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What Is the Value of Infrastructure Maintenance? A Survey

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Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of the country more nearly upon a level with those in the neighboring town. They are upon that account the greatest of all improvements.
ADAM SMITH, *The Wealth of Nations* (1776)

Public infrastructure has been established as the foundation for the productive activities of a country. Road and rail networks, water systems, power generating and distribution systems, and telecommunications are essential inputs for an economy's production of goods and services. Of course, it matters not only how much public infrastructure a country has, but what condition the infrastructure is in. Infrastructure wears out with time and use, so proper and timely maintenance must be periodically conducted. According to the U.S. Congressional Budget Office (CBO), operations and maintenance expenditures are those that are "generally required to provide the services needed for infrastructure to function and that are often necessary for the repair and safe operation of existing infrastructure" (Congressional Budget Office 2007). Neglecting proper maintenance leads to a decline in infrastructure's condition: pothole-filled roads, loss of irrigation water, power outages, dropped phone calls, and so on. In the

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short run, infrastructure in bad condition imposes costs on users. In the long run, failure to maintain infrastructure in a timely fashion leads to greater costs of rebuilding.

Consider the following examples of costs imposed on users. First, as estimated by the American Society of Civil Engineers (ASCE) in 2009, bad road conditions in the United States impose a cost on motorists of $67 billion annually. The ASCE study assigned grades to various types of infrastructures. Five sectors received a grade of D minus: drinking water, inland waterways, levees, roads, and wastewater. Second, to see how private producers can be affected by maintenance neglect, consider the following example from Zambia reported by Heggie (1995). In 1992, the Federation of Zambian Road Hauliers commissioned a study on the effects of bad road conditions on a vehicle's operating costs. One set of vehicles (a truck and a tractor-trailer) traveled for one year along a road in good condition. Another set of vehicles traveled along a pothole-filled road in bad condition. The vehicles were delivering products to the market or bringing needed materials for production. The study compared the costs of repairing shocks, springs, brake shoes, clutch, and so on. The additional costs are detailed on table 13.1. At the end of the year, the company had spent about $14,000 more on repairing the vehicles using the pothole-filled road.

Table 13.2 presents data on the condition of infrastructure around the world. The first data column shows the transmission and distribution losses of electrical power as a percentage of total output. Countries are grouped according to the World Bank's (2008, 2011) classification system. In the Low Income countries group, 22 percent of power is lost. Middle Income countries fare a little better, with 11 percent of power lost. Both groups, however, have higher losses than the High Income countries, where the power loss is only on average 6 percent.

Table 13.1
Additional Operating Costs Due to Using a Road in Bad Condition

Item	Quantity	Extra Annual Cost (US$)
Tires and tubes	10	5,952
Clutch and pressure plate	1	1,071
Wheel bearings	4	803
Set of brake shoes	1	1,050
Set of springs	1	1,667
Spring hangers and bushes	4	452
Welding and steering assembly	—	2,826
Shock absorbers	4	510
Total extra costs		14,331

Source: Adapted from Heggie (1995). Heggie reports on a study of the Federation of Zambian Road Hauliers Ltd., which describes the additional costs to a set of vehicles used to transport goods and materials along a pothole-filled road for one year.

Table 13.2
The Condition of Infrastructure

Country Group	Electrical Power	Telephones	Roads
	Transmission and Distribution Losses (% of Output)	Faults per 100 Mainlines	Percentage Paved
Low Income	22		21
Middle Income	11	8	54
Lower Middle	9	22	49
Upper Middle	13	8	
Low and Middle Income	12		45
East Asia and Pacific	7		62
Europe and Central Asia	12	10	86
Latin America and Caribbean	16		22
Middle East and North Africa	17	24	79
South Asia	24		54
Sub-Saharan Africa	9		19
High Income	6		81
European area	6	8.3	87

Source: World Bank (2008, 2011). Electrical power data are for 2005. Telephone data are for 2006. Road data are for 2009.

A similar picture emerges from loss indicators in telephone communication, as measured by the number of faults per 100 mainlines. The Lower Middle Income group and the Middle Eastern and North African countries have on average 22 to 24 faults per 100 mainlines. Conversely, Upper Middle Income countries only have about eight faults, which is two-thirds less. Table 13.2 also presents the percentage of paved roads in these country groups, although this is not explicitly a measure of infrastructure condition.

An article by Reinikka and Svensson (2002) further illuminates how private firms react when the infrastructure is in poor condition. The authors studied data at the firm level in Uganda. They found that, due to disruptions in infrastructure services (which they proxy by an unreliable and inadequate electric power supply), the firms themselves attempt to fill this void by investing in power generators, waste disposal equipment, and so on. As a result of these extra expenditures, however, the firms reduce their investment in noninfrastructure capital needed for their productive activities, and this reduction in investment leads to a decrease in productive capacity.

The long-term consequence of neglect is the high cost of major reconstruction of infrastructure. According to the *World Development Report* (WDR) (World

Bank 1994b), in sub-Saharan Africa about $13 billion worth of roads built in the 1970s and 1980s had eroded due to deficient maintenance. In Latin America the report estimated that every $1 not spent on maintenance will eventually cost $3 to $4 in premature reconstruction. A well-maintained road should last 10 to 15 years before it needs to be resurfaced. The lack of maintenance can cause severe deterioration requiring resurfacing in as little as five years.

In the case of power lines, the expenditure of $1 million to reduce power line losses could save $12 million in generating capacity (World Bank 1994b). Often new construction takes place while the maintenance of existing infrastructure is neglected. Between 1979 and 1984, for example, 6,000 kilometers (km) of paved road were built in Brazil. During this same period, another 6,000 km of roads declined from "fair" to "poor" condition, and 2,000 km went from "good" to "poor" due to maintenance neglect (Harral 1988). In the United States, the National Surface Transportation Policy and Revenue Study Commission (2008) recommended spending between $225 and $340 billion annually to maintain the surface transportation network. Put in perspective, these figures are between one-third and one-half of the size of the American Recovery and Reinvestment Act (the fiscal stimulus) of 2009.

The condition of infrastructure is very much related to the achievement of the Millennium Development Goals set by the United Nations (Estache 2004). For example, infrastructure in good condition can play a key role in reducing poverty and improving access to education and to health care facilities. According to Estache and Fay (2007), maintenance needs have been estimated to be between 1.5 percent and 3.3 percent of gross domestic product (GDP) for developing countries, yet most developing countries spend much less than this.

Not only is actual maintenance of infrastructure neglected, but also the study of maintenance as a topic has been somewhat neglected, perhaps because data on infrastructure maintenance are hard to come by, while data on new construction are readily available. This chapter reviews several issues associated with infrastructure maintenance. It does not attempt to be encyclopedic on all maintenance-related issues, but simply tries to survey some of the salient issues. Four main questions are discussed. First, what theoretical framework explains the channels through which maintenance is effective, and what determines its optimal level? Second, what do the available data on maintenance tell us about its economic rate of return? Third, what has the empirical evidence found on the effects of maintenance on productivity and growth? Fourth, how have countries funded maintenance expenditures? Finally, an interesting case study from Peru is discussed, which provides a creative approach to the maintenance of rural roads.

Theoretical Framework

The study of the role of infrastructure in growth models goes back to at least Arrow and Kurz (1970). Barro (1990) wrote one of the seminal papers introducing productive public expenditures into a growth model in which public capital is an essential input in the production function. About the same time, Aschauer (1989) found large returns from investment in infrastructure. This survey will follow Rioja's (2003a) framework, which introduces infrastructure maintenance into a neoclassical growth model and applies it to a developing country scenario. By introducing maintenance and exploring its role, the model extends previous theoretical work on public capital by Barro (1990) and Glomm and Ravikumar (1994), among others.[1]

The economy has many firms that operate in a competitive market and produce a final good, y_t, according to the following production function:

$$y_t = f\left(K_{Gt}, k_t, l_t\right).$$

where k_t is private capital, l_t is labor, and K_{Gt} is the stock of public infrastructure, which is a government-provided input.[2] The production function f exhibits constant returns to scale to private inputs. Specifically, the calibration part of Rioja (2003a) uses a standard Cobb-Douglas form as $y_t = K_{Gt}^{\theta} k_t^{\alpha} l_t^{(1-\alpha)}$. The elasticity of output to public infrastructure is measured by the parameter θ, which has been estimated with various data, methods, and countries. (For a summary and meta-analysis, see Bom and Ligthart 2009.) The government taxes firm output at rate λ_t, so firms maximize net-of-tax profit, $\Pi_t = \left(1-\lambda_t\right) f\left(K_{Gt}, k_t, l_t\right) - w_t l_t - r_r k_t$. The government collects tax revenue equal to $\lambda_t y_t$, and in this simplified framework all of the revenue is spent on maintenance of infrastructure m_t, so that $\lambda_t y_t = m_t$. Maintenance expenditures, in turn, affect the depreciation rate of infrastructure, which is endogenous:

$$\delta_{Gt}\left(m_t, k_t\right).$$

Hence, this depreciation rate, δ_{Gt}, depends on how much is spent on maintaining the infrastructure (m_t) and on how much the infrastructure is used, which is proxied by k_t.[3] The depreciation rate is reduced with more maintenance expenditures, and it increases with more use.[4]

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1. Papers by McGrattan and Schmitz (1999), Schmalensee (1974), and Feldstein and Rothschild (1974) studied how private firms choose optimal maintenance of their capital stock.

2. Feehan (1998) states that a consensus in the public inputs literature has emerged to model productive public inputs (e.g., infrastructure) as factor augmenting.

3. This specification is similar to McGrattan and Schmitz's (1999). Alternatively, in Kalaitzidakis and Kalyvitis (2004), usage is proxied by output so their depreciation rate is a function of maintenance as a share of GDP, $\delta_{Gt}(m/y)$.

4. Another way that maintenance can affect this model is developed in Rioja (2003b), in which it also affects the effective stock of infrastructure.

Given that Rioja's (2003a) model is focused on developing countries, new infrastructure construction is financed entirely by foreign donations or aid in amount D_t. Aid and concessional loans are in the real world the most common ways of financing new public projects.[5] Public infrastructure then accumulates as follows:

$$K_{Gt+1} = D_t + \left(1 - \delta_{Gt}\left(m_t, k_t\right)\right)K_{Gt}.$$

Donations from foreign countries finance new public infrastructure investments, so they augment the next period's infrastructure stock. Reducing maintenance expenditures, however, increases the depreciation rate and reduces the next period's stock of infrastructure.

Households in the model maximize utility subject to budget constraints. For briefness of exposition, the household problem is not specified again (see Rioja 2003a). The government seeks to determine its optimal policy, that is, to choose the tax rate that maximizes social welfare. Hence, the government must choose the optimal level of maintenance to maximize well-being. The details are specified in Rioja (2003a). The optimal tax rate, which is also the optimal share of GDP that should be devoted to maintenance, is found to depend on the following:

$$\lambda_t^* = g\left(\theta, other\ parameters, k_t, K_{Gt}, \frac{D_t}{K_{Gt}}\right).$$

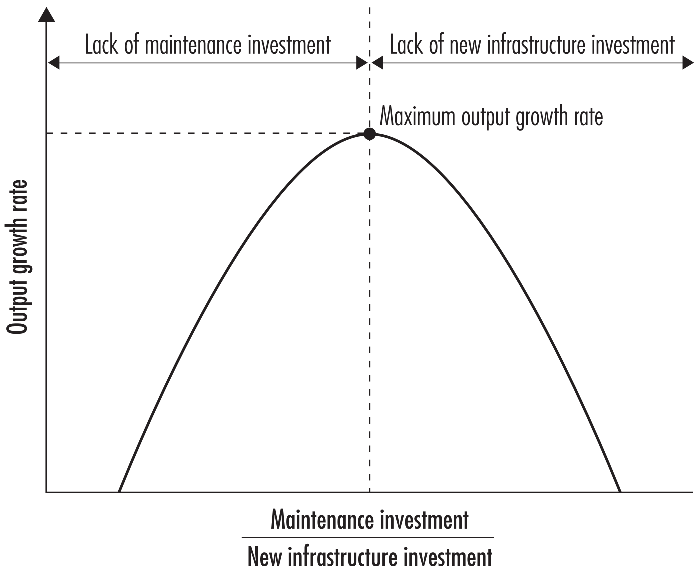
Two points about this optimal solution are worth emphasizing. First, the higher the ratio of donations to existing infrastructure (D_t/K_{Gt}), the lower the optimal rate of maintenance will be. The intuition is that if international donors raise the amount they spend on building new infrastructure, the home government finds it optimal to reduce its maintenance expenditures for existing infrastructure. The government in the model cares about the total stock of infrastructure that raises output and, hence, consumption and the welfare of the population. As donors fund more and highly visible projects, they add to the infrastructure stock, and it is optimal to reduce maintenance expenditures, which have to be raised by painful taxation. This point is certainly born out in the Brazilian example discussed earlier (Harral 1988), where 6,000 km of new paved roads were built, while at the same time another 6,000 km declined from "fair" to "poor" condition and 2,000 km went from "good" to "poor" condition. Second, the solution for optimal maintenance share implies that the more productive infrastructure is (i.e., the higher θ), the more the government should spend on maintaining it.

5. Even when some of the funds to finance new infrastructure are borrowed from industrial countries' governments or international organizations, some of this debt may effectively be forgiven later or never fully repaid. Of course, the model can be generalized in several ways with countries borrowing or using tax revenue to finance infrastructure.

Subsequent work has extended this framework in several directions. Kalaitzidakis and Kalyvitis (2004) present an endogenous growth model in which the government has to finance both maintenance and new infrastructure. They also study how maintenance may affect the impact of infrastructure on growth. While Barro (1990) had derived that the optimal share of GDP to be devoted to infrastructure should be equal to the elasticity of infrastructure in production, Kalaitzidakis and Kalyvitis (2004) find that, once the model accounts for maintenance, the optimal share of GDP devoted to overall public investment (infrastructure and maintenance) should be larger than this elasticity. In addition, they derive a nonlinear relationship between the ratio of maintenance to new investment and economic growth. Figure 13.1 illustrates this nonlinear relationship. Growth increases when the maintenance to new investment ratio increases up to an optimum, but growth decreases thereafter. Another recent contribution by Agénor (2009) further extends the framework of analysis of this issue by noting that maintenance could also affect the durability of private capital. The longevity of a firm's machines, like the Zambian company's trucks described in the introduction, can be affected when infrastructure is in bad condition.

In summary, theoretical frameworks have modeled maintenance as affecting primarily the depreciation rate of public infrastructure. Neglecting maintenance

Figure 13.1
Relationship Between Growth and the Ratio of Maintenance to New Investment



Source: Kalaitzidakis and Kalyvitis (2005).

increases the depreciation rate and, hence, reduces the overall flow of services provided by the infrastructure network.

Maintenance Data

ECONOMIC RATE OF RETURN

According to the WDR (World Bank 1994b), returns on maintenance on road projects were almost twice as much as those on projects that involved mainly new construction. This is a benchmark comparison that should be kept in mind when reviewing the returns on various maintenance projects. Most of the estimates of the rate of return for maintenance come from infrastructure projects that involved the World Bank and other multilateral institutions. In particular, the economic rate of return (ERR) is most commonly reported by these studies, a few of which are listed in table 13.3. The Congressional Budget Office (1988) also provided some estimates of the ERR for highway maintenance in the United States. The CBO calculates a range of 25 to 38 percent. Several different strategies were evaluated. One strategy was to sustain existing levels of maintenance expenditures. This strategy had the largest ERR. On the other end, a strategy that fixed all deficiencies involved the highest cost, which would exceed the reductions in transportation costs. An intermediate strategy of raising expenditures to achieve minimum standards yielded an ERR of about 29 percent.

The remainder of ERR estimates in table 13.3 are from World Bank projects. For example, in the 1990s the World Bank helped finance the maintenance of roads in Bolivia (World Bank 2001). Maintenance was performed on 781 km of gravel roads and 765 km of paved roads in various areas of the country. The costs per km of maintenance were $43,000 for gravel roads and $97,660 for paved roads. The average ERR for the maintenance was 34 percent for gravel and 36 percent for paved.

Another maintenance project financed by the World Bank in Jamaica consisted of (1) asphaltic concrete applied to existing pavement on about 160 miles of roads; (2) asphaltic sealing and resealing with double surface treatment of some 360 roads; and (3) drainage improvement and surface patching for (1) and (2). The periodic maintenance was justified on the basis of lower vehicle operating costs and time savings for road users resulting from improved surfaces and higher average speeds. The final project report (World Bank 1992) indicates that the ERR for the completed portion of the project was 42 percent. Table 13.3 lists several other similar road maintenance projects and their ERRs, which vary according to country but are on average fairly high. With a rough average of 30 percent, the maintenance of roads has a very high return.

Of course, one question that arises is this: if maintenance has such a high ERR, why do countries not prioritize these expenditures? Typically, financing may be the issue. Governments have an easier time accessing lending (typically at concessional low rates) or grants from international institutions for the construction of new infrastructure than for maintenance. Unlike some of the projects

Table 13.3
Economic Rate of Return for Maintenance Projects

Country	Source	Project Description	Economic Rate of Return (%)
United States	Congressional Budget Office (1988)	Study calculated the return of various federal highway maintenance projects.	25–38
Bolivia	World Bank (2001)	Maintenance plan for 1992–1995 that included periodic maintenance of 781 km of paved roads and 765 km of gravel roads.	34.4–35.9
Gambia	World Bank (1994a)	Road maintenance activities mainly comprised regraveling, resealing, and routine maintenance of national and local road networks and low-cost paving of gravel road sections.	23
Jamaica	World Bank (1992)	Project comprised periodic road maintenance that included asphaltic concrete applied to existing pavement on 160 miles of road and asphaltic sealing and resealing with double surface treatment of 360 roads. Only 70% of the project was completed.	42
Burkina Faso	World Bank (1993)	Four-year program (1982–1985) of road maintenance that consisted of graveling roads and routine maintenance.	50 (graveling) 100 (routine maintenance)
Tunisia	World Bank (1990)	The Program for Highway Maintenance included expanding road maintenance activities and improving the efficiency of the maintenance organization.	70
Nepal	World Bank (1986)	The Road Maintenance Project consisted of purchasing maintenance equipment, training mechanics, and providing technical assistance for maintenance programming and operations.	32.9

listed in table 13.3, which had financing from the World Bank, in most cases once the infrastructure is built, the government must raise the maintenance cost from its general revenue sources. Many of the resulting competing spending priorities cannot be delayed as they carry political costs. Maintenance can be delayed, however, so in times of budget tightening, infrastructure and maintenance may bear most of the burden, as described by Easterly, Irwin, and Servén (2008). More discussion on the funding of maintenance, in particular for roads, is presented in the following section.

EMPIRICAL EVIDENCE

Data on maintenance have not been collected in many countries or are not available due to issues identified by McGrattan and Schmitz (1999). There is no market transaction for much maintenance expenditure, so collecting data requires the surveying of public organizations. Furthermore, data may be recorded in different accounts in different countries, if they are recorded at all. One of the few known systematic collections of maintenance data is the Canadian Survey of Capital and Repair Expenditures. This survey has data on maintenance spending for government organizations and private firms. Kalaitzidakis and Kalyvitis (2005) provided the first study of the role of maintenance using these data. From 1956 to 1993, Canada's total public infrastructure-related spending (new construction plus maintenance) was 7.4 percent of its GDP. Maintenance spending accounted for 1.5 percent of GDP, so it was about 21 percent of total public spending on infrastructure. Kalaitzidakis and Kalyvitis empirically tested the effect of maintenance on Canadian growth. Their findings are somewhat counter to expectations. Their results show that Canada would actually have benefited from a *reduction* in public infrastructure-related expenditures. These findings imply that at 7.4 percent of GDP, Canada's public spending was too high. The authors calculate the optimal share at 6.7 to 7 percent of GDP, which would have yielded higher growth in Canada. Furthermore, the findings imply that most of the proposed reduction should come from a decrease in maintenance expenditures. Maintenance was 21 percent of total infrastructure-related public spending during the period studied. The authors find that this share should be reduced to about 14 percent. Kalaitzidakis and Kalyvitis's findings can be also interpreted in the context of figure 13.1. Canada's ratio of maintenance to new investment was to the right of the optimal share. Hence, reducing this share would yield higher growth.

While the results for Canada are interesting, they are not necessarily representative. Many developing countries likely underinvest in new infrastructure and especially in maintenance. Furthermore, a study by Brox (2008) shows that infrastructure-related spending in Canada has recently fallen to half of its level in the 1960s and that maintenance has been neglected, leading to the crumbling of some infrastructure.[6] Brox estimates that Canada would need about $72 billion for new projects and $123 billion for maintenance of existing infrastructure.

Kalaitzidakis and Kalyvitis (2005) attempt to estimate the effects of infrastructure and of operations and maintenance (O&M) expenditures on total factor productivity (TFP) by accounting for potential spillover effects that infrastructure in one state may have on neighboring states. The spillover variables are weighted averages of infrastructure and O&M spending in neighboring

6. A notable example cited by Brox (2008) is the collapse of an overpass on the Boulevard de la Concorde in Laval in 2006.

states.[7] Capturing the spillover effects involves estimating nonlinearities, which the authors do by using semiparametric estimation techniques. They find that O&M expenditures in one state have positive effects on a neighboring state's TFP and that these effects are larger than the impact of within-state O&M expenditures. On average, a 1 percent increase in O&M spending by one state raises output in a neighboring state by about 0.4 percent. In addition, they find that the spillover effect of O&M is about eight times higher than that of capital expenditures. While these estimates are mostly confirmed in their sensitivity analysis, it is unclear why O&M has a much larger spillover effect than that of construction.

In a related study, Kalyvitis and Vella (2011) look at the effects of public expenditures by different levels of government in the United States. The data, published by the Congressional Budget Office (2007), include infrastructure-related spending at the federal, state, and local levels. The three levels of government share responsibilities in infrastructure provision and maintenance. Table 13.4 presents a summary of the data. In the United States, about 2.6 percent of GDP is devoted to infrastructure expenditures (with almost half of that going to transport infrastructure). Of the total devoted to infrastructure, O&M accounts for about 49 percent. As the table shows, state and local governments spend a larger share than does the federal government.

One question the authors consider concerns where the marginal dollar of spending is most productive: maintenance or new investment? In addition, they

Table 13.4
Capital and Operations and Maintenance Expenditures on Public Infrastructure in the United States, 1956–2004

Expenditure	Federal	State and Local	Total
Capital and O&M (% GDP)	0.7	1.9	2.6
O&M (% of total expenditure)	25.0	58.4	48.8
Capital and O&M, transportation (% GDP)	0.5	1.3	1.8
O&M, transportation (% of total transportation expenditure)	23.8	58.1	47.9
Capital and O&M, water (% GDP)	0.2	0.6	0.8
O&M, water (% of total water expenditure)	30.0	59.0	50.9

O&M = operations and maintenance; GDP = gross domestic product
Source: Adapted from Kalyvitis and Vella (2011) using Congressional Budget Office (2007) data. Averages are presented for all variables.

7. These weights are designed to capture the degree of interdependence of each neighboring state. Hence, states are weighted by the flow of goods across states and alternatively by the relative size of their economic activity.

attempt to determine which level of government should spend the marginal dollar. According to public finance theory, some public goods may be more efficiently provided at the state or local level. The empirical results show that the productivity growth rate would not be very much affected by changing U.S. aggregate infrastructure spending or by shifting the allocation of funds between new investment and O&M. These results would imply, then, that U.S. expenditures have been close to optimal between 1956 and 2006. The disaggregated results by level of government, however, show that increasing infrastructure spending by states and localities, and especially increasing O&M, would have positive effects. Given that the national-level allocations are close to optimal, this means that any increases in the public expenditures at the federal level would then have a detrimental impact on productivity growth. A potential explanation of these findings is offered by Holtz-Eakin (1994), who proposes that because the federal government provided incentives to states and localities by offering matching grants for new construction of infrastructure, states and localities did not spend enough on maintenance.

The Funding of Maintenance Expenditures for Roads

As described in the previous section, the rates of return for maintenance are typically very high, but adequately financing maintenance has presented challenges over the years. This section focuses on the financing of roads, which are one of the largest components of infrastructure. Various financing schemes have been tried over the years. One early approach to financing road maintenance, which the World Bank (2007a) calls "the budget approach," involved drawing funds from the country's general budget. The view was that since infrastructure was publicly owned, then the funding to maintain it should come from the government budget. One problem with this approach was that the fungibility of revenue sources implied that the priority placed on maintenance by the government du jour could vary from year to year. Often, funding was directed to many more pressing political priorities. The drawbacks of the budget approach were identified back in the 1970s and were described by the World Bank (1979).

As a potential solution, the World Bank and the International Monetary Fund supported the creation of separate agencies, known as "road funds," which many developing countries subsequently established. According to Gwilliam and Shalizi (1999), "first-generation road funds" were established in the 1960s and 1970s in Africa, Asia, and Latin America. These funds were "extrabudgetary arrangements through which an earmarked stream of tax revenues was put at the disposal of a road department or agency" (183). Typically, fuel taxes were the source of these tax revenues. However, first-generation road funds had several weaknesses and did not work well. One weakness, according to Heggie (2000), was the lack of oversight over these agencies and the lack of transparency in their activities. Cabinet ministers could borrow from the fund to fill an immediate need like paying the salaries of government workers. Government corruption was found to be associated with lower operations and maintenance expenditures (Tanzi and Davoodi 1998; see also Tanzi 2005). Often, these agencies were not technically audited to check if the funds had been properly disbursed on approved projects. Another weakness was that some revenues were raised from activities unrelated to road use. In addition, the earmarking of revenues took away revenues from other sectors, creating inefficiencies.

Having identified these and other weaknesses in the first generation of road funds, a second generation began to be established in the 1990s. According to Gwilliam and Shalizi (1999), these funds no longer use earmarked revenues; rather, "they are funded by levies or surcharges designated as 'user charges' and identified separately from general taxation" (161). Fuel taxes are still the main source of revenue for these funds. Typically, road funds are managed by a board composed of several members from the private and public sectors. This managing board identifies the projects needing maintenance and allocates funding. Then the board contracts out the necessary work in a transparent way. For example, Zambia's road fund was established in 1994. The private sector is well represented on the board (7 out of 11 members), and the chairperson is also a private sector actor (Gwilliam and Kumar 2002). The makeup of the board varies in different countries, and in some places the minister of works becomes the chairperson.

While many developing countries have established road funds, most western European countries use the budget approach, in which maintenance is a line item in the general budget (World Bank 2007a). This approach appears to work well in countries with strong institutional frameworks. However, a few industrialized countries, like the United States, Japan, and New Zealand, have had road funds for a long period. For example, the U.S. Highway Trust Fund, established in the 1950s, originally funded just highway construction and maintenance, but since 1983 it has also funded mass transit projects.

How well have second-generation funds performed? The Independent Evaluation Group (IEG), an independent group within the World Bank, examined several reports produced by World Bank staff and summarized their findings (World Bank 2007a). The maintenance-related outcomes evaluated include the level of funding, the quality of the road work, and the efficiency of operations.[8] According to the IEG, there has generally been an increase in the percentage of roads in good condition from year to year compared to before the establishment of a road fund. For example, in Zambia, the annual change in the percentage of roads in good condition was 4 percent, which is roughly the average for the countries considered. In terms of the level of funding, most countries for which data were available had more funds available for maintenance after they established a second-generation road fund. Also, the share of maintenance that was contracted out

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8. Some of the studies and countries surveyed include Gwilliam and Kumar (2002)—seven African countries; Zietlow (2004)—six Latin American countries; and Benmaamar (2006)—27 African countries.

increased to as high as 90 percent in Zambia and Ghana. This resulted in an improvement in operational efficiency as the cost of maintenance per kilometer decreased by about 15 percent.[9]

Second-generation funds have not solved the maintenance issue, however. According to a survey administered by the IEG to World Bank transportation staff (World Bank 2007a), only about 40 to 50 percent of estimated maintenance needs were being covered. The remaining available funds were allocated to other uses, only some of which were related to transportation. Another issue identified in the IEG survey was that spending was focused on maintaining main roads at the expense of secondary roads. In summary, while second-generation funds have improved maintenance in many countries, much work remains to be done, as the state of roads, and infrastructure in general, is deficient.

Case Study: Peruvian Rural Roads Project

One of the most interesting and successful case studies of infrastructure maintenance is the Peruvian Rural Roads Project described in Fay and Morrison (2007) and the World Bank (2007b). In Peru about half of the population is considered "extremely poor" (living on less than $1 per day), and the largest share of the poor population lives in rural areas. The lack of roads and the poor condition of roads have played a role in the population's endemic poverty, as people living in these rural communities cannot access markets, jobs, and services. In 1995 the Peruvian government embarked on an innovative approach to road management. The World Bank and the Inter-American Development Bank helped with the financing of this project. The approach involved letting the rural communities set priorities for the roads to be rehabilitated. Community meetings were organized and plans drafted at numerous gatherings. The management of rural roads was decentralized over time, giving provincial municipalities authority, budget responsibility, and technical expertise.

About 38 provincial road institutes were created with many local authorities as members. These road institutes then contracted the rehabilitation and maintenance of the roads to newly formed micro-enterprises comprised of some of the poorest members of the communities. In all, more than 500 micro-enterprises were formed, employing 5,700 workers (30 percent of whom were female). The timeliness and efficiency of maintenance improved significantly, while at the same time increasing entrepreneurial capacity and reducing poverty. About 13,000 km of roads were receiving adequate and timely maintenance by 2005. As a first step,

9. In addition, some countries have had success using "performance-based contracts." Contractors agree to maintain roads so that they meet certain specified physical conditions. Hence, contractors have incentives to maintain and repair roads in an adequate and timely fashion to receive payments. See Zietlow (2005) for a summary of the experience of industrial and developing countries using performance contracts.

these mostly gravel roads were rehabilitated. Then, the maintenance involved "simple works regularly performed throughout the year to maintain the drainage systems (ditches, culverts, vegetation) and the running surface (filling potholes and ruts, maintaining the surface camber), supplemented from time to time with spot interventions to restore passage" (World Bank 2007b, 7). Given the efficiencies gained with this program, according to Greenstein (2012), the costs of routine road maintenance decreased from $1,200 per km to $750 per km.

One evaluation of this project by Escobal and Ponce (2003) focuses on the question of the project's effect on welfare: how did better-maintained roads affect household per capita income and consumption? Escobal and Ponce used a "propensity score matching" methodology that allowed them to compare the income of a household located near a rehabilitated road with an estimate of the income that the household would have earned had the rehabilitation not occurred. They found that the income of households near roads that were maintained was indeed higher *ex post*. In particular, these households were able to increase nonfarm income as transportation to towns became easier.

Another effect of the Peruvian Rural Roads Project has been its effect on democracy and civic participation. Because the program gave the communities decision-making power over projects, it improved inclusion and participation. According to Remy Simatovic (2008), the rehabilitation and periodic maintenance of roads decreased the rural population's costs of getting to towns or voting stations. This increased the rural population's participation in the political process, which reached the levels of participation common in urban areas. Furthermore, many individuals who became involved with the project as community board members or as part of the micro-enterprises were elected to municipal management positions in later years (Remy Simatovic 2008).

In summary, the Peruvian Rural Roads case may constitute a benchmark for many developing countries' rural road networks, as it succeeded in rehabilitating and maintaining roads by employing many poor local workers, allowing their communities to participate in decisions affecting them, and expanding their economic possibilities.

Conclusions

This chapter has reviewed research on several aspects of infrastructure maintenance. First, it reviewed how maintenance can play a role within standard growth models by reducing the depreciation of public infrastructure. These models show that an optimal level of maintenance expenditures can increase a country's growth rate. Second, a survey of the economic rates of return in a variety of countries and projects found that estimated rates of return for maintenance are uniformly high. Third, empirical studies have found that maintenance can have a significant and positive effect on productivity and economic growth.

Given these positive findings, it remains somewhat of a puzzle why maintenance has been neglected in industrial countries as well as in developing countries. One possible reason has been inadequate financing. Different countries have experimented with various ways to finance maintenance. With regard to roads in particular, the creation of second-generation road funds has met some success by establishing dedicated funding sources (e.g., fuel taxes) and letting independent boards decide on the proper allocation of expenditures, hence improving efficiency and transparency. While these second-generation road funds have been an improvement, in many countries the amount and allocation of funds is still below optimal. Often, considerations of political economy have played a role in the insufficient funding for maintenance. At times, governments have diverted some of the funds designated for maintenance or have favored new infrastructure investments over the maintenance of existing infrastructure. That is, politicians may perceive that they receive more support when they complete new infrastructure investments than when they repair an ailing network. It has been easier for the governments of developing countries to access donor aid and concessional lending for new infrastructure construction, though more recently multilateral institutions have factored future maintenance expenditures into the amount of their contributions.

The Peruvian Rural Roads Project is a notable success story. The project was designed to involve communities and hire local workers, improving the economic condition of the affected population. Various evaluations of its outcomes have found that the timeliness and efficiency of maintenance increased as a result of the project. In addition, the project led to job creation, higher incomes, and increased participation in the political process by the affected communities. Adapting and replicating this approach may be a way to improve maintenance and economic outcomes in other countries.

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