or merit-based pay increases.
- Base leadership nominations or appointments on technical expertise, not political connections, to avoid "revolving doors". Even after entities have been corporatized, little will change unless change comes from the top. The Massachusetts Port Authority, for example, removed controversial political appointees and installed an independent chief executive officer (CEO) unburdened by political obligations. He established clear criteria for decision-making, in line with strategic business objectives; assigned accountability for cash flows to business unit managers; revamped hiring procedures, staff evaluation and bonus principles; and introduced a system for reporting political pressure to the board. In combination, these varied measures finally reduced political interference.[196]

A good example of corporatization's benefits is Aqaba Water in Jordan. The effects of corporatization included a sharper commercial orientation, leading to a 30% increase in sales; additional investment, such as renewal of 90% of the network; performance improvements; increased training for employees; and enhanced customer service including a 24/7, one-stop service centre, and quicker response time for complaints.[197]

Corporatization is often a first step to broader reforms, such as privatization and competition. (See Figure 34 for an example from Singapore, and refer to the following discussion for more details.)

Foster cooperation between public agencies

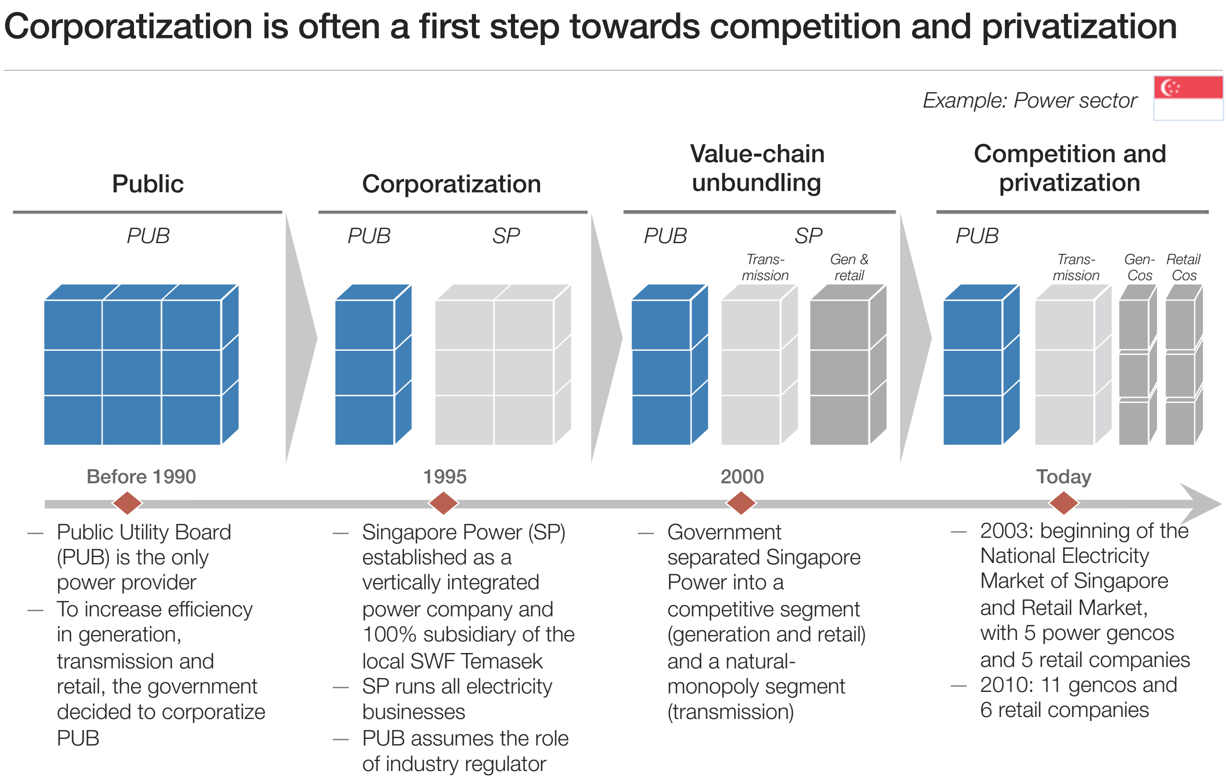
Reforms of the institutional framework should extend beyond individual agencies, and should also address the need for more coordination and cooperation between agencies.

Coordinate across assets and different levels of national, regional and local government.

In many countries, responsibilities for operating and maintaining infrastructure are fragmented across different levels of government and jurisdictional boundaries. Individual regions or even municipalities might be assigned responsibility for a large share of the infrastructure, and might well give their regional interest priority over national interests.

- Develop metropolitan or regional infrastructure plans to coordinate the O&M and rehabilitation plans. For instance, in a regional airport system as in Paris and London, each airport could be assigned a particular role – catering to full-service, low-cost or cargo carriers – to enable specialization and economies of scale.
- Establish a designated coordinating institution, and define clear roles and responsibilities for all other agencies involved. The EBRD has coordinated changes of tariff structures and public service contracts by taking an integrated, multicity approach across 20 cities in Tajikistan.
- If appropriate, enter into performance contracts with regional or municipal subsidiaries to hold them more accountable, increase

Figure 34: Examples of Long-term Sector Reforms



Note: PUB = Public Utility Board; SP = Singapore Power; SWF = Sovereign Wealth Fund

Source: *National Energy Policy Report*; 2007. Singapore: Ministry of Trade and Industry Singapore; "*Essay: Corporatization Of Singapore Electricity Industry Economics*", http://www.ukessays.com/essays/economics/corporatization-of-singapore-electricity-industry-economics-essay.php, 2010

managerial autonomy, introduce performance incentives and increase coordination across the system.

– Design budget allocation mechanisms across different levels of government wisely. In many countries, the federal government supports regions and municipalities in financing new infrastructure, but there are often no appropriations for O&M and rehabilitation. (This system encourages myopic decisions that favour the option receiving the greatest federal support, rather than the one with the lowest life cycle costs).

Coordinate across sectors.

Traditionally, the management of infrastructure assets has been assigned to sector-specific agencies. While that might make sense from a day-to-day operational point of view, it disregards potential cost and demand synergies in the long term. Agencies should consider the following measures to improve their joint O&M:

– Integrate system operations. In public transportation, for example, the various modes can be better coordinated by integrating information, fare systems and networks.

– Seek and exploit cost synergies in maintenance and rehabilitation. For instance, a "dig once policy" aims to synchronize various works that require road excavation, such as installing broadband fibres, renewing the paving and upgrading water, sewer or electricity systems, by coordinating across agencies and utilities.

– Plan O&M improvements and expansion across the whole system, addressing the main bottlenecks. A good example of the problem is the central corridor railway through Tanzania, which currently carries only 10% of its capacity. In addition to problems with the railway itself, one of the main issues is attributable to slow customs checks at borders and the port of Dar es Salaam, where delays of three to four days are frequent.[198]

Cooperate across national borders.

A lack of coordination across borders often underlies major inefficiencies. Trucks in Africa, for example, often remain idle at border posts for days, owing to a combination of incompatibilities in technical standards, regulations and procedures. As a result, transporting a 20-foot container by truck from Durban to Lusaka and crossing two borders costs more than US$ 5,000, compared to only US$ 1,500 to ship the same container from Japan to Durban.[199]

– Harmonize technical standards. For example, the European Rail Traffic Management System enables rail interoperability across borders, and thus reduces international rail traffic costs.

– Harmonize regulations, such as truck operator registration, vehicle fitness and vehicle overload control.

– Harmonize procedures. Clearance times at borders can be greatly reduced, such as by using one-stop border posts, coordinated border management and cross-border data exchange systems. In 2013, to take a different example, the European Commission adopted an EU-wide gas network code to facilitate gas trading. The harmonized auctions use online booking platforms and are held concurrently to ensure fair access to pipelines for all users; that process eliminates the risk of being stuck with capacity rights for just one side of a cross-border interconnection point.[200]

In some cases, of course, such coordination and cooperation might still prove insufficient, and an integration of activities, and thus mergers, will be needed to optimize joint operations.

Merge agencies to optimize scale and scope.

In some countries, infrastructure is characterized by small and potentially inefficient management units, owing to a fragmented municipal structure or a complex system of local, regional and federal assets. Of the 150,000 public water supply systems in the US, more than 93% are very small, each serving fewer than 3,300 people.[201] Consolidating operators is thus one way of enhancing the ratio of overhead to operations and achieving an efficient scale and scope. Mergers are most beneficial when the assets in question are homogeneous; the economies of scale and scope are large; the network effects are pronounced; and some individual parts of the businesses are unprofitable and reliant on cross-subsidies. However, demerging of agencies may be indicated in some cases when increasing complexity outweighs the benefits of scale and scope.

– Optimize scale. In Romania, local water utilities were consolidated on a regional level to attain the required scale for operating efficiently; for instance, suppliers from several towns and municipalities around Cluj were merged to form Apa Somes.[202]

– Optimize scope. By consolidating seven separate local agencies into one multimodal transportation agency, the Orange County Transportation Authority in California secured efficiency gains and eliminated duplicate functions. On a national level, both Sweden and Finland have combined their road and railway administrations into a single agency in each case.[203] And on an even broader scale, nine cities with a combined 42 million inhabitants in China's Pearl River Delta are considering merging into one megacity to provide more seamless transportation.[204]

– Optimize scale and scope across different sectors and regions. For example, the Port Authority of New York and New Jersey (US) operates five airports, two tunnels, four bridges, three bus terminals and five port terminals across the two states.[205]

Consider private-sector participation and competition

Private-sector participation can improve O&M by tapping the private sector's financial resources, as well as its skills in operating and maintaining infrastructure efficiently and effectively on a whole life-cycle cost basis. Many benefits tend to emerge, in efficiency and quality of operations, as well as in revenue and service innovation. For instance, in water treatment, savings of more than 30% in operating costs have been recorded in some major US cities, such as Indianapolis and Milwaukee.[206]

The present time offers a good opportunity to sell brownfield infrastructure assets on favourable terms. Many government budgets are still constrained in the wake of the global financial crisis, while institutional investors have large amounts of private capital at their disposal. Encouraged by the current low-interest-rate environment, these investors, notably pension funds and insurance firms, are seeking low-risk, long-term and inflation-hedged investments such as infrastructure. They are particularly interested in the O&M phase, as the main risks have already been resolved; namely, the most difficult to manage, early-life-cycle risks – design, construction and ramp-up of demand.

Currently, there is considerable dry powder available for infrastructure investment in OECD countries. The 145 unlisted infrastructure funds collectively reached an all-time high in October 2013, seeking global aggregate capital of US$ 97 billion. Yet recently, the number of deals has been flat relative to the past five years, suggesting a "money chasing deals" phenomenon. Investors are paying high prices – witness the recent privatization of ANA Aeroportos de Portugal – and that means a potential concession or sell-off opportunity for the public sector, enabling it to recycle capital into new infrastructure assets, to pay down debt or to expand social services.

Governments need to proceed with caution, however – for their own sake and for that of the users. By simply aiming to maximize the proceeds of privatization ("monetization deals"), a government could be consigning its citizens to disproportionately high user charges, and restricting its own flexibility for the long term.

Review the private participation options thoroughly.

– Clarify the policy objectives. On the one hand, there might be an interest in safeguarding public-sector control of the asset's operations and future development; on the other, there are the economic objectives of improved operations and investment decisions. These competing considerations will become part of the calculation when deciding which option to favour.

– Assess stakeholder readiness of the private sector (whether sufficient competition and skills are present), civil society (how acceptable private participation will be) and government institutions (what their oversight and regulatory capabilities are).

– Consider the various forms of private-sector participation, including service- or performance-based contracts, PPPs and privatization. (See Figure 35 and the Phase II report of this initiative.)

– Scrutinize any proposed private involvement, by means of a rigorous value-for-money analysis, to determine whether it really would be the most beneficial option for society (chapter 1.6). Private-sector participation has challenges of its own, related to higher costs of finance, regulatory failures, long-term inflexibility, labour transition issues and disregard of certain public objectives.

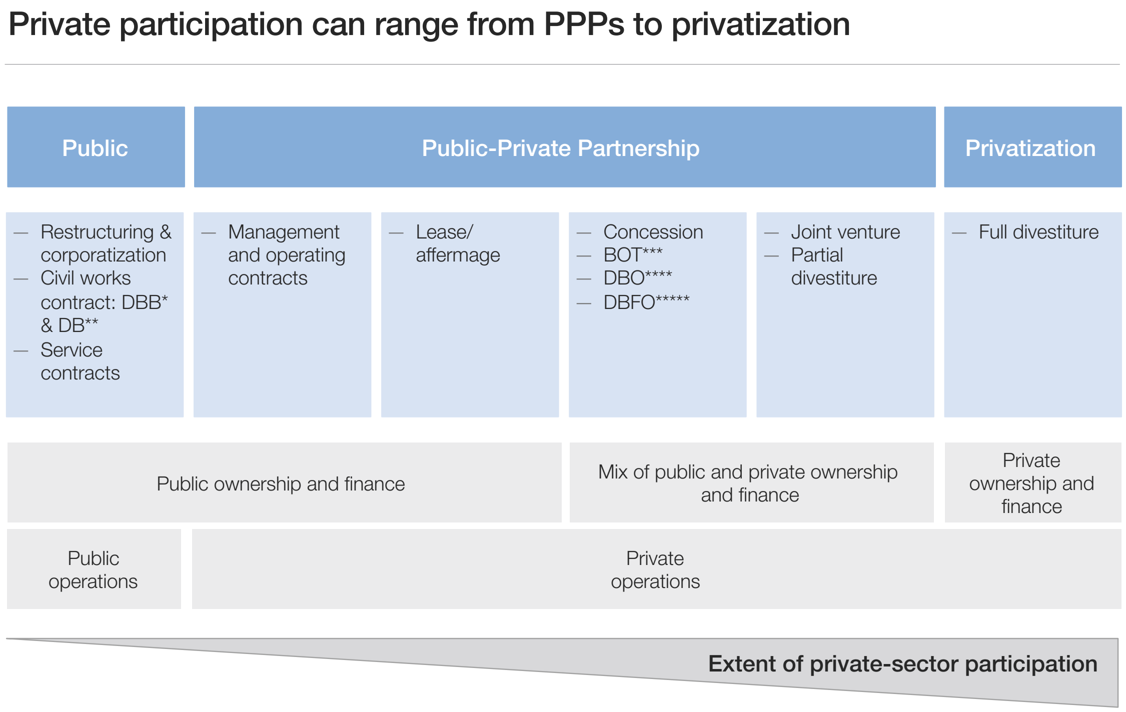
At times, merely the spectre of privatization will motivate public utilities to improve O&M performance, as was the case for many US public water utility systems. And public agencies can learn from their interaction with private-sector operators. For example, the Central Highlands Region Water Authority in Victoria, Australia was able to acquire new knowledge and skills from a PPP for a water treatment plant, and duly improved water quality in other water distribution areas.[207] But if private participation is the way forward, governments should make proper provision for it beforehand.

Prepare private participation diligently.

– Engage in a restructuring or optimization programme prior to initiating the privatization process, to boost valuations and sell assets at a good price.

– Put in place the institutional and

Figure 35: Models of Private Participation in Infrastructure



DBB = design-bid-build **DB = design-build ***BOT = build-operate-transfer ****DBO = design-build-operate *****DBFO = design-build-finance-operate
Source: “World Bank PPP Arrangements / Types of Public-Private Partnership Agreements.”, http://ppp.worldbank.org/public-private-partnership/agreements, 2014

capability prerequisites for a productive relationship with the private participant. Even if most activities are outsourced, a strong and competent government involvement has to be maintained.

- Prepare for a fair, transparent and competitive procurement process. Consider amending the rules and regulations for foreign direct investment to enable both foreign and domestic investors to participate in the procurement to get the best deal for the government.
- Anticipate the public reaction. One way of securing public buy-in for privatizations is to reinvest the proceeds into new infrastructure (“asset recycling”). For example, the Australian government applied this concept of “social privatization” by selling Port Botany to public pension funds, with the express intention of devoting the proceeds to other public services.

Devise a balanced risk allocation and an astute regulatory system.

Private participation usually involves a regulatory or contracting arrangement for decades – a time frame during which major changes are possible in the service and the partnership. To weather the uncertainties and fulfil the expectations of both the public and private sides, much depends on the quality of the risk allocation and the system of regulating prices, standards of service, and investment. The fundamental objective is to strike a balance between attracting the private sector on the one hand, and safeguarding public interests and maximizing overall economic returns on the other – by allocating risks to the party best able to manage them.

- Increase investor attractiveness by sharing or mitigating difficult-to-manage risks (e.g. traffic volume) through sliding scales, guaranteed minimum offtakes or availability-based concessions.
- Protect the public interest by choosing a concession model and pricing regime that encourages the concessionaire to operate and maintain the assets efficiently; for example, through incentive regulation using benchmarks or the RPI-X formula (which increases prices only by the change in the retail price index as a proxy for inflation, minus a required efficiency increase), rather than the rate of return (cost-plus) regulation.
- If appropriate, protect the user interest by regulating the quality of service, using incentives such as bonus and penalty schemes. In the Netherlands, electricity network regulation includes compensation payments to customers for outage time.

Consider market design reforms as well.

As the academic literature shows, the efficiency of infrastructure services is enhanced not only by the ownership structure, but also by the market structure – to the extent that the latter facilitates competition. Different assets lend themselves to different forms or degrees of competition. For some assets, direct in-market competition is feasible; for instance, among ports or nearby airports. Sometimes only indirect competition is possible, as with intermodal competition between road and rail. In contrast, for natural monopoly portions of the value chain, such as rail and electricity transmission networks, the only competitive options are horizontal unbundling across geographies and for-market competition for the concessions.

3. The Way Forward

To neglect O&M is an easy option, but a false economy. Maintaining an existing asset is nowhere near as glamorous as building a new infrastructure asset; the payback in positive public perception and political reward is negligible. Maintenance is thus easily cut, and dangerously so. "Neglect is patient, but eventually it does lose its temper" – and when that happens, the consequences can be very costly.

Presumably, policy-makers have always been aware of the dangers, but have frequently failed to translate that awareness into action. They are now finding that, after decades of operational mismanagement and underinvestment in maintenance, their policies have come back to haunt them. In many countries, a huge backlog of maintenance work has accumulated; it cannot be delayed without serious danger to the continuity of vital infrastructure services, and it is going to cost far more than timely maintenance would have.

O&M is now becoming a strategic issue on the agenda of many nations. Their competitive edge is at stake. Even in this digital age, physical infrastructure remains a foundation of competitiveness, just as much as education is. Company executives, trade groups and even EU officials warn that Europe will fall further behind unless recent cuts in infrastructure spending are reversed.[208] In the US, repeated presidential comments about America's "crumbling" highways have highlighted the issue, as has former Secretary of Transportation Raymond LaHood's remark that "America is one big pothole".[209]

Time for action and investment

The moment to invest in O&M is now. First, the conditions are right:

- When combined, two factors – high unemployment and a sluggish economic recovery on the one hand, and the large economic multiplier effects associated with infrastructure on the other – make a compelling case for investing now, as a means of stimulating the economy and avoiding a legacy of deferred maintenance for the next generation.
- The increasing pressure on public budgets should be a spur to operational excellence. The solution to infrastructure problems can no longer be just more funding; it also needs to involve greater efficiency and effectiveness, in keeping with the new paradigm: "More with less".

Second, the key building blocks are already within reach. As opportunities go, successful O&M is a very realistic one:

- It is doable. Many examples exist of good practice and lessons learned (as discussed throughout this report).
- It is affordable. The O&M interventions are hardly expensive when compared with capital-intensive construction.
- It is backed by numerous technological and managerial innovations. While many new innovations are already available, many more are in the pipeline; but, what is also needed is to apply the current innovations on a broader scale.

Only the political will is missing. So, what is needed is a wake-up call for society and the will to reform the current infrastructure system.

O&M is a wide-ranging responsibility

It concerns developed and developing countries, national and state governments, cities and municipalities, and private-sector infrastructure operators. Developed countries are under particularly heavy pressure to enhance O&M, as a higher proportion of their infrastructure stock is ageing. Developing countries need to address O&M issues of their own: their current operations are often seriously inefficient, and the rapid build-up of their infrastructure assets entails a corresponding surge in necessary maintenance work in the near future. And in fragile states, O&M is crucial for sustaining essential infrastructure services to keep the economy and society working.

Cities, too, will have to upgrade their O&M, in the effort to stretch their infrastructure services, increase efficiency and reduce their environmental footprint. Greater demands are being made on existing infrastructure resources, as cities move from the traditional model of urban sprawl towards more concentrated growth and greater density.

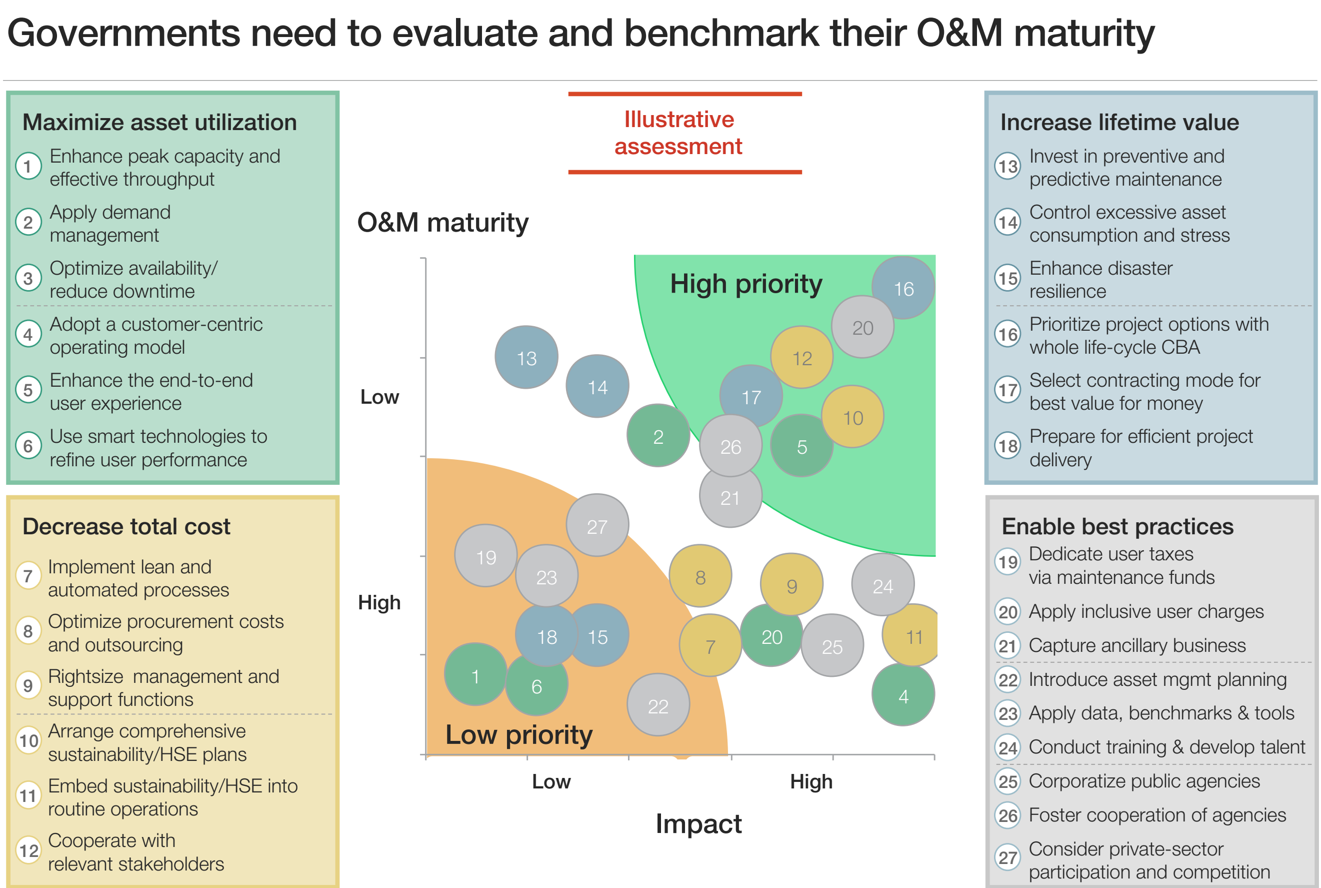
As for private infrastructure operators, they have a double inducement to pursue O&M excellence: rising regulatory pressure (e.g. the move from cost-plus to incentive or benchmark regulation) and the pressure to create shareholder value.

Prioritization is needed

The challenges are so formidable that countries will not be able to implement all best practices at the same time. A staged solution is otherwise acceptable, so long as work begins on it promptly and continues regularly. As a first step, policy-makers should benchmark the maturity of their country's O&M practices, to identify the areas of lowest sophistication and greatest need. They should then evaluate the potential impact of resolving each issue, and prioritize the issues accordingly (see Figure 36 for a suggested evaluation tool). The next step is to develop solutions, drawing on the insights of this report and leveraging the ideas from multistakeholder workshops, with a particular emphasis on win-win solutions that can overcome the traditional trade-offs between dimensions. In addition, policy-makers should not only seek more funding for refurbishing or expanding existing infrastructure assets (usually the main object of attention), but also look for operational levers that improve throughput and quality, reduce costs and extend an asset's lifetime.

There is no one-size-fits-all O&M approach. Different approaches are needed according to country, sector, asset size and criticality. The scheduling and sequencing of the measures will vary as well. In some cases, a quick fix – by realizing some of the implementation best practices – is possible and sufficient, as long as the specialist engineering and operational know-how is available in-house or from contractors. In other cases, the journey will be more expensive and take far more time, involving technology investments or large-scale organizational transformations. For many countries, sustainable O&M solutions will only be possible once the enabling conditions are improved – notably, reliable funding and the right governance structure.

Figure 36: O&M Evaluation Tool



Note: HSE= Health Safety Environment, CBA = Cost-Benefit Analysis

The O&M challenge requires all stakeholders to participate and cooperate

The public sector. The public sector needs to build an enabling environment for O&M by developing appropriate legislation, institutions and capabilities. In addition, governments should enable the private sector by developing a resourceful and competitive set of local industries and a skilled workforce, and should effectively communicate its agenda to civil society.

The private sector. To supplement the role of the public sector, firms can contribute by building the necessary skills and organizational capabilities. Key means by which the private sector can help to optimize O&M include the following:

- Efficient operations through excellence in project management, lean methodologies, modularization, standardization and better risk management
- Technical innovation, especially in smart city and intelligent infrastructure solutions
- Transfer of learnings from other capital-intensive sectors (e.g. oil and gas, manufacturing), for instance by redeploying engineers across different industries and sectors

O&M also presents the private sector with opportunities. O&M is a source of additional stable revenues for the volatile construction industry; some companies have already adapted their strategies, and have transformed from purely construction-focused to either O&M-focused or integrated businesses.

Multilateral development banks. MDBs have a valuable role to play as well, as their financing arrangements can influence the way countries spend their maintenance budgets and operate existing assets. MDBs should direct more of their lending and technical support to the issue of O&M. Several years ago, for example, the Asian Development Bank deliberately suspended loans to Cambodia for new road construction until the country adopted stronger road maintenance measures.

The EBRD's engagement with Ukraine can be considered as a longer-term approach. It exemplifies an evolutionary reform, through a sovereign lending programme coupled with policy dialogue and technical assistance. Each of the four loans for highway rehabilitation was contingent on road sector reforms regarding funding, the institutional set-up and private participation. Specifically, the old road funding system was replaced by a new user tax system that ensured adequate funds for maintenance. In addition, the road agency Ukravtodor was restructured, which included devolving responsibility for local roads from national to local authorities. Finally, the bank also helped to develop a PPP framework, and piloted a performance-based maintenance contract for the M06 highway.[210]

Multistakeholder partnerships. Collaborations between government, business and civil society organizations are very valuable. They have traditionally focused on areas of public service delivery and supply, and should continue to do so, but similar public-private joint efforts should also be launched for assessing the infrastructure O&M needs of regions and cities, and for prioritizing the key actions from an economic, social and environmental perspective.

O&M is not a silver bullet, but it is a key part of the solution to the infrastructure crisis

Even superlative O&M would not be able to close the global infrastructure investment gap on its own. So long as demand increases, construction of new assets will also be required. Still, by optimizing existing capacity, O&M best practice can reduce the need for new construction (and, in so reducing the costs of existing infrastructure, it can also free up financial resources for new construction). Of course, O&M can ease current congestion far faster than new construction, given the latter's long lead times.

With the vast existing infrastructure asset base worldwide, even a modest improvement in O&M will make a significant impact. Certainly the baseline is fairly low in many countries and sectors at present, so the potential for improvement is great; and, thanks to recent innovations and the existing models of good practice, the improvements can be made at a relatively modest cost.

By enabling better management of existing assets, O&M best practices will contribute generously to increased competitiveness, economic growth and social progress around the globe.

4. O&M Case Study: The Panama Canal Authority

The Panama Canal, about 80 km (50 miles) in length, connects the Atlantic and Pacific Oceans at one of the narrowest points of the American continent. After more than 100 years, it still stands out as a masterpiece of engineering. Since its opening in 1914, more than a million vessels from around the world have transited the waterway, on any one of 144 maritime routes linking more than 80 countries. Every day, about 38 ships on average pass along the canal.

The canal contributes considerably to Panama's economy. While the direct contribution to the government budget is about US$ 1.2 billion a year (8% of the budget), considering all indirect effects, such as the maritime and logistics industry it supports, the canal influences about 25% of Panama's GDP. The canal is also key to global trade, and plays a prominent role in many of the leading economies in the world. About 5% of total global cargo is transported through the canal, including 10% of US exports and imports.

The canal is managed, operated and maintained by the autonomous government agency Autoridad del Canal de Panamá (ACP), or the Panama Canal Authority. The management principles currently applied at the ACP exemplify the various best practice areas in the O&M framework – maximizing asset utilization, enhancing quality for users, reducing operating costs, mitigating externalities, extending asset life and reinvesting with a life cycle view. In all of these areas, the ACP strategists have taken targeted actions.[211] This conscientious approach comes as no surprise: after the handover from the US in 1999, the ACP developed as a disciplined commercial canal operator, leaving behind the previous administrative model. The change was fostered by the Government of Panama, which put the right enabling factors in place, helping to ensure funding, build capabilities and reform governance, and thereby facilitating sustainable O&M. (See Figure 37 for an overview of the ACP's O&M strategies.)

Maximizing asset utilization

The ACP optimizes throughput. It has reduced the average vessel transit time from 27 to 24 hours by fine-tuning transit processes and thus enabling more transits per day. Transit times are not only shorter now, but also more predictable, so the canal is attracting more container liners that have to keep to strict schedules. In 1995, 200,000 containers were transported through the waterway; the number now exceeds 12 million Twenty-foot Equivalent Units (TEUs).

The ACP maximizes availability. It provides a 365-day, 24-hour service, and has increased the reliability and continuity of service by minimizing downtimes. That has been partly due to a policy of incorporating redundancy into the key system components, such as the lock gates. For example, each lock chamber has two valves, so a valve can be replaced without suspending normal operations (the water-filling process is slowed down somewhat, but service is not interrupted).

The ACP uses a mixed demand management system – partly price-based and partly rules-based. Its booking system allows pre-booking of slots, and reserves a certain number of slots for each vessel size category and for specified pre-booking periods, so there will always be some slots available for late-bookers. While slots for the first three booking periods are awarded on a first come, first served basis (rules-based), a short-notice slot (i.e. one day prior to the transit) is awarded through an auction (price-based).

Enhancing quality for users

In running its infrastructure business, the ACP applies various marketing strategies and tools. It has introduced customer segmentation by vessel type, commodity and geography. (The segments include: container, dry bulk, liquid bulk, passenger, car, refrigerated goods and general cargo.) It has created dedicated teams to conduct market research on each segment, and to serve each of them appropriately.

The ACP has also introduced technology for forecasting user traffic, and adopted scenario planning to assess the different customer markets and the changes to the underlying drivers. For example, it studies the competitiveness of coal production in different regions, and the evolving fortunes of shale gas and consequent potential for exports of liquified natural gas (LNG) from the US. In addition, the ACP is continuously engaged in analysing its own competitive position. Given the competition from the Suez Canal and the land bridge across the US, it monitors those competitors constantly, assessing their competitive advantages and disadvantages.

The ACP is customer-oriented, and intent on improving the customer experience. Its online booking system allows vessels to conveniently register many months in advance for an assured transit time – a service that is much appreciated by cruise lines and

Figure 37: Case Study on the Panama Canal

The Panama Canal Authority pursues a holistic O&M strategy

Increase utility	1.1. Maximize asset utilization	— Increased throughput by reducing transit from 27 hours to 24 hours — Optimized availability by redundant lock valves enabling "hot" replacement — Mix of rule-based and price-based demand management
	1.2. Enhance quality for users	— Customer segmentation (e.g. by vessel type) and monitoring of competitors — New just-in-time service that allows vessels to avoid waiting
Decrease total cost	1.3. Reduce O&M costs	— Detailed overhaul planning 1 year ahead, enabling maintenance "in one go" — Procurement with life-cycle evaluation and performance specifications
	1.4. Mitigate externalities	— Integrated water resource mgmt and operation of hydro power plants — Well-resourced environmental division with external audits and clear KPIs
Increase lifetime value	1.5. Extend asset life	— Mix of preventive and corrective maintenance depending on equipment — Significant investment in regular maintenance
	1.6. Reinvest with a life cycle view	— Maintenance function involved in planning, procurement and reconstruction — Contractor has to maintain new locks for 3 years with failure mode analysis
Enable O&M best practice	2.1. Ensure funding	— Tolls optimized to different cargoes and tolls kept in ACP to cover opex — >20% ancillary revenues and exploring e.g. container and Ro-Ro terminals
	2.2. Build capabilities	— >8,000 employees trained p.a.; maintenance circle among employees — Centralized balanced scorecard system; modern maintenance software
	2.3. Reform governance	— ACP not privatized but corporatized: independence keeps out politics — CEO selected based on experience and not a political nominee

Note: KPI = Key Performance Indicator; ACP = Panama Canal Authority; LNG = Liquefied Natural Gas; Ro-Ro = Roll-on Roll-off

container shippers. In fact, a special allocation is reserved for cruise ships, which can access the allocation more than a year in advance, prior to all other types of vessel.

To reduce the user's costs, and thus enhance its own competitive appeal, the ACP has recently initiated a new just-in-time service that allows vessels to pass more efficiently. The vessels receive notification of their required arrival time and provisional transit time 96 hours prior to their scheduled transit, and can thereby accurately pace the final leg of their voyage to the canal entrance; in that way, they can use fuel more efficiently and reduce anchorage time.

These various measures have proved their worth by yielding high levels of customer satisfaction. In 2012, the customer satisfaction index, based on a survey of Ship Masters after transit, registered 97.8%.

Reducing O&M costs

The ACP conducts central corporate planning, and sets financial targets and goal-oriented budgets to drive efficiency in the organization. The planning metrics, however, are concerned with more than mere financial performance: the aggregate performance index is composed of 40% financial metrics (e.g. the operating margin), 25% human resource metrics (e.g. occupational safety, staff well-being, productivity) and 35% client and operations metrics (e.g. vessel transit time, energy and water efficiency).

Great importance is accorded to analysis and planning. Any proposed construction or maintenance projects first have to undergo a whole life-cycle return-on-investment analysis before they get the go-ahead for implementation. And, overhauls are planned in detail a full year in advance. The ACP aims to pre-assemble components and pre-order materials and equipment to avoid waiting times during the actual maintenance works. Its maintenance planning makes use of Gantt charts, where the activities are itemized by the minute, and generates the optimal sequence of steps for repair work. The value of such detailed planning and preparation is evident from the results. To fix a major gate outage now takes 4.5 days on average, compared with 14 days in the past. A further boost for maintenance efficiency has come from the new "all-in-one-go" maintenance model, which has replaced the old policy of carrying out maintenance work in multiple sequential packages.

The ACP's procurement system promotes competition and transparency, with open specifications and whole life-cycle evaluation of major parts. Responses to tendering are evaluated twice over – from a technical and a financial perspective.

And where appropriate, the ACP uses performance-based procurement; for example, the specifications for new locks stipulated a target time for filling and emptying the lock chambers rather than the type of technology to be used.

The ACP's corporate culture has also changed with the times. The traditional, tight process control culture ("instructions for everything") has given way to a culture of continuous improvement that values entrepreneurial decision-making. In addition, a formal, continuous improvement process is now in place, whereby staff can propose innovations through an intranet platform, and a dedicated team of professionals has been established for analysing and improving processes.

All of these measures, in the cause of operational excellence, contribute to an operating profit margin of around 45% and returns on equity of about 20%. (Being wholly owned by the state, the ACP is not charged for the use of water and land, which would definitely alter these results.)

Mitigating externalities

The ACP runs comprehensive programmes of environmental mitigation, with the aim of becoming carbon-neutral. For example, a reforestation programme along the canal has involved the planting of 600,000 seedlings so far. The agency also operates a filtration plant to provide water to about 500,000 people in Panama; and, it operates various hydraulic and thermal power plants for the canal's own operations, selling the excess energy to the external market.

Operating the canal involves a vast consumption of water, thus water management is a priority concern for the ACP. Under its Integrated Water Resource Management scheme, the agency monitors and modifies the level of the canal's lake, taking into account the hydrological and meteorological forecasts, and allocates water for the various needs, including lock operations, utility consumption and electricity generation. The agency also works actively to reduce water consumption. The new locks currently under construction, despite being 60% wider and 40% longer than the existing locks, will actually consume 7% less water, as 60% of the water required for each transit will be salvaged in the new reservation basins and then reused.

The ACP has deliberately integrated environmental stewardship into its regular business processes. It established an energy efficiency committee, and has instituted environmental impact assessments at various project stages. It also undergoes an external environmental audit every six months. Its environmental division is well resourced, with 45 staff, about 20 of whom are working exclusively on environmental issues related to the expansion project. In addition, the ACP's integrated management dashboard includes environmental KPIs.

Finally, the ACP engages proactively with external stakeholders and the surrounding communities. It operates a community outreach programme, which includes providing training for teachers, and its water governance approach is based on six regional advisory councils and 30 local committees. It also publicly discloses key environmental performance metrics (e.g. a water quality index).

Extending asset life

The ACP maintains an elaborate maintenance schedule, with the required interventions for each asset being carefully planned well in advance. The approach is a mix of preventive maintenance used for critical assets, and corrective "run-to-failure" maintenance used for non-critical components. The preventive maintenance is implemented in any of three ways – time-based, usage-based or condition-based – depending on the asset's criticality and the availability of information on the asset's condition.

Substantial resources are dedicated to maintenance; the agency has spent nearly US$ 2 billion on upgrades and improvements to the canal since 2000. The main areas of maintenance include

dredging operations in the navigation channel, controlling erosion and landslides, improving locks and their components, and maintaining dams, landfills and power plants.

Reinvesting with a life cycle view

The ACP looks to the future, and makes plans constantly. The current expansion should secure its place in the global supply chain, and safeguard it, to some extent, against new competition from the projected rival canal in Nicaragua and the increasingly de-iced Arctic route. But the canal's expansion programme was actually prompted by the increased demands of world trade, and the consequent surge in both the number and the size of cargo ships. The latest container vessels can carry about 18,000 TEUs, while the canal's old locks could only accommodate ships with a maximum of about 5,000 TEUs. While the old canal was too limited in the number of vessels it could transit each year, that number is about

to double. All the new measures are aimed at maintaining the canal as the route of choice for international trade.

The expansion programme involves an investment of US$ 5.2 billion. It consists of various major works, including the construction of new larger locks, the dredging of navigational channels and a new Pacific access channel. The programme was approved by a national referendum in 2006, in which Panamanians voted heavily in favour of expansion. The ACP believes that the expansion, once completed in 2015, will boost Panama's annual GDP growth rate by 1.2%, which would lift 100,000 Panamanians out of poverty.

The expansion plans have taken into account the canal's O&M needs and costs over the whole life cycle. The ACP's maintenance department was an early participant in the planning of the construction and the purchase of new equipment, notably the new locks. The planners conducted a full total-cost-of-ownership analysis, and gathered external benchmarks to validate the results. Maintenance concerns are also incorporated into the construction contracts; specifically, the contractor for the locks is obliged to maintain them for three years, and also has to perform failure mode analysis and reliability analysis to support future preventive maintenance works.

Looking ahead, the Government of Panama has created the right enabling conditions for optimizing the O&M of the canal for the long term. They are:

Ensuring funding

During the US era until 1999, tolls were set on the basis of covering costs, but the canal took a more advanced approach to increase its revenues and optimize its yield. It segmented the market, and adapted tolls to different cargoes, using a sophisticated pricing model that included the estimated total landed cost of transporting the goods from origin to destination (not only the canal costs) as well as the price sensitivity of the relevant user segment.

There is no political interference in the use of the canal's proceeds. By law, after covering the costs of O&M, modernization and expansion, the agency disburses the surplus funds to the National Treasury. (In the last financial year, the country gained more than US$ 1 billion in this way.)

In addition to the toll revenues, ancillary businesses currently contribute more than 20% of the ACP's revenues: notably, through the sale of electricity, water and transit-related services. The ACP is studying additional ancillary business opportunities, including an LNG terminal, a roll-on/roll-off terminal, a ship repair yard, a bunkering terminal, logistics parks, a container terminal and container-on-barge services.

Building capabilities

Panama has no university-level programme focusing on maintenance, nor a professional maintenance association. Given this, the ACP itself provides most of its staff training, and runs its own apprentice school. More than 8,000 employees attended its training courses in 2012. The agency also uses state-of-the-art software to optimize its maintenance planning and works.

The ACP has nurtured a maintenance culture among its staff. A team of dedicated maintenance professionals has even set up a maintenance circle, with about 70 members, who get together after work hours to discuss issues and best practices. The team recently organized a conference attended by professionals from across the region.

Reforming governance

The ACP was not privatized, but corporatized with a professional structure. Although a government agency, it has financial autonomy and functions quite independently: politics are kept well clear of the canal, so the agency enjoys long planning horizons while the government benefits from receiving the full profits. This independence is also reflected in its leadership personnel. The CEO is selected on the basis of experience and competence, and is not a political nominee.

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