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Assessing Economic Efficiency of Long-Term Road Asset Management Strategies

WORLD BANK GROUP
QUALITY INFRASTRUCTURE INVESTMENT PARTNERSHIP
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THE GOVERNMENT OF JAPAN

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Acknowledgments

This report was elaborated by a group of World Bank staff led by Satoshi Ogita (Senior Transport Specialist), Gylfi Palsson (Lead Transport Specialist), and Leslie Nii Odartey Mills (Transport Specialist), with support from Andreas Schliessler (former World Bank staff), Evans Ochola (Consultant for the World Bank), Damon C. Luciano (Consultant for the World Bank), and Giang Le (Program Assistant).

The report also draws on work carried out by the consulting firm Opus International Consultants Ltd (New Zealand) under a contract with the World Bank.

The authors would like to thank other contributors who provided valuable inputs to the report, including Atsushi Iimi (Senior Economist), Veronica Raffo (Senior Infrastructure Specialist), Pablo Santos (Consultant for the World Bank), Esteban Travaglianti (Consultant for the World Bank), Sombath Southivong (Senior Infrastructure Specialist), Kulwinder Rao (Lead Transport Specialist), John Richardson (Senior Transport Specialist), Rodrigo Archondo-Callao (former World Bank staff), Ben Gericke (former World Bank staff), Christpher Bennett (former World Bank staff), and Aris Pantelias (European Investment Bank).

The report also benefitted from contributions provided by *Dirección Nacional de Vialidad* (Argentina), *Dirección Nacional de Vialidad*, La Rioja District and Catamarca District (Argentina), the Ministry of Public Works and Transport (Lao People's Democratic Republic,) the Department of Roads (Lao PDR), the Road Sector Governance and Maintenance Project (Lao PDR), the Infrastructure Implementation Unit of the Ministry of Public Works (Liberia), the Western Bay of Plenty District Council and Whakatāne District Council (New Zealand), the Roads Department of the Ministry of Transport (Botswana), the Botswana Integrated Transport Programme, the Florida Department of Transportation (Florida, United States), Swedish Transport Administration, Norwegian Public Roads Administration, Danish Road Authorities, and Japan International Cooperation Agency. Staff from these organizations shared their knowledge with the World Bank team.

The study team would also like to thank the management of the World Bank, namely Benedictus Eijbergen (Practice Manager) and Almud Weitz (Practice Manager), for their guidance and support.

Finally, the team would like to acknowledge the funding for this study which was provided by the Quality Infrastructure Investment (QII) Partnership and thank the Government of Japan which established the QII jointly with the World Bank. This report was designed by Victoria Adams-Kotsch.

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Abbreviations & Acronyms

AADT	Annual Average Daily Traffic
AASHTO	American Association of State and Territorial Highway Officials
AC	Asphalt Concrete
ADB	Asian Development Bank
AM	Asset Maintenance
AMPER	Asset Maintenance Contractor Performance Evaluation Report
BCR	Benefit-Cost Ratio
BITP	Botswana Integrated Transport Project
BPR	Bureau of Public Roads
BoQ	Bill of Quantities
CBM	Community-Based Highway Maintenance Contract
CI	Condition Index
CREMA	Performance-Based Road Rehabilitation and Maintenance Contracts (*Contratos de Recuperación y Mantenimiento*)
DBST	Double Bituminous Surface Treatment
DOR	Department of Roads
DOT	Department of Transportation
DST	Double Surface Treatment
EIRR	Economic Internal Rate of Return
ESIA	Environmental and Social Impact Assessment
FDOT	Florida Department of Transportation
FIDIC	International Federation of Consulting Engineers (*Fédération Internationale Des Ingénieurs-Conseils*)
FHWA	Federal Highway Administration (United States)
FTE	Full-Time Equivalent
FWD	Falling Weight Deflectometer
FWP	Forward Works Plan
GDP	Gross Domestic Product
IWG	G20 Infrastructure Working Group
HDM	Highway Development and Management Model
IBRD	International Bank for Reconstruction and Development
ICR	Implementation Completion and Results Report
IDA	International Development Association
IFI	International Financial Institution
IRI	International Roughness Index
IRR	Internal Rate of Return

JVCA	Joint Venture Capital Association
KPI	Key Performance Indicator
KPM	Key Performance Measure
KRA	Key Results Area
LCCA	Lifecycle Costs Analysis
MPW	Ministry of Public Works
MPWT	Ministry of Public Works and Transportation
MRP	Maintenance Rating Program
MTO	Ministry of Transportation in Ontario
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value
NZTA	New Zealand Transport Agency
O&M	Operation and Maintenance
OPBRC	Output- and Performance-Based Road Contract
OPM	Operational Performance Measure
PBC	Performance-Based Contracting/Contract
PBM	Performance-Based Highway Maintenance Contract
PBMC	Performance-Based Maintenance Contract
PPIAF	Public-Private Infrastructure Advisory Facility
PPP	Public-Private Partnership
PRIF	Pacific Region Infrastructure Facility
PSMC	Performance-Specified Maintenance Contract
QII	Quality Infrastructure Investment
RAC	Road Agency Cost(s)
RAMS	Road Asset Management System
RAP	Resettlement Action Plan
RUC	Road User Cost(s)
SANRAL	South African National Road Agency (SOC) Limited
SBD	Standard Bidding Document
SBST	Single Bituminous Surface Treatment
SCF	Standard Conversion Factor
SPD	Standard Procurement Document
STE	Smooth Travel Exposure
VKT	Vehicle Kilometers Travelled
VOC	Vehicle Operating Costs
WBOP DC	Western Bay of Plenty District Council

Executive Summary

In 1988, the Government of British Columbia, Canada, pioneered a new 'proactive approach' to road asset management, known as performance-based contracting (PBC[1]), by designing a road works contract that transferred responsibility for long-term road conditions to a contractor. PBC was a clear departure from the incentive scheme of traditional road works contracts which pay contractors for the amount of work executed and therefore create an incentive for contractors to increase their work volume to maximize profits. The fixed lump-sum payment terms introduced in PBC reversed this incentive; to maximize profit, contractors must minimize their work by carrying out intelligently designed preventive interventions which nevertheless ensure full compliance with the service-level requirements. The preventive maintenance necessary to consistently deliver good road conditions results in lower operating costs for road users and prevents premature deterioration of roads that is costly to fix. PBCs have since been carried out in all regions of the world as a complement to traditional civil works contracting for roads.

In the early 1990s, the World Bank found that PBCs could be used in developing countries to address the issue of sustainability of road infrastructure investments. The implications of introducing PBCs in developing countries are mostly quite different than in developed countries. The typical situation in developing countries is characterized by severely inadequate expenditures for road maintenance. Roads are often let to deteriorate to poor condition, leading to bad service levels for road users and requiring costly road reconstruction. In such cases, 'saving money' on road maintenance is rarely possible because spending on road maintenance is already far too low. It was hoped that the long-term commitment to fund road maintenance under PBCs and the successful demonstration of the value of quality road maintenance would lead to policy changes supporting more sustainable road maintenance funding levels in develop-

1 Throughout this report 'PBC' refers to performance-based contract(s) and performance-based contracting.

ing countries. Combining the rehabilitation of deteriorated roads with an incentive to efficiently carry out preventive maintenance needed to sustain them in good condition over time was also a way to guard against premature pavement deterioration, which could dramatically undercut the intended development outcomes of road projects.

More than 30 years of implementation of PBCs has resulted in a broad base of global experiences with PBCs and demonstrated their strengths across diverse environmental, economic, and engineering circumstances. Proponents of PBCs claim that they have the potential to significantly reduce lifecycle costs compared to traditional contracting approaches. The most frequently cited research on the efficiency of PBC versus traditional contracting modalities was done by Pekka Pakkala (2002, updated in 2007). The comparisons between PBCs and traditional contracting approaches in those studies need to be treated with caution, however, as both studies report potential savings rather than confirmed and proven savings based upon comparative analysis of the actual spending on PBCs and traditional civil works contracts.

The research effort described in this report sought to carry out an evidence-based analysis of the cost-effectiveness of PBCs by undertaking a comprehensive ex post performance assessment of road projects and road assets from the viewpoint of evaluating different long-term road asset management strategies. In doing so, this research activity also attempted to answer the following question on adoption of PBCs as much as possible: Are PBCs actually leading to more efficient road asset management than traditional civil works/maintenance contracts?

An international literature review undertaken for this study found a dearth of case evidence-based analysis of the following two key topics: (a) lifecycle economic benefits and costs of road assets in a range of investment and operation and maintenance (O&M) scenarios and (b) comparison of the economic efficiency of PBC and traditional road works contracting.

While there is a wide range of published research on road lifecycle costs, very little of this draws on case evidence to compare lifecycle costs of road investment and O&M scenarios. Most practitioner research drawing on case evidence focused on road agency cost (RAC) savings for preventive maintenance in developed countries, while academic research focused on the development of methodologies for comparisons which researchers themselves could not undertake as they lacked access to the necessary data. No research was found that might give an indication of potential differences in the performance of investment and O&M strategies commonly implemented under PBCs and traditional road works contracts in developing countries.

Existing research comparing PBC and traditional contracting approaches has likewise not produced robust or globally representative findings. The existing research has instead tended to focus on potential or perceived savings to road agencies from adopting a PBC model. The few studies that demonstrated actual savings do not provide globally robust conclusions about the relative efficiency of these two contracting models. Some studies found that cost savings were achieved, but certain other intended outcomes were not.

Drawing on the literature review findings, this study undertook extensive data collection for case studies with the objective of comparing the efficiency of road works undertaken through PBC and similar road works undertaken contemporaneously in similar local environments but through traditional contracting approaches.

Based on a stocktaking of global experience with PBCs and other findings from the literature review and interviews with practitioners, the study identified a globally representative group of six case study countries with experience implementing road works through PBCs and traditional road works contracts: Argentina, Botswana, Lao People's Democratic Republic (Lao PDR), Liberia, New Zealand, and the United States (Florida). These six case studies were selected as a representative sample of diverse environments in which PBCs have been implemented globally, because they included different types of PBCs and government agency counterparts reported willingness to share the data necessary to compare costs of comparable road works undertaken through both contracting approaches.

To enable more direct comparisons, the road works compared in each case study were as similar as possible in terms of the scope of works undertaken, socioeconomic environment, climate, topography, geology, traffic, geometry, and other factors that could distort outcomes. Data were sought concerning environmental and social externalities, RAC, road user costs (RUC), and factors affecting contract procurement and administration as well as other relevant experiences.

Conclusions

Comparison of the economic efficiency of PBC and traditional contracting approaches based on hard data collected through the case studies faced major hurdles. It was not possible to undertake the direct comparison of lifecycle and economic costs between PBCs and traditional contracts with an adequate level of rigor due to extensive gaps in data availability. In particular, the historical data for contract expenditures, road conditions, and traffic for the traditional contracts were found to be insufficient in all countries covered by the study, including in the developed countries. Significant gaps also existed in the data sets pertaining to PBCs.

Another challenge was related to sample sizes. To obtain a robust result, case study countries were selected to provide a globally representative sample. Even if critical missing information could be obtained, the size of networks maintained under PBC in many countries is too small to reach statistically relevant conclusions. This was found to be true after extensive consultation with road agencies from 22 countries that have the most extensive experiences implementing PBC. To fully achieve the objectives this study set out to deliver, a deliberate and significant effort will be necessary to systematically collect and record networkwide data over a sufficiently long time, such as 15 or 20 years, in a breadth and depth that is currently not done by road agencies.

It may be time to take stock of global practices for road agency data collection and management and identify possible areas for improvement and even coordination and information sharing between road agencies. Such an exercise may help researchers understand how to expand the collection of more valuable data more rapidly and cheaply for a range of future studies and may enable development of econometric approaches that could overcome some of the challenges faced under this study. It may also help international financial institutions (IFIs) and industry associations better refine their support to road agencies, potentially including some efforts toward data standardization that could help road agencies better utilize data and enable future research.

Findings from this research point to the benefits, risks, and challenges of adopting PBCs. PBCs can produce benefits in terms of budget forecasting, consistency of outcomes, faster completion of emergency repairs, risk transfer to the private sector, lower long-term procurement costs, and ease of contract administration. They are more likely to encourage innovation and development of contractor capacity. They also encourage governments to place more emphasis on defining levels of service as part of setting agency goals. These findings on benefits mostly confirm the conclusions of other published research on PBC.

Use of PBCs requires governments to carefully define service levels to avoid underinvesting or overinvesting in roads. Long-term PBCs also require a significant funding commitment and therefore place a greater onus on governments to link and prioritize investments to desired outcomes and ensure that funding is available to meet public policy goals. PBCs likewise encourage contractors to manage risks and costs that are under their control and optimize investment around the level of service targets. This division of responsibility allows contractors and governments to prioritize their respective energy and efforts toward mandates that each is uniquely best able to deliver upon.

Another major finding is that PBCs are not without drawbacks and challenges. One of these is that the PBC model is more complex for many public entities and some private sector firms to implement. While the theory behind PBC is sound, preparation of PBCs deviates from the practical experience of many professional engineers because it requires a sound understanding of both the underlying engineering and economic theory. Mistakes in preparation of PBCs are therefore relatively easy to make. Errors and oversights in certain aspects of PBCs have more substantial consequences than those professionals preparing the PBCs might have anticipated.

The review of the case studies and other PBCs also pointed to the need for extensive training, not only for practitioners in road agencies intending to undertake PBCs but also for staff of the IFIs frequently supporting these endeavors. More training is needed to help ensure that PBCs are properly prepared and procured and that they actually create the intended performance incentives and accountability, allocate risks clearly, and set appropriate levels of service. Contractor training at the bidding stage is also important to ensure that bidders fully understand and respond to the contract incentives and price their bids appropriately.

PBCs also appear to require more flexibility from governments and IFIs, whose practices may be better suited to traditional contracts. PBCs impose long-term budgetary obligations on governments, which, as a result, have less capacity to shift budgetary resources elsewhere in cases of unforeseen circumstances. These issues could be partially addressed by reducing the required levels of service under PBCs to fit the expected costs within the available budget and introducing special-purpose funds for road maintenance.

Finally, the findings of the study demonstrate that PBCs help contractors and governments focus on long-term efficiency of road investments and promote two of the principles of Quality Infrastructure Investment (QII): (a) Principle 2 on improving economic efficiency in view of lifecycle cost and (b) Principle 6 on strengthening infrastructure governance.

1 Introduction

1.1 Background of Study

For most institutions tasked with managing road assets across the globe, the traditional practice has been a ‘reactive approach’ of identifying existing defects within the road network and fixing as many as possible, subject to the available funds, with little regard to overall lifecycle costs (Porter et al. 2014).

In 1988, the Government of British Columbia, Canada, pioneered a new, more ‘proactive approach’ to road asset management by designing a road works contract that transferred responsibility for long-term road conditions to a contractor and, in doing so, created a commercial incentive for the contractor to carefully plan and implement preventive maintenance to ensure their own profitability. This was envisaged to produce better roads for road users—who are the ultimate ‘clients’ of the road agency—and, to a large extent, preempt emergence of pavement defects that are expensive to fix.

The practical means for putting in place the new ‘proactive approach’ was to (a) define road maintenance as a service instead of works, (b) establish ‘service level’ criteria that describe the desired outcome for road users, (c) use private sector contractors to carry out the road maintenance services, and (d) link the payment for the service provided to compliance by contractors with the specified service levels. If the performance indicators are not fully met, the monthly or quarterly payments are reduced; persistent failure to meet performance targets can result in contract termination.

The approach pioneered in British Colombia was a clear departure from the incentive scheme of traditional road works contracts. Traditional works contracts compensate contractors for the amount of work executed and therefore create an incentive for contractors to maximize their work volume and profits.

The fixed lump-sum payment terms introduced in British Colombia reversed this incentive. To maximize profit, contractors needed to carry out intelligently designed preventive interventions wherever possible, thereby largely avoiding road deterioration which would require costly repairs or trigger contractual payment deductions. By design, this innovation created an incentive for contractors to implement works in a manner that, when well implemented, is cheaper in the long term than repairing road damage after damage appears. There was also the potential that savings that may arise from this proactive maintenance approach may be passed on to road agencies through competitive bidding, possibly resulting in both lower costs to the government and higher quality of service for road users.

This 'proactive approach' has since become known as a performance-based contracting (PBC) in the road sector. In recent decades, numerous national and subnational road agencies around the world have developed and/or adapted different bidding documents and model contracts for PBC that reflect their own priorities, market conditions, legal frameworks, and lessons from experience.

The terminology for these PBCs differs around the world, and the same terms can sometimes mean different things. To minimize confusion, this report collectively refers to the input/output-based[2] contracting approaches as 'traditional contracting'. This includes common contracting arrangements such as Force Account and the approach used in the International Federation of Consulting Engineers (*Fédération Internationale des Ingénieurs-Conseils*, FIDIC) Red Book model contract. Some of the PBC models discussed in this report are performance-based road rehabilitation and maintenance contracts which follow the World Bank's Standard Bidding Document (SBD) for Output- and Performance-Based Road Contracts (OPBRCs) which is used under many World Bank-financed road projects worldwide (including two of the case studies described in this report: Liberia and Botswana). Other PBCs include *Contratos de Recuperación y Mantenimiento* (CREMA) used in Argentina and asset maintenance (AM) contracts used in Florida, United States. As shown in Table 1.1, the commonality among these different forms of PBC—and what differentiates them from traditional road works contracting—is that payment under PBCs is linked to compliance with contractually defined performance indicators.

Gradual emergence of PBCs during the past three decades led to a debate over whether PBCs have led to savings in the long-term cost of maintaining road assets compared to traditional contracting methods. Proponents of PBC have often claimed that they improve efficiency in road asset management, citing research by Pakkala et al. (2007). This research indicated that adoption of PBCs in some countries (mainly developed countries) could deliver roughly similar results as traditional contracts at 15 to 40 percent lower cost to road agencies (see Table 1.2). However, the expected savings were based on rough estimates provided by road sector officials in the respective countries, but without providing any underlying evidence-based analysis.

2 The definition of output also varies in each literature, which is often confusing for readers. In some documents, output-based contracts refer to PBCs rather than traditional contracts. In this report, output is defined as work outputs or quantities, not performance as road surface condition. Accordingly, output-based contracts are categorized as traditional contracts. Meanwhile, output and performance-based contracts refer to PBCs.

TABLE 1.1: TRADITIONAL CONTRACT APPROACHES VERSUS PBCS

	Traditional Contracting Model		PBCs
Common name	Force Account, executed by a government agency working as contractor for another government agency (sometimes referred to as input-based contracts)	Traditional civil works contracts executed by private contractors, similar to the FIDIC Red Book model (sometimes also referred to as output-based or ad-measurement contracts)	OPBRCs and other contracts executed by private contractors where payments are linked to the achievement of performance standards over time(sometimes referred to as 'outcome-based contracts'[3]).
Payment mode	Payment is made for the inputs used, such as fuel, labor, materials, and so on.	Payment is made for works outputs, such as cubic meters of backfill, linear meter of pavement marking, and so on.	Payment is by lump sum, typically monthly, if required service levels are fully achieved; deductions are applied for failure to meet performance targets.

TABLE 1.2: PROJECTED COST SAVINGS OF PBCS VERSUS TRADITIONAL CONTRACTS

Country	Cost Saving (%)
Netherlands	30–40
Estonia	20–40
Brazil	15–35
New Zealand	15–38
Australia	10–40
United States	10–15
Canada	Approximately 20
Finland	18
Norway	20–40
Sweden	Approximately 30
England	Minimum 10

Source: Pakkala 2005; Pakkala et al. 2007.

When assessing potential cost implications of adopting PBCs, it is important to acknowledge that the motivation behind the adoption of PBCs has not been the same in both the developed and the developing countries. In most developed countries, road maintenance expenditures are typically fairly adequate, which means that roads are mostly in good condition. The initial focus of PBC in Canada and other developed countries was primarily on maintaining existing roads in good or fair condition, but at a lower cost. In developed countries today, switching to PBCs is often undertaken to save costs for broadly achieving the same or slightly better outcomes, by using the incentives under PBC for the contractor to optimize road asset management and maintenance strategies.

In the early 1990s, the World Bank found that PBC could also be used in developing countries to address the issue of sustainability of road infrastructure investments, by combining the rehabilitation of deteriorated roads with an incentive to efficiently carry out the maintenance needed to sustain them in good condition over time. In 2002, the World Bank started to offer to its clients the first version of a standardized bidding/contract documents for PBC as well as sample specifications which had to be adapted to specific country conditions. These documents were subsequently revised (major revisions in 2006 and 2021) and are published by

3 In this report, unless expressly stated otherwise, the term 'outcome' refers to performance and quality of road infrastructure over time.

the World Bank as Standard Procurement Documents (SPDs) for OPBRCs and Sample Specifications for OPBRCs. Most PBCs used in developing countries are based on the World Bank's documents described above.

The implications of introducing PBCs in developing countries are mostly quite different than in developed countries. The typical situation in developing countries is characterized by severely inadequate expenditures for road maintenance. The result is that roads are often allowed to deteriorate to poor condition, leading to bad service levels for road users and requiring costly road reconstruction. In many or most developing countries, 'saving money' on road maintenance is rarely possible because spending levels are already far too low. The push for adopting PBCs in these contexts is mainly geared toward obtaining better outcomes and service levels for road users, accepting that with the PBCs the annual spending level for maintenance per kilometer of road will be significantly higher. It is also hoped that the broader use of PBCs in developing countries could help secure more and steadier financing for road maintenance by demonstrating positive results and building government commitment to funding longer-term contracts.

Another common characteristic in developing countries is the lower capacity of the public sector in designing road operation and maintenance (O&M) strategies, which often results in inefficient and costly investment from the long-term perspective. While it is theoretically possible for the public sector to optimize road investment and O&M, the private sector could be more capable of optimizing the O&M than the public sector in many developing countries. A proactive involvement of the private sector in designing O&M under PBCs could bring more potential in long-term financial and economic savings.

While more than 30 years have passed since PBCs were first introduced in the road sector and a fairly large number of PBCs have by now been implemented, little quantitative evidence is available to demonstrate economic benefits of PBCs. Independent of the prevailing motivation for introducing PBCs, the common underlying claim of their promotors is that PBCs will improve efficiency in road asset management. The experience with PBCs, reflected in literature, has shown that they can deliver the intended outcome of sustaining high-quality road conditions for users and other contractual objectives. PBCs can do this in a wide range of country contexts and for different types of road networks. However, while numerous studies and papers have been published describing the adoption of PBCs and deriving lessons from their implementation, there is no numeric evidence based on hard cost data to prove the cost-effectiveness of PBCs compared to traditional procurement approaches.

This is probably because of the complexity of making comprehensive comparisons between PBCs and other contracting modalities. Comparison of the cost-effectiveness of different contracting approaches is not as simple as comparing unit costs for specific work items. Among other reasons, the unit costs of maintenance activities by themselves do not necessarily reflect whether works are well planned on the basis of a functioning road asset management system (RAMS) and—equally important—whether they were carried out efficiently and effectively and are therefore capable of producing lasting benefits that justify their financial costs. Proponents of PBCs respond to both these concerns that handing over long-term responsibility for the condition of a road asset to contractors creates commercial incentives for them to plan interventions as efficiently as possible and ensure good workmanship. While these incentives should, in theory, ensure efficiency in both planning and execution, actual differences in road agency costs (RAC) can only be proven through the collection and analysis of cost and other data over a long time, at least covering the expected lifetime of road pavements.

Moreover, comparison of PBCs and traditional contracting approaches must account for road user cost (RUC), i.e., the costs incurred by the road users. RUC vary greatly depending on road conditions such as smoothness, safety, and reliability (for example, whether roads are open at all times or are sometimes closed or congested). A significant portion of the benefits of preventive maintenance consist of a transfer of value from road agencies paying for maintenance to the road users who benefit from improved road conditions.

Comparison of PBCs and traditional contracting approaches is therefore by necessity also a question of whether the contracting approaches have an impact on the long-term asset performance—that is, the net present value (NPV) of future annual streams of costs (RAC and externalities) and benefits (mostly reduced RUC and savings related to the longer life of the road and therefore delayed future rehabilitation investments).

Assessment of potential implications of PBCs for road sector efficiency is increasingly important because the use of PBCs has expanded globally as an instrument for delivering international development assistance by international financial institutions (IFIs) such as the World Bank. IFIs invest heavily in road infrastructure. Roads and highways constitute important shares of the IFIs' lending portfolio. A comprehensive assessment of quantitative and qualitative benefits and disbenefits, including an evidence-based analysis of whether PBCs are reliably more efficient than traditional contracting approaches at delivering desired outcomes, would be extremely valuable to the World Bank and its clients.

For practitioners, adoption of PBCs carries still further implications and questions. These include the costs of contract procurement and administration, staff retraining or changes in staffing needs, impacts on the competitiveness of procurement, and other potential costs and benefits—many of which are difficult to quantify. Widespread adoption of one approach or another will shape the contracting industry and market for construction, potentially leading to changes in the typical level of quality, kinds of services available, amount of competition, and bid prices. Resilience to natural hazards—particularly climate events—and road safety outcomes are also important considerations for road managers with substantial cost implications.

1.2 Study Objective

The objective of this study was to undertake a comprehensive ex post performance assessment of road projects and assets to evaluate different long-term road asset management strategies and answer the following question on adoption of PBCs as much as possible: Are PBCs actually leading to more efficient road asset management than traditional civil works/maintenance contracts?

1.3 Study Approach

The study approach was to compare the economic benefits of PBC and traditional contracting approaches by examining case evidence. The research approach focused on identifying cases of comparable PBCs and traditional contracts and obtaining data sets to assess the economic performance of each using traditional methods of cost/benefit analysis for road project appraisal. This approach avoided the difficulties of econometric methods but relied upon the identification of cases where PBCs and traditional contracts were implemented contemporaneously on similar types of networks, in similar environmental conditions, and with similar traffic levels but using a PBC for one network and a traditional contracting method for the other.

It was assumed that a rigorous comparison of PBCs and traditional road maintenance contracts would reveal observable patterns and lead to other worthwhile observations. At the outset of the research, several other assumptions were also made: (a) the growing use of PBCs had given impetus for more comprehensive evaluation of their impacts and implications; (b) the large number of PBCs executed around the world had created a richer set of experiences and hard data to draw on; and (c) sufficient hard data could therefore be obtained to undertake a robust evaluation of whether PBCs have in practice resulted in lower average long-term RAC and RUC than traditional contracting approaches.

1.4 Study Methodology

The research carried out included the four tasks described in this section.

Task 1: Review and referencing international literature. Among the initial tasks was the undertaking of a global literature review from which the study team would develop a stronger understanding of the use of PBCs globally and which would facilitate the selection of case studies and the development of the case study methodology. The literature review questions focused on (a) lifecycle costs of road assets in a range of design/maintenance scenarios and (b) comparison of the efficiency of PBC and traditional contracting methods. The literature review scope encompassed the range of global studies and research covering lower-, middle-, and upper-income countries; paved and unpaved roads; and differences in PBC approaches.

Task 2: Case study comparisons of PBC and traditional contracting approaches. The international literature review identified 52 countries that could potentially be selected as PBC case study countries. To produce representative and robust results, cases were selected across a range of PBC contract types, geographic regions, socioeconomic conditions, topographical and geological differences, and road geometries representing as broadly as reasonably possible the diverse contexts in which PBCs are implemented today.

Interviews enabled the research team to select the final case study countries based on the expected availability of information, resulting in a final list of six case studies: Argentina, Lao People's Democratic Republic (Lao PDR), Liberia, New Zealand (Western Bay of Plenty District Council [WBOP DC]), Botswana, and United States (Florida). These include some PBCs implemented as part of World Bank-financed projects and others where the World Bank was not involved. The case study selection methodology is described in more detail in Chapter 3. Where necessary, the study team visited case study countries to collect further data. The literature review findings also informed the development of the case study methodology.

Task 3: Comparative analysis of PBC and traditional contract methods. The objective of this task was to undertake a comprehensive comparison of the PBC and traditional contracting approaches using the available information and data sets from the case studies and other PBCs evaluated. This task has resulted in a number of conclusions on the following subjects: (a) criteria and preconditions for the successful implementation of PBCs, (b) qualitative findings from the case studies, (c) economic comparison of PBCs and traditional contracts within the available data limitations, (d) noneconomic comparison of PBCs and traditional contracts, and (e) summary findings on the impacts of PBCs on the fiscal capacity of case study countries. The results of Task 3 are presented in Chapter 4.

1.5 Structure of the Report

The structure of this report largely follows the sequence of the abovementioned tasks.

Chapter 2 begins by defining the differences between PBC and traditional contracting approaches and then presents findings from Task 1 covering the two main topics of this research. The first topic concerns the cost efficiency in a range of O&M scenarios, to demonstrate the literature findings of the cost-effectiveness of various maintenance strategies. This chapter then reviews the existing literature comparing the efficiency of PBC and traditional contracting approaches and summarizes key lessons from the literature review.

Chapter 3 presents the case study selection process and the criteria applied for identifying the six case studies. Each case study is presented in a summary format beginning with a description of the context, the networks managed under PBC and traditional contracting, and the contract formats. This is followed by a contract data summary table summarizing available data, differences in data availability for the PBCs and traditional contracts, and additional relevant observations. The case study summaries conclude with reflections highlighting key observations. (Detailed case studies are presented in Appendix 4: Details of Case Studies.)

Chapter 4 presents the main study findings. This chapter discusses the gaps between the needed and the available data, the efforts to obtain supplemental data, and findings regarding overall data availability. The chapter then presents the main findings grouped in the following manner: Section 4.3 presents a summary of key qualitative findings, Section 4.4 presents the quantitative findings that were available based on case studies, and Section 4.5 describes trade-offs of the different contracting approaches. The chapter concludes with a discussion of the study's findings concerning the impacts of PBCs on fiscal space.

Chapter 5 summarizes the overall findings of the study.

2

Definition of Performance-Based Contracting and Global Literature Review

2.1 Introduction and Definition of PBC and Traditional Works Contracting

Over time, almost all governments worldwide have sought to improve efficiency and lower costs of road construction and maintenance through the introduction of competitive procurement of road works among private contractors acting in the market. Gericke, Hennings, and Greenwood (2014)[4] describe the most common evolution of contracting models for road works and services as a progression from ‘input’ to ‘output’ and, in some instances, proceeding to ‘outcome-based’ models.[5]

‘Input-type’ contracting has typically been the starting point for governments. This has usually taken the form of execution of works by ‘Force Account’, through government-operated public works departments within the public administration structure. These public works departments were paid for the inputs they used for construction (essentially labor and materials). The employer (usually the government’s Public Works Ministry) was responsible for organizing and overseeing construction and carried all risks related to the quality of design, efficiency of execution, workmanship, and, generally, the achievement of the desired outcomes. Under this system, there is little incentive for the executing agency to innovate or improve efficiency. Nevertheless, Force Account arrangements are still used extensively in many developed countries, especially in Europe, and mostly at the local (municipal) and regional levels.

4 Gericke, Ben, Theuns Henning, and Ian Greenwood. 2014. “Review of Performance Based Contracting in the Road Sector: Phase 1.” Transport Papers Series No. TP-42A.,Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/18648.

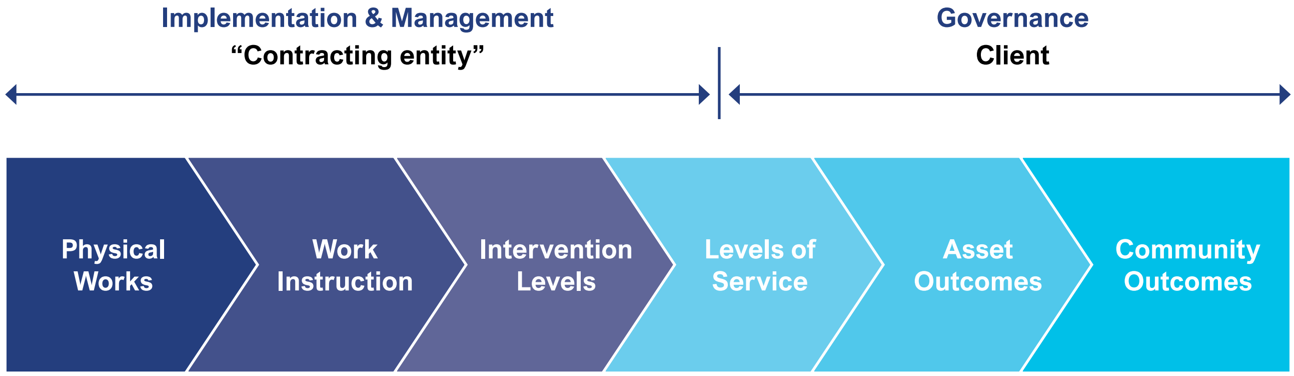
5 The contract types corresponding to ‘input’, ‘output’, and ‘outcome’ are explained in Table 1.1.

The outsourcing process then started by transforming the public works departments into government-owned contractors working under commercial law and by signing formal contracts with those entities. The government-owned contractors were paid for specified work outputs or quantities, on the basis of unit rates agreed with the line ministry in charge of roads. While these 'output-type' contracts introduced more accountability for the government-owned contractor, this arrangement still proved unsatisfactory in many countries. It is, however, widely used until today in China, where it seems to work quite well, and in other countries of the former Communist bloc.

The outsourcing process continued by introducing open competitive bidding procedures for public works, directed at private contractors (and in some cases even state-owned contractors) who would compete against each other. The bidding processes are often based on SBDs published by professional agencies such as FIDIC which has published the 'Red Book' SBD which is widely used in many countries. Contractors are paid for specified work outputs or quantities (for example, cubic meters of earth moved and compacted, or square meters of asphalt installed) on the basis of unit rates they offered in their bids. The contracts signed are 'output- or quantity-based contracts' which are also commonly called 'traditional civil works contracts'. Today, this contracting modality is probably the most widely used worldwide. While this contracting modality shifts construction-related efficiency risks and quality risks to the contractor, the state retains the design quality risk in most cases. Only in very few well-functioning construction markets can quality assurance and a limited number of design decisions be safely handed over to contractors.

Finally, PBCs, which are the subject of this research, shift much more risk and responsibility to the private sector. Under PBCs, contractors are paid fixed lump-sum rates (usually monthly) provided that they achieve and maintain clearly defined performance indicators over the lifetime of the contract, usually five to ten years or longer. These performance indicators reflect the requirements imposed by the government (or the road agency) on the contractor in terms of service levels for road users, such as pavement roughness, presence of pavement markings, guardrails, traffic signals, and many others. Use of lump-sum and outcome-based payments under PBCs provides flexibility for contractors in designing and implementing interventions and thus creates a potential to minimize the long-term costs to achieve the required performance.

FIGURE 2.1: INCREASED LEVEL OF CONTRACTOR RESPONSIBILITY FOR ROAD MANAGEMENT UNDER PBC



Source: Gericke, Henning, and Greenwood 2014.

When the contract period corresponds to the service life of the assets constructed under the PBC (which is often not the case because the PBC is usually shorter in duration than the average service life of pavements), the PBC can establish a strong incentive for contractors to present an offer during bidding that minimizes the lifecycle cost of the road asset (to win the contract award) and to be efficient during contract implementation (to maximize their own profits). The incentive structure built into PBCs often induces governments to hold back profit from the initial construction or rehabilitation works (by setting a price cap for those in the bidding document) and pay the deferred profit through the monthly payments for maintenance services. This avoids the so-called 'front-loading' of contracts and establishes a financial incentive for the contractor to execute the maintenance activities necessary until the end of the contract period.

The purpose of PBCs is thus to apply commercial incentives for efficiency to a much larger proportion of the chain of activities needed to design, build, maintain, and operate roads. This allows PBCs to benefit from certain economies of scope (for instance, between design and civil works, between rehabilitation and maintenance, and possibly others). Combining the design and rehabilitation in a single contract reduces the incentive to over-design (because it would result in a high bid price), and combining construction and maintenance creates an incentive to ensure quality of workmanship and optimize the investment and operations and maintenance plan.

As contractors are paid on the basis of the outcomes, that is, the performance of the asset over the contract period, PBCs are called 'outcome-based' or 'output- and performance-based'. The change in responsibility when moving from input-based arrangements to outcome- and performance-based contracts and the financial incentives for efficient road asset management are described by Porter et al. (2014). Table 2.1 summarizes the principal characteristics of the different modalities.

TABLE 2.1: COMPARISON OF TRADITIONAL CONTRACTS AND PBCS

	Traditional Contracts		PBCs
Common name	Force Account, executed by the government agency working as the contractor	Traditional civil works contracts executed by private contractors	PBCs executed by private contractors
Payment mode	Payment is made for the inputs used, such as fuel, labor, and materials.	Payment is made for works outputs, such as cubic meters of backfill and linear meter of pavement marking.	Payment is by lump sum, typically monthly lump-sum payments, if required service levels are fully achieved.
Contractors' capacity level required for maintenance strategy	Low	Medium	Medium to high
Contractors' motivation and responsibility	No profit motive, and little or no motivation for improving efficiency or ensuring outcomes, since full costs are paid/reimbursed	Maximization of profits through maximization of work volume and efficient achievement of outputs but limited responsibility for outcomes	Maximization of profits through optimization of design, work, and inputs, while delivering the required outcomes with the minimum necessary work and input and therefore at least cost

Practical experience has helped road agencies identify critical factors for cost-effectiveness and overall success of PBCs. These include:

- Limiting the contractor's liability to those risks that it can effectively control is essential to keep bid prices low;
- Having a competitive market of well-qualified firms with adequate turnover who are able to accurately anticipate their costs and internalize savings from operating efficiencies into competitive bid prices;
- Limiting front-loading and profit taking from the initial construction/rehabilitation and/or repair phase and paying the profits to contractors over the remaining contract period, to maintain a strong incentive for the contractor to stay engaged throughout the contract period; and
- Ensuring a stable and reliable source of funding for the payments to be made to the contractor during the entire contract period.

PBCs imply that employers compensate contractors for the risks they assume as well as pay interest on costs and profits deferred from the period of the initial construction, rehabilitation, and/or repairs. At the same time, PBCs must also allow the contractor to reap at least a part of the benefits of their own high efficiency in contract execution.

PBCs are more challenging to develop and procure than traditional civil works contracts, and long-term funding requirements for PBCs can pose challenges and risks for employers in contexts where political incentives are short-term.

2.2 Literature Search on Use of PBCs Globally

A search of international academic research literature and published professional studies identified 80 references relevant to PBCs in the road sector. A large share of those sources covers the two key themes that are relevant for this research study:

a. Lifecycle costs of road assets and economic benefits in a range of investment and O&M scenarios.
b. Comparison of the efficiency of PBC and traditional road contracting.

A list of these references is included in Appendix 1.

2.3 Summary of Literature Search and Relevant Findings

The volume of information identified indicates that a significant body of knowledge exists regarding the implementation and operation of PBCs covering low-, middle-, and upper-income countries and for a variety of road network types. There is broad examination of a variety of contract performance and operational outcomes, and several documents have focused on the perceived advantages that PBCs can provide compared to other contracting models.

The overall findings of the literature review are summarized below:

- The few research papers that attempted to quantify the benefits of PBC from an economic or financial perspective lack the level of detailed analysis that is being sought through this research study. Many more of the references have taken a qualitative approach.
- There are very few cases where a long history of detailed information has been recorded by the road agency, the monitoring and supervision consultant, and/or the contractor. Identification of suitable baseline data—either before the implementation of the PBC or operating in parallel—is a major practical constraint.

- Reports published by road agencies tend to have limited meaning outside the individual agency; this is not surprising as they have access to case evidence, but their knowledge development objectives are primarily inward focused.
- In contrast, academic institutions have broader analytical and knowledge development goals and are much more limited in their capacity to generate and collate the data necessary to carry out quantitative comparison of contracting approaches.

2.3.1 Lifecycle Economic Benefits and Costs of Road Assets in a Range of Investment and O&M Scenarios

In the literature reviewed, the lifecycle benefits of proactive and preventive maintenance strategies appear to be universally accepted. While a wide range of literature on road lifecycle costs exists, there is relatively little published research that utilizes case evidence to evaluate lifecycle costs and economic benefits of road investment and O&M scenarios and makes specific recommendations.

Most of the research encountered on lifecycle costs is theory based, focusing on methodologies for agencies to undertake their own analysis, such as the establishment of a RAMS as the basis for decision-making. This in a way demonstrates the complexity of the problem as the circumstances faced by each road agency will differ in terms of road condition, road surface material, labor and equipment costs, and so on.

Academic, marketing, and practitioner papers on the topic tend to focus on the principles of lifecycle analysis for estimating the NPV or calculating cost-benefit ratios for comparison of various intervention scenarios rather than drawing on case evidence.

The few papers that report on lifecycle cost savings based on actual case data tend to present relatively high-level conclusions that are valid for a specific country or jurisdiction; this may reflect the difficulty in extracting comparable data from multiple contexts.

Some quantitative findings in some research papers are generally applicable for road maintenance strategies and lifecycle costs, as follows:

- Thiessen et al. (England, 2016): “Compared with continued use of the current budget, a scenario of a temporarily increased budget provides a benefit in terms of reduced user costs of 2.70 (discounted) for each extra £1 spent on direct works costs. Reducing the budget for 5 years, resulted in a reduction in benefits of £2.90 for every £1 saved in direct costs.”
- Transport Scotland (Scotland, 2012): “for every £1 reduction in road maintenance [expenditures], there is a cost of £1.50 to the wider economy, based on the ratio of reduction in benefits to reductions in expenditure from the analyses used.”
- Zaniewski and Mamlouk (1996): “The New York DoT[6] found preventive maintenance to be 3.65 times more cost-effective than a “do nothing” strategy.”

Other authors (Anastasopoulos et al. 2010; Queiroz 2014) have developed alternative models and tools to specifically assess the costs and the cost structure of PBCs, which can be used for comparative and planning purposes.

6 DoT = Department of Transportation.

Specific References of Note

Valuing the Wider Benefits of Road Maintenance Funding (Thiessen et al. 2016)

"The earlier study of road maintenance in Scotland concluded (Transport Scotland 2012) that "for every £1 reduction in road maintenance, there is a cost of £1.50 to the wider economy" based on the ratio of reduction in benefits to reductions in expenditure from the analyses used."

"The national level analyses for England (excluding London) using the new tool reinforce and indeed strengthen these earlier conclusions that investing in local highways maintenance can offer high to very high value for money."

"Compared with continued use of the current budget, a scenario of a temporarily increased budget provides a benefit in terms of reduced user costs of £2.70 (discounted) for each extra £1 spent on direct works costs. Reducing the budget for 5 years, resulted in a reduction in benefits of £2.90 for every £1 saved in direct costs."

"These benefit cost ratios represent the value for changing funding levels at the margin (around current spending) rather than the value of the total spending, as no such analysis was undertaken. The results confirm that the marginal benefit of additional spending is lower at higher levels of spending."

"A further scenario demonstrates the use of targets in the model. An ambitious quality target for the network is achieved over a ten-year period of significant additional investment. The network is then maintained at that level over the remainder of the analysis period. While substantial additional funding is required in that scenario, the benefits exceed costs by 4.5 times."

"While more detailed analyses of this kind will be required at local authority level, this analysis could be supporting claims made that a backlog of repairs is preventing the adoption of proactive asset management approaches that would provide better value for money."

Benefit-Cost Analysis of Road Maintenance (Carter and Olmstead 2016)

"AASHTO[7] pavement services estimate every $1 of preventative maintenance avoids $6-10 of rehabilitation"

A Financial Model to Estimate Annual Payments Required under Performance-Based Contracts (Mladenovic and Queiroz 2014)

"The paper presented the development of a user-friendly model to assess the required annual payments under Performance Based Contracts (PBC)."

Road Projects Cost Benefit Analysis: Scenario Analysis of the Effect of Varying Inputs 81577 (Tsunokawa 2010)

"The objective of the study was to obtain insights regarding the effects of varying inputs and parameters on the viability of road projects through case studies using HDM-4, thereby to facilitate the formulation and implementation of road projects that increase the welfare of the society under the environment of increased uncertainty in an economic downturn. It was found that the variability ranges differ by country reflecting the degree of decrease in transport demand and relative change in factor prices due to economic downturn."

Pavement Maintenance Effectiveness (Zaniewski and Mamlouk 1996)

"The New York DoT found preventive maintenance to be 3.65 times more cost-effective than a "do nothing" strategy. A Corp of Engineers study found chip seals to be four times more cost-effective than allowing a pavement to deteriorate."

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7 AASHTO is the American Association of State and Territorial Highway Officials.

2.3.2 Comparison of the Economic Efficiency of PBC and Traditional Contracting

The majority of research comparing PBC and traditional contracting has focused on potential or perceived savings to road agencies. Some studies have demonstrated actual savings, including in Brazil (Lancelot 2010). While there have been many places and instances of successful implementation of PBCs and associated efficiencies, some recent studies found that savings were achieved, but the desired outcomes were not fully achieved, for example, Alberta (McLorg 2017), Nepal (Mulmi 2016), and Highways England (Conference of European Directors of Roads 2017).

The most frequently cited research on the efficiency of PBC versus mostly outsourced delivery was carried out by Pekka Pakkala (2002, updated in 2007). The comparisons between PBCs and traditional contracting approaches in these studies need to be treated with caution, however, as both studies report potential savings rather than actual savings confirmed on the basis of actual spending on contracts. Moreover, both studies relied on data from developed countries that had well-established and well-funded road maintenance systems. That said, the comparisons all showed PBCs had the potential to deliver significant savings over traditional contracting.

More recently, a study of procurement models undertaken by the UK National Infrastructure Commission found that it was not possible to complete a robust analysis of costs and benefits of private financing versus public procurement of road transport infrastructure due to the lack of access to the required data concerning the public road projects (National Infrastructure Commission 2019).

Other studies focusing on the wider economic benefits of PBCs compared to traditional contracting approaches have been less conclusive (Iimi et al. 2017; Pike et al. 2014). In both cases, the research failed to identify any significant benefit of PBC over and above other forms of contract when looking at benefits to agricultural production and road user safety, respectively.

A significant portion of the literature comparing PBC and traditional contracting focuses on the incentive structure of PBCs and traditional contracts and the hurdles to achieving a transition from traditional contracts to PBCs.

Specific References of Note

Country-specific reports on road maintenance procurement (Conference of European Directors of Roads 2017)

Highways England (HE): “However, while cost savings were substantial, expected and desired performance outcomes were not always achieved. This was due to missing competences to achieve true integration at the contractor. At the same time, HE had limited control to manage required maintenance outcomes. Renegotiations and conflicts between HE and its contractors occurred. In order to be able to confidently report on asset performance and maintenance costs, supportive systems and processes (e.g., management maintenance information system) needed to be put in place. In the near future, HE is looking at managing contracts more closely and splitting works into multiple contracts. Also, interviewees stated that as HE gains relevant competences and knowledge of particular assets, certain procurement activities and the intelligence/decision making may be brought back in-house.”

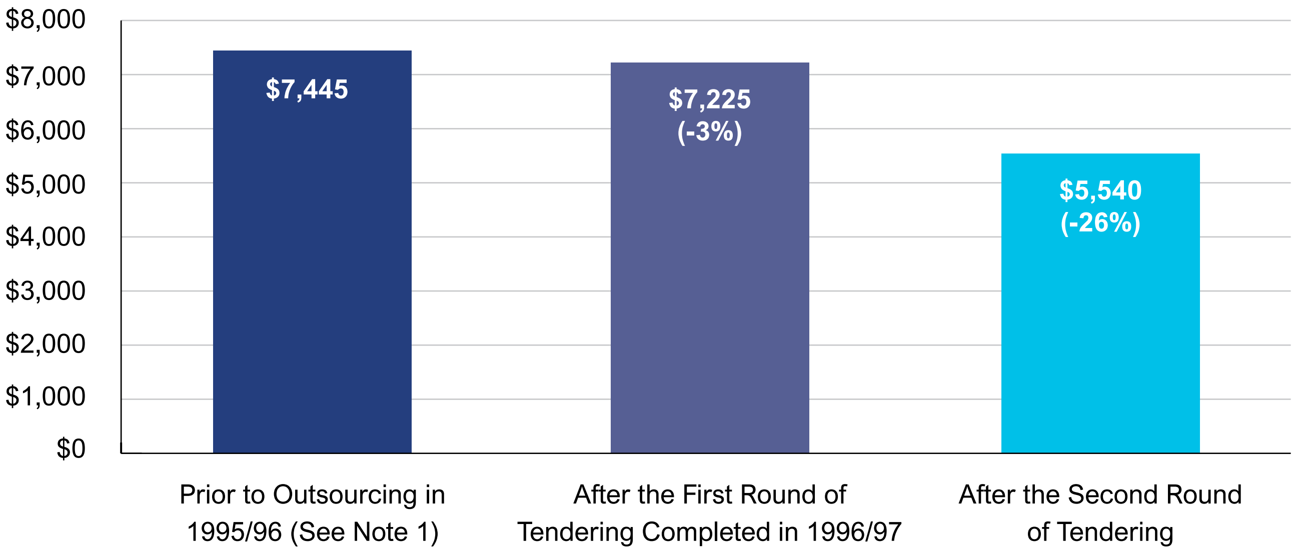
Output- and Performance-Based Road Contracts and Agricultural Production: Evidence from Zambia (Iimi and Gericke 2017)

“…it is found that the OPRC has a significant impact on agricultural production. This is mainly attributed to the positive impact on production of maize and groundnuts, two major crops grown in the study region.”

"Most of the measured OPRC impacts are associated with actual road improvement works regardless of contractual arrangements. This is obvious: Without actual works, people's connectivity would not be improved. On the other hand, any road work can improve people's connectivity if it is not OPRC. The most important effect of the OPRC's is that the OPRC can increase the probability of receiving necessary road works whenever needed."

Alberta's Highway Maintenance Program: A Privatized Approach (McLorg 2017)

FIGURE 2.2: HIGHWAY MAINTENANCE COSTS COMPARISON



Source: McLorg (2017). Based on 2003 dollars.

- "During each round the Alberta Department of Transport has continuously improved existing specifications and contracts, using lump sum payment
- The Department has continued to receive very good prices as compared to original in-house and previous tenders (current prices even 25% lower as compared to 2003 prices)
- The department prices have been significantly less than Ontario and B.C.
- Unit price payment allows the department flexibility to change level of service and is less risky for contractor."

Assessment of Performance Based Road Maintenance Practices in Nepal (Mulmi 2016)

"The cost comparison made between the two shows that Performance Based Maintenance Contracts are more cost effective than the SMD Maintenance practices. The minimum cost saving of 0.82% is observed in contract RMDP/PBMC/ICB02 and the highest cost saving of 54.08% of maintenance cost is observed in contract RMDP/PBMC/ICB01. The cost saving from 31.6% to 42.05% have been observed in the other projects. This does not consider the saving of overhead of each year procurement which have to be done in the case of SMD Process."

Evaluating the Effectiveness of Performance Based Pavement Marking Maintenance Contracts in Texas (Pike et al. 2014)

"The results from both safety and retro-reflectivity performance evaluations indicate that the agencies' choice of contracting mechanism, whether it is traditional contract or PBPMMC, will not affect either safety or retro-reflectivity performance of the facilities. The agencies can select the contract type based on their experience, the cost-effectiveness, and the availability of local contractors."

Performance-based Road Rehabilitation and Maintenance Contracts (CREMA) in Argentina: A Review of Fifteen Years of Experience (1996–2010) (Silva and Liautaud 2011)

"… for that price the CREMA incorporates a number of additional features that would normally be separately priced under a traditional ad-measurement type of contracts. Those costs that would normally be borne by the road agency under a traditional contract are estimated to be in the order of 39 percent of the contract value as detailed below. Considering these additional benefits, the overall net cost effectiveness of the CREMA is in order of 24 percent."

Performance Based Contracts in the Road Sector: Towards Improved Efficiency in the Management of Maintenance and Rehabilitation Brazil's Experience (Lancelot 2010)

"CREMA final unit costs over a full 5-year rehabilitation and maintenance cycle has been 19 percent lower than the rehabilitation and maintenance cumulative costs on the 13 identified roads at the federal level benefiting from separate contracts for rehabilitation works and maintenance services afterward…"

Cost Savings Analysis of Performance-Based Contracts for Highway Maintenance Operations (Anastasopoulos et al. 2010)

"Since the presence of cost savings indicate the preference of the innovative method over in-house practices and the preference of the PBC over in-house in the case of the PBC model results, our findings indicate that PBC or Incentive/Disincentive are preferred, over warranties, with respect to the amount and likelihood of cost savings."

Use of OPRC Contracts Through Small Local Enterprises Using Labor-Based Methods (Flintsch 2007)

"Peru: Provided a wide geographic and social coverage directly benefiting 250 people per kilometer [investment ~$100 per capita]:

- Provided permanent (all weather) access to 3.5 million rural individuals
- Generated 7,000 permanent jobs and 50,000 temporary employment opportunities.
- Saved at least $10,000/km every four years on road rehabilitation and maintenance costs.
- Contributed to poverty alleviation, generation of new economic activities, and development of local engineering firms
- Introduced new economic agents:
  - » road maintenance micro-enterprises
  - » small engineering and consulting enterprises
  - » other productive initiatives."

International Overview of Innovative Contracting Practices for Roads (Pakkala 2007)

"It should be noted that the main contribution to the savings achieved was reportedly due to the combination of outsourcing and the long duration of the contract. Another contribution to the savings portion is the inclusion of outcome-based criteria or some form of performance requirements that allows flexibility and innovations on the methods chosen to meet the quality requirements. This allows the potential for cost savings measures and practices, although it is difficult or virtually impossible to measure.

Typically, the savings from the initial years of outsourcing have ranged from 10 to 40%, but it is difficult to determine the actual reasons why some countries have achieved better results than others. It would be speculation to describe the reasons, but some of the following aspects might be contributing factors.

- Union and wage issue
- Competitive market in maintenance
- Asset distribution (any favoritism)
- Competence and know-how of the private sector
- Immediate transformation from in-house to outsourcing
- Lack of benchmarking and lessons learned
- Strong leadership in transformation process
- Marketing and working with the industry
- Contracting method used."

TABLE 2.2: INTERNATIONAL OVERVIEW OF INNOVATIVE CONTRACTING PRACTICES FOR ROADS

	In-house	Out-sourced	Activities Included	Contract Type	Contract Duration
Alberta, Canada		X	Routine maintenance	Unit hybrid	5, 6, & 7 years
British Columbia, Canada		X	Routine maintenance	Lump sum	10 years
Ontario, Canada		X	Routine maintenance	Hybrid (lump sum & unit prices)	7–9 years
Estonia	X	X	Routine maintenance	Hybrid	5 years New–7 years
Norway		X	Routine maintenance	Hybrid	4 years
Sweden		X	Routine maintenance	Hybrid	3–6 years
Finland		X	Routine maintenance	Hybrid & lump sum	3, 5, & 7 years
Holland		X	Different activities	Lump sum	1–3 years
Australia (VIC-Roads)	X	X	Routine maintenance	Lump sum	2–3 +1+1 years
Australia, Western Australia		X	Basically all	Lump sum	10 years
England		X	Basically all	Lump sum (unit price for undefined)	5 + 2 years
New Zealand		X	Routine maintenance plus all	Unit price hybrid lump sum	3+1 years 3+1+1 years 10 years
USA (NCDOT)	X	X	Activity based	Unit price	1 year
USA (MDSHA)	X	X	Activity based	Unit price	1 year
USA (MNDOT)	X	X	Activity based	Unit price	1 year
USA (DDOT)	X	X	Basically all	Lump sum	5 years
USA (VDOT)	X	X	Basically all Proposed	Lump sum Lump sum	5 years (New) 3+3+3
USA (FDOT)	X (about 20%)	X	40% routine maintenance 40% salesman	Lump sum Unit priced	7+7 years Yearly

Source: Pakkala et al. 2007.

Contractor Selection Criteria	Area or Corridor Contracts	Quoted Savings	Comments
95% price 5% past performance	30 areas	25%	Winter maintenance standby receives about 35% lump sum payment
60% price 40% other	28 areas	10%	Line marking and lighting are not included. A single contractor can only win 4 area contracts.
95% price 5% other	48 areas	12%	16 performace-based area contracts remainder — “maintenance outsourced” by the “salesman model”
75% price 25% other	16 areas	Up to 20%	Own in-house forces compete against private contractors. 63% of maintenance is tendered.
Lowest price Conforming tender	107 areas	20–30%	Client maintains most inspection.
98% price 2% other	136 areas	20–30%	New winter maintenance payment scheme based upon actual weather conditions.
75% price 25% other	85 areas	Over 30%	Now separate contracts for line marking, resurfacing, and bridges are long-term duration.
100% price	Many areas	30–40%	Future — investigating MAC model from England and will adapt to Holland situation.
100% price	About 50% of network	Some	Competition between in-house forces and private sector. Still quite input-based.
50% price 50% other	8 areas	20%	
25% price 75% other E-MAC is 100% quality (target price)	14 areas	Over 10%	Includes up to £500k worth of periodic maintenance (bridges or resurfacing). E-MAC is similar to the “alliance model.”
Low bid weighted average QTPO	24 areas	10–15%	Still using about 50% traditional maintenance contracts. Very small staff.
100% price	Corridor	NA	Outsource those activities that are more efficiently done by contractor or balancing work.
100% price	Corridor	NA	
100% price	Corridor	NA	
50% price 50% other	Corridor	NA	Does not include major bridge rehabilitation.
50% price 50% other 100% price	Corridor	10–15%	Still basically in-house. Only one integrated contract (VMS). New contracts planned for routine maintenance. 3+3+3 years, with low bid.
40% price 60% other 100% price	Corridor	20%	Goal is to achieve 80% outsourced. Using a maintenance rating prograpm (MRP) to measure performance. 10 year rest area contract.

Notes: DDOT = District Department of Transportation; FDOT = Florida Department of Transportation; MDSHA = Maryland State Highway Administration; MNDOT = Minnesota Department of Transporation; NCDOT = North Carolina Department of Transportation; VDOT = Virginia Department of Transportation.

Contracted Maintenance Services at the Ministry of Transportation, in Ontario (MacLean et al. 2005)

First round of PBC tendering: “In 2001, the ministry retained the services of Deloitte and Touche to determine the savings attributable to outsourcing. They conducted a detailed assessment of costs of delivery and determined the government’s savings attributable to outsourcing was 12.5% annually.”

Second round of PBC tendering: “As of May 2005, tendering of the second-generation contracts is complete. The second generation had a total of 16 AMC areas with a combined total of 21 contracts totaling 13,945 two-lane equivalent kms. Six contractors have been successful in obtaining contracts. Only about 40% of the work was awarded to the incumbent contractor indicating that a competitive bidding environment exists.

Overall tender prices remain extremely competitive with normally 4-6 bidders per contract. Ministry of Transportation in Ontario (MTO) cost estimates of the work are based on the value of the previous contract, plus the cost of new work added into the contract, plus inflation. Second generation contract prices are lower than this amount by almost 9% over the entire program.”

In summary, “Generally overall costs have increased from about $211 M to $241 M or about 13%. Taking all the above into account, the maintenance program should have experienced cost increases of about $42.6 M or 20% since outsourcing began. The shift to outsourcing has allowed the ministry to contain these potential cost increases.”

2.4 Literature Review Conclusions

While several case-evidence-based studies confirmed that maintenance spending has produced substantial benefits in terms of RAC and RUC savings, the literature review found little case-evidence-based research comparing investment and O&M scenarios in terms of their impacts on lifecycle costs and identifying recommendations for practitioners. Findings that do exist are more generic, high-level estimates of the cost-effectiveness of maintenance that represent a limited number of contexts.

In contrast, case-data-derived research findings on the relative economic efficiency of PBCs and traditional contracting approaches have focused on RAC almost exclusively. While available research seems to confirm that PBCs can deliver intensive maintenance levels for lower RAC than traditional contracts in some contexts where road maintenance programs are well funded, this appears to be the current limit of research findings on this question. It has limited applicability to the impact of PBCs on RUC or RAC savings in low-/lower-middle income economies. The literature review did not identify globally representative case-evidence-based research on lifecycle costs or economic efficiency of PBC compared to traditional contracting.

3

Case Studies of PBCs and Traditional Contracts

3.1 Introduction

The international literature review in Chapter 2 resulted in an initial list of 52 potential case study countries. This list was narrowed to six case studies that were believed to be representative of global experience and for which data on comparable PBCs and traditional road contracts were expected to be available: Argentina, Lao PDR, Liberia, WBOP DC (New Zealand), Botswana, and Florida (United States). This chapter presents the case study selection method and a summary of each of the six case studies and concludes with a discussion of the data collection challenges the study faced. These challenges ultimately prevented the achievement of an important study objective, namely the quantitative comparison of lifecycle costs of roads under PBCs and traditional contracts. Further case study data and qualitative assessment of performance, contract administration, and other aspects of the case studies are presented in Appendix 4.

3.2 Case Study Selection and Data Collection

The study sought to identify six case studies that would be broadly representative of the diverse contexts in which PBCs are implemented around the world and for which similar and comparable 'networks'—sometimes consisting of a single road—were managed under PBCs and traditional approaches and therefore would enable a direct comparison.

The 52 countries that do or did undertake PBCs span the full spectrum from pilot contracts to full 'mainstreamed' implementation, lower- to upper-income economies, differing climates, topographies, and regions of the world. This list of case study candidates was narrowed down further based upon the following assessment parameters:

- The PBC has a sufficient number of truly performance-based elements.
- The PBC size is large enough to draw lessons.
- Several years of PBC implementation have transpired or PBCs have been fully completed.
- The road agency was believed to have the necessary data to undertake a quantitative analysis and had expressed willingness to share the data for this study.
- Data were available for similar comparison contracts or networks under a traditional contract(s).
- There were other aspects of potential interest (for example, growth in traffic volumes during the PBC term and unique aspects of the PBC contract).

The study assessed 23 short-listed case study countries to identify the suitability of each (see the details in Appendix 2). As the study sought to develop globally robust results, the final list was designed to be broadly representative of the global experience implementing PBCs in respect to national income, topography, climate, road construction and geometry, traffic demand, legal frameworks, and socioeconomic characteristics. The six case studies selected are shown in Table 3.1.

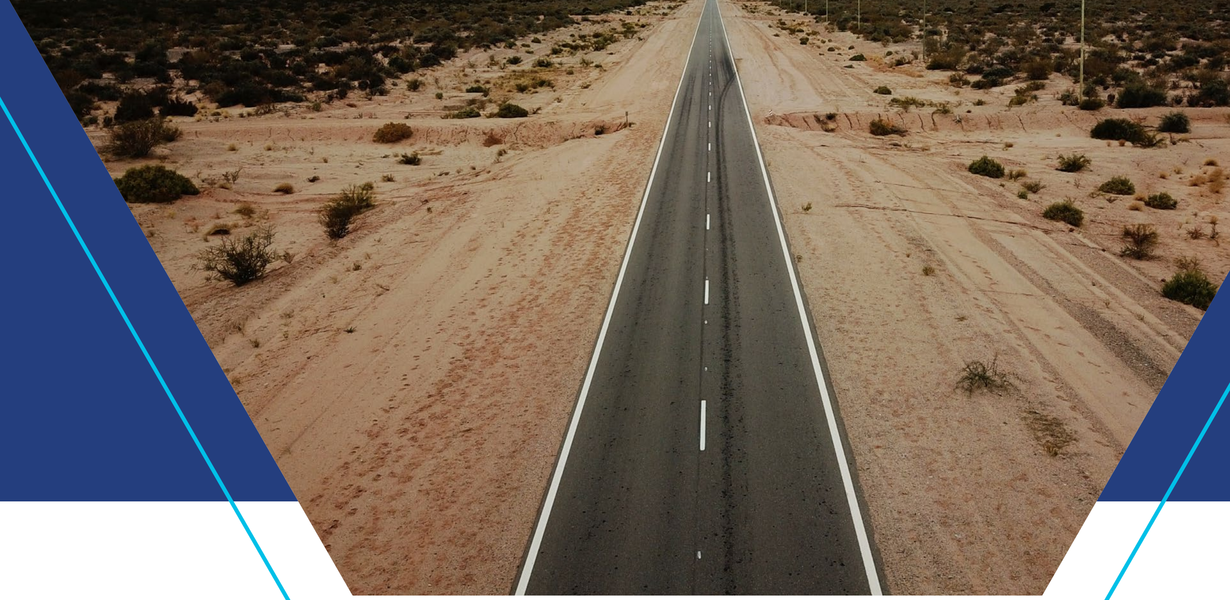
TABLE 3.1: CHARACTERISTICS OF CASE STUDIES

	Argentina	Lao PDR	Liberia	New Zealand	Botswana	Florida (dropped)
National-level income classification	Upper-middle	Lower-middle	Low	High	Upper-middle	High
Region	Americas	Asia	SSA	Pacific	SSA	Americas
Geography	Plain	Mountainous	Lowlands/ coastal	Rolling	Plateau	Primarly coastal and lowlands
Climate	Semiarid (with wet season)	Tropical (with monsoon)	Tropical (with monsoon)	Subtropical/ temperate	Semiarid	Subtropical
Traffic (AADT)	1,000 to 4,000		Up to 2,400	Ranges from low up to at least approx. 16,800		Ranges from 5,000 to more than 200,000
Construction	Asphalt concrete (AC) and/ or DBST	DBST and gravel	AC	Unpaved DBST and AC	DBST and gravel	Primarily AC, concreate

Note: AADT = Annual average daily traffic; SSA = Sub-Saharan Africa.

3.3 Summary of Data Obtained through Case Studies

The case studies were selected based on the interviews with relevant stakeholders and data collection through country visits. Questions used for interviews are provided in Appendix 3. Despite extensive efforts, it was not possible to obtain the information necessary to complete the Florida case study, and it is omitted from this chapter. An abbreviated Florida Case Study is included in Appendix 4. This section presents a brief summary of the case studies, focusing on quantitative data for the cost analysis.



Case Study 1

Argentina *Contratos de Recuperación y Mantenimiento* (CREMA) Performance Based Contract and Traditional Maintenance Contract

ROADS SELECTED

Argentina has been outsourcing road works using the CREMA model, which is a PBC with a five-year term, since 1997. It evolved from a previous DNV practice of outsourcing on a kilometer-month basis. CREMA typically comprise two years of rehabilitation and maintenance followed by three years of maintenance. The case study network is situated in Catamarca and La Rioja Provinces of Argentina. Both provinces are located northwest of Buenos Aires and border Chile. CREMA is one of three options applied by the national road agency, *Dirección Nacional de Vialidad* (DNV), based on level of road traffic: Concession (AADT >4,000–5,000),CREMA (AADT >1000), and Force Account AADT <1,000).

The PBC selected for the case study is the *La Rioja CREMA* (240 km) covering of a two-lane, single-carriageway road on a desert plain. Much of the topography of the study route is alluvial sandy silt with some low-lying wetland areas including salt rise. Within the province, there is varying topography and geology. In addition to the relatively desert-like conditions in the southeast, the remainder of the province includes hilly and mountainous sections made up of essentially weathered and highly fractured granites. Rainfall is seasonal and recent torrential rain has caused severe washouts and extended road closures.

For traditional contracts, the entire Force Account operation for Catamarca Province was compared to the PBC as a reference point as it was not possible to obtain disaggregated data on the cost and performance of Force Account by location. The scope of maintenance of non-CREMA and non-concession roads is the responsibility of the road department (DNV) which then manages and maintains the road using Force Account within a budget allocation. Force Account is usually constrained to safety critical activities as budgets are limited and includes emergency works and—in limited cases—periodic maintenance.

After CREMAs end, roads were maintained under Force Account and were not subject to similar levels of maintenance. As a result, the parts of the network that were under CREMA tended to substantially exceed the agency performance target for pavement condition, while those maintained under Force Account often fell below the target. The fact that the case study CREMA and Force Account works were quite different in scope makes cost comparison difficult.

TABLE 3.2: CONTRACT DATA SUMMARY — ARGENTINA

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehablitation Works		
See commentary	Nil	The PBC included only very little full-depth pavement rehabilitation. Little or no pavement rehabilitation is undertaken by traditional method.
Item 2: Periodic Maintenance Works		
US$15.57 million = US$64,875/km	200–300 m of thin overlay (see Data Item 3)	Most of the rehabilitation work included in CREMA was actually periodic maintenance (pavement overlays). Under the traditional approach, periodic maintenance works only occur in exceptional cases.
Item 3: Routine Maintenance Works		
US$1,700/km/year	US$2,247/km/year Note: This rate includes periodic maintenance and emergency works.	The outcome achieved between the two models is different. On average CREMA achieves a pavement serviceability score[8] of ~8. The traditional contracts barely maintain a pavement serviceability score of 4. Force Account includes administration, emergency works, thin overlays on short sections of road, and winter maintenance (where it occurs).
Item 4: Emergency Works Expenditure — Average Annual		
Nil	Included in routine maintenance works costs above	When emergency events occur, having a contractor on hand under CREMA leads to a more rapid response. In contrast, repairing roads under Force Account requires a funding approval from the head office, which can delay.
Item 5: Contract Administration — Procurement		
Approx. US$50,000 for 3 full-time equivalents (FTE)[9] for 6 weeks	Nil	
Item 6: Contract Monitoring/Supervision/Administration		
Approx. US$1.0 million = US$4,100/km	US$1,000/km	For CREMA, both the contractor and DNV have five people each. For the traditional contract, 22 people are engaged for 1,020 km.
Item 7: Non-pavement Maintenance Works		
Included above	Included above	Breakdown of costs was not available.

8 Pavement serviceability includes roughness, rutting, cracking, and raveling.

9 An FTE, or full-time equivalent, is equivalent to the level of effort of an individual working full-time for the time specified.

DNV staff reported that they found CREMA easier to administer, and CREMAs are well regarded within the country, which uses them for rehabilitation works (which primarily consists of repairs and overlay). Recognizing their own liability, CREMA contractors undertook in-house materials testing (with varying levels of oversight by DNV) and were more responsive to materials issues than if testing was carried out by DNV. Innovations by CREMA contractors have been adopted by DNV, emergency repairs were faster, and non-pavement maintenance was more consistent (including drain clearing). Moreover, inflation had reduced funding for—and frequency of—CREMAs, which provide a higher level of service but come at a higher cost for DNV.

CREMA faced procurement and funding challenges during the case study period. Specification of the required rehabilitation works by DNV and use of a 'lowest price conforming' bid mechanism (required by law) discouraged innovation by contractors and can result in the implementation of suboptimal engineering solutions. Procurement delays also resulted in increasing numbers of contract amendments (for instance, due to the need to increase overlay thickness) to ensure that the required performance outcomes were achievable. CREMAs are not 'full PBCs' because contractors can negotiate changes with DNV.

Case Study 2

Lao People's Democratic Republic

ROADS SELECTED

The Lao PDR Department of Roads (DOR) had six contracts including some rehabilitation/major maintenance works followed by performance-based maintenance until contract completion, which were called performance-based highway maintenance contracts (PBMs). These contracts cover approximately 600 km of both paved (double bituminous surface treatment [DBST]) and unpaved (gravel surface) national and local roads in southern Lao PDR.[10] The six PBMs comprise two packages:

- Package 1: Three contracts totaling 321.2 km in Salavan, Xekong, and Attapeu Provinces (see Figure A4.5). Each contract includes one national road and one local road. Package 1 commenced in Q2 of 2018 and finishes in Q3 of 2021 (3.5 years in total)
- Package 2: Three additional contracts in southern provinces (including Champasak).

The PBM delivery schedule included a 12-month rehabilitation phase and 30-month maintenance phase. The contractor was only liable for defects from the rehabilitation phase for 12 months, a significant deviation from conventional PBM approaches globally. PBM contractors were required to remediate sites with slope stability challenges using a provisional sum included in the contract and based on a bill of quantities (BoQ).

Community-based highway maintenance contracts (CBMs) ran concurrently with the PBMs. CBMs encompassed 2 to 3 km road sections adjacent to villages and were negotiated with local village leaders. They involved delivering routine non-pavement maintenance (including vegetation control, ditch clearing, debris removal, minor slip removal, sign cleaning, and straightening) through community areas and/or local villages adjacent to the highway corridor. Some key features of the CBM included the following:

- The CBM typically commenced once the rehabilitation and/or major maintenance phase was completed. In some instances, the CBM was also concurrent with rehabilitation and/or major maintenance.
- Tools and equipment were provided by the DOR.
- The CBM was funded by the DOR and/or Ministry of Public Works and Transportation (MPWT).

10 The contracts are funded by the Asian Development Bank (ADB) (approximately 90 percent) and the Government of Lao PDR (approximately 10 percent).

TABLE 3.3: CONTRACT DATA SUMMARY — LAO PDR

PBM Values (2018)	Traditional Contract Values (2019)	Commentary
	Item 1: Rehabilitation/Major Maintenance	
National roads: US$7,000/km Local roads: US$54,000/km[11]	Not part of the traditional contracts	The PBMs only include major repairs/patching/improvements to reach the initial level of service for PBM. National roads are well formed and maintained to some degree. Local roads, on the other hand, require relatively significant upgrading, and this is reflected in the rehabilitation rates.
	Item 2: Periodic Maintenance Works	
Not part of the PBMs	Not part of the traditional maintenance contracts	As the PBMs do not include periodic maintenance, the traditional contracts chosen for comparison also do not.
	Item 3: Routine Maintenance Works	
US$3,145/km/year for national roads US$1,590/km/year for local roads[12]	US$650/km/year	Routine maintenance on the PBM network excludes the cost of CBM (US$300/km).
	Item 4: Emergency Works	
US$170/km/year for national roads US$310/km/year for local roads (provisional contract sums)		Bulk spent on slope stabilization repairs on the mountainous section of the PBMs. Paid through a provisional sum.
	Item 5: Contract Administration — Procurement	
Bid cost unknown Bid every 3.5 years	Bid cost unknown Bid annually	Bid costs were not available. However, the annual tendering of the traditional contracts is likely more expensive compared to tendering multiyear PBMs.
	Item 6: Contract Monitoring/Supervision/Administration	
Administration costs unknown (see commentary)	Administration costs unknown (see commentary)	Specific administration costs were not available. However, the DOR administration effort was the same irrespective of the contract model. Contributing to this was the level of effort required by the DOR (training, supervision, and technical support) to ensure the PBM was a success. PBM administration costs may decline over time as contractors and DOR staff become more familiar with the PBM model.
	Item 7: Non-pavement Maintenance Works	
US$300/km/year for non-pavement maintenance works	Non-pavement maintenance works unknown (see commentary)	Minimal non-pavement maintenance work is completed on roads outside of the PBM.

11 Average unit prices obtained from PBM bid evaluations.

12 National road and local road costs are the average costs of maintenance across the Package 1 Contracts.

Traditional highway maintenance contracts were found to be the best for comparison with the PBM for the objectives of this study. The traditional maintenance contracts were awarded annually and cover all road and shoulder maintenance up to 1 m beyond the edge of seal/paving.

Under the traditional maintenance contracts, the DOR and MPWT directed maintenance activities and developed work plans in partnership with the contractor. Levels of service were subject to budget availability and varied depending on prior highway condition, traffic volumes, and surface type (AC, concrete, or DBST). Payment was based on a BoQ. Payments to contractors for work completed were often delayed, sometimes by up to two years, due to limited funding at the DOR/MPWT.

As noted in Table 3.3, the traditional works did not include rehabilitation works, and cost comparison of this aspect was therefore not possible. Even after the rehabilitation and routine maintenance costs of the PBM were disaggregated, the routine maintenance expenditure under the PBM was significantly greater than under the traditional contract. As in other case studies, this reflected the required higher service levels under the PBC.

As neither the PBM nor traditional contract included periodic maintenance or full rehabilitation, a comparison of the pavement condition outcomes is not a reliable indicator of the relative performance of each contracting approach. The site visits did find that the PBM provided a consistent level of service while traditional maintenance contracting prioritized repair of more deteriorated sections and therefore resulted in more variable conditions. Roads maintained under the PBM and CBM had more consistent maintenance of non-pavement assets such as drainage and street furniture.

The scope of work and the contractor's liability under the PBM differentiate this PBC from the PBCs examined in the four other case studies. First, the PBM model did not involve full rehabilitation or periodic maintenance. Second, the limited defect liability of the PBM model and 30-month routine maintenance period meant that the PBM format placed less responsibility for outcomes on contractors than the contracts utilized in the other case studies.

Case Study 3

Liberia Lot 1 Output and Performance-Based Road Contract and Cotton Tree to Port Buchanan Road Traditional Maintenance Contract

ROADS SELECTED

The case study compared two vital transport corridors in Liberia. The PBC corridor (Red Light-Gate 15-Gbargna) extends from the Red Light market in Monrovia—the largest market in the country—to Gbargna, the second largest city in Liberia, which is located halfway between Monrovia and a key border crossing into Guinea. This road provides access to the central and northeastern regions of Liberia, the Guinea border, and inland areas of southeastern Liberia. The PBC was a 10-year OPBRC encompassing a rehabilitation phase during the first three years followed by seven years of routine maintenance and a periodic overlay at the eighth year of implementation.

The road section under traditional contracting arrangements that was selected for comparison extends from Monrovia to Buchanan Port, located southeast of Monrovia; it was the first link in a mostly unimproved route extending from Monrovia along the cost to Harper (near the Côte d'Ivoire border) via the coastal towns of Buchanan and Greenville. Both routes were used for transport of produce, goods, fuel, wood, and other material from Monrovia to hinterlands, while the PBC route was also used for commerce with other countries, especially Guinea.

The OPBRC included clauses limiting bid prices for rehabilitation works as a proportion of the total bid price. This shifts costs from the rehabilitation payments to the maintenance payments, which were paid overtime on a performance basis based on the contractor's achievement of the contract performance targets. While road condition data were available for the road maintained under the OPBRC, this information was not available for the Cotton Tree to Port Buchanan Road maintained under a traditional contract.

The OPBRC overcame numerous challenges. Government delays funding resettlement compensation substantially delayed the construction, resulting in cost escalation and a contractual dispute. The OPBRC road rehabilitation works were also suspended due to the West Africa Ebola Virus Disease (EVD) epidemic in 2014. Despite these challenges, the OPBRC contractor completed rehabilitation within the three years specified in the contract.

TABLE 3.4: CONTRACT DATA SUMMARY — LIBERIA

OPBRC (PBC) Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehablitation Works		
US$669,541/km[13]	US$538,531/km	
Item 2: Periodic Maintenance Works		
US$212,689/km Expected to be close to the actual cost for a 40 mm AC overlay. This has not yet been undertaken on the PBC.	Periodic maintenance is not planned for the road maintained under traditional contracting.	
Item 3: Routine Maintenance Works		
Payment — US$46,611/km/year Estimated actual routine maintenance cost US$9,322/km/year	Estimated expenditure — US$1,394/km/year	Routine maintenance payments under the OPBRC include a portion of the rehabilitations works price as noted above, all maintenance items, and biannual condition surveys (International Roughness Index [IRI[14]] and pavement deflection – falling weight deflectometer [FWD]).
Item 4: Emergency Works Expenditure — Average Annual		
US$842/km/year	Budget amount US$28,400. Actual expenditure unknown but the network is more prone to flooding due to the flat topography, lower elevations, and proximity to major rivers.	Bulk spent on landslide retaining wall repairs on the PBC
Item 5: Contract Administration — Procurement		
Bid cost 0.235% of contract price (US$2,836/km)	Bid cost unknown	Employer administration costs for either contract is uncertain but likely to be less than two FTEs[15].
Item 6: Contract Monitoring/Supervision/Administration		
US$47,818/km (5.14% of the contractor's price) covering rehabilitation, routine maintenance, and periodic maintenance works	US$36,980/km (5.17% of the contractor's price), covering the rehabilitation phase only	The OPBRC cost is based upon a total of 276 months (FTE) input by key personnel and includes remuneration and reimbursable costs.

13 Actual price paid to the contractor is only approximately 80 percent of true price. The difference (20 percent) is paid as part of the routine maintenance payments. US$ Contract Price Adjustment Factor Applied = 0.3001.

14 IRI is the estimated vertical movement (often in meters) of a standardized vehicle suspension per unit of road length (typically km), yielding a unit m/km. A lower-quality riding surface results in more suspension movement and a higher IRI score.

15 It has not been possible to verify the level of effort indicated.

TABLE 3.4: CONTRACT DATA SUMMARY — LIBERIA, CONTINUED

OPBRC (PBC) Values (2019)	Traditional Contract Values (2019)	Commentary
Item 7: Non-pavement Maintenance Works		
Service levels include vegetation control, sign maintenance, pavement marking, drainage maintenance, guardrail repairs, cut slopes and embankment maintenance, structures inspections, and management performance measure reporting.	BoQ only lists signs, pavement markings, stone masonry repairs, and guardrail maintenance.	All OPBRC maintenance works included under a single lump-sum item as per Data Item 3.

Both roads have performed satisfactorily. Retention of payments from the rehabilitation phase to the maintenance phase, as explained above, created financial pressures for the OPBRC contractor to cut costs. As a result, pavement markings and signs have required additional maintenance. Some pavement subsidence has also occurred and, in the nine areas where repairs were required, the contractor completed those at its expense.

The case study illustrated that the OPBRC approach can motivate contractors to innovate to reduce lifecycle costs. In this instance, the contractor voluntarily exceeded the minimum shoulder pavement design (DBST) by constructing shoulders using the same AC as it had used for the carriageways. This decision lowered the contractor's preventive maintenance costs and produced a better result for road users and the employer.

The OPBRC included an overlay in the eighth and ninth years of implementation. The overlay has proven challenging for the Government of Liberia to fund in light of competing road construction priorities. Testing of the residual pavement strength suggests that it should be possible to defer this maintenance several years. Doing so would require a contract change with additional financial costs to the Government of Liberia. This experience demonstrates the potential risks of requiring periodic maintenance late in a PBC in a context where the employer faces severe budget constraints.

Case Study 4

Western Bay of Plenty District Council (WBOP DC) Performance-Based Contract and Whakatāne District Council Traditional Maintenance Contract

ROADS SELECTED

This case study compared a road network maintained under a large PBC in the WBOP DC to one maintained under traditional road maintenance contracting arrangements undertaken by a neighboring jurisdiction, the Whakatāne District Council. Both are located on the northeast of the second largest island, known as the North Island or Te Ika-a-Māui. The case study region is predominantly rural. The WBOP DC undertook an ambitious endeavor by tendering a single, large PBC for its entire 1,027 km network. The PBC commenced in 1999. Under the PBC, the WBOP DC determined the outcomes by specifying:

- The network condition required, when it must reach that condition, and how to measure and assess the condition;
- Asset strength and durability—covered by key performance measures (KPMs) related mainly to the average condition of the roads; and
- Road user performance measures such as comfort, serviceability, and safety. These were identified as being more about the tail of the condition distribution curve and covered by 54 operational performance measures (OPMs).

As a reference of traditional contracts, the study selected the Whakatāne District Council's 902 km road network which comprises approximately 200 km of unpaved roads and 702 km of paved roads. The paved roads are predominately two-lane undivided carriageways with sprayed chip seal surfacing. This contract model relies on a combination of factors to drive quality outcomes. These types of incentives are common in traditional maintenance contracts:

- Direct control by the contractor of asset management decisions in respect to the need, timing, justification, and treatment selection. It therefore carries the ownership and risk on treatment outcomes and performance other than the contractor's direct liability workmanship, which typically is limited to a 12-month defect liability period.
- Negative assessments of the contractor's performance may have a bearing on the contractor's eligibility to bid for future contracts or be appointed to future supplier panels.
- Persistent failure to achieve performance requirements may lead to reduced contract tenure, ineligibility for additional work under the contract, and/or a loss of a performance payment.

The final lump-sum price of the awarded bid was US$38 million lower than the estimated cost of continuing to maintain the same network under traditional contracting. The estimated cost savings were sufficient for WBOP DC fund additional road improvements.

TABLE 3.5: CONTRACT DATA SUMMARY — NEW ZEALAND

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehabilitation Works — Paved		
US$240,000/km Approximately 0.34% of the PBC paved network was rehabilitated each year.	US$360,000/km Approximately 0.2% of the traditional paved network was rehabilitated each year.	Average 10 m paved carriageway width
Item 2: Pavement Rehabilitation (strengthening) — Unpaved		
US$22,500/km	US$21,000/km	Based upon a 150 mm aggregate overlay compacted Average 5.8 m carriageway width
Item 3: Periodic Maintenance Works		
US$34,200/km	US$32,200/km	Based on a spray chip seal Average 10 m paved carriageway width
Item 4: Routine Maintenance Works		
US$1,250/km/year	US$2,340/km/year	Average annual expenditure
Item 5: Emergency Works Expenditure — Average Annual		
US$74/km/year The WBOP DC PBC required the contractor to be responsible for (and include in their lump-sum price) the first US$530,000 of emergency works within a single contract year. The PBC emergency works cap was exceeded only once over the eventual 12-year term of the contract.	US$2,630/km/year Whakatāne Road Network has suffered damage because of several major cyclone events over the analysis period.	The emergency works expenditure for each contract is averaged over the duration of the contract.
Item 6: Contract Administration — Procurement		
Contractor's bid cost 0.19% of contract price (US$401/km) There were three bidders. Overall procurement cost for the WBOP DC was US$3,500,000 (1.67% of the contract price), or US$360/km/year Procurement savings achieved US$44.2 million	Approximately US$600/km/year	Whakatāne District Council traditional maintenance contractors were selected from various supplier panels: sealed and unsealed pavement maintenance, sign maintenance and renewals, structure maintenance, drainage maintenance and renewals, incident response; and environmental works (for example, tree trimming).

TABLE 3.5: CONTRACT DATA SUMMARY — NEW ZEALAND, CONTINUED

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 7: Contract Monitoring, Supervision and Administration		
3 FTEs at US$514/km/year	US$1,210/km/year	PBC agency supervision fees unknown
Item 8: Non-pavement Maintenance Works		
Bid price of US$219,260,000 (US$18,400/km/year) inclusive of all rehabilitation, periodic maintenance, routine maintenance, and emergency works for 10 years	Prices for all other non-pavement maintenance works are included in above costs/km.	For the Whakatāne District Council traditional maintenance contract, suppliers were selected from a supplier panel for sign maintenance and renewals, structure maintenance, drainage maintenance and renewals, incident response, and environmental works. The suppliers are invited to submit prices for defined work packages Works excluded from the supplier panel are cyclic maintenance, sealed road periodic maintenance (resurfacing), pavement marking, vegetation control, streetlight maintenance, and pavement rehabilitation works

The two networks, one maintained under PBC and the other using traditional contracting, performed well over the period of comparison (2007 to 2013). While the network under a PBC remained very close to the levels of service specified in the PBC and outperformed the national average for comparable roads, the condition of the pavement in the comparison network maintained under traditional contracting exceeded that of the PBC network. This is believed to be because the PBC terms motivated the contractor to achieve but not exceed the contract level of service targets, while the traditional network was managed with a focus on preventing any significant defect from emerging, which resulted in maintenance outcomes that exceeded the service levels specified under the PBC. The difference in pavement condition outcomes is an indication that potential efficiencies were missed in the network maintained under the traditional contracting arrangement. This lends support to the theory that a well-designed and implemented PBC could deliver lower lifecycle costs than traditional contracting approaches.

Another noteworthy outcome is that the PBC contract established a strong emphasis on customer service, including closer monitoring of public perceptions. While the overall condition of the PBC network was not quite as good as the traditional network, the PBC contractor's emphasis on customer-facing aspects resulted in higher customer satisfaction ratings than were achieved on the network maintained under the traditional contracting method.

The WBOP DC PBC is unique among the case studies in that a single PBC encompassed a larger, more diverse, and more complete network than any of the other four PBC case studies. Moreover, as it was in fair to good condition at the start of the PBC, the contractor assumed responsibility for long-term performance of assets that it did not construct. Compared to a design-build-operate-maintain-transfer arrangement, much more extensive data collection and analysis of asset conditions were needed to minimize the risks of lump-sum tendering undertaken by WBOP DC.

The experience also illustrated that even competent and experienced contractors who are familiar with the PBC format could face implementation challenges in complex PBCs. About three years were required for the contractor to adapt to its role fully, including establishing all the required systems and procedures and working out kinks. It established a strong maintenance culture during this time, however, as demonstrated by the PBC outcomes. This experience offered an important lesson for adoption of PBCs elsewhere.

Case Study 5
Botswana

ROADS SELECTED

The Botswana Roads Department initiated two pilot OPBRCs with support of the World Bank. The case study focused on the national roads in Lot 1/Package 1 (123.12 km), which was a 10-year PBC consisting of rehabilitation, improvement, and routine maintenance works. Although Lot 1 included national and local roads, the OPBRC only provided for routine maintenance of national roads A2 and A10. Rehabilitation and improvement works included subgrade, subbase, base course construction with a double surface treatment (DST) and AC surfacing. The rehabilitation phase of this contract was completed, and the contract was in the maintenance phase in many places at the time of the case study data collection.

Traditional contracts selected for comparison for this case study were maintained under a series of annually awarded contracts using local contractors and BoQ rates. Contract lengths for the four contract areas included in this case study are relatively short, ranging from 23 to 40 km. They were located on the A1 Road in South-East District. The total length of the four contracts is 128 km.

The OPRC payments were weighted so that the rehabilitation costs could not be fully recovered during the rehabilitation period, with the remainder recovered through higher maintenance prices. As the OPBRC contractor was only finishing construction at the time of the case study, comparison of the pavement long-term performance of the OPBRC and traditional road works is not possible.

The Lot 1 OPBRC contractor faced significant challenges implementing the OPBRC model. Key personnel mobilized to the site were not familiar with the OPBRC model and personnel changes intended to address this were not immediately effective. Both the personnel initially mobilized to the site as well as their replacement staff had to learn the differences between the OPBRC model and traditional contracts over time in the field. Other challenges included poor work program management, poor management of the subcontracting arrangements, and cash flow challenges. For instance, although the contractor was to be paid for each completed 5 km section, it initiated earthworks in large areas. This delayed completion of segments, and the contractor began to run low on cash. Some works failed IRI and FWD tests. Asphalt overlay was required where double seal was installed improperly. The rehabilitation phase of the contract was also extended on account of contractors' delays. Some of these challenges were related to the contractor's evident misunderstanding of the OPBRC model, while others were not.

TABLE 3.6: CONTRACT DATA SUMMARY — BOTSWANA

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehabilitation Works		
US$153,069/km	US$280,350/km	PBC rehabilitation designs were based on widening and overlay
Item 2: Periodic Maintenance Works		
US$129,539/km (AC overlay)	US$66,825/km (DST)	
Item 3: Routine Maintenance Works		
US$10,513/km/year Rehabilitation costs are not fully recovered in the rehabilitation phase and are paid during the maintenance phase.	US$32,200/km	Both the PBC and traditional maintenance contract used similar specifications.
Item 4: Emergency Works Expenditure — Average Annual		
Lot 1: US$970/km/year Moshupa bridge repairs and river protection works to be completed as emergency works, along with pavement damage from vehicle accident and flood damaged culvert replacement	Data not available	Values equate to the contract allowance only.
Item 5: Contract Administration — Procurement		
Consultant = 370 FTE months for both OPBRCs for development and bidding[16] For 10-year contract = 37 FTE months per year = 0.14 FTE months/km/year	Four annual contracts bid and evaluated taking 5 FTEs × 5 months = 100 FTE months per year = 3.6 FTE months/km/year	The annual procurement of the traditional contracts appeared administratively demanding and time-consuming with each contract taking around five months to prepare, bid, and award.
Item 6: Contract Monitoring/Supervision/Administration		
US$25,938/km (US$2,594/km/year) or 2.95% of the combined contractor's prices for both lots)	US$1,500/km/year or 18.25% of the average contract price	OPBRC administration costs for monitoring and supervision consultant only Traditional contract costs for the contractor's overheads, facilities, and vehicle running only Excludes cost of Road Department personnel
Item 7: Non-pavement Maintenance Works		
All included within the OPBRC scope of works	As itemized above	

16 It has not been possible to verify the indicated level of effort.

Observation from the site visits indicated that, despite the OPBRC implementation challenges, repairs made by the OPBRC contractor were much higher quality than those made under the traditional contracts. This was also true for non-pavement maintenance. Additionally, treatment selection and timing were observed to be significantly worse under traditional contracting. The OPBRC contractor was, in general, more invested in outcomes and more attentive to other issues. For instance, the OPBRC contractor sought to address the need for adequate fencing to keep cattle out of the roadway, which was a significant safety risk and challenge in the case study area. The OPBRC contractor was also more responsive to emergency repairs, which were paid using the reserved provisional sums.

Overall, the Roads Department reported that the OPBRC model was not more difficult to implement than traditional contracting approaches. Substantial work is required to prepare traditional contractors for tender, identify the needed repairs, and verify them. Had the OPBRC contractor better understood the OPBRC model, the OPBRC may have been much easier to implement than traditional contracts.

3.4 Summary of the Case Study Data

Table 3.7 details each of the case study contracts and tabulates the respective financial and economic metrics from each of the contract models.

TABLE 3.7: SUMMARY OF CASE STUDY DATA

	PBC vs.Trad.	Argentina	Botswana
Asset(s) under Contract (existing)	PBC	Approximately 240 km inter-urban roads (two-lane [single carriageway] AC)	123 km of national roads A2 and A10[17]
	Trad.	All primary roads in Catamarca Province that are not under CREMA (averaged)	128 km of national road A-1 under four contracts
Type of Contracts Compared (defect liability period)	PBC	CREMA. Up to two years for rehabilitation and three years for maintenance (defect liability extends to whole contract term)	World Bank OPBRC SBD. Up to three years of rehabilitation and seven years of maintenance (defect liability extends to whole contract term)
	Trad.	Force Account	Annual input-based contracts based on BoQ
Other Contract Details	PBC	CREMA applies to roads with AADT ranging from 1,000 to 4,000. The type of rehabilitation work is specified by the road agency before bidding. Contract includes retentions to be repaid on a performance basis during the maintenance period[18]	Subcontracting allowed for up to 30% of reconstruction/rehabilitation. 10% of contract was provisional sum eligible for funding emergency works
Contract Term	PBC	5 years	10 years
	Trad.	Based on scope of works	12 months
AADT	PBC	NA	NA
	Trad.	NA	NA
Pavement Rehabilitation Works	PBC	(See Periodic Maintenance Works)	US$153,069/km (DBST and AC)
	Trad.	Nil	US$280,350/km

17 The OPBRC included rehabilitation of both national roads and access roads but only provided for maintenance of the 123 km of national roads. The access roads were therefore excluded from the case study.

18 Retentions are held against the rehabilitation payments and are repaid to the contractor during the maintenance period subject to achievement of the performance targets.

Lao PDR	Liberia	New Zealand
600 km of national and local roads (DBST and gravel)	178.7 km Inter-urban highway (two-lane [single carriageway] AC)	1,027 km rural network, of which 69% paved (primarily sprayed chip-seal and gravel)
National and local roads (AC, concrete, and DBST)	51.5 km Inter-urban highway (AC)	902 km rural network, of which 78% paved (primarily sprayed chip-seal and gravel)
PBM. 12 months rehabilitation/major maintenance period and 30-month maintenance phase (12-month defect liability period)	World Bank OPBRC SBD. Up to three years of rehabilitation and reconstruction, seven years of maintenance, and periodic mainte-nance in Year eight (defect liability extends to whole contract term)	PBC. Includes renewals, maintenance, and minimum condition at hand back (defect liability extends to whole contract term)
Annual input-based maintenance contracts based on BoQ	Design-build-transfer based on con-ceptual design	Supplier panel contracts (12-month defect liability period)
Initial works were limited to repair/ patching/improvement needed to reach initial levels of service. Contract included provisional sum for emergency works	No provisional sum for emergency works due to funding constraints. The bid documents limited the bid price for rehabilitation, creating a retention	Contractor responsible for paying up to US$530,000 for emergency works within a single contract year as part of its lump-sum price. PBC included 54 operational performance measures and works encompassed the entire rural network of the District Council
3.5 years	10 years	10 years
12 months	Based on scope of works	Based on scope of works
NA	2,392	433
NA	NA	630
National roads: US$7,000/km Local roads: US$54,000/km	US$669,541/km	US$240,000/km
Not part of the traditional input contracts	US$538,531/km	US$360,000/km

TABLE 3.7: SUMMARY OF CASE STUDY DATA, CONTINUED

	PBC vs.Trad.	Argentina	Botswana
Periodic Maintenance Works	PBC	US$15.57 million = US$64,875/km (the PBC included very little full-depth rehabilitation; rehabilitation typically comprised 4–5 cm overlay)	US$129,539/km (AC overlay)
	Trad.	Periodic maintenance (typically 200–300 mm overlay) occurs under Force Account only by exception. See Routine Maintenance Costs	US$66,825/km (DBST)
Routine Maintenance Works	PBC	US$1,700/km/year	US$10,513/km/year
	Trad.	US$2,247/km/year (Note: This rate includes emergency works and some periodic maintenance)	US$8,190/km/year
Emergency Works Expenditure — Average Annual	PBC	Nil	Lot 1: US$970/km/year
Contract Administration — Procurement	PBC	Approximately US$50,000 for 3 FTE for 6 weeks	Consultant = 370 FTE months for both OPRCs for development and bidding. For 10-year contract = 37 FTE months per year = 0.14 FTE months/km/year
	Trad.	Nil	4 annual contracts bid and evaluated taking 5 FTEs x 5 months = 100 FTE months per year = 3.6 FTE months/ km/year
Contract Monitoring/ Supervision/ Administration	PBC	Approximately US$1.0 million = US$4,100/km	US$25,938/km = US$2,594/km/year or 2.95% of the combined contractor's prices for both lots
	Trad.	US$1,000/km	US$1,500/km/year or 18.25% of the average contract price

Lao PDR	Liberia	New Zealand
Not part of the PBMs	US$212,689 /km	US$34,200 /km
Not part of the traditional input contracts		US$32,200/ km
National roads = US$3,145/km/year Local roads = US$1,590/km/year	Payment - US$46,611/km/year Estimated actual routine mainte-nance cost US$9,322/km/year	US$1,250/ km/year
US$650/km/year	Estimated expenditure — US$1,394/km/year	US$2,340/km/year
US$170/km/year for national roads US$310/km/year for local roads.	US$842/km/year	US$74/km/year
Unknown. Bid every 3.5 years	Bid cost 0.235% of contract price (US$2,836/km)	US$360/km/year
Bid cost unknown. Bid annually	Bid cost unknown	US$600/km/year
Administration costs unknown	US$47,818/km or 5.1% of contractor's price — covering both rehabilitation, routine maintenance and periodic maintenance works	US$524 /km/year
Administration costs unknown	US$36,980/km or 5.2% of the contractor's price — rehabilitation phase only	1,210 US$/km/year

3.5 Road O&M Scenario Simulation

Based on the data obtained through the case studies, multiple road asset management strategies commonly utilized in PBC and traditional contracting approaches were simulated as part of this study to compare long-term economic benefits under different contracting approaches. The study used HDM-4 workspaces calibrated to three of the case study countries (Argentina, Liberia, and Lao PDR) to estimate and compare lifecycle economic costs and benefits of various road investment and O&M scenarios. The scenarios simulated in this analysis include (a) preventive maintenance strategies, which are normally required by the PBC approach, and (b) reactive maintenance strategies, which are commonly observed under the traditional contracting approach. To assess various road and traffic characteristics, the simulation compared 32 intervention scenarios of initial investment and O&M approaches under three starting road conditions (good, fair, and poor) and three traffic bands (AADT of 750, 3,000, and 7,500).

The findings indicate that road asset management strategies that emphasize preventive maintenance are highly cost-effective in these case studies. Moreover, although confidence in the data is only medium, the simulations showed that more intensive maintenance was more important to lowering lifecycle costs than the level of investment in the initial construction. These findings support the underlying theory that preventive maintenance strongly promoted by well-designed PBCs can help lower lifecycle costs for road agencies as well as increase road user benefits by preventing road deterioration. The details of the simulation are provided in Appendix 6.

3.6 Data Collection Challenges and Their Impact on the Study

Considering its objectives, the study gathered as much information as possible to undertake a comparative analysis, based on both hard data and other information, of PBCs and traditional civil works and maintenance contracts. The comparative analysis was to focus on economic efficiency, user benefits, challenges, advantages, and disadvantages. Despite extensive efforts and the collection of a substantial amount of information and data, it turned out that it was not possible to obtain sufficient data which would enable a reliable and robust quantitative comparison of the two contracting modalities in terms of lifecycle costs or economic benefits.

A meaningful comparison would have required the following characteristics:

- Several contracts of each type (PBC and non-PBC) in the same country, with both types of contracts covering a sufficient length of similar roads, so that comparisons would be statistically relevant.
- For comparing lifecycle costs, both types of contracts would need to have resulted in similar service levels and work standards and been carried out on roads with similar characteristics and in similar climate zones.
- Clear information on the actual expenditures incurred by the road agency for each contract during long periods.
- Contract durations sufficiently long to cover the life cycle of the pavement.

Upon close inspection, the case study data from the various countries had several limitations:

- They lacked sufficient detail, for example, historical cost data of contracts.
- They covered only a relatively small length of roads or very few PBCs, which means that they were not statistically relevant.
- The service levels achieved through the PBCs were not comparable with the service levels on other parts of the road network.
- Data were only available for one of the two contracting approaches, but not for both the PBCs and traditional contracts.

The detailed assessment of the data sets for the case studies revealed the following:

- The amount and scope of available data were different for the various case studies. While some case studies had a large volume and scope of data (for example, Liberia), others had very little useable data (for example, Florida).
- None of the six case study data sets had all the required information to undertake a comparison and ex post economic analysis of PBCs and traditional contracts on all the attributes listed above. Moreover, the shortcomings were in terms of both data density and data completeness. The problem was twofold: (a) most of the data sets had no information on several of the attributes and (b) only three data sets had information that would allow comparing PBC and non-PBC situations to at least some degree.

Table 3.8 summarizes the available data and the data gaps identified with reference to the attributes established above. In the table, '√' indicates available data while 'x' indicates that data are not available. Without accounting for quality of the information, only around one-third of the data sought for the study were available from the case study road agencies. Although more information was available for PBCs than for traditional contracts, only Botswana and New Zealand were able to provide the majority of the information sought for the PBCs. To overcome the data issues of the case studies, the study team made a significant effort to collect additional data from other countries. These efforts are described in Section 4.2.

TABLE 3.8: DATA FROM THE SIX ORIGINAL DATA SETS RECEIVED AND DATA GAPS

Details	Argentina		Botswana		Florida (U.S.)		Lao PDR		Liberia		New Zealand	
	PBC	Trad.	PBC	Trad.	PBC	Trad.	PBC	Trad.	PBC	Trad.	PBC	Trad.
No. 1: Cost of various work types												
Improvement/ rehabilitation	X	X	✓	✓	X	X	✓	X	✓	✓	✓	X
Periodic/resealing maintenance	X	X	✓	✓	X	X	X	X	✓	✓	✓	X
Routine maintenance	X	X	✓	✓	✓	✓	✓	X	✓	✓	X	X
Emergency works	X	X	✓	X	X	X	✓	X	X	X	X	X
No. 2: Contract administration and monitoring costs												
Monitoring/ supervision costs	X	X	✓	X	X	X	X	X	X	X	X	X
No. 3: Travel time benefits												
Vehicle-kilometer travelled	X	X	X	X	X	X	X	X	X	X	✓	✓
No. 4: Vehicle operating costs (VOC)												
	✓	✓	X	X	X	X	✓	✓	✓	✓	X	X
No. 5: Vehicle crash costs												
Vehicle crashes/km	X	X	X	X	X	X	X	X	✓	X	✓	X
No. 6: Environmental impacts												
Vehicular emissions	X	X	X	X	X	X	X	X	X	X	X	X
No. 7: Customer satisfaction												
Surveys	✓	X	X	X	X	X	X	X	X	X	✓	✓
No. 8: Nonfinancial benefits												
Advantages/ disadvantages	✓	X	✓	X	✓	✓	✓	✓	✓	✓	✓	✓

Note: ✓ = Data available; X = Data not available.

4

Comparative Analysis of Performance-Based Road Contracts and Traditional Contract Methods

4.1 Introduction

The two objectives of this chapter are to (a) describe the work undertaken under this study towards carrying out a comprehensive comparison of the PBC and traditional contracting approaches using the available information and the data sets from the case studies and others, and (b) utilize the available evidence to evaluate, as much as possible, whether aspects that are vital to achieving efficient road asset management were present in the PBCs for which data were provided.

As described in the previous chapter, it turned out during the study that the data collected through the case studies were insufficient to carry out a meaningful comparative evaluation of the life-cycle cost of roads managed under PBC versus traditional contracting methods. This chapter therefore begins with a description of the efforts made by the study team to gather additional data and the results obtained. The chapter then presents the main findings of the comparative analysis that was actually possible, grouped in the following sections: Section 4.3 presents a summary of key qualitative findings; Section 4.4 presents the quantitative findings that were available based on case studies; Section 4.5 describes trade-offs of the different contracting approaches. In the last two sections, 4.6 and 4.7, the chapter discusses the study's findings on the impacts of PBCs on fiscal space of governments, on social and environmental management, climate resilience, and on road safety.

4.2 Gathering Additional Data

To overcome the insufficiency of data obtained through the six case studies, two additional data collection efforts were undertaken.[19] The first one consisted of the collection of additional information and data on 16 PBCs awarded between 2005 and 2017 in Georgia, Thailand, Egypt, Yemen, Bangladesh, Albania, China, India, Tonga, Papua New Guinea, and Tajikistan. The additional data gathering also included a second PBC project implemented in Liberia.

The second additional effort was undertaken to gather data from several Nordic countries that are known to have applied at least some of the principles of PBC. This very substantial effort was undertaken through dialogue with officials in road agencies in Denmark, Sweden, Norway, and Finland, with the objective of obtaining data sets which would allow a quantitative comparison of lifecycle costs between PBCs and traditional road works contracts.

This additional data gathering effort yielded the following results:

- A substantial amount of additional information was obtained, but it was primarily qualitative in nature. The full amount and quality of quantitative data which was identified in Section 3.4 as necessary for the comparative analysis was, however, not available from the additional projects and sources described above.
- The additional information (and, in some cases, the additional data) obtained were for PBC projects only; comparator data were not available for similar road works implemented through traditional civil works contracts on similar roads in the same countries.
- Many countries, including developed ones, do not keep records of historical contract data for specific road sections that are older than five years; this makes it difficult to estimate lifecycle costs under traditional civil works contracts.
- Several PBCs for which information was obtained were in the initial stages of implementation and therefore not suitable for the intended analyses.

The additional data did, however, provide a better basis for evaluating the 'success factors', risks, and drawbacks for PBCs.

4.3 General Findings

The findings of a general nature from the case studies and the review of 22 additional data sets, and the discussion with road agencies of Nordic countries, are the following:

a. **Design responsibility**. In over 90 percent of the reviewed PBCs, the contracts did require road rehabilitation works and delegated design responsibility to the contractor. In all those cases, the road agency provided at least a conceptual design at the bidding stage. In many cases, a detailed design was provided. The objective of providing a design is to reduce the risk to the employer that bidders estimate wrongly the nature and volume of works required, and subsequently offer prices for rehabilitation works that are either much too low or too high, with underestimation of costs being the bigger risk. The team found that including either conceptual or detailed designs for all major rehabilitation and improvement works, and the definition of clear design requirements (including minimum pavement strength in terms of accumulated standard axles) is considered a necessary feature of PBCs. On the other hand, this means that PBCs involving road rehabilitation require the completion of fairly

19 The expanded data sets are presented in Appendix 5. The appendix table presents the following main contract features of each of the additional data sets: contract scope (activities covered), contract type (hybrid or pure PBC), network size covered, contract duration, financing source, level of skill set needed by parties to the contract, payment conditions incentives, risk allocation, and so on.

detailed technical studies during the preparation stage. This, in turn, means that project preparation for PBCs involving rehabilitation is generally not cheaper and quicker than for traditional rehabilitation works contracts.[20]

b. **Timing of rehabilitation works and periodic maintenance.** About 70 percent of the reviewed PBCs required that the contractor carry out rehabilitation and/or improvement works during the first two years, followed by maintenance services. Less than 10 percent of the PBCs reviewed involved routine maintenance only. The remaining 20 percent of contracts involved a combination of parallel execution of periodic maintenance works and routine maintenance services. About half of the reviewed PBCs had provisions for emergency works. In contrast, traditional contracts did not typically provide for emergency works or include downstream periodic maintenance; instead, the need for these activities would be identified through the annual planning and budgeting exercises, often resulting in significant delays for those works due to procurement processes (for instance, in Botswana) or budget processes.

c. **Sequencing of rehabilitation and maintenance.** Most of the contracts reviewed were prepared on the basis of the previous version of the World Bank's SPD for OPBRCs and covered individual roads in deteriorated conditions that required initial rehabilitation. Those contracts defined a 'rehabilitation phase' during the early part of the contract period, followed by a 'maintenance phase' which started after the rehabilitation works were completed. As most contracts did not include service-level requirements during the rehabilitation phase, road users were not assured of reasonable service levels during the rehabilitation works. This was a shortcoming in many contracts that has led to poor quality of service-level outcomes during the rehabilitation phase. This shortcoming was, however, addressed in the new 2021 version of the World Bank's SBD for OPBRC and the sample specifications, where the idea of a 'rehabilitation phase' followed by a 'maintenance phase' was abandoned and replaced by parallel execution of both rehabilitation and maintenance.

d. **Bunching of works and cash flow early in the contract period.** Under most PBCs reviewed, the rehabilitation works constitute a large share (typically above 70 percent and sometimes above 80 percent) of the total contract amount. This gives rise to the risk that contractors may lose interest in the contracts once the rehabilitation works are completed. This risk is only partially attenuated by provisions, in some of the bidding documents, that the contractor's bid price for rehabilitation works is capped at a certain percentage of the total bid price. In some contracts (for example, in Liberia), the payment structure was therefore formulated such that the contractor could not make any profits during the rehabilitation phase; all profit taking would have to occur during the maintenance phase, with the intent of keeping the contractors involved and interested throughout the contract period. This practice of capping the price of rehabilitation works does, however, entail significant price distortions between rehabilitation works (for which the contract prices appear less expensive than they really are) and maintenance services (which appear more expensive than they are). There is, however, no possibility of knowing the exact degree of these price distortions. As a result of these price distortions, the reliability of any comparative analysis of each cost element (such as rehabilitation, periodic maintenance, and routine maintenance) between PBCs and traditional contracts would have been low.

e. **Contract duration and transfer of risk related to the quality of pavement rehabilitation.** The risk transfer for the quality of rehabilitation works did not materialize under all of the reviewed PBCs because contract durations were usually shorter than the pavement design life. While the expected life of an AC pavement is typically 15–20 years, the typical duration of the PBCs was much shorter, with the most common contract duration being 5 years, which is far below the expected pavement life span. The relatively short contract duration (five years or less) was often dictated by IFIs' reluctance to fund projects with a duration beyond five years. Short contract periods are sometimes also attributable to legal requirements (Argentina) and the use of weaker and more short-lived pavements, such as DBST.

20 Evaluation of the case studies found that procurement costs for PBCs are generally lower for the same scope of services, that is, when comparing a single PBC to multiple traditional contracts for rehabilitation and maintenance over a five-to-ten-year period.

As pavement defects arising from substandard construction quality typically occur only after several years, in the case of a PBC with a duration of five or fewer years, defects are likely to become apparent only after the end of the contract, when the contractor is no longer obligated to remedy such defects. The intended risk transfer did occur to some degree in only very few PBCs with durations of 10 years or more. It is to be noted, however, that a five-year PBC is perfectly adequate for unpaved roads, where the road surface (typically gravel) needs to be reworked/renewed fairly frequently.

f. **Requirements for pavement works later during the contract period.** Only a few of the contracts reviewed (in Georgia, Liberia, and India) included a requirement for a minimum residual pavement life. These were also the PBCs with the longest contract duration. Some bidding documents (for Liberia and Papua New Guinea) stipulated that the contractor had to carry out periodic pavement maintenance works (such as overlays) toward the end of the contract period, before handing over the projects. This also resulted in spreading out pavement works during the contract period (that is, reduced bunching of works in the beginning of the contracts). This feature of 'staggered' pavement works for different road sections is also present in some new PBCs funded by the World Bank which are currently under preparation or under procurement (Niger and Chad). This approach carries certain risks, however; if traffic volumes are lower than expected and part or all the overlay is not needed, the road agency would need to renegotiate this aspect of the contract. A second risk is that planning the pavement strengthening measures and overlays many years in advance reduces road agency flexibility to shift spending priorities among different parts of the road network. These risks have materialized to some degree in Liberia.

g. **Hybrid PBC versus full PBC.** About 62 percent of the bidding documents reviewed by the team entailed hybrid PBCs, where the rehabilitation and improvement works were paid on the basis of traditional priced BoQs (listing unit prices and quantities of work to be executed). This opened the unwanted possibility that contractors would push for unnecessary design modifications during contract execution that would increase quantities and therefore the overall contract price. There was, however, no information whether this undesirable scenario materialized in practice. Generally, the high share of hybrid PBCs shows that many employers are not yet comfortable with the concept of lump-sum payments for rehabilitation and improvement works, and pro rata payments of those lump sums on the basis of actual progress in completing certain milestones.

h. **Length of roads covered under PBCs.** The lengths of roads covered by individual PBCs varied from 17 km to over 400 km. This is partly due to the considerable variation of conditions in the various countries that used PBCs and the different types of roads covered (urban and non-urban).

i. **Quality of technical preparatory work.** Some bidding documents and specifications were prepared on the basis of grossly inadequate technical preparation, particularly an inadequate or outright wrong assessment of the roads before bidding. This issue was sometimes exacerbated by the long time elapsed between undertaking technical preparation studies and the actual signing and start-up of the PBCs. This problem in some cases resulted in low-priced bids that did not reflect the true extent of rehabilitation works needed to achieve the required service levels. While this would, in theory, be the contractor's risk, in reality these contracts were often amended through negotiations between the road agencies and the contractors, which resulted in higher contract prices or lower service levels than included in the original bidding documents and the bids of winning contractors.

j. **Funding source.** Nearly 85 percent of the PBCs reviewed were financed by IFIs such as the ADB, the World Bank (IBRD or IDA),[21] Pacific Region Infrastructure Facility (PRIF), and Public-Private Infrastructure Advisory Facility (PPIAF). Most of these projects were in developing countries where maintenance financing is typically insufficient. Among the developing countries, only Bangladesh and Papua New Guinea had self-funded PBCs.

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21 IBRD = International Bank for Reconstruction and Development; IDA = International Development Association.

k. **Island syndrome.** Some PBCs, especially successful ones undertaken for a limited part of a road network or conducted as a pilot project, resulted in 'islands of good roads in a sea of bad roads'. This is commonly seen in countries which are largely dependent on IFIs for funding road investments. The level of service set under these PBCs was often far above what was affordable for the country as a whole, given the severe limitation of domestic maintenance funding. The fact that road agencies do not typically utilize levels of service for planning interventions on the road network may have been a further contributing factor to the 'island syndrome'. In such cases of 'island PBCs', the concept of PBC as such was proven to be successful and feasible, but the intended expansion or 'mainstreaming' of the PBC model to large parts of the road network was outside the financial reach of the country and could not be pursued. In Zambia, the World Bank project addressed this issue by reducing the scope and the required levels of service of PBCs to expand implementation to additional roads in the network, while maintaining the principles of PBC and remaining within the existing available budget.

l. **Use of World Bank SBDs for OPBRCs.** For PBCs where IFIs were the funding source (which was the case for almost all PBCs in developing countries), the contracts were prepared on the basis of the World Bank's earlier SPD and model specifications for OPBRCs. While this meant that they had a similar contractual framework and similarly framed performance criteria, there were nevertheless important differences in several aspects, such as the level of detail for defining performance requirements, the presence (or rather the absence) of clear procedures for verification of compliance and for application of payment reductions, the quality assurance framework, monitoring arrangements, and other differences. The World Bank's SPD was published in 2006 and remained mostly unchanged in its essential provisions, with only minor changes introduced to reflect the World Bank's changing institutional requirements on environmental, social, and procurement aspects. The practical use of the SPD and the model specifications since 2006 led to many lessons learned, which in 2021 led to a major revision of the two documents by the World Bank.

m. **Ease of implementation.** Some data sets had information (mostly of anecdotal nature) on the ease (or difficulty) of implementation. Most of the 'failed' PBCs did fail before they effectively got started. At least one contract was never awarded due to exorbitant bid prices (Egypt). This was apparently due to inadequate preparation of bidders, who did not understand the concept of PBC. Other contracts were awarded and started, but were not completed due to various reasons, including the outbreak of civil war (Yemen). For other contracts, inadequate technical preparation contributed to serious implementation challenges (Lao PDR and Albania) and major adjustments to the contracts had to be carried out during implementation (Albania). For yet other contracts, implementation stopped when the government was unable to pay for its share of the funding. Inadequate contractor performance was a major challenge in Botswana.

n. **Monitoring arrangements.** Most of the sampled PBCs from Asian countries (that is, Bangladesh, India, Tonga, and Papua New Guinea), regardless of project size, preferred to carry out the monitoring/supervision of PBCs directly in-house through the implementing agency, as they also do for traditional road works contracts. This revealed those implementing agencies' preference for more direct control over the projects. Nearly all other countries relied on engineering consulting firms for contract monitoring/supervision, both under PBCs and traditional contracts.

o. **Advance payment.** Only about half of the reviewed bidding documents for PBCs provided for advance payments to contractors. About 25 percent of the bidding documents offered incentives to contractors in terms of bonuses for early and satisfactory completion of rehabilitation works.

p. **Price adjustment.** Provisions for price adjustment during the contract period were included in most PBCs due to their relatively long duration and the likelihood of price fluctuations for inputs needed by the contractors.

q. **Risk evaluation and risk sharing.** Only a few of the bidding documents reviewed included a more detailed description of risk sharing and risk allocation than what is found in the standard World Bank contract template. Apart from force majeure and similar 'catastrophic' events that are covered in all PBCs, most countries did not prepare a detailed risk-sharing strategy. Of all the contracts reviewed, only Liberia and India made provisions for the payment of compensation to the contractor if traffic volumes and axle loads exceeded the estimated values.

r. **Variation among PBCs.** While in developing countries most PBCs were (and continue to be) based on the World Bank's SPD and model specifications, the situation is different in developed countries. Almost each developed country using PBCs has its own version of PBC model documents, and sometimes different versions exist contemporaneously. Furthermore, PBCs in the same country have usually changed and developed over time, sometimes based on lessons learned during implementation and in other cases due to changing political priorities or budget constraints. Many PBCs in developed countries only have some performance-based elements, usually related to routine maintenance, but rely on traditional concepts of quantity-based contracting for all periodic maintenance and rehabilitation works.

4.4 Comparison of Economic Costs for Rehabilitation and Maintenance under PBCs and Traditional Contract Methods

Of all the data sets obtained and evaluated, only two (for Botswana and Liberia) included the data necessary to undertake at least some degree of comparative numeric analysis between PBCs and traditional civil works/maintenance contracts. For those two cases, the study team calculated and compared the annual average costs per km for rehabilitation works and maintenance services between PBCs and traditional civil works contracts.

Assumptions made. In carrying out this comparative assessment, the study team assumed that the roads under consideration for the two contracting approaches were comparable in terms of (a) road characteristics, (b) initial road condition before rehabilitation, (c) scope and quality of road rehabilitation, and (d) the service level actually maintained by contractors.

Price distortion in PBCs. As already pointed out earlier in this chapter, most PBC bidding documents place a ceiling on the bid price for rehabilitation works as a percentage of the total bid price. For instance, a PBC may specify that the contractor's bid price for rehabilitation works cannot exceed 50 percent of the contractor's total bid price, even if the actual cost is estimated to be much higher. Such caps did also exist in the PBCs for Botswana and Liberia, and most probably skewed the results of the comparative analysis to a significant extent, since it is unknown what the contractor's bid prices for rehabilitation and maintenance would have been without this artificial restriction. This issue may have further reduced the reliability of the results obtained.

Overall, it is suggested to take the results of the comparison as indicative only.

TABLE 4.1: COST DIFFERENCES BETWEEN PBC AND TRADITIONAL CONTRACTS (BOTSWANA)[22]

Work Type	Botswana		
	PBC Contract (US$/year/km)	Traditional Contract (US$/year/km)	PBC Cost as % of Traditional Contract Cost
Improvement/ rehabilitation works	182,649	471,444	38%
Periodic maintenance (resealing)	77,763	123,798	63%
Routine maintenance	20,759	14,385	144%

TABLE 4.2: COST DIFFERENCES BETWEEN PBC AND TRADITIONAL CONTRACTS (LIBERIA)[23]

Work Type	Liberia		
	PBC Contract (US$/year/km)	Traditional Contract (US$/year/km)	PBC Cost as % of Traditional Contract Cost
Improvement/ rehabilitation works	173,584	580,000	30%
Periodic maintenance (resealing)	165,447	150,000	110%
1,300%	13,073	1,000	144

In the case of Botswana, the numbers indicate that considerable savings seem to have been made in improvement/rehabilitation works and periodic maintenance but not for routine maintenance works. In the case of Liberia, savings were made in improvement/rehabilitation works but not for periodic and routine maintenance works. It is, however, not clear to which degree this result is caused by the price distortion between rehabilitation works and maintenance services.[24]

Savings in the cost of rehabilitation and periodic maintenance works would broadly confirm the rule of thumb which has been known for many years among road professionals: One additional dollar spent on maintenance will reduce the long-term cost for rehabilitation and reconstruction by about three dollars.

It does, however, appear from simple observation of roads in Botswana and Liberia that the higher cost of routine maintenance under PBCs is accompanied by a higher and more constant service level, which is maintained on a day-to-day basis during the entire contract period. This means that the original assumption made of a similar service level for both cases may not be true. None of the other roads in those

22 The cost data shown here are estimated based on the actual contract data obtained from the case study and additional research after the case study. Accordingly, the values are slightly different from the case study.

23 Same as above.

24 The Liberia contract did, however, cap the bidding price for rehabilitation and improvement works, which most probably distorted the price. Had the contractor been free to set his price for rehabilitation and improvement work, this price would have been higher (and the price for maintenance services lower) although it is unknown by how much. In theory, a contract could include a financial model that differentiates the rehabilitation and maintenance costs, but the differentiation among those is not always possible even if a financial model is available.

countries that are maintained under traditional contracts appear to be in a similarly good condition as the roads maintained under PBCs. This would indicate that one cannot necessarily assume that the data on maintenance costs under PBCs and traditional contracts are comparable and that the reliability of the results of this comparison is fairly low.

4.5 Analysis of Noneconomic Benefits and Risks Associated with PBC and Traditional Contract

It is a fact that the number of PBCs being prepared and implemented worldwide has steadily increased during the past years. More and more countries are using PBCs, mainly developing countries, with the encouragement and funding from IFIs such as the World Bank. The increase in PBC use is more robust in developing countries than in developed countries, where the share of the road network under PBCs continues to be relatively small. PBC principles are also being introduced through road concessions which have become widespread worldwide.

PBC advantages that have been identified by road professionals knowledgeable about PBC are mostly long term and are the following:

- **Cost/revenue predictability.** Once a PBC is awarded, the payments due to the contractor can be budgeted and programmed over the long term (at least for the term of the contract) with reasonable certainty. PBCs also provide a more certain income stream for the contractor, which enables the contractor to in turn engage subcontractors and make an investment in upskilling their staff and buying new plants to deliver more efficiently over the term of the contract. For instance, in Liberia, the 10-year OPBRCs created an incentive for contractors to invest in training local labor and reduce reliance on foreign staff. This has increased local employment opportunities and skills and contributed to the development of local enterprises.
- **Consistency of outcome.** PBCs tend to result in more consistent and often better maintenance of pavements and other road assets, particularly ancillary assets such as drainage (which increases resilience), signs, and striping/line marking (which increases safety).
- **Increased responsiveness to defects.** Contractors respond more quickly when defects are found because defects are linked to contract performance which is linked to payments. For example, in case of a pothole repair, the traditional contractor would probably prefer to have a bigger pothole to repair than the PBC contractor. Also, the expectations and outcomes under PBCs are better defined, performance is measured and monitored, and it is easier for untrained eyes to see when performance is not being met.
- **Risk transfer.** Under PBCs that are sufficiently long to cover the pavement life, the risk transfer to the contractor provides greater clarity to all parties about who owns and manages the risks—particularly the risks of poor workmanship. It is in the contractor's interest to manage these risks and undertake higher-quality work to avoid having to redo the work or risk reduced contract payments. However, under a traditional contract, the national or local agency will typically carry the quality risk when the defects warranty period is over (typically one year after the works are completed).
- **Easier to administer and manage.** Generally, apart from the initial procurement and contract establishment period, a well-designed and well-prepared PBC executed by a qualified and capable contractor is typically easier to administer and manage for the road agency. On the other hand, a less-well-prepared PBC or one executed by a less-capable contractor can become impossible to implement in an orderly fashion and may become a serious problem for the road agency.
- **Increased ownership of the network by the contractor.** Because of the nature of PBCs, the contractor must take ownership of the network during the contract period. This requires a great deal of trust between the client and the contractor, partly because the public will judge the client (road agency) far more than the contractor working for the client. But the client will only be able to require the contractor to perform up to the level specified in the PBC. Therefore, the details of the performance measures and indicators in the tender and contract documentation are vital to how the PBC and the contractor will perform.

- **Enhanced innovation.** The feedback and evidence from some of the case study countries were that when there are well-established outsourcing markets, the introduction of PBC can stimulate innovation by the contractor.
- **Lower overall procurement cost.** The initial procurement costs for PBCs is usually higher for both the employer and the bidder. However, for the road agency, there is a reduction in procurement cost in the long run due to the much longer contract duration and the smaller number of contracts tendered.
- **Longer tenure.** The longer contract period for most PBCs leads to better staff retention and hence knowledge retention, mainly within the contractors and sometimes also within the road agency. Over time this has significant benefits in managing contracts, building trust, and delivering quality outcomes.
- **Better targeted investment.** Generally (because of the need to have successful contracts), PBCs have better-defined outputs and outcomes, the risks are better quantified and understood, and the financing is more certain, which together lead to more effective and efficient investment by the agencies.
- **Road condition data.** Because the collection and delivery of road condition data is a performance indicator linked to payments under many PBCs, a road agency can automatically collect historical and updated road condition data, which is crucial to improving road asset management over time.

The challenges and disadvantages of PBCs that have been identified are the following:

- **The technical preparation of PBCs.** The technical preparation for PBCs is more complex than for traditional contracts and requires qualified professionals who may not easily be found, particularly for countries where PBCs are not common yet. The availability of fully updated road and pavement condition data within the framework of the RAMS is a highly desirable precondition for high-quality technical preparation of PBCs. If such data are not available, the risk of design failures for the OPBRC greatly increases. Specific and in-depth technical studies must be carried out to establish the pre-bidding road network condition, the appropriate service levels to be applied under the contract and the allocation of risks between the employer and contractor
- **The preparation of the contract document and the specifications.** The skills required for preparing the OPBRC contract document and the technical/performance specifications are higher for a PBC than for a traditional contract. Qualified professionals for carrying out this task are difficult to find, especially for developing countries.
- **The potential loss of agency capacity.** The number of road agency staff required to administer contracts will diminish if traditional maintenance contracts are replaced by PBCs on a larger scale. This could result in an erosion of knowledge within the road agency.
- **The time needed to change the culture.** Because of the need for culture change in preparing, managing, and supervising road work contracts, it can take time to embed the PBC culture in staff of road agencies and contracting firms.
- **The potential loss of control by the employer.** For the road agency, a shift to PBC means that the agency is no longer involved in the day-to-day delivery of management and maintenance activities. This can also lead to a view that there is a loss of transparency about contractor activities. This change in focus can develop into a loss of ownership of the road network by the road agency.
- **Reskilling/upskilling.** If a road agency moves from traditional contracts to PBCs, the agency staff managing the contract will need a higher skill level and broader experience than previously needed to manage the contractor effectively. This is especially difficult for developing countries.
- **Contractor skill may not be available.** For the contractor to achieve maximum efficiency, the staff need to have higher skills to determine and execute the tactical decision-making that PBCs require. Such skill may not be available in some countries.
- **Choosing the wrong contractor has consequences.** Choosing the wrong contractor to undertake a PBC can be disastrous (and there are some examples of this in the case studies). This is because the term of the PBC is much longer than in most traditional contracts, and the cost for the road agency of terminating the contract in case of persistent contractor failure to meet performance requirements is high.

- **Reduced flexibility for adjusting the agency budget.** At times of fiscal strain, governments will find it difficult to cut expenditures under PBCs due to the long-term commitment made through those contracts. While this is a good thing for the roads and road users, it is often seen as a problem by governments.
- **Termination of contracts due to noncompliance of contractor.** Although most contracts include provisions allowing the road agency to terminate the contract in case of persistent failure to comply with service-level requirements, very few, if any, contracts ever do get terminated, even if the contractor's performance is not good. In most cases, termination is considered a greater problem for a road agency than trying to 'muddle through' somehow. This is because termination requires a new procurement process and leaves the road without maintenance until the new contract is procured.

4.6 Effects of PBCs on Fiscal Space

Road works and the long-term maintenance of road networks always involve large public expenditures which make up a significant share of public budgets. The term 'fiscal space' often comes up when those expenditures are partially or fully funded through borrowing by public entities. The funding agencies evaluate if there is sufficient 'fiscal space' to allow additional loans without introducing excessive budgetary risks or rigidity. In other cases, the term 'fiscal space' is used to describe the amount of money the government will have available in the future to spend over and above what it is already spending on public services.[25]

Thus, PBCs affect fiscal space in the following ways:

- **Flexibility.** PBCs, especially long-term PBCs, do commit public agencies to certain spending levels for substantial periods in the future and therefore reduce the fiscal space in terms of future flexibility for adjusting spending that may be needed, for example, in case of revenue shortfalls or when there are cases of large-scale emergencies when unexpected government spending is needed. This reduction of spending flexibility becomes especially critical if a large part of the road sector budget is committed through long-term PBCs. Since long-term PBCs may not be limited to the road sector alone but may cover other infrastructure (airports, ports, water supply systems, power distribution networks, and so on), a government policy of large-scale PBCs in several sectors may severely reduce the government's flexibility to adjust spending in response to changes in spending priorities or the need to respond to emergencies.
- **Cost reduction.** PBCs will increase fiscal space if they do lead to a reduction in the long-term expenditures for the upkeep of road networks. This may potentially be the case in some developed countries that have a history of maintaining their road networks well. However, the widespread introduction of PBCs in those developing countries which have so far allocated insufficient funding for the upkeep of its road networks would almost certainly reduce fiscal space dramatically, to the extent that such widespread introduction of PBCs would become impossible. This is because in those countries, the long-term performance requirements in terms of road conditions will almost certainly lead to a higher maintenance spending per km of road and thereby to the need to allocate more funding for road maintenance. The result will be reduced fiscal space. Conversely, when a developing country has through use of PBCs reached a stage where its road network is largely maintainable, the reduced need for capital investments for rehabilitation works will result in opening up of the fiscal space.
- **Revenue growth.** On the other hand, improving road conditions could eventually lead to better economic growth and higher tax revenues for the government and thus offset the higher spending for improved road conditions. The degree to which the higher spending is compensated by higher revenues would determine if fiscal space increases or decreases. The average traffic density on the road network and the government's ability to make road users pay, through road tolls or fuel levies, will determine if revenue growth can be achieved as a result of the implementation of PBCs.

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25 For instance, Heller (2005) defined it as "room in a government's budget that allows it to provide resources for a desired purpose without jeopardizing the sustainability of its financial position or the stability of the economy."

In summary, the effect on fiscal space when moving from traditional contracts to PBCs depends on various factors and conditions, as described above. The data which are available for this study do not allow to go beyond the rather general statements on how PBCs may affect flexibility, cost reduction, and revenue growth and thereby fiscal space.

4.7 Effects of PBCs on Social and Environmental Management, Climate Resilience, and Road Safety

PBC and traditional contract modalities are not inherently different in respect to social and environmental management and road safety strategy implementation. In any given country, the bidding documents and specifications for PBCs and traditional civil works/maintenance contracts will probably have the same requirements, which are those imposed by the road agency itself and the national legislation, and regulation on environment and social aspects of civil works.

There may, however, be one difference. In traditional civil works contracts, the employer prepares the Environmental and Social Impact Assessments (ESIAs) and Resettlement Action Plans (RAPs) on the basis of the final design which is imposed on the bidders through the specifications. In PBCs, however, the contractor is responsible for the final design, and the final version of the ESIA and RAP can in principle only be prepared (or at least finalized) after the employer has accepted the contractor's final design. This is, however, not a real issue for most PBCs, where (a) the contractor's final design follows the existing alignment of the road, (b) the general characteristics of the rehabilitation works are well known in advance and reflected in the preliminary (or detailed) design included in the bidding document, and (c) the design modifications made by the contractor rarely are so substantial as to require a change in the ESIA, Environmental and Social Management Plan, and/or RAP.

For the PBCs with no preliminary or detailed design proposed by the employer, a greater reliance on environmental and social frameworks is required rather than on site-specific social and environmental documentation.

Concerning climate resilience, it is reasonable to assume that the long-term nature of the PBCs and their imposition of continuous requirements for the integrity and cleanliness of the drainage structures along the road would result in a higher climate resilience of a road than under traditional civil works contracts, where the continuous cleaning and repair of drainage structures is not imposed. Anecdotally, observations from case study site visits for this research appear to validate this.

Similarly, concerning road safety, PBCs also impose the continuous maintenance and repair of all road safety-related aspects and road safety devices along the road and therefore are more likely to lead to better road safety than under traditional contracts. For example, PBCs usually include performance indicators to reduce potholes and surface irregularity, cutting of grass along lanes, and good quality of road signage, all of which are known to mitigate road crash risks.

Conclusions

The study aimed at assessing, based on hard cost data from actual contracts executed over past years, if the PBCs indeed led to more efficient road asset management than directly comparable traditional civil works/maintenance contracts under similar conditions.

To do this, the study set out to accomplish the following tasks:

a. Compare real contract data for PBCs and traditional contracts, using six case studies (from Argentina, Lao PDR, Liberia, New Zealand, Florida [United States], and Botswana) that were broadly representative of diverse contexts around the world and for which data on comparable civil works and maintenance characteristics were believed to be available (see Chapter 3.)
b. Review the data from these individual case studies and verify the comparability of data for PBCs and traditional contracts, on items such as rehabilitation works, maintenance characteristics (service levels), and duration (see Chapter 3).
c. Undertake an economic assessment and comparison of economic costs/benefits on various road investment and O&M scenarios to demonstrate the advantage of PBC in terms of lifecycle costs (see Chapter 3).
d. Undertake a quantitative comparison of PBCs and traditional contracts (see Chapter 4).
e. Identify the qualitative factors that lead to PBCs success or otherwise, based on their track record relative to traditional road works contracting (see Chapter 4).
f. Identify generic and qualitative advantages and challenges of PBCs in relation to traditional contracts in road management (see Chapter 4).

This research project was undertaken against a backdrop of limited previous evidence-based analysis of the efficiency of road asset management strategies based on the PBC and traditional contracting methods. This is in part due to the complexity of controlling for differences in the physical and economic contexts, not least of which is the difficulty controlling for the many diverse factors affecting construction costs, such as differences in regulatory environments. Exhaustive efforts were undertaken to collate comparable PBC and traditional contracting data from countries on all continents.

Comparison of the economic efficiency of PBC and traditional contracting approaches based on hard data collected through the case studies faced major hurdles. It was not possible to undertake the direct comparison of lifecycle and economic costs between PBCs and traditional contracts with an adequate level of rigor due to extensive gaps in data availability. In particular, the historical data for contract expenditures, road conditions, and traffic for the traditional contracts were found to be insufficient in all countries covered by the study, including in the developed countries. Significant gaps also existed in the data sets pertaining to PBCs.

Another challenge was related to sample sizes. To obtain a robust result, case study countries were selected to provide a globally representative sample. Even if critical missing information could be obtained, the size of networks maintained under PBCs in many countries is too small to reach statistically relevant conclusions. This was found to be true after extensive consultation with road agencies from 22 countries that have the most extensive experiences implementing PBCs. To fully achieve the objectives this study set out to deliver, a deliberate and significant effort will be necessary to systematically collect and record networkwide data over a sufficiently long time, such as 15 or 20 years, in a breadth and depth that is currently not done by road agencies.

It may be time to take stock of global practices for road agency data collection and management and identify possible areas for improvement and even coordination and information sharing between road agencies. Such an exercise may help researchers understand how to expand the collection of more valuable data more rapidly and cheaply for a range of future studies and may enable development of econometric approaches that could overcome some of the challenges faced under this study. It may also help IFIs and industry associations better refine their support to road agencies, potentially including some efforts toward data standardization that could help road agencies better utilize data and enable future research.

Findings from this research point to the benefits, risks, and challenges of adopting PBCs. PBCs can produce benefits in terms of budget forecasting, consistency of outcomes, faster completion of emergency repairs, risk transfer to the private sector, lower long-term procurement costs, and ease of contract administration. They are more likely to encourage innovation and development of contractor capacity. They also encourage governments to place more emphasis on defining levels of service as part of setting agency goals. These findings on benefits mostly confirm the conclusions of other published research on PBCs.

Use of PBCs requires governments to carefully define service levels to avoid underinvesting or overinvesting in roads. Long-term PBCs also require a significant funding commitment and therefore place a greater onus on governments to link and prioritize investments to desired outcomes and ensure that funding is available to meet public policy goals. PBCs likewise encourage contractors to manage risks and costs that are under their control and optimize investment around the level of service targets. This division of responsibility allows contractors and governments to prioritize their respective energy and efforts toward mandates that each is uniquely best able to deliver upon.

Another major finding is that PBCs are not without drawbacks and challenges. One of these is that the PBC model is more complex for many public entities and some private sector firms to implement. While the theory behind PBC is sound, preparation of PBCs deviates from the practical experience of many professional engineers because it requires a sound understanding of both the underlying engineering and economic theory. Mistakes in preparation of PBCs are therefore relatively easy to make. Errors and oversights in certain aspects of PBCs have more substantial consequences than those professionals preparing the PBCs might have anticipated.

The review of the case studies and other PBCs also pointed to the need for extensive training, not only for practitioners in road agencies intending to undertake PBCs but also for staff of the IFIs frequently supporting these endeavors. More training is needed to help ensure that PBCs are properly prepared and procured and that they actually create the intended performance incentives and accountability, allocate risks clearly, and set appropriate levels of service. Contractor training at the bidding stage is also important to ensure that bidders fully understand and respond to the contract incentives and price their bids appropriately.

PBCs also appear to require more flexibility from governments and IFIs, whose practices may be better suited to traditional contracts. PBCs impose longer-term budgetary obligations on governments, which, as a result, have less capacity to shift budgetary resources elsewhere in cases of unforeseen circumstances. These issues could be partially addressed by reducing the imposed levels of service under PBCs to fit the expected costs within the available budget and introducing special-purpose funds for road maintenance.

Finally, the findings of the study demonstrate that PBCs help contractors and governments focus on long-term efficiency of road investments and promote two of the principles of Quality Infrastructure Investment (QII): (a) Principle 2 on improving economic efficiency in view of lifecycle cost and (b) Principle 6 on strengthening infrastructure governance.

APPENDIX 1
International Literature Search Reference Material Summary

TABLE A1.1: INTERNATIONAL LITERATURE SEARCH REFERENCES

No.	Agency/Publication	Title
1	Federal Highways Authority	Successfully Integrating P3s and Contracted Highway Maintenance into an Agency's Transportation Asset Management Plan (Draft)
2	National Infrastructure Commission (United Kingdom)	Evaluating the Performance of Private Financing and Traditional Procurement
3	Federal Highways Authority	Successfully Integrating P3s and Contracted Highway Maintenance into an Agency's Transportation Asset Management Plan — Literature Review
4	CAREC, ADB	Guide to Performance-Based Road Maintenance Contracts
5	Audit Office of New South Wales	New South Wales Auditor-General's Report Performance Audit Sydney Region Road Maintenance Contracts Roads and Maritime Services
6	World Bank	Output- and Performance-Based Road Contracts and Agricultural Production — Evidence from Zambia
7	Lawrence National Centre for Policy and Management	The procurement of Public Infrastructure: Comparing P3 and Traditional Approaches
8	Maintenance Office, Provincial Highways Management Division, Ontario Ministry of Transportation	Winter Highway Maintenance Action Plan
9	Infrastructure Ontario	Value for Money, Civil Infrastructure Projects, DBFM Highway Projects
10	Applied Mechanics and Materials	Impact of Performance Based Contract Implementation on National Road
11	Journal of Construction Engineering Management	New South Wales Auditor-General's Report Performance Audit Sydney Region Road Maintenance Contracts Roads and Maritime Services
12	94th Annual Meeting of the Transportation Research Board	The Efficiency Claim of Public-Private Partnerships: A Look into Project Operations and Maintenance Costs
13	World Bank	Delivering Good Asset Management in the Road Sector through Performance Based Contracting
14	World Bank	Review of Performance Based Contracting in the Road Sector – Phase 1
15	World Bank	Review of Performance Based Contracting in the Road Sector Phase 2: Review of Training Materials and Resources

Supplementary Title/ Reference Information	Year	Authors	Comments
	2019	WSP	Unpublished work
	2019		
	2018	WSP	Unpublished work
	2018	Zietlow, G	
	2017		
Policy Research Working Paper 8201	2017	Atsushi Iimi and Ben Gericke	
	2015	Paul Boothe, Felix Boudreault, Dave Hudson, David Moloney, and Sandra Octaviani	
	2015		
	2015	MMM Group Limited (now WSP)	Unpublished work
	2015	Betty Susanti, Reini D. Wirahadikusumah, Biemo W. Soemardi, and Mei Sutrisno	
	2017		
	2014	Sergio E. Martinez and C. Michael Walton	
TRN 46, 87825	2014	Tony Porter, Ian Greenwood, Theuns Henning, and Katsuya Abe	
TP-42A, 87826	2014	Ben Gericke, Theuns Henning, and Ian Greenwood	
TP-42C	2014	Ben Gericke, Theuns Henning, and Ian Greenwood	

TABLE A1.1: INTERNATIONAL LITERATURE SEARCH REFERENCES, CONTINUED

No.	Agency/Publication	Title
16	Texas Department of Transportation	Performance-Based Maintenance Results
17	Michigan Department of Transportation	Maintenance Contracts in Ontario
18	Washington State Joint Transportation Committee	Evaluation of Public Private Partnerships
19		The Management of Road Projects in Papua New Guinea
20	Transportation Research Record: Journal of the Transportation Research Board, No. 2366	Findings from the International Scan on Managing Pavements and Monitoring Performance
21	Florida Transportation Commission	FTC Study of Cost Savings for Expressway Authorities
22	International Journal of Productivity and Performance Management	A Review of Performance-Based Maintenance of Road Infrastructure by Contracting
23	World Road Association, UK National Committee	Road Maintenance Review International Comparison
24	AASHTO Subcommittee on Maintenance	Highway Maintenance in Ontario
25	World Bank	Performance-Based Road Rehabilitation and Maintenance Contracts (CREMA) in Argentina A Review of Fifteen Years of Experience (1996–2010)
26	Nevada Department of Transportation	Cost and Benefit Study Associated with Outsourcing Roadway Maintenance Activities
27	World Bank	Performance Based Contracts in the Road Sector: Towards Improved Efficiency in the Management of Maintenance and Rehabilitation Brazil's Experience
28	Office of the Auditor General of British Colombia	Upkeep of the Provincial Roads Network by the Ministry of Transportation and Infrastructure
29	Journal of Infrastructure Systems	Cost Savings Analysis of Performance-Based Contracts for Highway Maintenance Operations
30	TRB 2010 Annual Meeting	Performance Based Contracting: The US versus the World
31	23rd Australian Road Research Board Conference	Pavement and Surfacing Condition Data in Western Australia with Ten-Year Maintenance Contracts
32	Land Transport New Zealand	Evaluating the Network Condition Changes of Transit Networks Managed under PSMC Procurement Options
33	NZIHT and Transit NZ 8th Annual Conference 2006	Assessing the Effectiveness of Unsealed Road Key Performance Measures

Supplementary Title/ Reference Information	Year	Authors	Comments
AMOTIA Annual Conference, October 2, 2014	2014	John F. Obr	
Potentially In-House	2014		
For State Transportation Projects	2012	AECOM	
	2012	R. H. Mumu and J. B. K. Kiao	
	2012	K.A. Zimmerman, J. Corley-Lay, J. B. Wlaschin, and R. M. Tetreault	DOI:10.3141/2366-05
	2012	Cambridge Systematics, Inc.	
	2012	Masuda Sultana, Anisur Rahman, and Sanaul Chowdhury	DOI:10.1108/17410401311309186
	2012	Justin Ward	
Area Maintenance Contracts	2011		
TP-36	2011	Maria Marcela Silva and Gerard Liautaud	
	2011	Halcrow	
TP-31, 56957	2010	Eric Lancelot	
	2010		
10.1061/(ASCE) IS.1943555X.0000012	2010	Panagiotis Anastasopoulos, Bob G. McCullouch, Konstantina Gkritza, Fred L. Mannering, and Kumares C. Sinha	
TRB Paper 10-0093	2009	Douglas D. Gransberg, Eric Scheepbouwer	
	2009	David Kennedy, and Bob Peters	
Research Report 324	2007	P. Kadar and T. Henning	
	2006	D. McDougall	

TABLE A1.1: INTERNATIONAL LITERATURE SEARCH REFERENCES, CONTINUED

No.	Agency/Publication	Title
34	American City and County	Performance Contracts Are Rare but Are Gaining Ground for Street Repairs
35	South Carolina Department of Transportation	Outsourcing versus In-House Highway Maintenance Cost Comparison and Decision Factors
36	IRF and ARF Asia Pacific Roads Conference, Sydney	Delivering Asset Management Services within the PSMC Environment
37	2005 Annual Conference of the Transportation Association of Canada	Contracted Maintenance Services at the Ministry of Transportation, in Ontario
38		Highway Management, The Highway Highlanders Way
39	University of Birmingham (UK) Senior Road Executives Course 2011	Cutting Costs and Improving Quality through Performance-Based Road Management and Maintenance Contracts
40	International Road Federation World Meeting, 14th	Investigation of Alternative Road Maintenance Delivery Methods
41	Transportation Research Record 1652	Areawide Performance-Based Rehabilitation and Maintenance Contracts for Low-Volume Roads
42	DOR, Ministry of Physical Infra-structure and Transport, Govern-ment of Nepal, Kathmandu, Nepal	Assessment of Performance Based Road Maintenance Practices in Nepal
43		Road Maintenance in Africa: Approaches and Perspectives
44	Indiana DoT	Performance Based Contracting for Roadway Maintenance Operations in Indiana
45	World Bank Group	Sanctions System
46	World Bank Group	Curbing Fraud, Corruption, and Collusion in the Roads Sector
47	World Bank Group	Deterring Corruption and Improving Governance in Road Construction and Maintenance
48	International Journal of Productivity and Performance Management Vol. 65 No. 1, 2016	Embracing Complexity in Performance-Based Contracts for Road Maintenance
49	Conference of European Directors of Roads	Country-Specific Reports on Road Maintenance Procurement
50	New Zealand Transport Agency (NZTA)	Review of Delivery Models for Works and Services
51		Road Maintenance Delivery in Australasia
52	Nevada DoT	Investigation of an Innovative Maintenance Contracting Strategy: The Performance-Based Maintenance Contract (PBMC)

Supplementary Title/ Reference Information	Year	Authors	Comments
	2006	M. Lameiras	
SCDOT Research Project 653: Maintenance Outsourcing	2006	R. J. Dlesk and L. C. Bell	
	2002	C. Barrett, G. Dunnet, and T. Porter	
	2005	M. MacLean, S. Gwartz, S. Skinner, and M. Houle	
	2003	M. Clarke	
The Latin American and OECD Experiences	2011	G. Zietlow	
	2001	E. Cottman and R. Chamala	
	1991	G. Cabana, G. Liautaud, and A. Faiz	
	2016	Abhiman Mulmi	References lifecycle cost
	2018	Mostafa Hassan M	
	2009	Bob G. McCullouch, Kumares C. Sinha, and Panagiotis Ch. Anastasopoulos	Some economic comparisons pp. 152
Annual Report FY18	2018		
64283	2011		
51748	2009		
	2014	Rob Schoenmaker and Hans de Bruijn	
	2017		
	2012	G. Porteous, R. Kyle, M. Darnell, and T. Porter	
Progress and Challenges after a Decade of Change	2008	P. Robinson and T. Toole	
Report No. 017-12-803	2015	P. Shrestha, A. Said, and K. Shrestha	Some economic comparisons pp. 37

TABLE A1.1: INTERNATIONAL LITERATURE SEARCH REFERENCES, CONTINUED

No.	Agency/Publication	Title
53	Journal of Service Science and Management, 2012 (5), 118—123	Performance Based Maintenance of Road Infrastructure by Contracting: A Challenge for Developing Countries
54	Texas DoT	Evaluating the Effectiveness of Performance Based Pavement Marking Maintenance Contracts in Texas
55	Texas DoT	TxDoT Update: Performance Based Contracts
56		Two-Stage Data Envelopment Analysis Method for Transportation Infrastructure Maintenance Management
57	Proceedings of 2009 NSF Engineering Research and Innovation Conference, Honolulu, Hawaii	Efficiency Measurement of Highway Maintenance Strategies Using Data Envelopment Analysis
58	Journal of Transportation Engineering	Comprehensive Evaluation of Virginia Department of Transportation's Experience with its First Performance-Based Road-Maintenance Contract
59	Alberta Infrastructure and Transportation	Alberta's Highway Maintenance Program: A Privatized Approach
60	Alberta Infrastructure and Transportation 2005 Annual Conference of the Transportation Association of Canada Calgary, Alberta	The Evolution of Highway Maintenance Outsourcing in Alberta
61	Technical Journal 21 (3)	Output and Performance Based Road Maintenance Contracting: Case Study Serbia
62	UK Government	National PFI Contracts
63	Virginia Tech Transportation Institute, Centre for Sustainable Transportation Infrastructure/ World Bank	Use of OPRC Contracts Through Small Local Enterprises Using Labor-Based Methods
64	Journal of Performance and Construction of Facilities	Optimal Maintenance and Rehabilitation Policies for Performance-Based Road Maintenance Contracts
65		A Financial Model to Estimate Annual Payments Required under Performance Based Contracts
66	International Bank for Reconstruction and Development/World Bank	Road Projects Cost Benefit Analysis: Scenario Analysis of the Effect of Varying Inputs
67		Evaluation of Public-Private Partnership Contract Types for Roadway Construction, Maintenance, And Rehabilitation
68	NZTA Report 605	Benchmarking the Operations and Maintenance of New Zealand's Roading Sector
69	Local Government Studies	Contracting Out Local Road and Park Services
70	Technical Journal 24(2)	Motorway Operation and Maintenance: Case Study Azerbaijan

Supplementary Title/ Reference Information	Year	Authors	Comments
	2012	Masuda Sultana, Anisur Rahman, and Sanaul Chowdhury	
	2014	Adam Pike, Praprut Songchitruksa, Srinivas Geedipally, Don Kang, and Ivan Damnjanovic	Cost assessment pp. 128
	2015	John Roberts	Includes some in-state comparisons
	2016	Emil Juni and Teresa M. Adams	Theoretical Economic Model
	2009	Jesus M. de la Garza, Konstantinos Triantis, and Saeideh Fallah-Fini	Theoretical Economic Model — VDOT
	2011	Mehmet Egemen Ozbek and Jesús M. de la Garza	Reference lifecycle costing
	2017	Chris McLorg	Reference to savings (3% in first round. 26% in second round)
	2005	Nick Bucyk Moh Lali	Cost-benefits of first round referenced pp. 12
	2014	Nebojša Radović, Katarina Mirković, Miloš Šešlija, and Igor Peško	Includes cost comparisons pp. 7
	2012		Includes total costs
	2007	Gerardo W. Flintsch	Reference to wider benefits with numbers
	2016	Soliman Abu Samra, Hesham Osman, and Ossama Hosny	Refers to lifecycle costing
	2014	Goran Mladenovic Cesar Queiroz	Generic Costing Model including lifecycle analysis
81577	2010	Koji Tsunokawa	Case study of 6 PBCs with HDM data
	2015	Seyedata Nahidi	Generic Model — public-private partnership (PPP) costs
	2017	Costello S., Henning T, and H Shivaramu	
Economic Effects and Their Strategic, Contractual, and Competitive Conditions	2018	Andrej Christian Lindholst, Ole Helby Petersen, and Kurt Houlberg	Provides actual cost comparisons
	2017	Igor Jokanović, Maurizio Rotondo, and Dragan Mihajlović	Generic Model — PPP costs

TABLE A1.1: INTERNATIONAL LITERATURE SEARCH REFERENCES, CONTINUED

No.	Agency/Publication	Title
71		Evaluation of Public-Private Partnership Contract Types for Roadway Construction and Preservation
72	Journal of Infrastructure Systems	Factors Affecting the Selection of In-House and Outsourcing Road Maintenance Methods and Assessment of their Benefits
73	Journal of Management Engineering	Analysis of Performance-Based Pavement Markings and Markers Contracts: Case Study from San Antonio
74	Journal of Construction and Engineering Management	Performance-Based Maintenance Contracting in Florida: Evaluation by Surveys, Statistics, and Content Analysis
75	The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)	Performance-Based Contracting for Roads: Experiences of Australia and Indonesia
76	The African Union Commission, Directorate of Infrastructure and Energy	Support to the Transport Sector Development Programme
77		Output-Based Aid in Chad
78	The South African National Road Agency (SOC) Limited (SANRAL)	Optimal Standards for Effective Infrastructure Delivery
79	World Bank Group	Performance-Based Road Contracting
80		Innovative contracting practices in the Road Sector: Cross-National Lessons in Dealing with Opportunistic Behaviour
81	Finnish Road Administration	International Overview of Innovative Contracting Practices for Roads
82	Finnish Road Enterprise	Innovative Project Delivery Methods for Infrastructure
83	DOR, Nepal ADB	Better Road Asset Management through Performance-Based Maintenance (PBM) Nepal
84	World Bank	Why Road Maintenance Is Important and How to Get It Done
85	44th European Transport Conference 2016	Valuing the Wider Benefits of Road Maintenance Funding
86	Millennium Challenge Corporation	Benefit-Cost Analysis of Road Maintenance
87	FHWA	Pavement Maintenance Effectiveness
88	National Cooperative Highway Research Program	Optimal Timing of Pavement Preventive Maintenance Treatment Applications

Supplementary Title/ Reference Information	Year	Authors	Comments
	2015 (Dec.)	Seyedata Nahidi et al.	
	2017	Pramen P. Shrestha, Kishor Shrestha, Aly Said, and Mylinh Lidder	Reference cost
	2018	Ivan Damnjanovic, Adam Pike, and Eduardo Martinez	
	2018	Jacob Fuller, Christopher J. Brown, and Raphael Crowley	
	2015	Reini Wirahadikusumaha, Betty Susantia, Vaughan Coffey, and Charles Adighibe	
Maintenance of Road Corridors; Performance Based Contract Experience and Private Sector Involvement	2016	Richard Smith	
Using performance-Based Contracts to Improve Roads	2015	Tim Hartwig, Yogita Mumssen, and Andreas Schliessler	
	2018	Andrew Mackellar	Asset management
A New Approach to Road Network Management	2014	Kulwinder S Rao	
	2010	Monica Alejandra Altamirano	Good theory
	2007	Pekka A. Pakkala, Dr. W. Martin de Jong, and Juha Äijö	
An International Perspective	2002	Pekka Pakkala	
	2016	Dr. G. Zeitlow	
	2005	Sally Burningham, Natalya Stankevich	
	2016	Philipp Thiessen, John Collins, Tom Buckland, and Richard Abbell	
A Dollar in Time Saves Nine	2016	Andrew Carter and Sarah Olmstead	
Pavement Maintenance Treatments	1996	John P. Zaniewski and Michael S. Mamlouk	
	2004	D.G. Peshkin, T.E. Hoerner, and K.A. Zimmerman	

APPENDIX 2
Potential Case Study Candidates

TABLE A2.1. CASE STUDY CANDIDATE SHORT LIST

	No.	Jurisdiction/Country	Started	Typical PBC Duration (years)
Africa	1	Botswana	2014	10
	2	Liberia	2014	10
	3	South Africa	1997	10
Asia	4	Vietnam		
	5	Lao PDR	2006	3
	6	India — Punjab	2012	10
	7	India — Tamil Nadu	2013	5
Europe	8	England — Birmingham	2015	25
	9	England — Isle of Wight	2012	25
	10	England — Portsmouth	2009	25
North America	11	Canada — BCMoT	1988	10 + 5 (now)
	12	Canada — BCMoT, PPPs		Various
	13	Canada —MTO	1996	
	14	Canada — Alberta	1995	
	15	United States — VDOT	1995	
	16	United States — FDOT	2000	7–14
South America	17	Argentina — CREMA	1995	5
	18	Bolivia — CREMA		
	19	Brazil — CREMA		5
Australasia	20	Australia — NSW	1990	
	21	Australia — WA	1999	3–10
	22	New Zealand — NZTA	2010	7–10
	23	New Zealand — WBOP DC	2002	10

Complete	World Bank Financed	Unsealed	Data Availability of PBCs
No	Yes	Yes	Yes
Substantially	Yes	No	Yes
Yes	No	No	Yes
Yes	Yes		
Yes	Yes	Yes	Yes
Substantially	Yes	No	
Yes	Yes	No	
Substantially	No	No	Yes
Substantially	No	No	Yes
Substantially	No	No	Yes
Yes	No	No	Yes
Substantially	No	No	Yes
Yes	No	No	Yes
Yes	No	No	Yes
Yes	No	No	Yes
Yes	No	No	Yes
Yes	No	No	Yes
Yes	Yes	No	Yes
Yes	Yes	No	Yes
Yes	No	No	Yes
Yes	No	No	Yes
Substantially	No	No	Yes
Yes	No	Yes	Yes

APPENDIX 3
Questions Used for Collecting Information on Benefit

TABLE A3.1. CASE STUDY BACKGROUND QUESTIONS

Issue/Parameter	Questions
A. Background Information	1. Country 2. Name of PBC 3. What exactly did the contract cover — scope of works? 4. What was the length of road specified in the contract — centerline km? 5. What was the road condition at the start of the contract — Poor, Fair, Good? 6. How was the pavement condition assessed and is there data to support the assessment? 7. What was the contract duration? 8. What previous contract type had been used — in-house, traditional? 9. What was the motivation/rationale for using a PBC? 10. Who is the contractor and their consultant — and their nationality? 11. Did you employ an independent monitoring consultant and, if so, who? 12. How many FTEs are engaged by the contractor, consultant, and the agency? 13. Have these FTE numbers changed over time?

TABLE A3.2. CASE STUDY DETAIL QUESTIONS

Topic	Questions	Information, Data, & Assessment of Importance
B. Contract cost and/or quality advantage due to contract type	14. What was the total cost of the PBC including any variations for the initial scope of works? 15. Did the scope increase during the term of the contract, and can the cost of scope changes be identified? 16. Can the PBC cost be broken down into component costs — BoQs for rehabilitation/reconstruction, improvement works, routine maintenance works, periodic maintenance works, emergency works — definitions are required? 17. What would have been the likely contract cost if using different contract types — may include a do minimum scenario of continued reactive maintenance? 18. Is there information on the previous contract costs and what were they? 19. Would the same scope of works, outputs, and outcomes have been specified for both the PBC and other contract types had they been used)? 20. Were any additional quality outcomes specified in the PBC — if so, what were these and can they be quantified in financial terms and if not then in qualitative terms?	Please provide information and data.

TABLE A3.2. CASE STUDY DETAIL QUESTIONS, CONTINUED

Topic	Questions	Information, Data, & Assessment of Importance
B. Contract cost and/or quality advantage due to contract type	21. Where there any additional quality outcomes delivered by the PBC even if these were not specified in the contract? 22. How has the contractor performed against the requirements of the contract — Excellent, Good, Average, or Poorly? 23. Can you supply asset condition information from surveys (for example, roughness/pavement deflection, and so on) or regular visual assessment (for example, formal inspections/ extent of defects)?	Please provide information and data.
C. Costs of administering contract	24. What is the cost of administering the PBC? 25. What was the cost of administering the previous non-PBC contract? 26. Are there any hidden additional costs of administering a PBC? 27. Are there any hidden cost savings when administering a PBC? 28. Is it easier or harder to administer a PBC compared to other contract types?	Please provide information and data. On a scale of 1 to 10 how important was this issue?
D. Funding availability (from outside source) due to contract type	29. Was external (to the country) funding more readily available due to using a PBC? 30. Was local funding more readily available (and secured) due to using a PBC? 31. What percentage of the total cost was met by external funding? 32. Was local funding required for any specific elements of the contract scope of works? 33. Was there more than one local (within the case study country) source of funding?	Please provide information and data. On a scale of 1 to 10 how important was this issue? Please rank issues (D) to (G) in order of importance.
E. Ease of decision making based on contract type	34. Is it easier for contracting agency managers to make decisions when using a PBC compared to other contract types? 35. Is it easier for contracting agency staff to make decisions (up to their delegation level) when using a PBC compared to other contract types? 36. What impact does other government agencies and country-specific legislation have on the O&M of the network (for example, existence and enforcement of traffic overloading legislation)? 37. Was overloading an issue in the contract area? 38. Was overloading policed in the contract area and, if so, how effective was the enforcement?	Please provide information and data. On a scale of 1 to 10 how important was this issue? Please rank issues (D) to (G) in order of importance.
F. Skills available to agency due to contract type	39. Do PBCs require managers and staff to have higher skill levels than other contract types or can lower skill levels be used for PBCs? 40. If higher skill levels are required for PBC then how easy or difficult is it for the agency to acquire the staff with the necessary skills?	Please provide information and data. On a scale of 1 to 10 how important was this issue? Please rank issues (D) to (G) in order of importance.

TABLE A3.2. CASE STUDY DETAIL QUESTIONS, CONTINUED

Topic	Questions	Information, Data, & Assessment of Importance
G. Level of transparency in contract implementation and management	41. Is the level of transparency with PBC greater than with other contract types for similar works? 42. What is the level of transparency that is provided by PBCs and other contract types? 43. Do PBCs provide the opportunity for more or less vigilance in managing the contract? 44. Have you any thoughts to offer as to whether there are any transparency and rigor benefits from PBCs compared to other contract types in terms of implementing and managing O&M contracts 45. Has the level of political influence been different under the PBC compared to other contracts?	Please provide information. On a scale of 1 to 10 how important was this issue? Please rank issues (D) to (G) in order of importance.
H. Travel time costs	46. Do you have data on travel times for the section of road covered by the PBC both before and after the PBC was implemented? (Note: The data may have been supplied before project funding approval by the World Bank. If this is so, please supply the data and indicate how it was obtained.) 47. If you do, what are the travel times before and after the PBC was implemented? 48. What dollar values do you put on travel times for the different vehicle types and different road users? 49. How were the travel time values established? 50. Do you have background material that was used to establish travel time values?	Please provide information and data. Please rank issues (H) to (N) in order of importance.
I. Vehicle operating costs (VOC)	51. Do you have data on VOC for the section of road covered by the PBC both before and after the PBC was implemented? (Note: The data may have been supplied before project funding approval by the World Bank. If this is so, please supply the data and indicate how it was obtained.) 52. If you do, what are the VOC before and after the PBC was implemented? 53. What dollar values do you put on VOC for the different vehicle types? 54. How were the VOC values established? 55. Do you have background material that was used to establish VOC?	Please provide information and data. Please rank issues (H) to (N) in order of importance.
J. Collision costs	56. Do you have data on accidents (crashes) for the section of road covered by the PBC both before and after the PBC was implemented? (Note: The data may have been supplied before project funding approval by the World Bank. If this is so, please supply the data and indicate how it was obtained.) 57. If you do, what are the accident statistics (data) before and after the PBC was implemented? 58. What dollar values do you put on accident costs for the different types of crashes and different types of severities? 59. How were the accident costs established? 60. Do you have the background material that was used to establish accident costs?	Please provide information and data. Please rank issues (H) to (N) in order of importance.

TABLE A3.2. CASE STUDY DETAIL QUESTIONS, CONTINUED

Topic	Questions	Information, Data, & Assessment of Importance
K. Resilience	61. How resilient is the section of road covered by the PBC? That is, a. If there is heavy rain, will the road still be usable by all the road users (including pedestrians and cyclists)? b. If there is a natural disaster, how quickly will the road be able to be reinstated (for example, earthquake and landslip)? 62. What is the volume of traffic (all modes) likely to be affected by any closure? 63. What is the average length of time for any closure? 64. What is the value in dollars to the contracting agency of any closure and does this value increase with the length of time the road or network of roads is closed? 65. Does a PBC offer any advantages over other contract types in terms of resilience?	Please provide information and data. Please rank issues (H) to (N) in order of importance.
L. Reliability	66. How reliable is travel on the section of road covered by the PBC for all road users? That is, a. Are the travel times on the road consistent or do they vary significantly by day of the week or time of the day? b. Can the trips be completed for certain or are there situations where trips cannot be completed? 67. What is the volume of traffic (all modes) affected by any reliability concerns? 68. What is the value in dollars to the contracting agency of any unreliability? 69. Does a PBC offer any advantages over other contract types in terms of reliability?	Please provide information and data. Please rank issues (H) to (N) in order of importance.
M. Access	70. Does the road provide access to all the activities that are needed or intended to be provided by the contracting agency? That is, does the road provide access: a. For people, goods, and services to reach their destinations? b. For people to get to health, education, and other public services? c. For people to get to law enforcement services and vice versa? 71. What is the volume of traffic (all modes) that needs access to the different services? 72. Can you supply traffic count data, traffic mix data, and vehicle overloading data on the network? 73. What are the distances that are covered by people, goods and services accessing the different destinations (for example, how critical is it for certain goods to be able to access their destination markets and what is the value of this access or what would it cost if these goods could not get to market)? 74. What is the value in dollars of having access? 75. Does a PBC offer any advantages over other contract types in terms of helping the contracting agency to provide access?	Please provide information and data. Please rank issues (H) to (N) in order of importance.
N. Any other benefits (specify what they are)	76. Are there any other benefit parameters which are highly important to the contracting agency? 77. If there are, does the contracting agency have data on these parameters both before and after a PBC has been initiated? 78. What is the value of these other parameters to the contracting agency in dollar terms and in qualitative terms?	Please provide information and data. Please rank issues (H) to (N) in order of importance.

APPENDIX 4
Details of Case Studies

For each of the case studies, an extensive effort was made to collect and collate data and information for both the PBC and comparator traditional contracts. Missions to Liberia, Argentina, Lao PDR, and Botswana were undertaken to collect the data, meet key personnel in government agencies and, where available, meet contractors in the supply chain. In addition, the mission teams met with the road agency and contractors involved in projects in the WBOP PBC (New Zealand) and the FDOT (United States).

Each case study includes the following:

- An introduction to the context.
- An overview of the attributes of the PBC and traditional contracts and networks.
- A condensed 'contract data summary' table outlining key contract data for both comparator networks.[26]
- A narrative of observed quality differences between the PBC and traditional road networks, including the description of road condition data where available. Direct comparisons of the quality of outcomes often cannot be made because of a lack of road condition data spanning both networks or because the baseline condition of the networks and funding levels may have been different. The choice of comparison contracts has attempted to minimize these differences and produce directly comparable results whenever possible.
- A value-for-money discussion, which details observations about factors affecting the value for money delivered by each contract type based on the available information. The value-for-money discussion focuses on best available information.
- An overview of other observations made, such as those related to tendering, contract administration, resilience, community benefits, or contractor performance.
- A summary of key observations from comparing observations about each contracting approaches.

Case Study 1: Argentina CREMA Performance-Based Contract and Traditional Maintenance Contract

The case study network is situated in Catamarca and La Rioja Provinces of Argentina, north-east of Buenos Aires. Catamarca is in northwestern Argentina and borders Chile on its west. Although Argentina is an upper-middle-income country, per capita income in Catamarca Province is significantly lower than for Argentina as a whole. Catamarca has a population of approximately 350,000 and a land area of 102,602 km^2. The province's capital is San Fernando del Valle de Catamarca (Catamarca) with a population of approximately 200,000.

26 The contract data tables are condensed as none of the case studies were able to provide all of the requested data.

Contract Details and Characteristics

Argentina CREMA Contract

Argentina has been outsourcing using the CREMA model since 1997. Large portions of the national road network have been rehabilitated and maintained under CREMA since that time. CREMA contracts were initially supported by the World Bank. DNV is now self-funding the program.[27] The CREMA approach was built on a previous history of outsourcing by DNV on a km/month basis. Links and networks are prioritized for rehabilitation at the provincial level by HDM-III analysis before being ratified by the head office.

CREMA is one of the three contracting options for maintenance used by DNV; the choice of approach is based upon each route's typical traffic volume:

- >4,000–5,000 AADT — Concession[28]
- >1,000 AADT — CREMA[29]
- <1,000 AADT — traditional (Force Account).

The CREMA model, though, is not always continuous—there are often gaps between contracts. When gaps occur, either extension of current contracts or Force Account arrangement is used to undertake routine and—in limited circumstance—periodic maintenance.

A CREMA has a five-year term: typically, two years of rehabilitation and maintenance followed by three years of maintenance. The two payment phases of CREMAs are 'PR2', which includes rehabilitation and comprises the first 24 months of the contract, and 'PR1', which includes payment for maintenance over the last 36 months of the contract. The PR1/PR2 approach has been adopted to limit the effects of inflation by paying for the costlier rehabilitation portion of works earlier. The PR2 (rehabilitation) payment phase does not fully cover the cost of works. Retentions are essentially held against the rehabilitation works. This keeps contractors interested in fulfilling their obligations to the end of the contract.

The average network length for a CREMA is approximately 200 km. There is no reason for this average length—it is historic, but it does seem to sustain a competitive market. Historically, the maximum extent of CREMA was 12,000 km. The CREMA model is always under review. New CREMAs have provisions to accept modifications during the rehabilitation/repair phase of the contract (but not during the maintenance phase).

Within the CREMA model, DNV advises the contractor what it requires done in each homogenous section. DNV specifies the following within each CREMA:

- For each homogenous section/link, the type of rehabilitation (if required) and other minor work activities to be completed in the two-year rehabilitation period (PR2).
- Maintenance standards to be met during the maintenance period of the contract (PR1).

In addition to the contractor's self-inspection unit, DNV undertakes its own contract surveillance/audit. Argentina has been suffering relatively high inflation since around 2015, which is affecting government funding. The consequent budget constraints have resulted in fewer and smaller CREMAs over time and increased reliance on Force Account contracting—also with limited budget.

As Argentina's economy has deteriorated, the funding and scope of CREMA have been reduced, putting more pressure on Force Account and potentially reducing network performance.

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27 The first round of CREMA (from 1997) rehabilitated 60 percent of the network. It was funded by the World Bank (42 percent) and the Argentine government (58 percent).

28 Concessions are operated on a PPP basis. Some subsidies were provided to some of the concessions.

29 This tends to apply to more than 25 percent of the primary road network.

Catamarca-La Rioja CREMA

The PBC road network which is the focus of this study is a two-lane, single carriageway on a desert plain. Much of the topography of the study route is alluvial sandy silt with some low-lying wetland areas including salt rise. Within the province, there is varying topography and geology. In addition to the relatively desert-like conditions in the southeast, the remainder of the province includes hilly and mountainous sections made up of essentially weathered and highly fractured granites. Rainfall is seasonal and recent torrential rain has caused severe washouts and extended road closures.

The Catamarca-La Rioja CREMA has been broken into 10 ‘homogenous’ sections with rehabilitation activities assigned to each by DNV and *‘Tipo be Obra’* (type of work) as shown in Table A4.1.

Typically, most CREMA rehabilitation works include 4–5 cm overlay. Roughness values shown are measured using the Bureau of Public Roads (BPR) roughometer and with the DNV roughness scale.

TABLE A4.1: CATAMARCA-LA RIOJA CREMA[30]

Rug. (Yr. 0)	Recovery Work		Maintenance			Type of Work	NPV*	IRR (%)
	Rug. (Yr. 1)	Rug. (Yr. 2)	Rug. (Yr. 3)	Rug. (Yr. 4)	Rug. (Yr. 5)			
2.1	1.9	1.9	1.8	1.9	1.9	4 cm AC overlay	19.97	23.1
2.1	2.1	2.1	1.8	1.9	1.9			
2.2	2.0	2.0	1.9	2.1	2.1	4 cm AC overlay	1.40	12.4
2.2	2.2	2.2	2.1	2.1	2.1			
2.1	2.3	2.2	2.1	2.1	2.1			
2.0	2.0	1.9	1.9	1.8	1.8	Crack sealing	1.63	13.2
2.0	2.0	1.9	1.9	1.9	1.8	4 cm AC overlay	6.10	15.3
2.1	2.0	1.9	1.9	2.0	2.0			
2.9	2.9	2.6	2.6	2.2	2.2	5 cm AC overlay	10.74	28.4
2.9	2.9	2.3	2.3	2.0	2.0	4 cm AC overlay	5.86	26.3

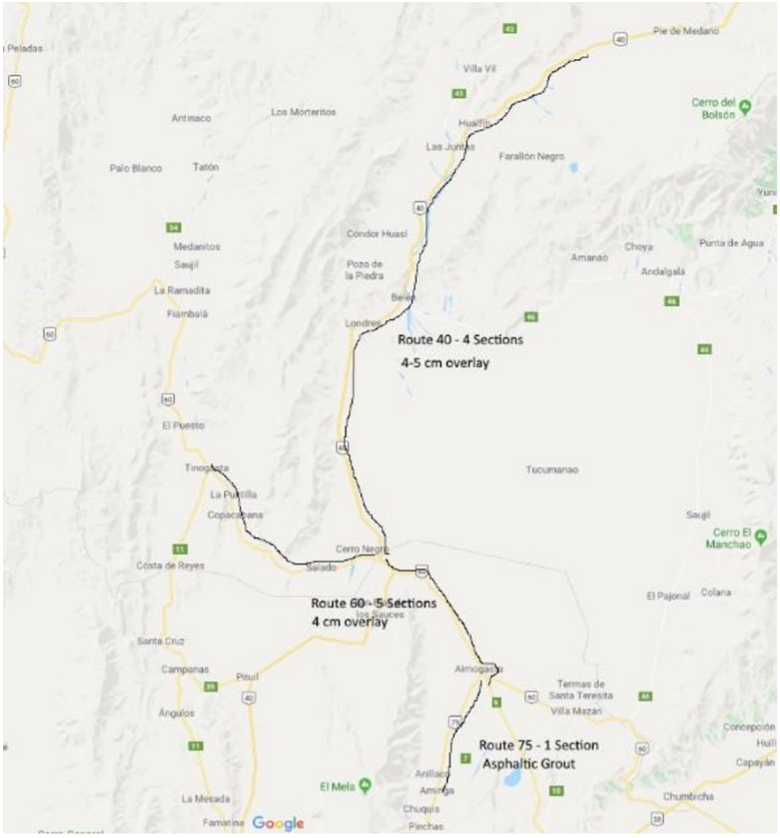
Note: Rug. = Roughness (BPR); * NPV in $US, milions.

30 BPR 89 = 0.6921 + 0.4571 IRI + 2.95 E-03 IR12 + 5.76 E-04 IR14. NPV and IRI are from HDM-3 analysis.

Routine maintenance activities included in CREMA are as follows:

- Cleaning the right-of-way
- Cleaning unlined (earth) ditches
- Drainage system cleaning, including inlets and culverts
- Maintenance of shoulders
- Pothole repairs
- Sealing joints and cracks in concrete walkways
- Crack sealing
- Vegetation control
- Pruning
- General drain cleaning
- Painting concrete and metallic bridges
- Cleaning the roadway
- Vertical sign cleaning
- Removal, replacement, and repair of vertical signals
- Maintenance of surface markings and delineation.

FIGURE A4.1: CATAMARCA-LA RIOJA CREMA EXTENT



Argentina Traditional Maintenance

When a CREMA ends, responsibility for maintenance transfers to DNV which then manages and maintains the road using Force Account within a budget allocation. This approach is used across the national road network. As it was not possible to obtain disaggregated data on the cost and perform-ance of Force Account by location, the entire Force Account operation for Catamarca Province was compared to the PBC as a reference point.

Force Account activities are usually limited to safety critical activities as budgets are limited. Within Catamarca Province, DNV currently invests an average of ARS 7,900/km/month (approximately US$2,247/km/year at May 1, 2019, exchange rates) in management, road and corridor maintenance, and winter maintenance. This rate also includes some periodic maintenance. DNV is not delivering an outcome comparable to that of CREMA. It is estimated that achieving an equivalent outcome would require four times the current level of investment.

The District can engage Contractors through traditional contracts for activities such as thin overlay, gabions, etc. up to a value of USD345,000 per contract.

National Data reporting systems

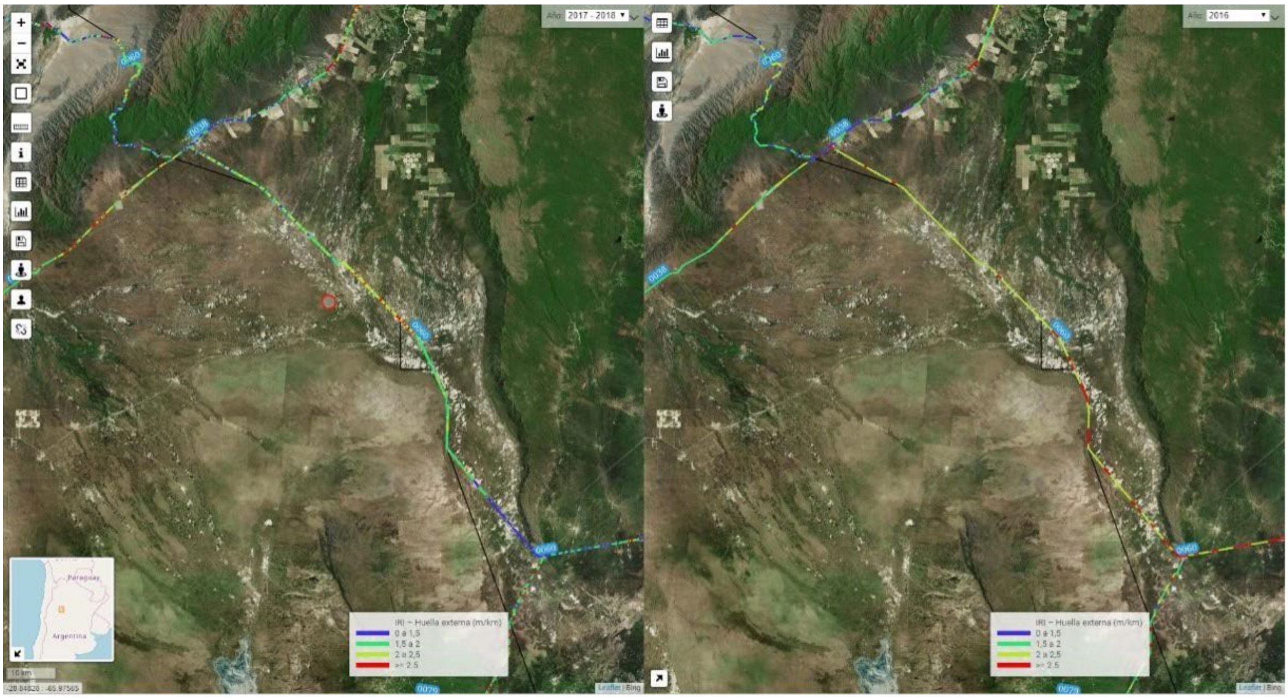
DNV operates a Geographic Information System (*SIG Vial*) for spatial-based reporting.[31] Condition data are reported at a highly aggregated level, limiting some of its usefulness, and in some cases only one or two years of data are available.

DNV also operates a national traffic database for permanent count stations containing traffic counts for approximately the last seven years.[32]

31 https://www.argentina.gob.ar/vialidad-nacional/sig-vial.

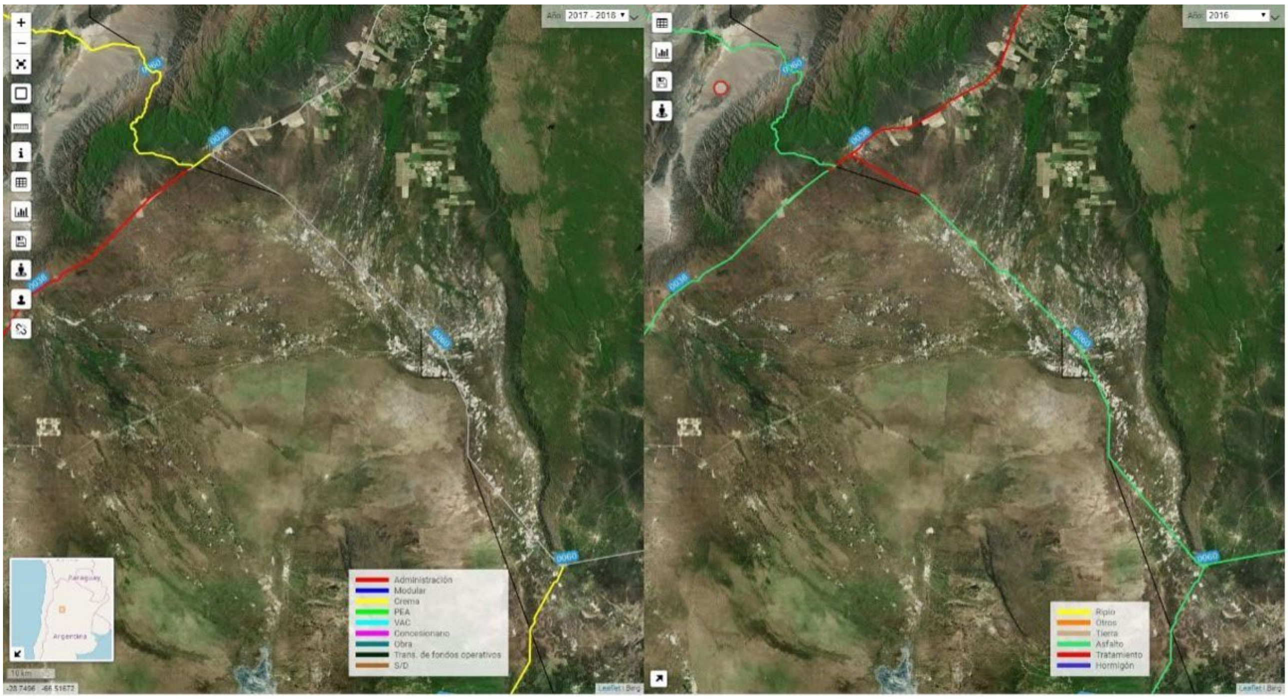
32 http://transito.vialidad.gob.ar:8080/SelCE_WEB/tmda.html .

FIGURE A4.2: SAMPLE OF THE NATIONAL CONDITION REPORTING SYSTEM SHOWING IRI BANDING



Source: DNV.

FIGURE A4.3: SAMPLE OF THE NATIONAL CONDITION REPORTING SYSTEM SHOWING CONTRACT TYPE VERSUS PAVEMENT TYPE



Source: DNV.

TABLE A4.2: CONTRACT DATA SUMMARY — ARGENTINA CREMA AND TRADITIONAL MAINTENANCE CONTRACTS

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehablitation Works		
See commentary	Nil	The PBC included only very little full-depth pavement rehabilitation. Little or no pavement rehabilitation is undertaken by the traditional method.
Item 2: Periodic Maintenance Works		
US$15.57 million = US$64,875/km	200–300 m of thin overlay (see Data Item 3)	Most of the rehabilitation work included in CREMA was actually periodic maintenance (pavement overlays). Under the traditional approach, periodic maintenance works only occur in exceptional cases.
Item 3: Routine Maintenance Works		
US$1,700/km/year	US$2,247/km/year Note: This rate includes periodic maintenance and emergency works.	The outcome achieved between the two models is different. On average CREMA achieves a pavement serviceability score[33] of ~8. The traditional contracts barely maintain a pavement serviceability score of 4. Force Account includes administration, emergency works, thin overlays on short sections of road, and winter maintenance (where it occurs).
Item 4: Emergency Works Expenditure — Average Annual		
Nil	Included in routine maintenance works costs above	When emergency events occur, having a contractor on hand under CREMA leads to a more rapid response. In contrast, repairing roads under Force Account requires a funding approval from the head office, which can delay.
Item 5: Contract Administration — Procurement		
Approx. US$50,000 for 3 full-time equivalents (FTE)[34] for 6 weeks	Nil	
Item 6: Contract Monitoring/Supervision/Administration		
Approx. US$1.0 million = US$4,100/km	US$1,000/km	For CREMA, both the contractor and DNV have five people each. For the traditional contract, 22 people are engaged for 1,020 km.
Item 7: Non-pavement Maintenance Works		
Included above	Included above	Breakdown of costs was not available.
Item 8: Resilience		
CREMA contracts contain measures focusing on drainage	Under Force Account, which is financially constrained, drainage is managed by exception leading to reduced resilience.	The anecdotal observations during the case study visits suggest that CREMA provided overall better resilience than the traditional approach.

33 Pavement serviceability includes roughness, rutting, cracking, and raveling.

34 An FTE, or full-time equivalent, is equivalent to the level of effort of an individual working full-time for the time specified.

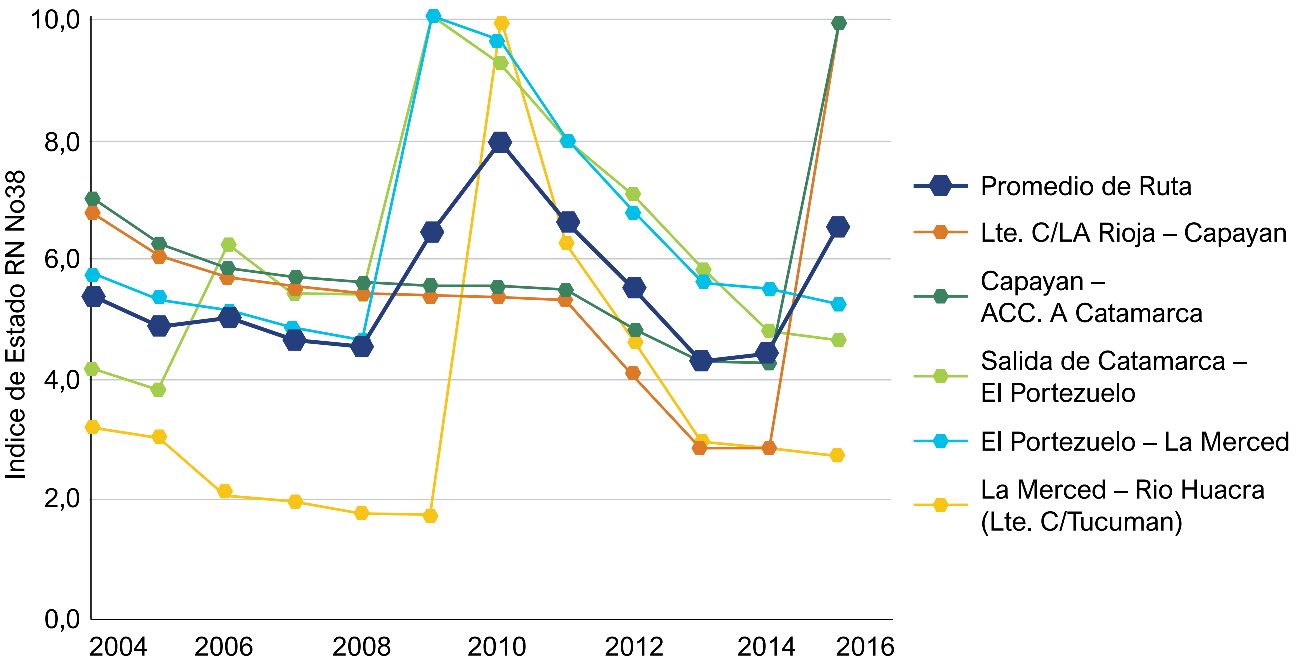
TABLE A4.2: CONTRACT DATA SUMMARY — ARGENTINA CREMA AND TRADITIONAL MAINTENANCE CONTRACTS, CONTINUED

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 9: Additional Nonfinancial Benefits		
a. Having a contractor on site means that issues can be dealt with more quickly. b. Domestic contractors have enhanced their road maintenance and management skills over time, and this appears to have increased knowledge within the country.		

Quality Differences

Comparison of the CREMA and traditional networks is challenging as the CREMA contracts included rehabilitation and/or periodic maintenance while the traditional contracts did not. There are quality differences in favor of CREMA, mostly because the level of investment is aligned to the specified maintenance standards. This is a significant difference as the CREMA budget is secured and therefore works proceed as planned while the traditional approach is subject to annual budget processes and variances.

FIGURE A4.4: EXAMPLE OVERALL CONDITION INDEX (CI) *(ÍNDICE DE ESTADO)*



Source: DNV.

The province's goal is to maintain Condition Index (CI) scores higher than 4,[35] as shown in Figure A4.4. By comparison, CREMA, on average throughout its five-year term, appears to achieve an CI score of approximately 7 to 8 with the benefit of newly rehabilitated roads.

There is evidence to suggest the CREMA performance management regime delivers better outcomes than if DNV was undertaking the work itself. Drainage and culvert clearing is to a higher standard under CREMA, thus increasing the road network's resilience and likely service life. The contractor's emergency response is typically better than DNV's, partly because the contractor usually operates in the network and partly because there is less bureaucracy when working with the CREMA contractor.

Force Account

Force Account uses the same maintenance standards as CREMA, but, due to budget constraints, evidence suggests that the standards are not being met, particularly for off-highway aspects such as drainage and signs. As the use of CREMA is declining, relatively poor sections of road that previously would have been rehabilitated under CREMA are instead being maintained under Force Account. As funding for rehabilitation and periodic treatments is limited, growing numbers of defects have diverted time and money from needed rehabilitation, ultimately increasing lifecycle costs.

Value-for-Money Discussion

There is anecdotal evidence that rehabilitation lasts longer under the CREMA approach, as the contractor has responsibility for road maintenance during and after the rehabilitation phase and is therefore more interested in the outcome. To minimize their risk during the maintenance phase, contractors seem to do a better-quality job, which is beneficial to DNV. Nonetheless, pavement surfacing lasts only for a relatively short period (five to seven years) with cracking appearing to be the predominant failure.

The CREMA contractor can be considerably more agile than DNV when undertaking its activities, as DNV is often hampered by internal bureaucracy, leading to more rapid responses saving time and money for DNV and the community.

DNV staff indicated that CREMA provides opportunities for contractors and DNV to learn from each other. Relatively few foreign contractors (from Brazil) have participated in CREMA. Therefore, Argentine companies have benefited most from the building their capacity to deliver CREMAs. DNV districts have adopted management practices employed by the CREMA contractors, resulting in improved performance of the traditional network.

Skills have changed and developed throughout the evolution of the CREMA model. Consequently, new staff often need about one to two years of 'on-the-job' training to upskill, depending on previous experience.

Contract Administration, Resilience, and Other Observations

Tendering and Prioritization

Within CREMA, the type and extent of rehabilitation are specified by DNV at the time of tender and the bid evaluation approach is essentially 'lowest price conforming'. Contractors rarely deviate from the specimen designs as any cost increases will count against the contractor when evaluated. Removing the incentive to improve the quality of designs could result in construction of inferior solutions in some instances.

There are indications that contractors operate within an area of geographical comfort, resulting in reduced competition. DNV has proposed measures to manage this risk.

- Advertise all opportunities online.
- Publicly advise tender outcomes.

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35 10 is a perfect score.

Selection of CREMA areas and rehabilitation treatments is heavily dependent on HDM-3. While HDM-3 considers several factors such as vehicle operating costs, the cost of reactive maintenance required to maintain minimum serviceability was not included in the prioritization analysis during the case study period.

Contract Implementation

DNV staff advise that it is easier to administer CREMA contracts than traditional contracts, and politicians are less inclined to offer advice during execution of the contract. Overall, contractors advised that they also prefer the CREMA model as it provides a base level of work to allow them to recruit and train staff and invest in machinery and equipment. The current rate of inflation, though, is a significant problem.

Due to budget constraints, contract awards are often delayed up to five years. As delays affect the type of rehabilitation work required, contractors are seeking variations such as increasing the overlay thickness to account for deterioration during the delay period. The contractor will sometimes increase the overlay thickness regardless of the approval process—which can take too long—to minimize their overall risk.

While each CREMA contractor operates a material testing laboratory to manage its risk and reports material properties, a similar level of testing and reporting is not as easily available under traditional contracts. Contractors are also generally more responsive to materials issues when they conduct their own materials testing than when DNV does the testing and reports its findings. DNV cannot and does not rely fully on the contractor's testing and quality assurance. While it continues to look over contractors' shoulders, the amount of 'looking' varies by contractor.

Contractors are starting to lose confidence in the CREMA model due to changes in government policy, high inflation, and increasingly limited access to finance. The CREMA bid prices have increased as contractors have started to more fully account for related risks going forward, although contractors do not perceive risk transfer to be a significant problem. CREMA contracts include an escalation methodology, albeit imperfect.

Summary

Argentina has adopted CREMA to strengthen the incentive for contractors to carry out rehabilitation work more efficiently and effectively. Despite an extensive history of CREMA implementation, it was not possible to obtain the data necessary to undertake a comparison of lifecycle costs and economic benefits for the contracting approaches. Despite this, CREMA has successfully demonstrated to the government the cost required to invest in and maintain roads.

Several benefits of CREMA have been identified.

- Administration of CREMA is readily acknowledged to be easier than traditional contracts.
- Contractors have expressed preference for the CREMA model because it enables them to invest in their own capabilities.
- CREMA are believed to have created a stronger incentive for contractors to ensure quality of rehabilitation and overlay workmanship, although there is no hard evidence of this.
- The performance measures under CREMA appear to result in better 'off pavement' maintenance—particularly drainage.

Much of the maintenance remains under traditional contracting approaches. Following the Phase 1 CREMA (1997), network condition increased. Initial CREMA were not followed up (2002 onward) and network condition declined again. As Argentina's economy has deteriorated and the funding and scope of CREMA have been reduced, less rehabilitation is occurring, and maintenance needs are increasingly met through Force Account with limited resources. The reduced level of funding will inevitably result in higher lifecycle costs and very likely reduce overall network performance.

TABLE A4.3: CASE STUDY 1: ARGENTINA CREMA AND TRADITIONAL MAINTENANCE CONTRACT DATA

Name	Description
Base de Datos CREMA.xls	Summary of all CREMAs
Planilla Impacto Mallas (v1).xls	More detailed listing of recent CREMAs' routes
Consolidado de planos.pdf	
Contratos C.Re.Ma. – Argentina.pptx	Typical cross-sections
Contratos CREMAS.pptx	Overview of the CREMA model
Correlacion IR – BPR.pptx	Conversion formula for BPR to IRI
Cronograma de hitos	National Maintenance Plan analysis
Eval CREMAS - DNV - MIRTA VAZQUEZ.pptx	Overview of the CREMA model
Gmail - RV_ Resumen de Antecedentes_ Malla Nº408 C y Malla Nº303	CREMA tender sums
Malla 3 Cordoba - Ejecutada	Overview of CREMA site selection process
Malla CREMA de Corrientes - En Proyecto.pptx	Corrupted file
Pliego 2011.pdf	2011 CREMA Model Document
Pliego CREMA 3.pdf	2007 CREMA Model Document
Red Vial Nacional y Provincial.pptx	Overview of the national network
HDM Files – Various	Exports from HDM-4 configuration tables
Ejemplo de calculo de IE.xls	Example condition calculations
Indice de Estado - Metodología DNV.docx	Condition guidelines and index calculation
M 303_Pr2 _PTP.pdf	Route 303 scope
M 408C_Pr2.pdf	Route 408C scope
M 408C_PTP	Route 408C scope
Malla 303_HDM 3 completo.pdf	Route 303 HDM-III analysis
Malla 408C_HDM 3 completo	Route 408C HDM-III analysis
Contratos CREMAS.pdf	Model contract
Cremas con avance PR1 Y PR2 20190424	Summary of all CREMAs
FI de la DNV - V01 21-04-19.pdf	Institutional Strengthening Plan

Case Study 2: Lao People's Democratic Republic

Output and Performance-Based Contract and Traditional Maintenance Contract

Country Description

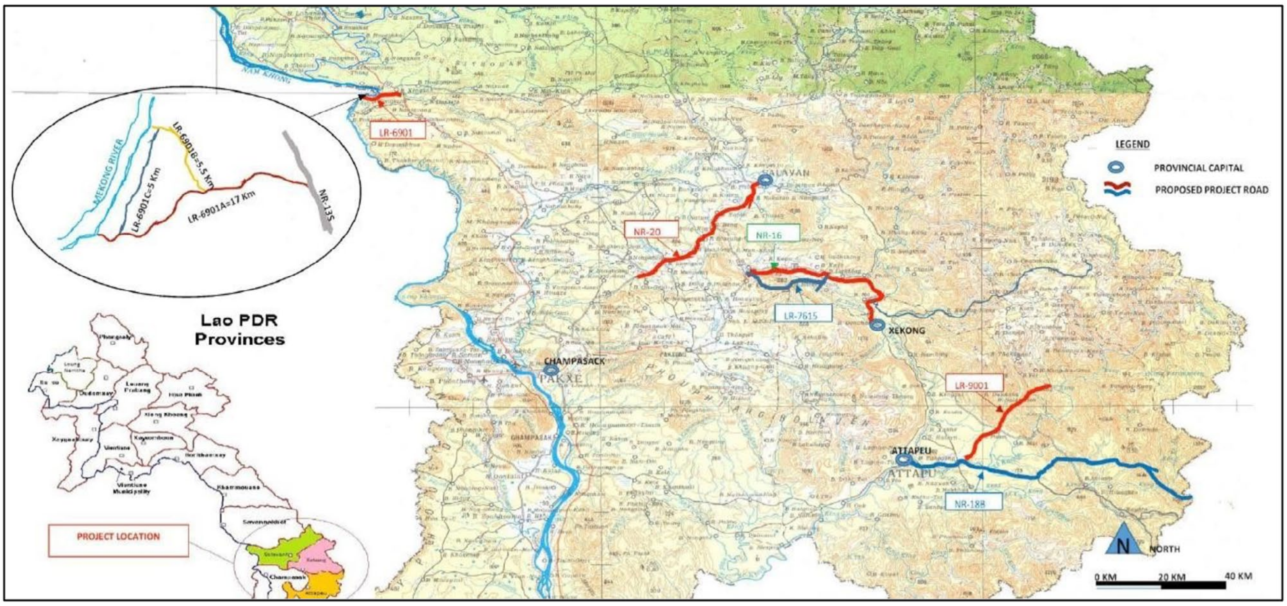
Lao PDR is a lower-middle-income country in Southeast Asia. Lao PDR is traversed by the Mekong River and has significant mountainous terrain as well as lowlands. It is bordered by Myanmar, China, Vietnam, Cambodia, and Thailand. The capital city is Vientiane, and other major cities include Luang Prabang, Savannakhet, and Pakse.

Lao PDR is a multiethnic country, with the Lao people making up about 55 percent of the population. The country has a total area of 237,955 km^2 (91,875 square miles) and a population of just over 7 million. At the time of the case study, Lao PDR's gross domestic product (GDP) on a purchasing power parity basis was approximately US$54 billion, which equates to approximately US$8,000 per person.

The Lao PDR road system is not extensive. There are approximately 21,700 km of roads, of which approximately 9,700 km are paved and 12,000 km are unpaved.

Waterways play an important role in transport in Lao PDR, due to the Mekong River. There are approximately 4,600 km of navigable water routes, primarily along the Mekong River and its tributaries, and a further 2,900 km of water routes that are navigable by craft drawing less than 0.5 m draft.

FIGURE A4.5: PACKAGE 1 PBMS IN SALAVAN, XEKONG, AND ATTAPEU PROVINCES IN SOUTHERN LAO PDR



Source: Asian Development Bank

Contract Details and Characteristics

Performance-Based Highway Maintenance Contracts

The Lao PDR DOR has six contracts including some rehabilitation/major maintenance followed by performance-based maintenance until contract completion. These contracts include approximately 600 km of both paved (DBST) and unpaved (gravel surface) national and local roads in southern Lao PDR.[36] The six PBMs comprise two packages:

- Package 1: Three contracts totaling 321.2 km in Salavan, Xekong, and Attapeu Provinces (see Figure A4.5). Each contract includes one national road and one local road. Package 1 commenced in Q2 2018 and finishes in Q3 2021 (3.5 years in total).
- Package 2: Three additional contracts in southern provinces (including Champasak).

The PBM delivery schedule, as shown in Table A4.4, includes a 12-month rehabilitation phase and 30-month maintenance phase. The contractor is only liable for defects from the rehabilitation phase for 12 months, a significant deviation from conventional PBM approaches globally.

36 The contracts are funded by the ADB (~90%) and the Lao PDR Government (~10%).

TABLE A4.4: PACKAGE 1 DELIVERY SCHEDULE

	2018				2019				2020				2021			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Initial rehabilitation																
Defect liability (12 months)																
PBM																
CBM																
Emergency works	As required, using BoO															

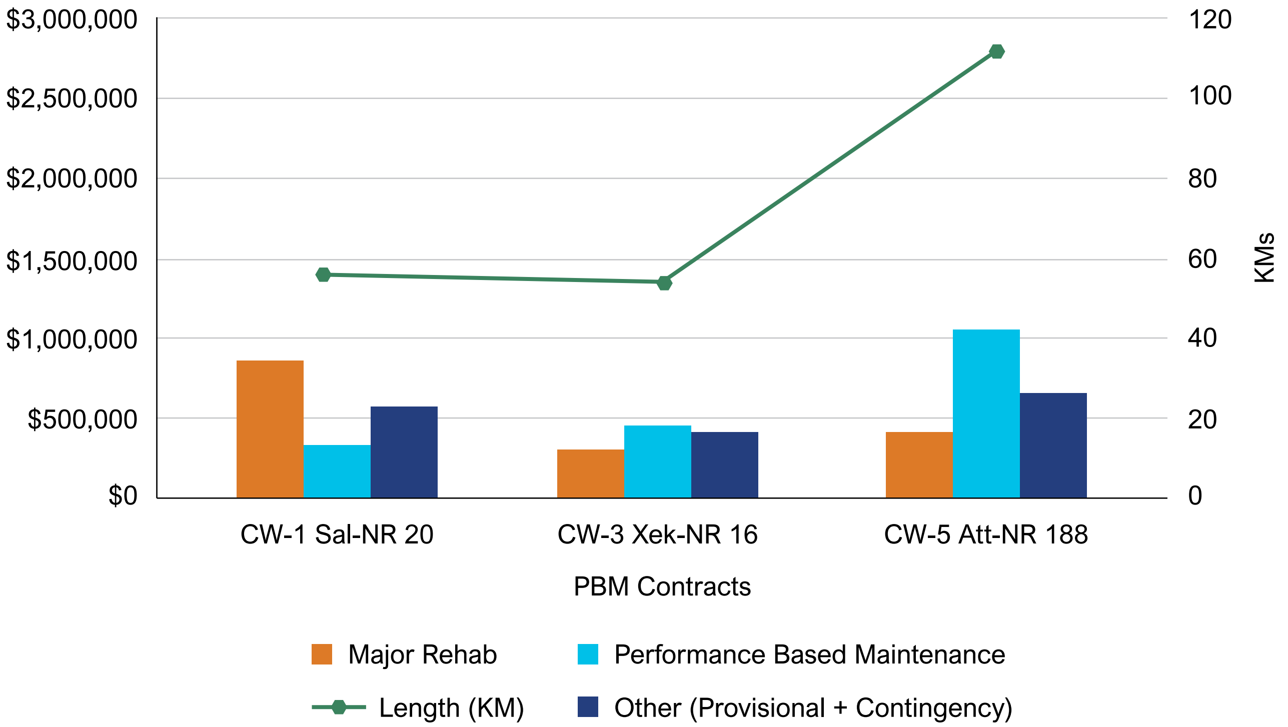
Source: DNV.

The maintenance scope includes surface maintenance, pavement maintenance, and shoulder maintenance with performance measures assessing potholes, cracking, raveling, and edge break. The level of service is well-defined and monitored monthly. Due to the contractors' lack of familiarity with the PBM model in southern Lao PDR, the DOR is working closely with them to ensure that the level of service is met and performance-based deductions are minimized. Each contract includes a Provisional Sum allocated for emergency works under a BOQ.

Figures A4.6 and A4.7 illustrate how the initial PBM rehabilitation and major maintenance were concentrated on local roads. It can also be inferred that, before PBM, national roads were maintained to a reasonable level of service compared to local roads.

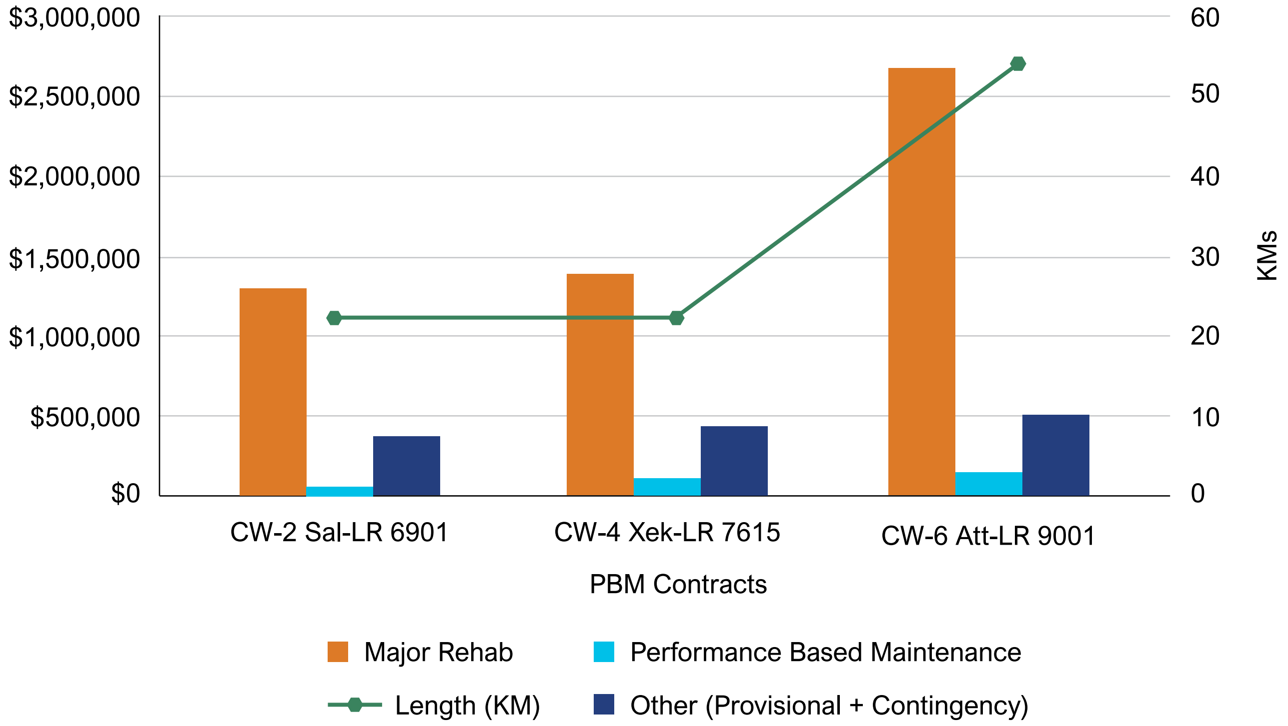
Routine maintenance work for Package 1 varies between US$1,280/km/year and US$3,396/km/year. This varies significantly between local and national road classifications. Average PBM cost is US$3,145/km/year for national roads and US$1,590/km/year for local roads.

FIGURE A4.6: PACKAGE 1 NATIONAL ROADS CONTRACT STRUCTURE



Source: DNV.

FIGURE A4.7: PACKAGE 1 LOCAL ROADS CONTRACT STRUCTURE



Source: DNV.

Community-Based Highway Maintenance Contracts

CBMs run concurrently with the PBMs. CBMs encompass 2 to 3 km road sections adjacent to villages and are negotiated with local village leaders. They involve delivering routine non-pavement maintenance (including vegetation control, ditch clearing, debris removal, minor slip removal, and sign cleaning and straightening) through community areas and/or local villages adjacent to the highway corridor. Some key features of CBM include the following:

- The CBM commences once the rehabilitation and/or major maintenance phase is completed. In some instances, it is also undertaken during rehabilitation and/or major maintenance.
- CBMs cost approximately US$300/km/year.
- Tools and equipment are provided by the DOR.
- They are funded by the DOR and/or MPWT.

Traditional Highway Maintenance Contracts

The PBM major maintenance is not readily comparable to traditional rehabilitation contracts as the latter generally involve more extensive rehabilitation. PBM maintenance programming adopts a more targeted approach focused on raising the PBM network level of service to the specified standards, while traditional periodic maintenance or rehabilitation contracts focus on improving homogeneous pavement sections using the same treatment. The traditional highway maintenance contracts were found to be the best contract for comparison with the PBM for objectives of this study.

The traditional maintenance contracts are awarded annually and cover all road and shoulder maintenance up to 1 m beyond the edge of seal/paving. Contracts commence January 1 each year and conclude December 31.

Under the traditional maintenance contracts, DOR and MPWT direct maintenance and develop work plans in partnership with the contractor. Levels of service are subject to budget availability and vary depending on prior highway condition, traffic volumes, and surface type (AC, concrete, or DBST). Payment is based on a BoQ. Payments to contractors for the completed work are often delayed, sometimes by up to two years, due to limited funding at the DOR/MPWT.

TABLE A4.5: CONTRACT DATA SUMMARY — PERFORMANCE-BASED HIGHWAY MAINTENANCE AND TRADITIONAL HIGHWAY MAINTENANCE CONTRACTS IN LAO PDR

PBM Values (2018)	Traditional Contract Values (2019)	Commentary
	Item 1: Rehabilitation/Major Maintenance	
US$7,000/km for national roads US$54,000/km[37] for local roads (See commentary)	Not part of the traditional contracts	The PBMs only include major repairs/patching/ improvements to reach initial level of service for PBM.
	Item 2: Periodic Maintenance Works	
Not part of the PBMs	Not part of the traditional maintenance contracts	As the PBMs do not include periodic maintenance, the traditional contracts chosen for comparison also do not.
	Item 3: Routine Maintenance Works	
US$3,145/km/year for national roads US$1,590/km/year for local roads[38]	US$650/km/year	Routine maintenance on the PBM network excludes the cost of the CBM (US$300/km).
	Item 4: Emergency Works	
US$170/km/year for national roads US$310/km/year for local roads (provisional contract sums)		Bulk spent on slope stabilization repairs on the mountainous section of the PBMs. Paid through a Provisional Sum.
	Item 5: Contract Administration — Procurement	
Bid cost unknown Bid every 3.5 year	Bid cost unknown Bid annually	Bid costs were not available. However, the annual tendering of the traditional contracts is likely more expensive compared to tendering multiyear PBMs.
	Item 6: Contract Monitoring /Supervision /Administration	
Administration costs unknown (See commentary)	Administration costs unknown (see commentary)	Specific administration costs were not available. However, the DOR administration effort was the same irrespective of the contract model. Contributing to this was the level of effort required by the DOR (training, supervision, and technical support) to ensure the PBM was a success. PBM administration costs may decline over time as contractors and DOR staff become more familiar with the PBM model.
	Item 7: Non-pavement Maintenance Works	
US$300/km/year for non-pavement maintenance works	Non-pavement maintenance works unknown (see commentary)	Minimal non-pavement maintenance work is completed on roads outside of the PBM.

37 Average unit prices obtained from PBM bid evaluations.

38 National road and local road costs are the average costs of maintenance across the Package 1 Contracts.

TABLE A4.5: CONTRACT DATA SUMMARY — PERFORMANCE-BASED HIGHWAY MAINTENANCE AND TRADITIONAL HIGHWAY MAINTENANCE CONTRACTS IN LAO PDR, CONTINUED

PBM Values (2018)	Traditional Contract Values (2019)
Item 8: Resilience	
a. The delivery of non-pavement routine maintenance under the CBM increases the drainage assets' operational characteristics and is expected to reduce the risk of landslips and subsidence in the mountainous environment. b. Encroachment on PBM highways appears to be less of an issue than on the traditional network. This may be partly because these highways are in less populated areas and partly because of the increased surveillance undertaken during the PBM inspections.	a. Drainage maintenance is carried out where funding is available. There is no committed funding to routine drainage maintenance unlike in the PBM environment. b. Encroachment on highways was perceived to be more common on the traditional network and can potentially compromise drainage in specific areas.
Item 9: Additional Nonfinancial Benefits	
a. Employment of local villagers for non-pavement routine maintenance works (approximately 300 local workers across 300 km of highway) b. Consistent service levels along the project road as a result of level of service-based payment terms c. Increased data capture and availability around road assets, work completed, and condition/level of service d. Increased certainty on financial expenditure e. Transfer of risk to the contractor for quality and performance, which resulted in increased quality of workmanship during the PBM period f. Improving market and agency capability and capacity in future performance-based highway maintenance initiatives through training contractors and DOR staff before contract commencement and once in the contract period	a. Simple maintenance contract which is easy to procure and administer

Quality Differences

The study team travelled on highways maintained by both models. Negligible difference in the level of service was observed between each model in terms of rideability, aesthetics, and functionality. The traditional method represents the majority of highway maintenance undertaken across Lao PDR.

Differences in roughness and deflection progression were not assessed because complete rehabilitation and periodic maintenance, which have the biggest impact on these outcomes, are not included in either of the contract models.

Based on a visual inspection of a small subset of both network types, there also appears to be very little difference in pavement and surfacing reconstruction and repair quality between the PBM and traditional maintenance contract delivery models. Both were constructed by reputable contractors and administered by dedicated monitoring and supervision resources.

The combined PBM and CBM service levels include line marking (striping), delineation, and guardrail repairs. This has resulted in higher maintenance standards for these assets compared to the traditional maintenance contract. This is expected to reduce the road safety risks compared to the roads under traditional maintenance contracts. For this reason, the PBM approach is considered to offer better overall quality of results.

FIGURE A4.8: POTHOLE REPAIRS UNDERTAKEN UNDER A TRADITIONAL CONTRACT

Note: Repairs undertaken under a traditional contract on Highway 13S approximately 35 km east of Vientiane (OPUS 2019).

FIGURE A4.9: HIGHWAY 16B LOOKING EAST TOWARD THE VIETNAM BORDER

Note: Figure shows extent and quality of completed pavement and surfacing repairs delivered under the PBM (OPUS 2019).

Greater security around long-term funding under the PBM enables appropriate levels of routinemaintenance activity to be undertaken during the contract to meet the targeted OPMs. This is also expected to result in better quality outcomes.

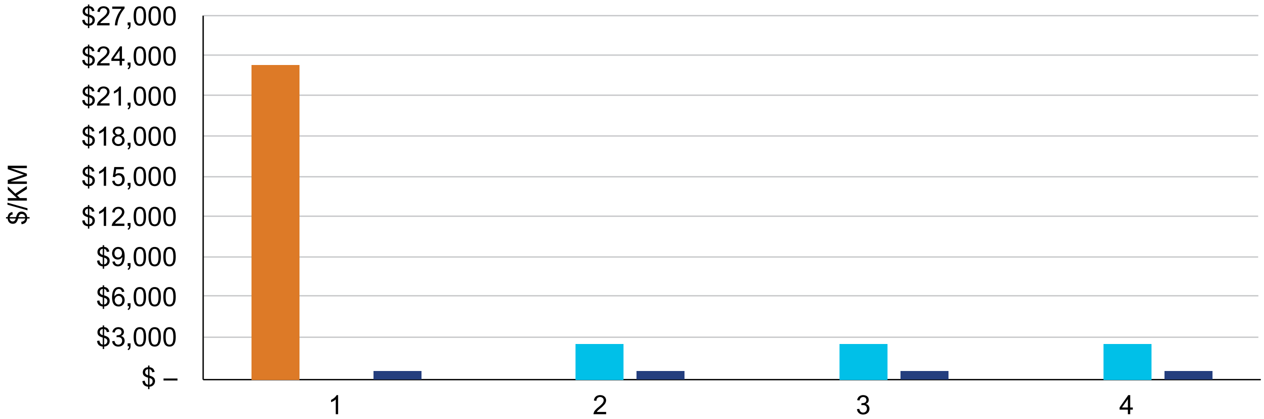
Value-for-Money Discussion

Limited data and the differences in the scope of work of the PBM and traditional contracts do not allow for a direct comparison of the NPV of costs and benefits. Compared to other PBCs, the PBM has a relatively short defect liability period for repairs of one year, which is the same as the defect liability period for traditional maintenance contracts. The maintenance periods of the case study PBMs was also shorter than international norms at only 30 months.

The principal difference between the contracting approaches is the level of routine and periodic maintenance funding available and the level of maintenance activity each contract model delivered over time. Figure A4.10 shows the breakdown of funding for the PBM and traditional contracts. The higher maintenance expenditure on the PBM network is notable. Even with the proportional value of rehabilitation works removed from the PBM routine maintenance works payments, there is a large difference in maintenance funding between the two contract models. It is estimated that the traditional contract network maintenance needs are underfunded by 70 percent.

This variance will have a significant impact on the respective asset life cycles as long as the higher levels of investment under PBM are sustained. It is reasonable to expect the life span of well-maintained pavement and surfacing assets to be 75–100 percent longer than those receiving no, or very little, routine maintenance.

FIGURE A4.10: PBM VERSUS TRADITIONAL O&M COST COMPARISON



	1	2	3	4
PBM — Major Mtc	$23,146.63			
PBM — O&M		$2,784.96	$2,784.96	$2,784.96
Traditional O&M	$650.00	$650.00	$650.00	$650.00

Contract Year

PBM — Major Mtc PBM — O&M Traditional O&M

Source: Opus 2019.

Contract Administration, Resilience, and Other Observations

Tendering

Both PBM and traditional contracts are relatively short in duration compared to international practices. This may reduce overall efficiency in tendering, contract administration, and fixed costs.

Contract Management

Administrative effort under the PBC was noted to be higher in Lao PDR than in some other case studies. A number of assets are monitored monthly under the PBC, even though changes in the asset condition are likely to occur more slowly.

Resilience

Slope stability and landslips present a problem in the more mountainous areas under both contract models. Under the PBM model, the contractor is tasked to complete work associated with remediating these sites (as a provisional item and paid for using a BoQ) and then maintain the highway. Dedicated funding for the remediation is critical to keeping these vital transportation links open and mitigating the risk. The risk of further landslips is mitigated by regular maintenance of drainage assets through the CBM program.

Community Engagement

The CBM program has enabled the DOR to contract work to local villagers, support the flow of money into the local economy, and build local enterprises and capabilities.

FIGURE A4.11: EXAMPLE OF SLOPE STABILITY ISSUES ON HIGHWAY 16B

Note: This is one of multiple sites on Highway 16B in the mountainous area immediately west of the Vietnamese border where slips and slope stability issues resulting from the rainy season and occasional typhoon are common (OPUS 2019).

FIGURE A4.12: HIGHWAY 16B NEAR SEKONG

Note: Figure shows the effectiveness of the CBM, particularly vegetation control along the highway corridor (OPUS 2019).

Summary

The PBM approach adopted by the DOR has limited performance-based incentives compared to other case study PBCs. A longer contract term would also shift more responsibility for work programming to the contractor and increase the role of competition driving efficiencies in long-term management.

FIGURE A4.13: VIEW OF LOCAL ROAD 7165 NEAR SEKONG

Source: Opus 2019.

Lack of data and monitoring has prevented clearer comparisons. In particular, the DOR does not collect data on the actual level of service achieved through traditional contracts. Although comparison of asset lifecycle costs was not possible, the higher expenditure for the PBM approach likely more closely matches the preventive maintenance funding levels needed to deliver a higher level of service and prolong the road asset life. The higher level of preventive maintenance can result in lower lifecycle costs (see Appendix 6).

The completed improvements (both rehabilitation and maintenance) provide improved resilience and travel time certainty for the road users.

TABLE A4.6: CASE STUDY 2: LAO PDR OPRC AND TRADITIONAL MAINTENANCE CONTRACT DATA

Document	Overview	Commentary	Size (MB) / # of pages
Particular Specifications for CW-5 Att-NR18B	Scope of services for rehabilitation and performance-based maintenance	Provided electronically via email in a PDF format	12 / 32
Bill of Quantities for CW-5 AttNR18B	Includes quantities/pricing for general provisions (Bill 100), earth-works (Bill 200), pavement (Bill 300), drainage systems (Bill 400), other works (Bill 600), small-size rehabil-itation works, performance-based maintenance work (Bill PB100), provisional quantities, dayworks, and so on	Provided electronically via email in a PDF format	3 / 16
PBM Concept Presentation (2018)	PBM presentation on the 6 ADB-funded contracts in southern Lao PDR.	Provided electronically via email in a PDF format	1.6 / 35
Bid Evaluation Reports x 6	Full evaluation reports with contractor pricing for each of the contracts.	Contract: CW-1 NR20	3 / 64
		Contract: CW2-6901	5 / 64
		Contract: CW3-NR16	3 / 62
		Contract: CW4-LR7615	5 / 62
		Contract: CW5-NR18B	4 / 62
		Contract: CW-6 Att-LR 9001	7 / 40

Source: MPWT.

Case Study 3: Liberia Lot 1 Output and Performance-Based Road Contract and Cotton Tree to Port Buchanan Road Traditional Maintenance Contract

Liberia is a small, low-income coastal West African country with an estimated population of just over 5 million. Liberia's GDP is estimated to be US$3.2 billion and per capita GDP is estimated to be US$633. Poverty rates are high, particularly in rural areas where road access is limited, and public and private investment are therefore constrained.

Roads are the primary means of transport. Liberia's road network is relatively small, at approximately 10,000 km, of which less than 10 percent is paved. Only a small proportion of roads in Liberia—less than 10 percent—are paved, and the majority of unpaved roads are in poor or very poor condition.

The case study compares two vital transport corridors in Liberia. The PBC corridor (Red Light-Gate 15-Gbargna) extends from the 14 Gobachop market just outside Monrovia—the largest market in the country—to Gbargna, the second largest city in Liberia, located halfway between Monrovia and a key border crossing into Guinea. The PBC road provides access to the central and northeastern regions of Liberia, the Guinea border, and inland areas of southeastern Liberia.

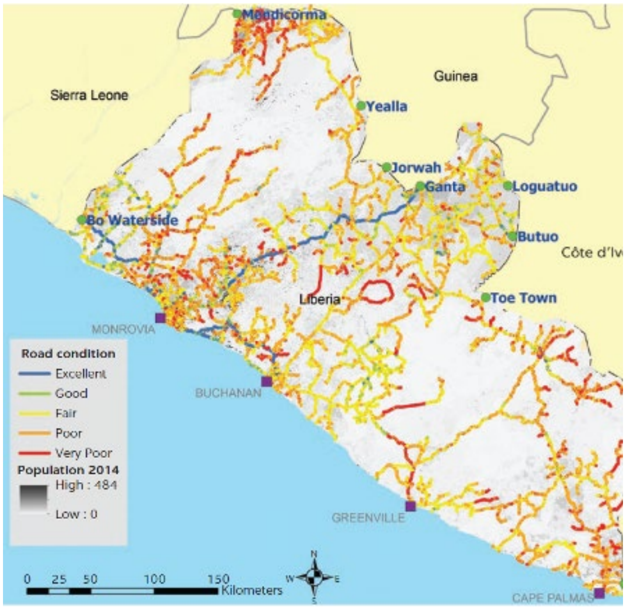
The traditional road section selected for comparison extends from Monrovia to Buchanan Port, located southeast of Monrovia; it is the first link in a mostly unimproved route extending from Monrovia along the cost to Harper via the coastal towns of Buchanan and Greenville. Both routes are used for transport of goods, fuel, wood, and other material from Monrovia to the hinterlands, while the PBC route is also used for commerce with other countries, especially Guinea.

Contract Details and Characteristics

Lot 1 Red Light-Gate 15-Gbarnga Road OPBRC
The PBC is a 10-year OPBRC encompassing a rehabilitation phase during the first three years followed by seven years of routine maintenance and a periodic overlay at the eighth year of implementation. The contract includes retention of most of the contractor's profit from the rehab-ilitation works, which is repaid with interest during the maintenance phase through quarterly performance-based routing maintenance payments. The OPBRC was awarded in 2012 and the monitoring and supervision consultant was appointed in 2013.

The contractor's rehabilitation program was delayed by nearly a year because the Government of Liberia was delayed completing the RAP requirements. The construction phase was also interrupted by an eight-month force majeure suspension due to the Ebola epidemic that started in mid-2014. Rehabilitation works exceeded the minimum contract requirements and were completed in September 2016.

FIGURE A4.14: ROAD CONDITIONS IN LIBERIA AS OF THE LAST COMPREHENSIVE ROAD CONDITION SURVEY (2016)



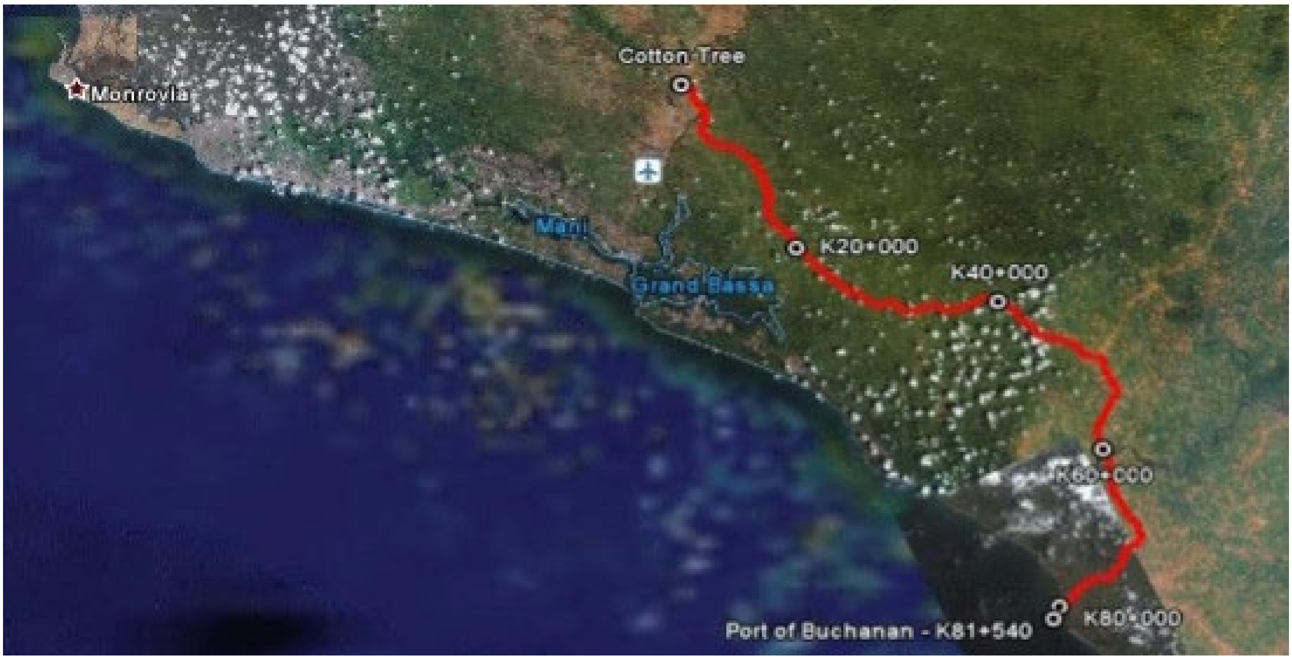
Source: Iimi and Rao, 2018.

The start of the periodic maintenance was deferred pending analysis of remaining pavement life. The analysis subsequently confirmed most of the road can achieve the 20-year design life without the planned overlay. The contract will close in October 2023.

FIGURE A4.15: IMAGERY LOT 1 OPBRC RED LIGHT-GATE 15-GBARNGA ROAD — 178.7 KM

Source: OPUS 2019.

FIGURE A4.16: IMAGERY OF COTTON TREE TO PORT BUCHANAN ROAD TRADITIONAL MAINTENANCE CONTRACT



Source: OPUS 2019.

Cotton Tree to Port Buchanan — Design and Build Rehabilitation Followed by a Traditional Maintenance Contract — 81.5 km

The Cotton Tree to Port Buchanan Road is a strategic transportation corridor linking the region southeast of Monrovia to the port facility. This road was in a poor condition and its rehabilitation was justified on economic grounds.

The contractor (CHICO) was awarded a two-year design and build rehabilitation contract in 2011. This contract was followed by a traditional maintenance contract undertaken by a separate contractor (BMC) which is administered by Liberia's Ministry of Public Works (MPW).

Summary of Economic Feasibility of the Project Investment

Both roads were planned as part of the post-conflict reconstruction of Liberia. Table A4.7 shows the economic analysis summary for both investments. The economic analysis in the final report also tested the sensitivity to: cost increases (by 25 percent), longer rainy seasons (increasing IRI for the 'do-nothing' option and increasing the benefits in the 'do-something' option) and reducing the benefits (by 20 percent). Even under these conservative scenarios, the project remained economically feasible with the projected economic internal rate of return (EIRR) ranging from 13 percent to 37 percent.

TABLE A4.7: ECONOMIC FEASIBILITY SUMMARY (BASE CASE) — DECEMBER 2009

	OPBRC Lot 1 Red Light — Gbarnga (178.7 km)	Traditional — Cotton Tree to Port Buchanan (81.5 km)
NPV (12%), US$, millions	128.4	19.8
EIRR, %	27.0	18.0
First-year benefit ratio, %	32.2	13.3
BCR	1.9	1.3
Payback period, years	7.0	1.3

Source: Final Report on the Conceptual Designs and Preparation of Tender Documents for 'Red Light-Gate 15-Gbarnga-Ganta-Guinea Border' and 'Cotton Tree to Port Buchanan' Roads, commissioned by the Government of Liberia.

TABLE A4.8: CONTRACT DATA SUMMARY — LIBERIA LOT 1 OPBRC AND COTTON TREE TO PORT BUCHANAN TRADITIONAL MAINTENANCE CONTRACTS

OPBRC (PBC) Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehabilitation Works		
US$669,541/km[39]	US$538,531/km	
Item 2: Periodic Maintenance Works		
US$212,689/km Expected to be close to the actual cost for a 40 mm AC overlay. This has not been undertaken on the PBC.	Periodic maintenance is not planned for the road maintained under traditional contracting.	
Item 3: Routine Maintenance Works		
Payment — US$46,611/km/year Estimated actual routine maintenance cost US$9,322/km/year	Estimated expenditure — US$1,394/km/year	Routine maintenance payments under the OPBRC include a portion of the rehabilitations works' price as noted above, all maintenance items, and biannual condition surveys (IRI and pavement deflection — FWD).
Item 4: Emergency Works Expenditure — Average Annual		
US$842/km/year	Budget amount US$28,400. Actual expenditure unknown but the network is more prone to flooding due to the flat topography, lower elevations, and proximity to major rivers.	Bulk spent on landslide retaining wall repairs on the PBC.
Item 5: Contract Administration — Procurement		
Bid cost 0.235% of the contract price (US$2,836/km)	Bid cost unknown	Employer administration cost for either contract is uncertain but likely to be less than 2 FTEs.
Item 6: Contract Monitoring/Supervision/Administration		
US$47,818/km (5.14% of the contractor's price) covering rehabilitation, routine maintenance, and periodic maintenance works	US$36,980/km (5.17% of the contractor's price), covering the rehabilitation phase only	The OPBRC cost is based upon a total of 276 months' (FTE) input by key personnel and includes remuneration and reimbursable costs.
Item 7: Non-pavement Maintenance Works		
Service levels include vegetation control, sign maintenance, pavement marking, drainage maintenance, guardrail repairs, cut slopes and embankment maintenance, structures inspections, and management performance measure reporting.	BoQ only lists signs, pavement markings, stone masonry repairs, and guardrail maintenance.	All OPBRC maintenance works included under a single lump-sum item as per Data Item 3.

39 Actual price paid to the contractor but only approximately 80 percent of true price. The difference (20 percent) is paid as part of the routine maintenance payments. US$ CPA Factor Applied = 0.3001.

TABLE A4.8: CONTRACT DATA SUMMARY — LIBERIA LOT 1 OPBRC AND COTTON TREE TO PORT BUCHANAN TRADITIONAL MAINTENANCE CONTRACTS, CONTINUED

OPBRC (PBC) Values (2019)	Traditional Contract Values (2019)	Commentary
	Item 8: Resilience	
Aside from a landslip, there have been no climate- or disaster-related closures on the road. Rapid urbanization in the north of Monrovia, facilitated by the road, has resulted in increased flood risks to the road. These outcomes were not anticipated in the initial design.	Lack of routine maintenance inputs around drainage and culvert structures is expected to reduce the hydraulic capacity of these structures and reduce resilience.	Both roads require a more dedicated focus on bridge management and maintenance. Neither contract included adequate funding for major structural maintenance works that have been identified. Unless these structural repairs are undertaken, there is an increasing risk of structural failure and loss of connectivity in the future.
	Item 9: Additional Nonfinancial Benefits	
a. Employment of local villagers for routine maintenance works (67 FTEs) b. Routine maintenance payments based upon service-level compliance resulting in consistent service levels along the project road c. Access to specialist resources through the existing long-term contracts enabling the agency to procure additional services efficiently d. Provision of depot and camp facilities for future use by the agency e. Increased data capture and availability around road assets and condition f. Increased certainty on financial expenditure g. Transfer of risk on quality and performance to the contractor	a. Simple maintenance contract which is easy to procure and administer	

Quality Differences

There appears to be little difference between the OPBRC and traditional contract rehabilitation works. Both were constructed by large international contractors and administered by separately contracted monitoring and supervision consultants. In both cases, travel time reduced by about 50 percent, primarily because of the extremely poor condition of the roads before rehabilitation.

The transfer of some rehabilitation profit to the routine maintenance phase of the OPBRC has resulted in the contractor losing money over the construction period, which the contractor is endeavoring to recover over the routine maintenance phase. This financial tension has resulted in a reduced focus on some quality issues (road signage is to be replaced due to premature fading—at the contractor's expense), health and safety, and environmental outcomes. However, overall pavement and wearing course construction quality has been generally of a good standard, assisted by good and locally accessible construction materials (laterite materials exist in the subgrade and subbase construction on both roads).

Design standards (20-year pavement design life) were based upon AASHTO in both cases. Both contracts involved a mixture of bridge replacement (where the original structures had been seriously damaged or destroyed) as well as maintenance of existing structures where these were considered adequate. Both contracts lacked sufficient provision for funding post-rehabilitation bridge maintenance.

FIGURE A4.17: SHOULDER OF COTTON TREE TO PORT BUCHANNAN ROAD

Note: Figure shows the absence of centerline markings (OPUS 2019).

To reduce its long-term maintenance costs, the Lot 1 contractor voluntarily chose to exceed the minimum pavement requirements of the contract in a limited number of instances. This includes installation of AC shoulders (the contract minimum called for DBST, which would need to be overlaid during the routine maintenance phase) and undertaking complete reconstruction of some road sections for which the minimum allowed scope of work was rehabilitation. This is assumed to have lowered the lifecycle costs to the contractor. While it is not clear whether any of these savings have been passed on to the Government of Liberia, this has resulted in a higher quality outcome than would have arisen if a traditional contract approach was used in this road section.

FIGURE A4.18: EXAMPLE OF PAVEMENT MARKINGS AND ROAD SIGN CONDITIONS ON TRADITIONAL CONTRACT

Source: OPUS 2019.

Other quality differences are related to the level of maintenance funding and completed maintenance and the contractor's sustained engagement in operating the road. Secure routine maintenance funding has resulted in a consistent and higher level of preventive maintenance on the OPBRC road. The OPBRC contractor responds to minor repair needs resulting from collisions (such as oil spills and damage to furniture) and has been tasked with removing breakdowns from the travel lanes.

OPBRC Lot 1 Recorded IRI and Pavement Deflection Progression

Roughness and pavement deflection surveys have been carried out on both lanes of the Lot 1 OPBRC road. Roughness surveys have been carried out since December 2016 and pavement deflection surveys since March 2018. The latest survey (March 2019) results are summarized for the whole road in Tables A4.9 and A4.10.

TABLE A4.9: OPBRC AVERAGE IRI AND AVERAGE ANNUAL IRI INCREASE PER LANE (MARCH 2019)

Average IRI RHS	Average Annual Increase in IRI/Year RHS	Average IRI LHS	Average Annual Increase in IRI/Year LHS
2.17	0.184	2.42	0.176

Note: LHS = Left-hand side; RHS = Right-hand side.

TABLE A4.10: OPBRC AVERAGE D0 PAVEMENT DEFLECTION AND AVERAGE INCREASE PER LANE (MARCH 2019)

Average Pavement Deflection D_0 RHS	Average Annual Increase in D_0/Year RHS	Average Pavement Deflection D_0 LHS	Average Annual Increase in D_0/Year LHS
0.3037 mm	0.0137 mm	0.2644 mm	0.0044 mm

Progression rates for both roughness and pavement deflection will not be linear over the entire life cycle of the pavement and surfacing assets. This is because deterioration is expected to accelerate toward the end of the life cycle. However, assuming a linear rate of deterioration at least through to the specified maximum values in the OPBRC (IRI = 4.0 m/km, D0 = 0.7 mm), the current progression rates are likely to result in a 40 mm AC overlay (periodic maintenance). This will be needed by March 2028 to correct the anticipated roughness deterioration and the next rehabilitation to restrengthen the pavement will be needed by March 2048 (that is, an average pavement service life of 33 years).

Both road networks are presumed to be subject to some traffic overloading as there is no effective means of axle load control or enforcement in place. The impact of overloading has not been quantified as axle load surveys have not been undertaken since the rehabilitation works were completed. In addition, although the legal axle load was increased from 8.8 tons to 11.0 tons during the OPBRC contract period, this increase was not accounted for in the pavement designs or OPBRC contract terms.

These issues lend support to the concept of implementing more conservative pavement designs. The designs would be likely to provide long-term benefits through longer life cycles and would be more resilient to the abovementioned issues and other unforeseen adverse environmental factors.

The pavement designs for both roads have been robust and generally well-constructed. This has resulted in surfacing and pavement assets that are resilient and can sustain a higher level of vehicle overloading. A conservative approach to pavement design therefore seems to offer long-term benefits, which come from sustained pavement and surfacing condition and an extended life cycle. The conservative approach's benefits are especially important given the level of uncertainty around routine maintenance funding and inputs beyond the OPBRC duration.

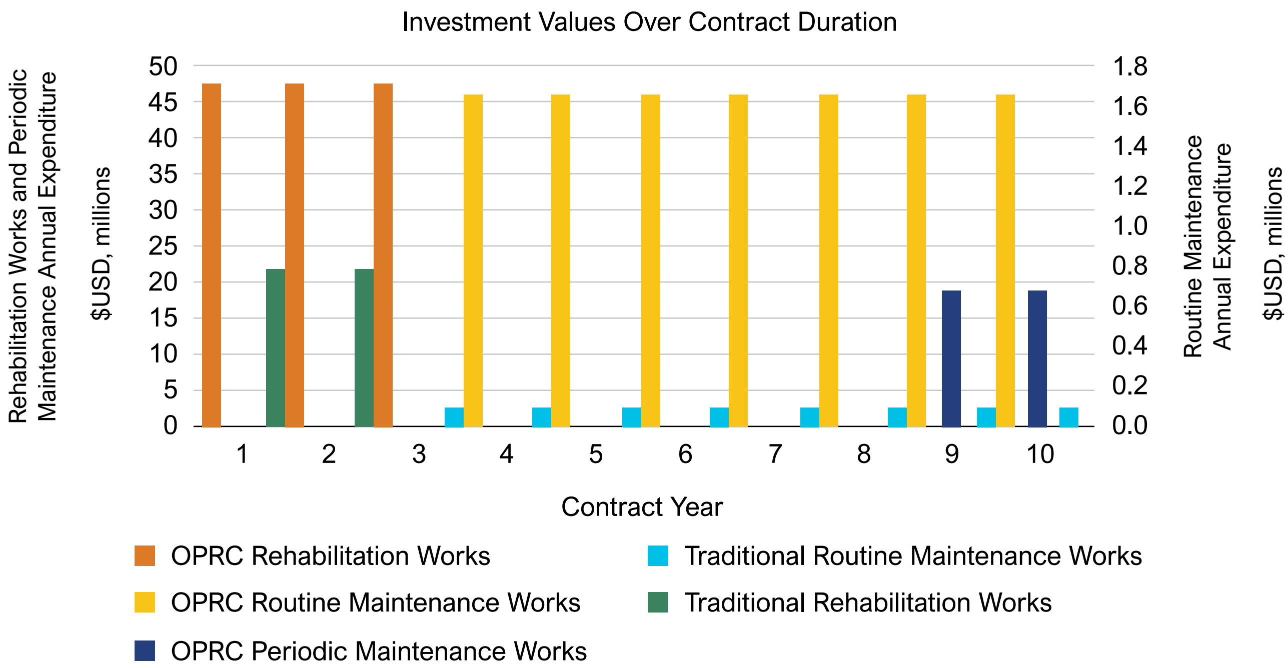
Value-for-Money Discussion

Contract prices were competitively bid resulting in relatively low rehabilitation prices in both cases. Significant differences in the contracts could have affected the value for money of each approach. As noted above, the OPBRC contractor opted to construct the road to a higher standard than the contract minimum (conceptual design). Withholding profits from rehabilitation has meant that the contractor has remained focused on ensuring that an acceptable service level is being provided and no payment deductions are applied.

Repairs to OPBRC Lot 1 have been undertaken at the contractor's expense in recent years. This includes nine areas of subsidence near culverts that were corrected at the contractor's cost. A further 5 km road section (134+000 to km 139+000) has experienced rising roughness due to the lower level of construction quality and grade control. While this section had not yet breached the roughness threshold for reconstruction (4 IRI), it was likely to warrant some rehabilitation or smoothing overlay repairs before the end of the contract at the contractor's expense. This transfer of the quality risk to the contractor has meant that the Government of Liberia has avoided paying for quality-related rework. The agency would also experience savings if performance targets were not met.

If the deferred payment for rehabilitation works is removed from the OPBRC routine maintenance works payments, the difference in maintenance funding between the two contract models is still significant. This variance will have a significant impact on the respective asset life cycles, particularly if the higher level of maintenance funding under the OPBRC is sustained through the entire asset service life. There is no certainty that this level of routine maintenance expenditure will be continued beyond the OPBRC contract period, however. If this is the case, the benefits of the initial investment would begin to diminish much more rapidly in the future. As preventive maintenance is an important component of lowering lifecycle costs and maximizing user benefits, consistent preventive maintenance under the OPBRC has the potential to deliver greater value for money.

FIGURE A4.19: SUMMARY OF ANNUAL INVESTMENT FOR THE OPBRC AND TRADITIONAL MAINTENANCE CONTRACT



Source: OPUS 2019.

Before government establishment of a road safety data collection process, proactive involvement of the OPBRC contractor clearing severe collisions from the roadway provided the only source of data on collisions in the OPBRC corridor. Therefore, information collected for invoicing also raised awareness of the scope of safety issues along the road, leading to a stronger government response.

A proportion of the routine maintenance works payments include the contractor's profit and overheads from the earlier rehabilitation phase. This means the contractor has remained focused on ensuring that an acceptable service level is being provided and no payment deductions are applied.

The defined OPBRC service levels include pavement marking, delineation, and guardrail repairs. This has resulted in a higher standard of maintenance for these assets compared to the traditional maintenance contract. While this has resulted in a relatively safer road facility under the OPBRC than under the traditional contract, there is insufficient evidence to determine if this resulted in additional value from improved safety outcomes.

The commitment to adequately fund routine maintenance and the duration of the OPBRC routine maintenance phase has enabled the contractor to subcontract out some routine maintenance work to small local suppliers. This has then increased the flow of money into the local economy due to these maintenance activities and contributed to development of small firms and skills.

The long-term OPBRC has resulted in a much higher level of project team retention and continuity of knowledge about the project road compared to the traditional maintenance contract, where this is lost after two years. This benefit is manifest through an understanding of how the rehabilitation phase was undertaken and where any areas of increased risk to the long-term performance of the road network may exist. These can then be closely monitored, and the contractor can be notified of any concerns or trends in advance.

Contract Administration, Resilience, and Other Observations

Tendering
Both contract models engaged the same consultant to undertake the investigation, design, economic evaluation, and procurement document preparation under a single contract. The total cost for the design and development phase work was US$1,961,500. This includes approximately US$1,067,000 for procurement of the 178.7 km OPBRC and approximately US$406,000 for traditional maintenance contract for 81.5 km of similar road. The per km cost of tendering these initial contracts is slightly higher for the OPBRC, and the OPBRC includes 10 years of maintenance.

Contract Administration
The case study data confirmed there is little difference between the monitoring and supervision costs as a percentage of the contractor's prices and indicates an added value for the PBC in the case of Liberia. For the same percentage of the contractor's price, the agency could purchase the same monitoring and supervision consultant inputs for rehabilitation, long-term routine maintenance, and periodic maintenance, for an additional US$1,084/km/year. This suggests economies of scale may be achievable by including the long-term maintenance activities within the traditional stand-alone rehabilitation works.

The OPBRC is much more complex. For instance, there is ambiguity about the portion of the quarterly performance-based routine maintenance payments that fund maintenance compared to the portion that is funding repayment for rehabilitation works. This has at times affected the government's perception of the contract.

The OPBRC lump-sum price includes periodic maintenance works to be undertaken during the eighth and ninth year of the contract. This allows for any surfacing deterioration to be addressed and ensures the pavement can meet the remaining pavement design life before the contract finishes and reduces the risk that the government will need to fund premature rehabilitation.

The initial construction quality of the OPBRC road was mostly sound and traffic volumes were lower than the initial design anticipated in many areas. Given the fiscal constraints faced by the Government of Liberia, the government is likely to postpone periodic maintenance. Negotiation of major changes to the OPBRC can however prove complicated. This is a potential downside including the periodic maintenance in the OPBRC.

Summary

Lack of data has prevented more direct quantitative comparison of the projects, particularly lifecycle costs and economic benefits. Nonetheless certain important observations can be made.

The Lot 1 OPBRC experience was largely successful in respect to ensuring quality of outcomes. Repairs that were needed due to workmanship were made by the contractor at its expense. Some quality issues arose due to the financing model, which imposed cash flow constraints during the rehabilitation phase, but the contractor was later liable to address these at its expense as well.

The OPBRC model has proven challenging in Liberia due to the government's fiscal constraints and because government acceptance of preventive maintenance is not widespread. Securing routine maintenance funding will positively affect the life span of the road, but the government is unlikely to carry out the full periodic maintenance activities due to fiscal constraints. Negotiation of this contract change is also relatively complex for the government.

TABLE A4.11: CASE STUDY 3: LIBERIA LOT 1 OPBRC AND COTTON TREE TO PORT BUCHANAN ROAD CONTRACT DATA

Name	Description
EU_Final contract document.zip	Traditional contract document
002-20170303 traffic count record	More detailed listing of recent CREMAs' routes
Annual Expenditure Graph.xls	PBC expenditure
Copy of Traffic count Summary 20162017.xls	PBC traffic count data
Copy of Traffic count Summary 2017–2018	PBC traffic count data
Copy of Traffic count Summary 2017–2018	PBC traffic count data
CPA Rehabilitation and Routine Maintenance	PBC payments
Data Summary Sheet_Liberia_OPRC_April_2019	PBC response to case study survey questions
RE Cotton Tree to Port Buchanan Road Rehab Monitoring and Supervision Cost.eml	Traditional supervision costs
TNM — OPRC Project Infor_.docx	PBC concept tender summary
Designs and Tender Documents for Liberia Projects	PBC tender documents and specimen designs
Contract Documents	Traditional final completion report
127128-PUB-PUBLIC-date-6-6-18.pdf	Spatial analysis of Liberia's transport connectivity and potential growth
Liberia-LR-Urban-and-Rural-Infra-RehabProject Copy.pdf	PBC Implementation Completion and Results Report (ICR) review
Rep. Liberia Design Build Transfer of Bokey to Buchanan Port.pdf	Traditional final design report
Copy of Motor Vehicle Accidents Analysis Data Collection as of 2013-2015.pdf	PBC crash data
Copy of Motor Vehicle Accidents Data Collection as of 2016-2018.pdf	PBC crash data

Case Study 4: Western Bay of Plenty District Council Performance-Based Contract and Whakatane District Council Traditional Maintenance Contract

New Zealand is an upper-income island country in the south Pacific located southeast of Australia. The population of New Zealand is slightly greater than 5 million and per capita income is approximately US$44,491. The case study areas, the WBOP DC and Whakatāne District Council, are located on the northeast of the second largest island, known as the North Island and Te Ika-a-Māui. The island is home to the largest city in New Zealand, Auckland (located in the central western part of the island), and the national capital, Wellington (located at the island's south).

The case study region is predominantly rural. The WBOP District, which owns the PBC network in this study, has one of New Zealand's highest population growth rates (1.5 percent a year), mainly because of its mild climate and desirable living conditions. The southeastern area of the WBOP DC shares a boundary with the Whakatāne District Council which owns the traditional network used for this case study. Both networks provide an essential and strategic link to Tauranga City, the region's port, airport, and surrounding industries for horticulture and forestry industries.

Contract Details and Characteristics

WBOP DC

The WBOP DC covers an area of approximately 2,120 km^2. Its network comprises approximately 1,027 km of roads, of which approximately 320 km are unpaved and 707 km are paved. The paved network is predominately a two-lane, undivided carriageway with sprayed chip seal surfacing.

The road network serves the area surrounding Tauranga City (population 141,600), its port (the largest export port in New Zealand), and two smaller townships: Katikati (population 4,700) and Te Puke (population 7,500). These townships provide services for intensive horticulture which is one of the region's largest industries. Much of the topography of WBOP is rolling, while the geology comprises mainly volcanic soils.

The WBOP DC undertook an ambitious endeavor by tendering a PBC for the entire 1,027 km network under a single large PBC, which commenced in 1999. Under the PBC, the WBOP DC determined the outcomes by specifying

- The network condition required, when it must reach that condition, and how to measure and assess the condition;
- Asset strength and durability – covered by KPMs which related mainly to the average condition of the roads; and
- Road user performance measures such as comfort, serviceability, and safety. These were identified as being more about the tail of the condition distribution curve and covered by 54 OPMs.

FIGURE A4.20: TYPICAL PAVED RURAL ROAD SERVICING AN INTENSIVE HORTICULTURE INDUSTRY AND PAVED TO UNPAVED RURAL ROAD TRANSITION

Source: OPUS 2019.

Whakatāne District Council Traditional Maintenance Contract

The Whakatāne District Council's 902 km road network comprises approximately 200 km unpaved roads and 702 km of paved roads. The paved roads are predominately two-lane undivided carriageways with sprayed chip seal surfacing.

The road network serves the area's dairy, horticulture, and forestry industries with a total population of 34,400, including the main coastal city of Whakatāne, which has a population of 19,750.

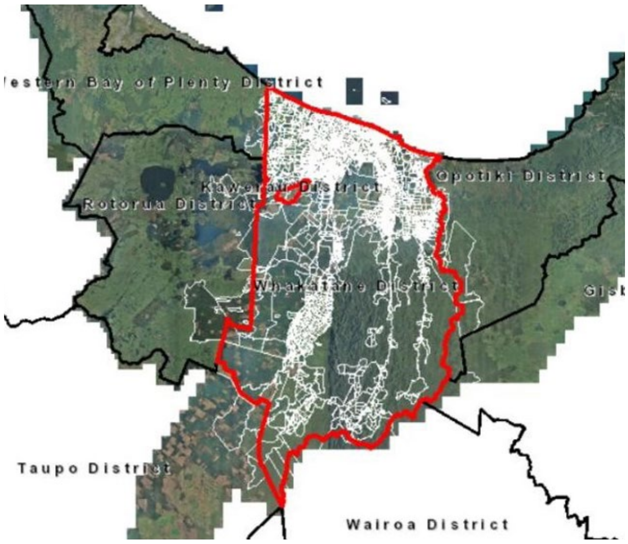
Whakatāne District covers an area of approximately 4,440 km^2 and extends from the flat coastal Rangitikei Plains through to rolling and hilly regions bordering the Wairoa District to the east and the Taupō District to the south. Most of its underlying geology is also volcanic in nature.

The Whakatāne District Council Traditional Maintenance Contract — General

This contract model relies on a combination of factors to drive quality outcomes:

- Direct control of asset management decisions in respect to the need, timing, justification, and treatment selection. The Whakatāne DC therefore carries the ownership and risk on treatment outcomes and performance other than the contractor's direct liability workmanship, which typically is limited to a 12-month defect liability period.
- Contractor performance assessments may have a bearing on the contractor's eligibility to bid for future contracts or be appointed to future supplier panels.
- Reduced contract tenure, eligibility for additional work under the contract, and/or a loss of a performance payment.

FIGURE A4.21: LOCATION OF THE WHAKATĀNE DISTRICT COUNCIL



Source: OPUS 2019.

FIGURE A4.22: TYPICAL PAVED RURAL ROAD SERVING AN INTENSIVE DAIRY INDUSTRY AND PAVED TO UNPAVED RURAL ROAD TRANSITION

Source: OPUS 2019.

FIGURE A4.23: TYPICAL PAVED URBAN ROAD THROUGH RESIDENTIAL/LIGHT INDUSTRIAL ZONE

Source: OPUS 2019.

These types of incentives are common in traditional maintenance contracts. They usually provide sufficient motivation for the contractor to deliver acceptable outcomes to the agency (subject to a sustainable bid price being accepted). The approach places a high level of importance on excellent communication and collaboration between the two contracted parties. Success is dependent upon establishing and retaining good working relationships at the senior management and operational levels. If any of these key elements break down, it is common for the contract outcomes to be seriously affected.

TABLE A4.12: CONTRACT DATA SUMMARY — WBOP DC PBC AND WHAKATĀNE DISTRICT COUNCIL TRADITIONAL MAINTENANCE CONTRACTS

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehabilitation Works — Paved		
US$240,000/km Approximately 0.34% of the PBC paved network rehabilitated each year	US$360,000/km Approximately 0.2% of the traditional paved network rehabilitated each year	Average 10 m paved carriageway width
Item 2: Pavement Rehabilitation (strengthening) — Unpaved		
US$22,500/km	US$21,000/km	Based upon a 150 mm aggregate overlay compacted. Average 5.8 m carriageway width
Item 3: Periodic Maintenance Works		
US$34,200/km	US$32,200/km	Based on a spray chip seal. Average 10 m paved carriageway width
Item 4: Routine Maintenance Works		
US$1,250/km/year	US$2,340/km/year	Average annual expenditure
Item 5: Emergency Works Expenditure — Average Annual		
US$74/km/year The WBOP DC PBC required the contractor to be responsible (and include in their lump-sum price) for the first US$530,000 of emergency works within a single contract year. The PBC emergency works cap was exceeded only once over the eventual 12-year term of the contract.	US$2,630/km/year Whakatāne Road Network has suffered damage because of several major cyclone events over the analysis period.	The emergency works expenditure for each contract is averaged over the duration of the contract.
Item 6: Contract Administration — Procurement		
Contractor's bid cost 0.19% of the contract price (US$401/km.) There were three bidders. Overall procurement cost for the WBOP DC was US$3,500,000 (1.67% of the contract price). Overall, US$360/km/year Procurement savings achieved US$44.2 million	Approx. US$600/km/year	Whakatāne District Council traditional maintenance contractors are selected from various supplier panels: sealed and unsealed pavement maintenance, signs' maintenance and renewals, structures' maintenance, drainage maintenance and renewals, incident response, and environmental works (for example, tree trimming).

TABLE A4.12: CONTRACT DATA SUMMARY — WBOP DC PBC AND WHAKATĀNE DISTRICT COUNCIL TRADITIONAL MAINTENANCE CONTRACTS, CONTINUED

PBC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 7: Contract Monitoring, Supervision, and Administration		
3 FTEs at US$514/km/year	US$1,210/km/year	PBC agency supervision fees unknown
Item 8: Non-pavement Maintenance Works		
Bid price of S$219,260,000 (US$18,400/km/year) inclusive of all rehabilitation, periodic maintenance, routine maintenance, and emergency works for 10 years	Prices for all other non-pavement maintenance works are included in above mentioned costs/km.	For the Whakatāne District Council traditional maintenance contract, suppliers are selected from a supplier panel for signs' maintenance and renewals, structures' maintenance, drainage maintenance and renewals, incident response, and environmental works. The suppliers are invited to submit prices for defined work packages. Works excluded from the supplier panel are cyclic maintenance, sealed road periodic maintenance (resurfacing), pavement marking, vegetation control, streetlight maintenance, and pavement rehabilitation works.
Item 9: Resilience		
Drainage and bridge structures were well maintained.	Drainage and bridge structures are older, and greater investment in renewal was needed.	Both networks are subjected to heavy rainfall events and prone to flooding and washouts where events have a return interval of greater than 1 in 10 years.
Item 10: Additional Nonfinancial Benefits		
a. Opus International Consultants was the lead contractor (three-way contractor alliance structure) for the PBC. This arrangement provided a depth of asset management experience to be directly applied to the way the contract was administered. This situation (consultant-led consortium) was unusual both in New Zealand and internationally.	a. The retention of the traditional maintenance contract has enabled the council to keep a high degree of control and asset management capability within the organization.	The analysis undertaken on the WBOP DC PBC considered only the local district roads so it would be comparable with the Whakatāne District Council traditional maintenance contract.

TABLE A4.12: CONTRACT DATA SUMMARY — WBOP DC PBC AND WHAKATĀNE DISTRICT COUNCIL TRADITIONAL MAINTENANCE CONTRACTS, CONTINUED

PBC Values (2019)	Traditional Contract Values (2019)
Item 10: Additional Nonfinancial Benefits	
b. The PBC included both local district roads and the state highways running through the district. This enables a high degree of synergy in the way the two road networks were managed. It also enabled an increased level of efficiency and productivity, as work programs and resources could be coordinated and shared across two road networks rather than independently. c. The PBC drove the development of a range of asset management systems for analyzing and reporting network performance and condition. The objective of these systems was to optimize the level of expenditure required to meet the specified performance outcomes within the lump-sum price. This provided a high level of understanding by the contractor and council around the network's performance. In turn, this enabled road users and the district's rate payers to be kept informed on condition trends and investment requirements. d. A detailed risk model was developed and used by the contractor to monitor the way risks were shared between the alliance partners.	b. The current use of a supplier panel as the means of selecting suppliers for various work packages has increased the efficiency and reduced the procurement cost to the council. This approach has also retained a healthy supplier market by ensuring work continuity for the local contracting industry.

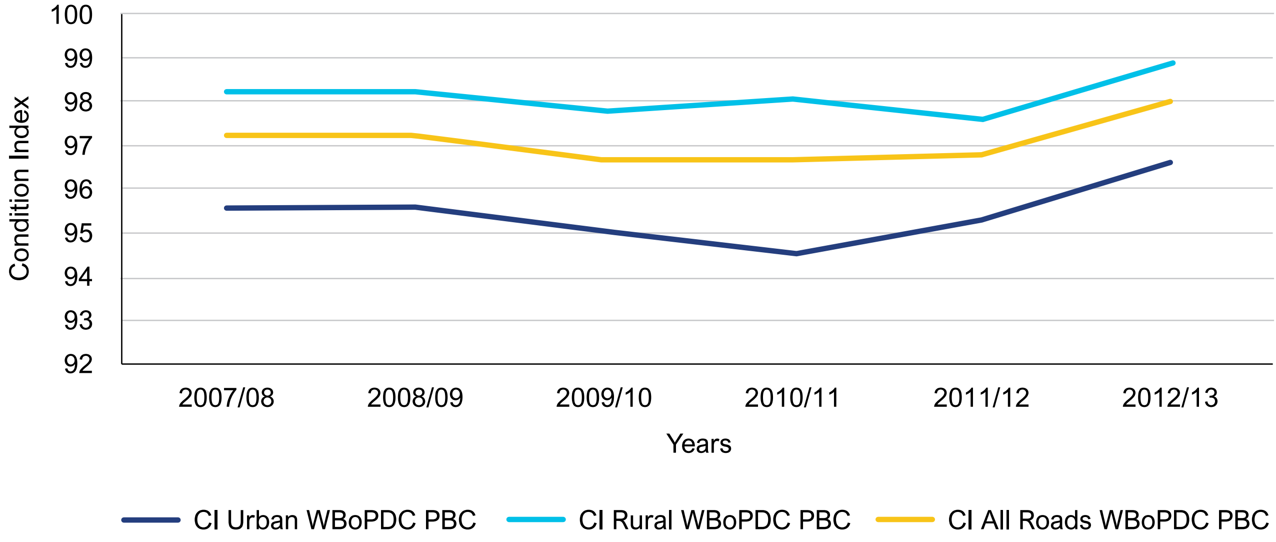
Quality Differences

The quality outcomes of both networks are considered to be directly comparable because both contracting approaches encompassed the same scope of works (rehabilitation through routine maintenance). Both the traditional and PBC networks met quality standards applied in New Zealand. The traditional network performed slightly better than the PBC network in most measures, however. Road conditions on the traditional network often exceeded the stated performance targets (reflecting excess maintenance expenditure).

Both the PBC and traditional networks experienced traffic growth over the case study period. Traffic along the PBM network increased by an average of 3 percent per year (a total of 38.9 percent gain over 13 years) compared to 1 percent per year for the traditional network. The PBM network met the contract performance requirements and traffic growth did not exceed the contract threshold for transferring traffic risks to the PBC contractor.

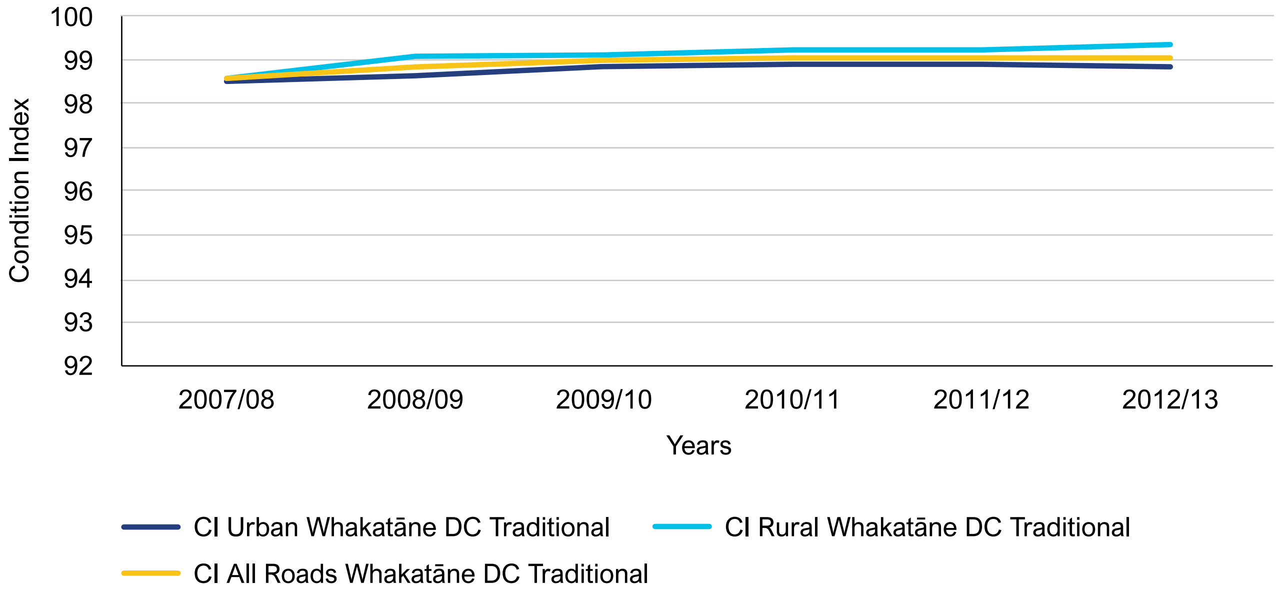
The pavement condition results recorded over 2007/08 through 2012/13 are shown in Figures A4.24 to A4.32.

FIGURE A4.24: WBOP DC PBC NETWORK CI 2007/08–2012/13



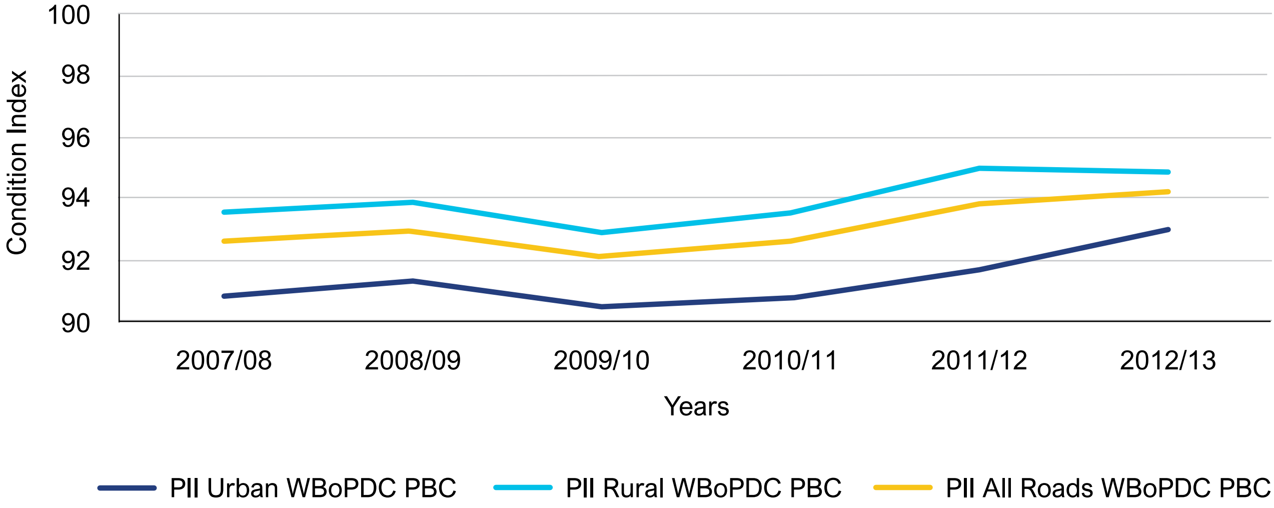
Source: WBOP DC.

FIGURE A4.25: WHAKATĀNE DISTRICT COUNCIL TRADITIONAL NETWORK CI 2007/08–2012/13



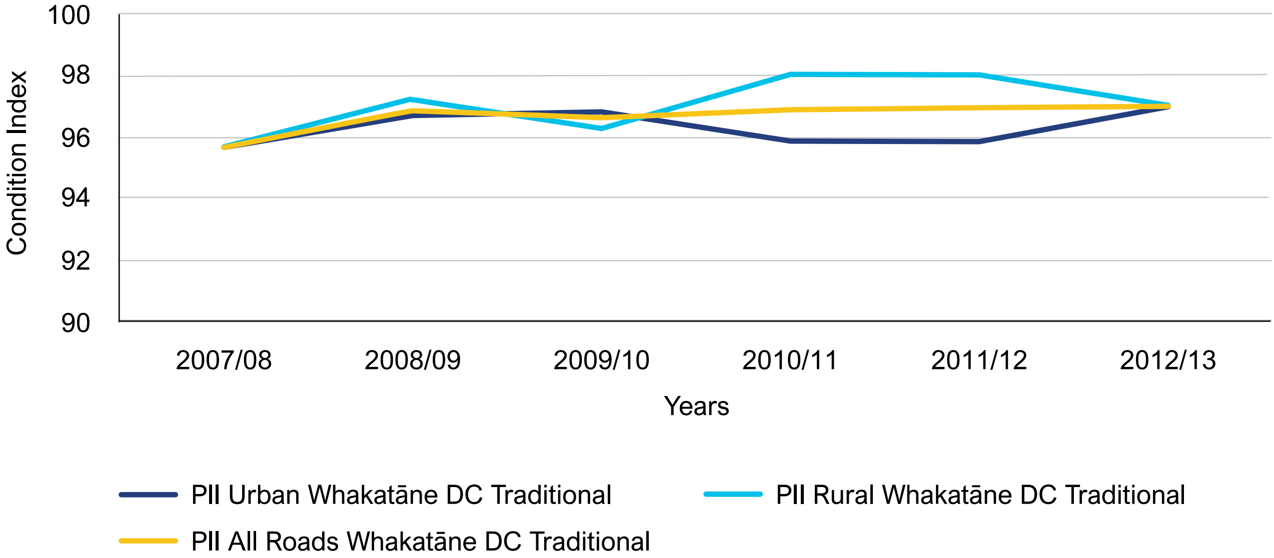
Source: Whakatāne DC.

FIGURE A4.26: WBOP DC PBC NETWORK PAVEMENT INTEGRITY INDEX 2007/08–2012/13



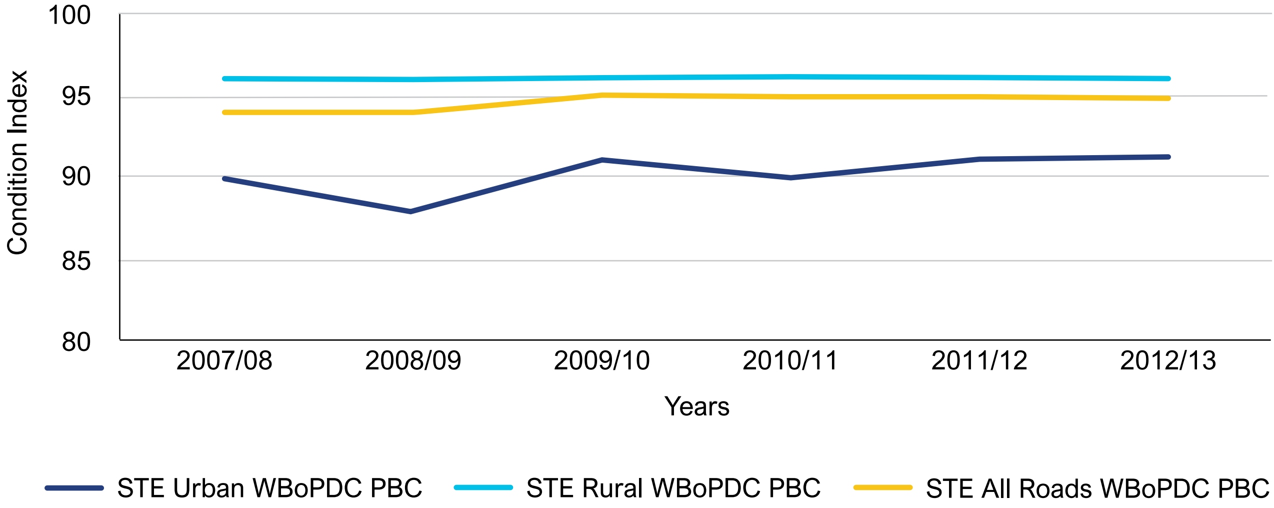
Source: WBOP DC.

FIGURE A4.27: WHAKATĀNE DISTRICT COUNCIL TRADITIONAL NETWORK PAVEMENT INTEGRITY INDEX 2007/08–2012/13



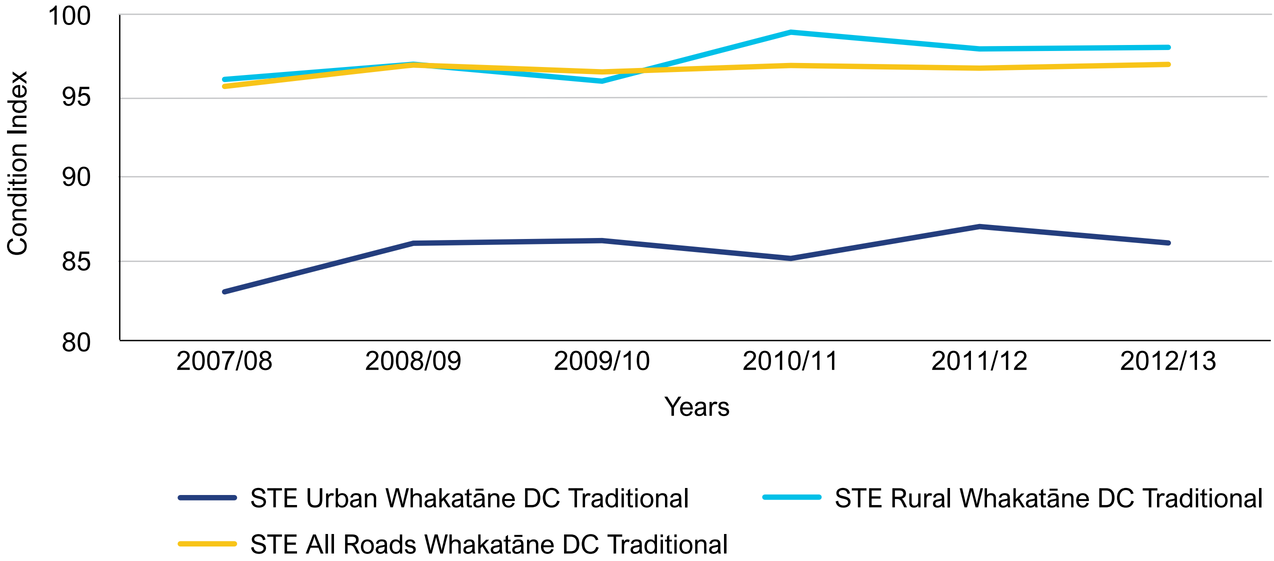
Source: Whakatāne DC.

FIGURE A4.28: WBOP DC PBC NETWORK STE INDEX 2007/08–2012/13



Source: WBOP DC.
Note: STE = Smooth Travel Exposure.

FIGURE A4.29: WHAKATĀNE DISTRICT COUNCIL TRADITIONAL NETWORK STE 2007/08–2012/13

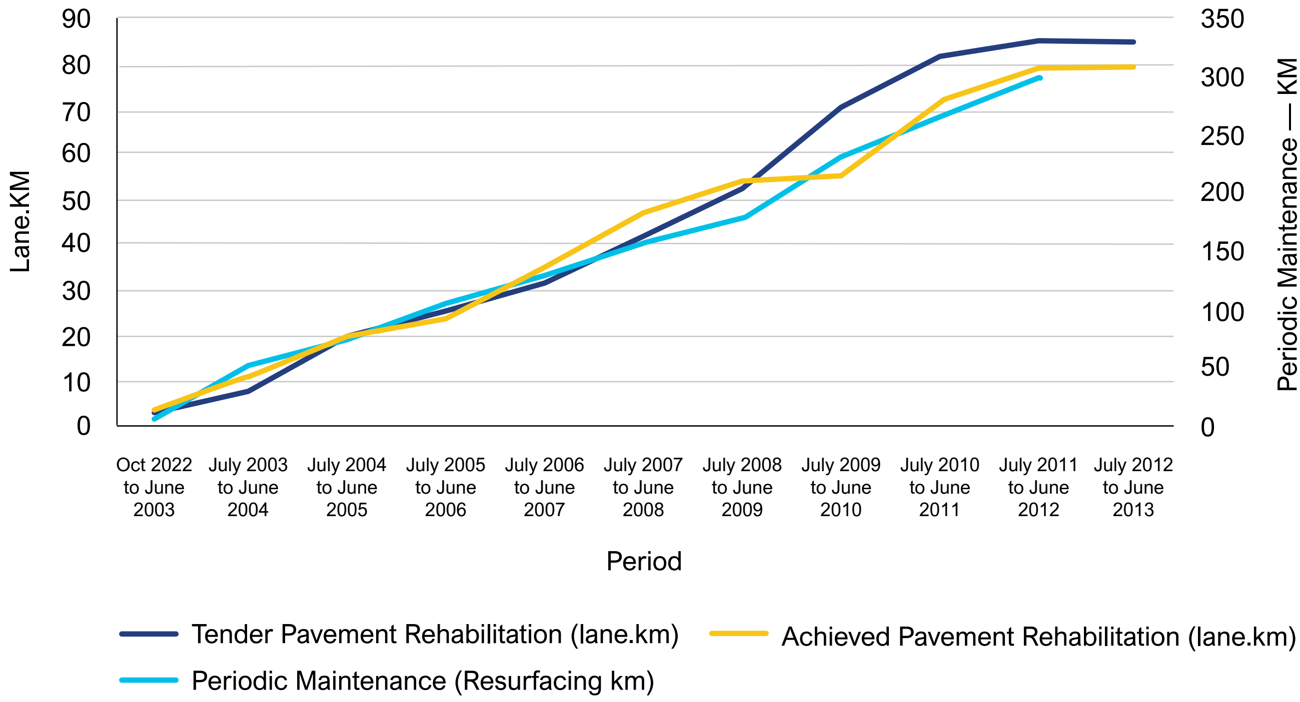


Source: Whakatāne DC.

WBOP DC Renewals Investment

Figure A4.30 summarizes the quantity of pavement rehabilitation and periodic maintenance works (resurfacing and smoothing overlays) undertaken on the WBOP DC PBC roads.

FIGURE A4.30: SUMMARY OF WBOP DC PBC RENEWALS (REHABILITATION AND PERIODIC MAINTENANCE WORKS)



Source: WBOP DC.

The quantity of actual rehabilitation works completed over the 10 years averaged 7.2 lane km per year (0.34 percent of total network length) which equated to 94 percent of the quantity identified at the time of bidding. The quantity to be completed had to be within a ±10 percent tolerance of the bid quantity to avoid financial penalties. The variance resulted from road sections being included in other capital works or deferred for other reasons.

Approximately 10 percent of the unpaved roads were strengthened each year under the PBC. This work was programmed to ensure that the minimum underpinned quantity of 17,000 m^3 of aggregate was applied for each contract year. In addition, key performance indicators (KPIs) were specified for the unpaved roads in the contract. This was based upon a Surface Defects Index and minimum gravel thickness for the unpaved roads.

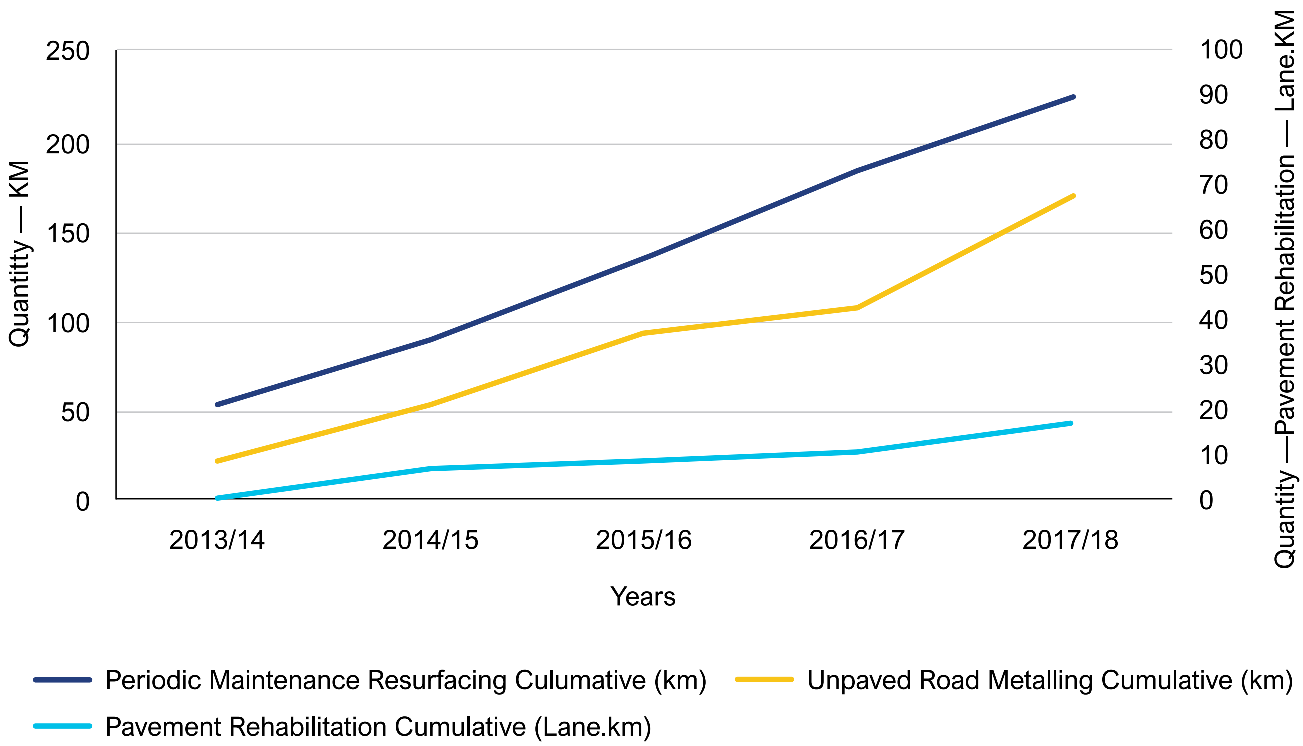
WBOP DC Economic Value of Renewal Works Quantities

Renewal quantities were selected based upon pavement deterioration modelling that considered future traffic demand and remaining pavement life considerations. Because of the variance in traffic loading on WBOP DC roads, there is a wide variance in the pavement asset life cycles. These range from approximately 30 years on high-volume paved roads to more than 70 years on low-volume rural roads.

Periodic maintenance (resurfacing) quantities show an average of approximately 4.2 percent of the paved network length being resurfaced each contract year. The requirement for resurfacing is driven primarily by safety requirements around minimum texture depth to prevent loss of traction. The sprayed seal surfacing also provides a vital waterproofing membrane to the underlying flexible pavement, which is often moisture sensitive in these volcanic regions. Loss of waterproofing through cracking and bitumen oxidation often results in rapid loss of pavement integrity. On low-volume rural roads, the rate of surfacing deterioration can be slow, and resurfacing can often be deferred for many years if there is no visible evidence of loss of condition or waterproofing.

Whakatāne District Council Traditional Maintenance Contract - Renewals Investment
The quantity of renewal works (periodic maintenance resurfacing and paved and unpaved rehabilitation works) completed over the previous five years on the Whakatāne District Council traditional contract is summarized in Figure A4.31.

FIGURE A4.31: WHAKATĀNE DISTRICT COUNCIL TRADITIONAL MAINTENANCE CONTRACT FINAL FIVE YEARS' RENEWAL QUANTITIES



Source: Whakatāne DC.

These quantities represent an annual renewal rate of 6.4 percent of the paved network length for periodic maintenance (resurfacing), 16.5 percent of the unpaved network length for metaling (unpaved road rehabilitation), and 0.2 percent of the paved network length for rehabilitation.

The high rate of unpaved road rehabilitation reflects the greater rate of surface material attrition on these roads. This is caused by aggregate loss from traffic and environmental effects.

The relatively low rate of paved network rehabilitation works reflects the lower traffic loadings on the network plus preventative routine maintenance practices like drainage maintenance and crack sealing, which extend average pavement life cycles. These life cycles are further extended by regular resurfacing (periodic maintenance) to ensure the pavement surface is waterproofed.

Value-for-Money Discussion

Despite extensive efforts and significant data collection, it was not possible to undertake a quantitative comparison of the traditional and PBC networks in terms of lifecycle costs or economic benefits due to the lack of data. Nonetheless, the case study did obtain information that the PBC offered a better value for money than the traditional contracting approach. The discussion focuses on three areas where evidence identified strengths of the PBC: (a) the PBC tender price, (b) optimization of investment and O&M, and (c) customer satisfaction.

Tender Price of the WBOP DC PBC Contract

The clearest indication of the value for money of the PBC is from comparing the tender price of the PBC to the estimated cost of maintaining the WBOP DC network under traditional contracting. The PBC tender price was NZD 56 million (US$38 million at 2019 exchange rate of 0.68) lower than the funding levels that the WBOP DC estimated would be needed to meet the same service levels using the traditional contracting approach. As the WBOP DC had capacity to make accurate estimates, there is reasonable confidence that real savings were achieved.

The WBOP DC PBC bid price of NZD 160 million was NZD 17 million lower than the award hurdle of NZD 187 million. This indicates that the anticipated savings were NZD 17 million more than the minimum needed to justify the risk of transferring responsibility for the road network to a single PBC contractor.

TABLE A4.13: WBOP DC CONTRACTING COST ESTIMATES (NZD, MILLIONS)

	Estimate[40]	Award Hurdle[41]	Contract Price	Savings
Council services	$206	$187	$160	$46 (22%)
NZTA services	$60	$55	$50	$10 (16%)
Combined total	$266	$242	$210	$56

These savings over 10 years allowed the WBOP DC to invest in additional capital works improvements on the road network. These included a further 50 km of surfacing of the unpaved network. This additional resurfacing generated environmental and social benefits because of improved road dust reduction, benefitting adjacent residents, horticulture, and farming activities. The value of these benefits has not been quantified. Thus, available information suggests the PBC did offer a significantly better value for money than continuing with the traditional approach. Table A4.13 presents a summary of these amounts.

The following factors were believed to have contributed to the greater value for money of the PBC:

- The contractor's 'ownership' of the network with an associated improved and consistent level of service was anticipated.
- There was cost certainty over 10 years.
- The council could transfer a lot of its normal risks to the contractor. These included the quantum of routine and periodic maintenance and rehabilitation works, quality of outcomes, asset lifecycle performance post construction, and pavement residual life at the time of handing back.

Optimizing Investment and O&M Costs

Funding for local district road maintenance is partially subsidized in New Zealand from national taxes collected from fuel excise levies (50–75 percent). The balance is funded from local property taxes imposed by the district council as the road controlling agency. Under the traditional contracting approach, funds cannot be carried over into the following financial year, and opportunities to defer some of the planned works were typically not exploited. This sometimes also resulted in work being undertaken under suboptimal weather conditions and with poor outcomes.

40 Estimate of the cost of service if done by traditional arrangement using an engineering consultant and measure and value contracts.

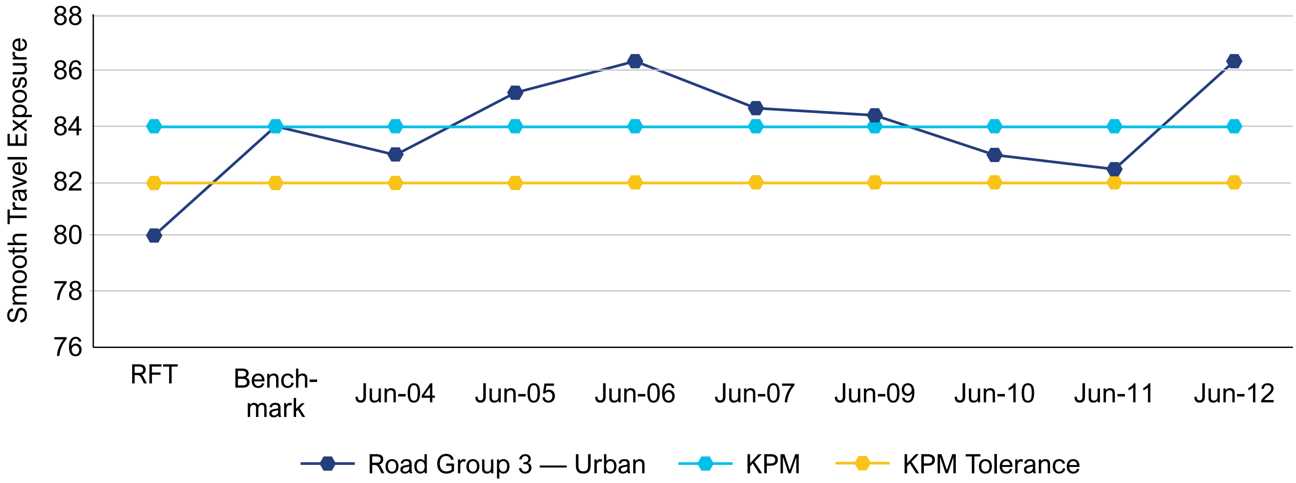
41 Clients decided this much saving must be available to make it worthwhile taking the risk of committing to the PBC.

With introduction of the lump-sum outcomes-based PBC, the WBOP DC was able to program future lump-sum payments and the contractor was able to constantly review deterioration and condition rates relative to required levels of service with a view to deferring work to the latest practical date. The contractor actively sought innovative ways of meeting the requirements at least cost.

The lead contractor's focus on asset management in the PBC consortium resulted in the development of innovative data analysis systems. These enabled investments to be optimized while still achieving the specified performance outcomes. Examples of this are outlined in the figures showing network STE. The target STE established by the WBOP DC for the PBC (shown in Figure A4.32) was met but is lower than the equivalent road classification (Arterial) on the Whakatāne District Council network (Figure A4.40).

The relatively low level of expenditure on routine maintenance work (see Data Item 4 in Table A4.12) would be expected under a lump-sum contract where the incentive is to minimize inputs while still achieving the required performance outcomes specified in the contract. This level of average expenditure/km is approx-

FIGURE A4.32: MAINTENANCE OF STE ON HIGH-VOLUME GROUP 3 URBAN PBC ROADS



Source: OPUS 2019.

imately 53 percent of the expenditure expected for the equivalent traditional maintenance contract. This saved the WBOP DC approximately US$11,300,000 on routine maintenance costs alone over the duration of the contract.

The Whakatāne District Council quality outcomes were higher but may not necessarily have offered a better value for money. Because service levels are often not well-defined for traditional maintenance contracts, there is a tendency for agencies to over-invest, especially in periodic maintenance and rehabilitation works. Agencies perceive benefits in maximizing pavement condition outcomes such as STE and often place less emphasis on optimizing O&M plans by calibrating expenditure to the targeted level of service.

In contrast to the PBC, the advantage of the traditional maintenance contract to the Whakatāne District Council is based on the contract model's relative simplicity and the flexibility it provides the Whakatāne District Council regarding the investment activities. The Whakatāne District Council asset management team used a range of systems and tools to develop the maintenance and renewal programs. These include a comprehensive national road asset management database (used by all road controlling agencies in New Zealand) to record all asset inventories, condition data, and a 10-year rolling forward works plan (FWP). This detailed information is used to identify condition exceptions around pavement faults, asset age, asset condition, and road collision data to support decisions around treatment selection and timing. Selections were made at a 'treatment length' level, which can be as short as 100 m. This approach results in a high level of granularity around pavement and surfacing performance and enables a refined FWP to be developed. This in turn allows the Whakatāne District Council to plan with a high degree of confidence around the quantity of treatments required over the next 10 years and to ensure sufficient funding is available when required.

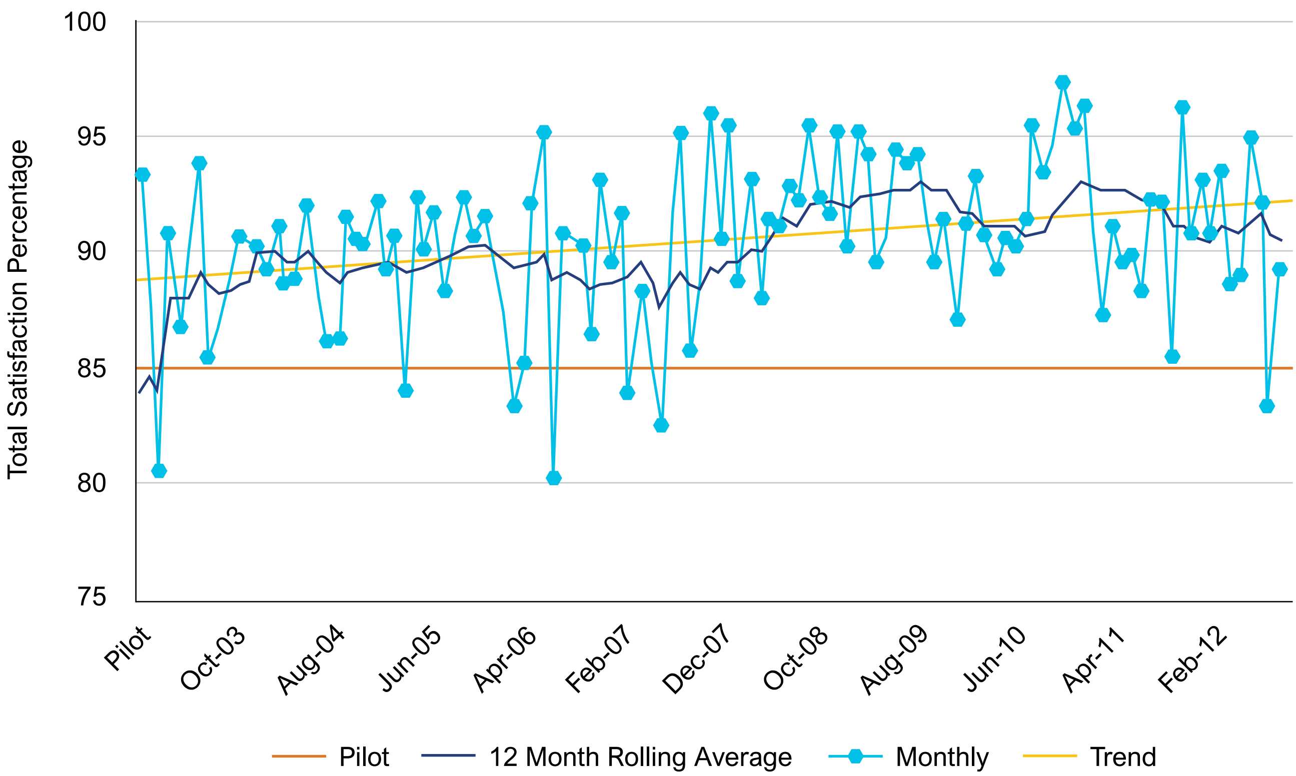
While the Whakatāne District Council retained control over the network, it lost flexibility. To obtain national funding for the local road network, agencies are required to submit a program of works and an annual request to the NZTA for funding approval. Thus, the actual amounts finally approved may vary from year to year, just as was the case for the WOPB DC before adoption of the PBC approach. While these variances are not normally large, they can have a bearing on the quantity of rehabilitation and periodic maintenance works finally undertaken.

Customer Satisfaction

The PBC contractor undertook an innovative approach to customer satisfaction by engaging a dedicated customer liaison manager as a key member of the contractor's team. The customer liaison manager was supported by a system which tracked requests and complaints to their final resolution. Customers could be kept informed over the status of any issue on request. The contractor measured customer satisfaction through a combination of rolling telephone surveys (50 surveys per month) and periodic satisfaction surveys of individuals raising service requests. This system is believed to have resulted in an increased level of satisfaction throughout the contract, which trended upward over time and reached more than 90 percent satisfaction at contract closing, as shown in Figure A4.33.

Improved customer satisfaction is notable as the network experienced 39 percent growth in vehicle kilometers travelled (VKT) (see Figure A4.34) and RAC were perceived to be lower than if the WBOP DC tried

FIGURE A4.33: CUSTOMER SATISFACTION INDEX — WBOP DC PBC (JANUARY 2003–SEPTEMBER 2012)

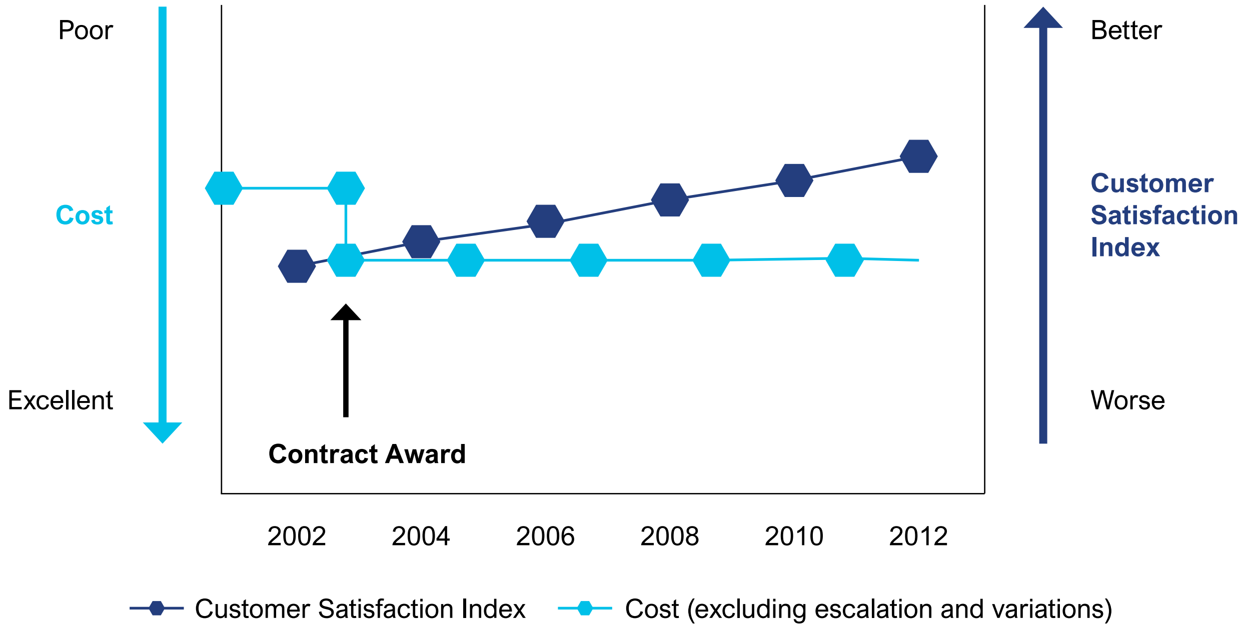


Source: OPUS 2019.

to achieve the same level of service targets using traditional maintenance contracts.

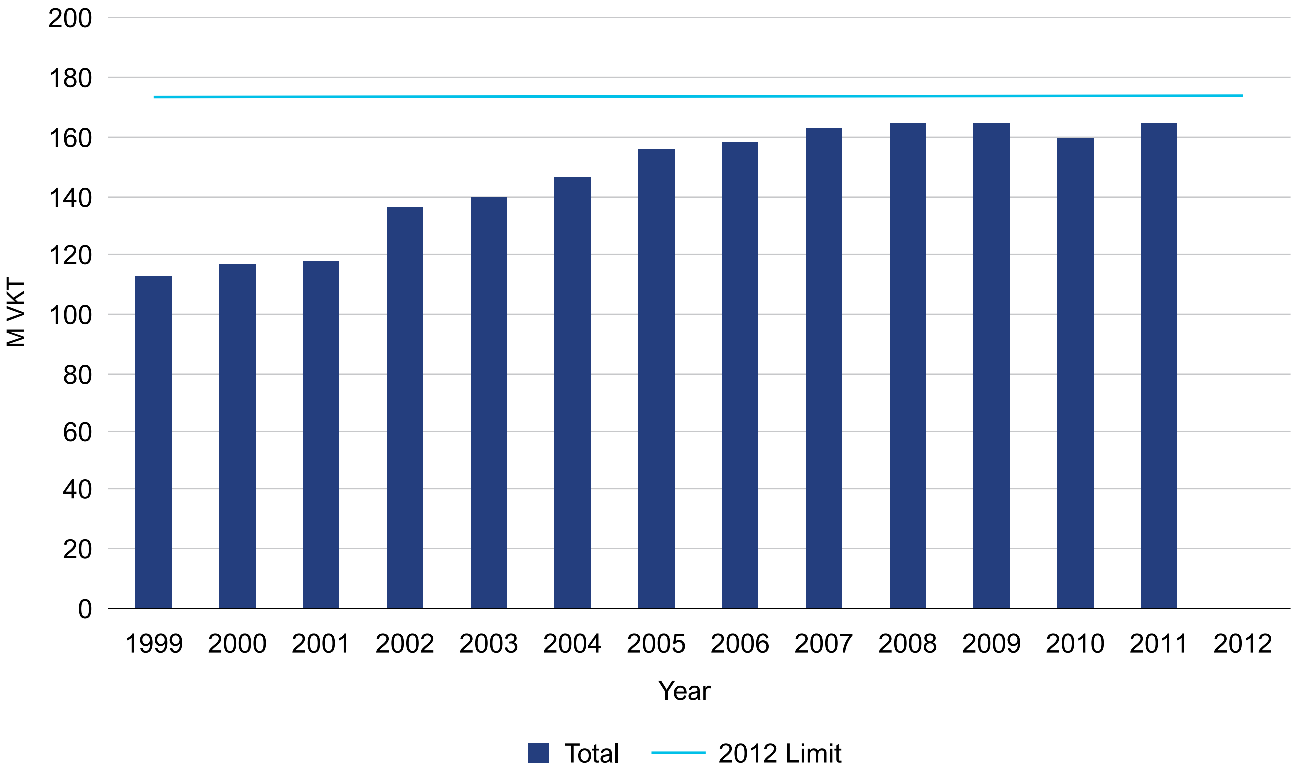
In contrast to the steady improvement in satisfaction under the PBC, customer satisfaction for the traditional network remained steady at around 86 percent of respondents. Typical survey results are shown in

FIGURE A4.34: TEN-YEAR SUMMARY OF THE PBC TRENDS FOR BOTH COST AND CUSTOMER CARE



Source: OPUS 2019.

FIGURE A4.35: SUMMARY OF VKT ON THE DISTRICT ROADS OVER THE DURATION OF THE PBC

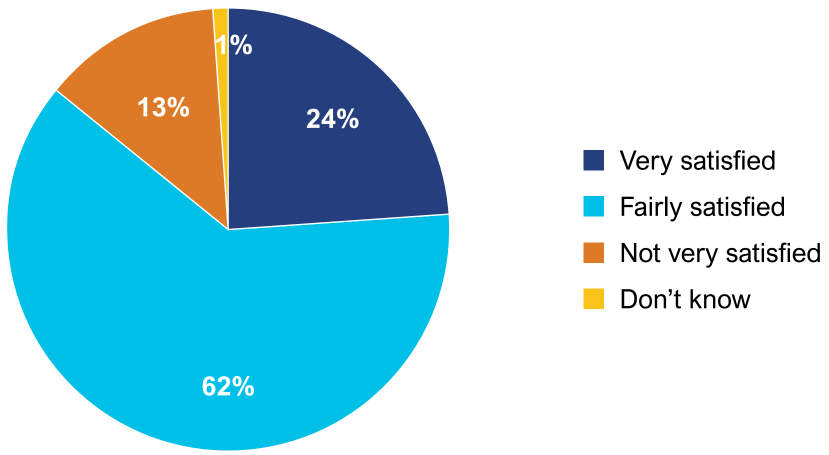


Source: OPUS 2019.

Figure A4.36. These results are better than the average of district councils in New Zealand. This appears to reflect relatively high quality of road conditions, as noted on the previous page.

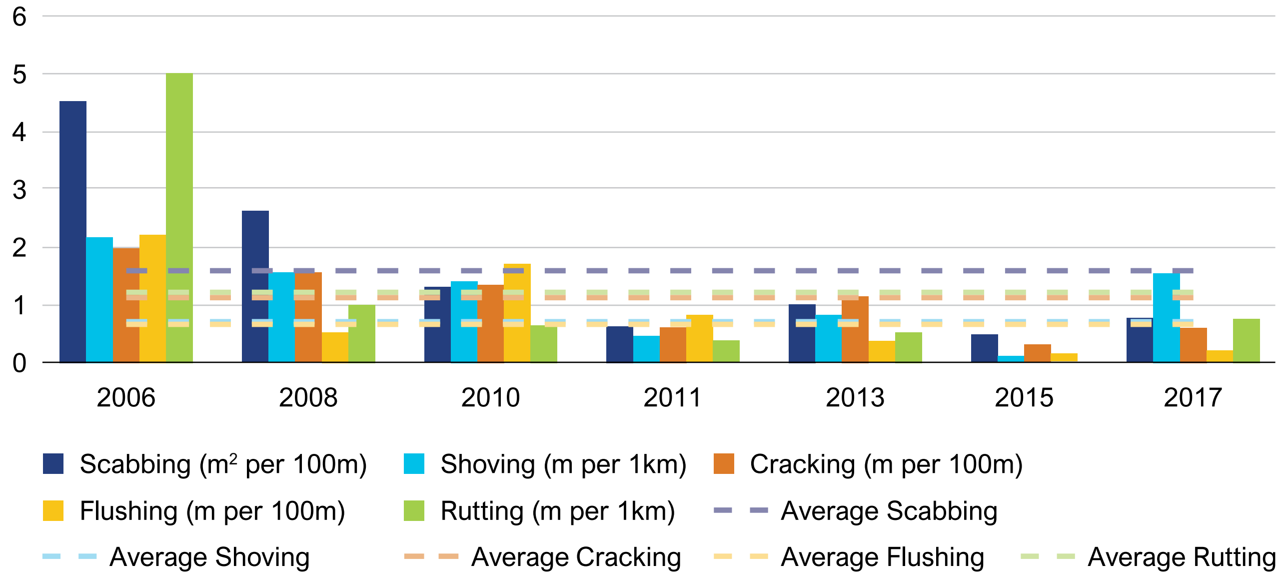
While this is a positive result, the customer satisfaction survey results diverge significantly from the observed improvement in road condition over the case study period of 2006–2017. Figures A4.37 through A4.40 which show that maintenance defects substantially declined during the traditional case study period even though customer satisfaction remained steady.

FIGURE A4.36: LEVEL OF OVERALL CUSTOMER SATISFACTION WITH WHAKATĀNE DISTRICT COUNCIL ROADS



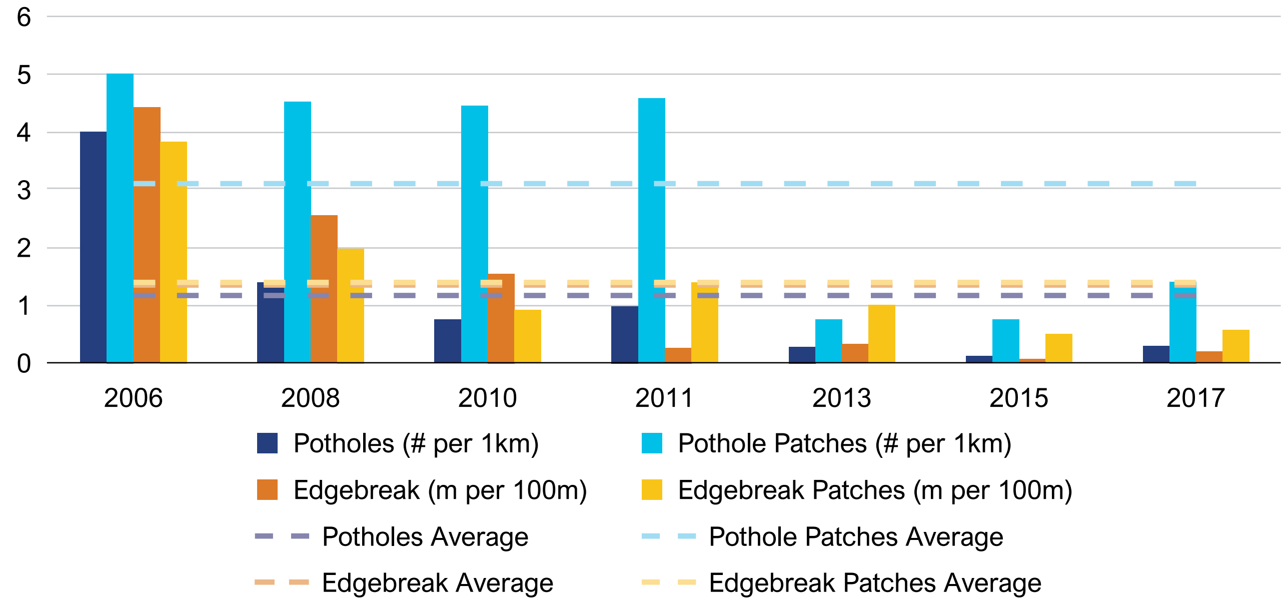
Source: Whakatāne DC.

FIGURE A4.37: WHAKATĀNE DISTRICT COUNCIL TRADITIONAL CONTRACT — PAVEMENT CONDITION DEFECTS: SCABBING, SHOVING, CRACKING, FLUSHING, AND RUTTING



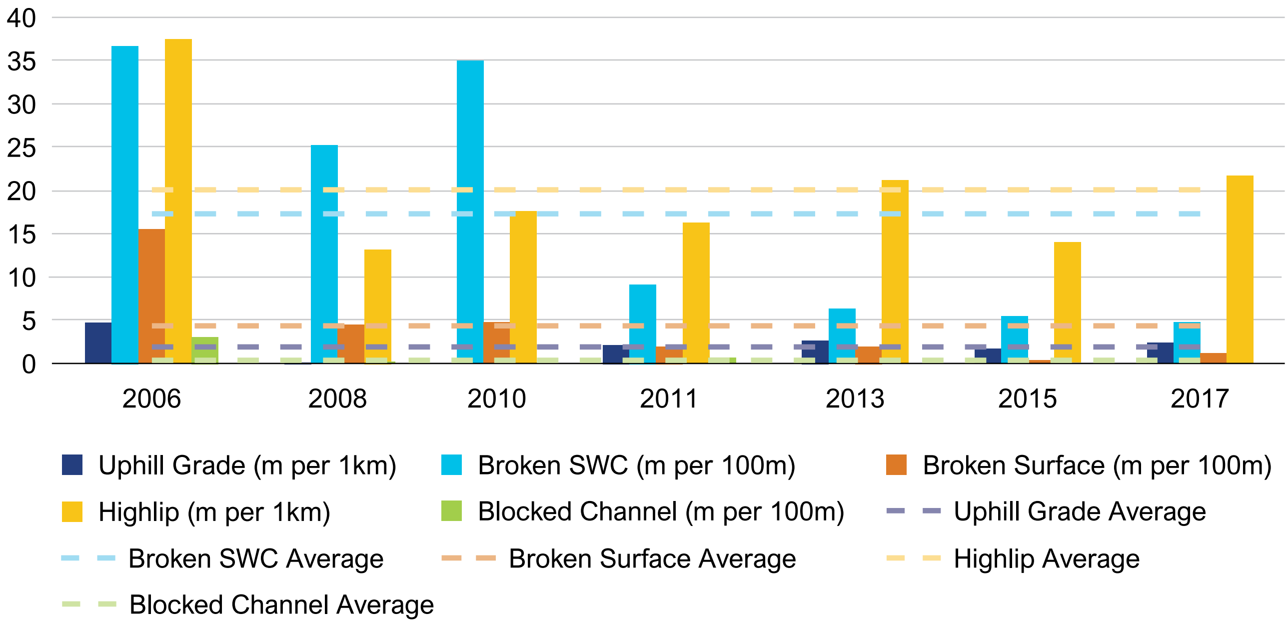
Source: OPUS 2019.

FIGURE A4.38: WHAKATĀNE DISTRICT COUNCIL TRADITIONAL CONTRACT — POTHOLES AND EDGE BREAKS



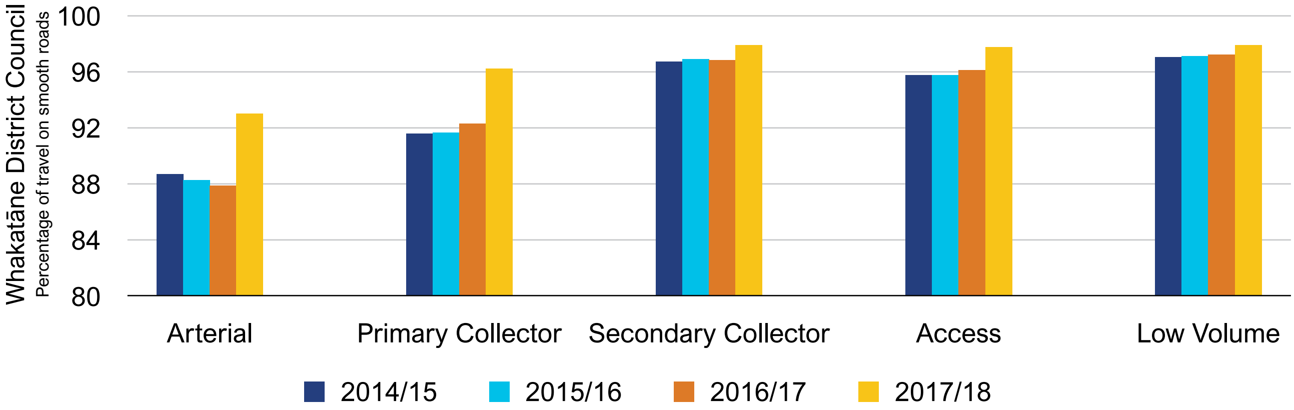
Source: OPUS 2019.

FIGURE A4.39: WHAKATĀNE DISTRICT COUNCIL TRADITIONAL CONTRACT — DRAINAGE DEFECTS



Source: OPUS 2019.

FIGURE A4.40: SMOOTH TRAVEL



Source: OPUS 2019.

The survey results show that the PBC was more responsive to customer perceptions and achieved a higher level of satisfaction despite lower expenditure. The results also may indicate that the Whakatāne District Council could achieve better value for money in respect to customer satisfaction by:

- Targeting slightly lower network condition outcomes that could achieve future savings without compromising public satisfaction and
- Exploring ways of improving customer-facing strategies.

Contract Administration and Other Observations

Tendering

The WBOP DC's commitment to move to the all-encompassing lump-sum PBC was significant because it was relatively expensive for the WBOP DC to collect the data and prepare the documents. Moreover, all tendering parties and the WBOP DC required a large tender team for an extended period. These teams minimized the substantial risk of lump-sum tendering by undertaking detailed research and deterioration modelling, which was expensive.

Contract Administration

The WBOP DC's choice of contractor was also a critical success factor. The contractor understood what the agency was trying to achieve, sincerely wanted to make it work, and was able (and wanted) to work collaboratively in partnership to deliver the contract. There was little doubt that the PBC could have become unworkably difficult if a poor choice of contractor had been made.

The contractor worked to understand, during the tender and implementation phase, the enormous amount of data available and optimized the inputs needed to deliver the specified levels of service. There has been a continuity of key contractor staff committed to pursuing opportunities for improve-ment throughout its duration.

Once awarded, it took the PBC contractor three years to overcome initial difficulties and become comfortable with the work. The contractor's resourcing level for ongoing contract management remained high. The contract's complexity and the time it took for systems to be developed and embedded with this form of contract should not be underestimated.

Nevertheless, the PBC was considered by the WBOP DC to offer significant benefits:

- The PBC contractor was free to develop its own working methods and work culture around the achievement of the PBC contract targets and therefore could optimize its work around the contract outcomes.
- The PBC contractor was not bound to complete works within a budget year or lose access to resources.

The PBC approach enabled more innovation by removing concerns about liability for rework. Since the contractor consortium was responsible for outcomes rather than outputs, it held the incentive to innovate as well as the liability for rework. This allowed greater freedom to push innovation boundaries without pushback from the WBOP DC about the risk of rework. The contractor consortium also introduced an 'inspect and program' culture as a key element of maintenance program development.

Summary

WBOP DC PBC

The WBOP DC achieved its objectives for cost savings and network performance outcomes through the PBC. The PBC also delivered several additional benefits:

- Significant cost savings which enabled an increased level of investment in additional capital works, for example, surfacing previously unpaved roads
- A high level of compliance with the specified KPIs and key results areas (KRAs) against a background of increasing traffic demand, which led to a high degree of WBOP DC and customer satisfaction
- Consistent service-level delivery to road users
- Development and implementation of a range of innovative asset management systems for defect management, work plan development, and reporting
- Advancing the level of asset management capability and expertise within the contracting industry.

These outcomes resulted in the contract duration being extended for a further two years and then being re-awarded for another nine years to the same contracting consortium under a revised, nationally consistent, PBC model.

The PBC's disadvantages include the following:

- An initial procurement cost to the contracting industry. Each bidder had to undertake extensive pavement deterioration modelling to understand the level of investment that would be necessary over the following 10 years to meet the specified performance criteria.
- A high cost to the WBOP DC in providing bidders the level of detailed data required for bidding. This information enabled bidders to adequately quantify the level of risk the WBOP DC was transferring to the contracting industry through the PBC.
- A high risk to the WBOP DC if the wrong contractor were appointed. Had this happened, it may have resulted in the contract failing and the network condition deteriorating. This in turn would have imposed high costs on the contractor and NZTA, involving terminating one contract and procuring a replacement.
- Difficulty incorporating inevitable changes in network assets and traffic demand that occur during long-term contracts beyond the specified risk caps.
- The WBOP DC loses network 'ownership' through this model. It effectively relinquished all control of the network to the contractor for a prolonged period. The WBOP DC did become frustrated at times because of its inability to influence outcomes beyond a governance level.
- The WBOP DC did lose some detailed asset management capability and control.
- The long duration of the contract, its scale, and its complexity limit the number of contractors who may be able to bid for similar contracts in the future. The incumbent contractor may continue to have a competitive advantage with any future bids that would be difficult to beat. This outcome could limit future interest from the contracting industry in bidding for this work, which would result in a loss of competitive price pressures.

Whakatāne District Council Traditional Contract

The traditional contract has achieved the Whakatāne District Council's objectives and resulted in a well-maintained road network. The benefits of the traditional contract model are as follows:

- The Whakatāne District Council has full control and ownership of the routine maintenance, rehabilitation, and periodic maintenance programs.
- The Whakatāne District Council has a high degree of flexibility around inputs and programs, so changes in demand or legislative requirements can be easily incorporated.

- The Whakatāne District Council has developed and retained its experienced and knowledgeable asset and contract management team in-house. This team is well supported by systems and data that enable a high level of decision support around future network needs and investment levels.
- The Whakatāne District Council has developed a relatively low-cost supplier panel procurement mechanism which has sustained a local contracting industry within the region. This provides assurance around a continuing competitive marketplace for road maintenance suppliers into the future.

The disadvantages of the model are as follows:

- There is a tendency to overinvest in the road assets without any commensurate benefits for road users.
- The Whakatāne District Council carries a higher level of risk around quality outcomes, program delivery, and changes in demand, especially where contractors have multiple contracts and limited resources at peak times throughout the year.
- The Whakatāne District Council carries an increased administration cost due to larger in-house capacity requirements to manage the network and administer the contract.
- There is less price certainty and activity expenditure is more likely to fluctuate each year, subject to funding availability. This limits the contracting industry's confidence to invest in resources such as plant, personnel, and training.

TABLE A4.14: CASE STUDY 4: WBOP PBC/WHAKATĀNE DISTRICT COUNCIL CONTRACT DATA

Name	Description
ACENZ Awards InRoads Performance Based Contract FINAL- March 2013.pdf	PBC award submission
Ingenium Application - PBC-01 Contract.pdf	PBC award submission
Ingenium Application - PBC-01 Contract_Summary.pdf	PBC expenditure
Ingenium Certificate 2013.pdf	PBC award
InRoads Project Profile.docx	PBC project profile
PBC-01 ALLIANCE PARTNERSHIP - P VENTER.pdf	PBC award submission
Roading NZ Excellence awards.pdf	PBC awards
Treasury 2012.pdf	PBC paper to the New Zealand Treasury
VfM Slide.pptx	PBC value-for-money presentation slide
Copy of Crash analysis for WBOP PBC and traditional contract.xls	PBC crash data
Copy of WB fatalities and serious casualties 1Oct02-31Oct14.xls	PBC crash data
Copy of WHK 2007-11 Fatalities and serious injuries_revised_17062019.xls	Traditional crash data
7.2 RoadCondition (1).xls	Traditional road condition data
Copy of 8.1 RAMM Crash Data - edits	Traditional crash data
Copy of Crash analysis for NZ PBC and traditional contract_confirmed	Traditional crash data
Copy of WBOP crash analysis for traditional contract network	Traditional crash data
Copy of WHK 2007-11 Fatalities and serious injuries	Traditional crash data

Case Study 5: Botswana

Output and Performance-Based Road Contract and Traditional Maintenance Contract

Botswana is a relatively large and sparsely populated country in the southern Horn of Africa with an estimated population of 2.2 million and land area of 581,730 km^2. Botswana is an upper-middle-income country whose economy is heavily dependent upon exports of natural resources. Most of the population resides in or near Gaborone, the country's capital, located close to the southeastern border with South Africa.

Much of the country is relatively dry and the materials for road construction are relatively weathered—particularly in the area where the case study roads are located. Mining, farming, and tourism are sources of national income and therefore a source of traffic on the network.

The agency responsible for national roads is the Roads Department of the Ministry of Transport and Communications. The PBC and traditional networks selected for this case study both serve as regional links in the country's southeast: the PBC network services towns and villages southwest of Gaborone and the traditional network services towns south of Gaborone down to the border crossing to South Africa at Ramatlabama.

In most cases, the roads are two-lane carriageways—there is a short section of divided carriageway in the traditional network. There is not known to be a significant overloading problem on either of the networks as they are close to the South African border where trucks are weighed. There is potentially some mine loading at the end of the network. Excess axle loading is not allowed on the network at all—not even by permit.

Contract Details and Characteristics

The Roads Department was fully outsourced in 2010 following an Act of Parliament. At the time, the number of Roads Department regions was increased from three to seven and the Roads Department took on local roads but with no additional resources.

FIGURE A4.41: TYPICAL ROAD IMAGES

PBC area (before Rehabilitation)

Traditional network north of Pitsane

Source: OPUS 2019.

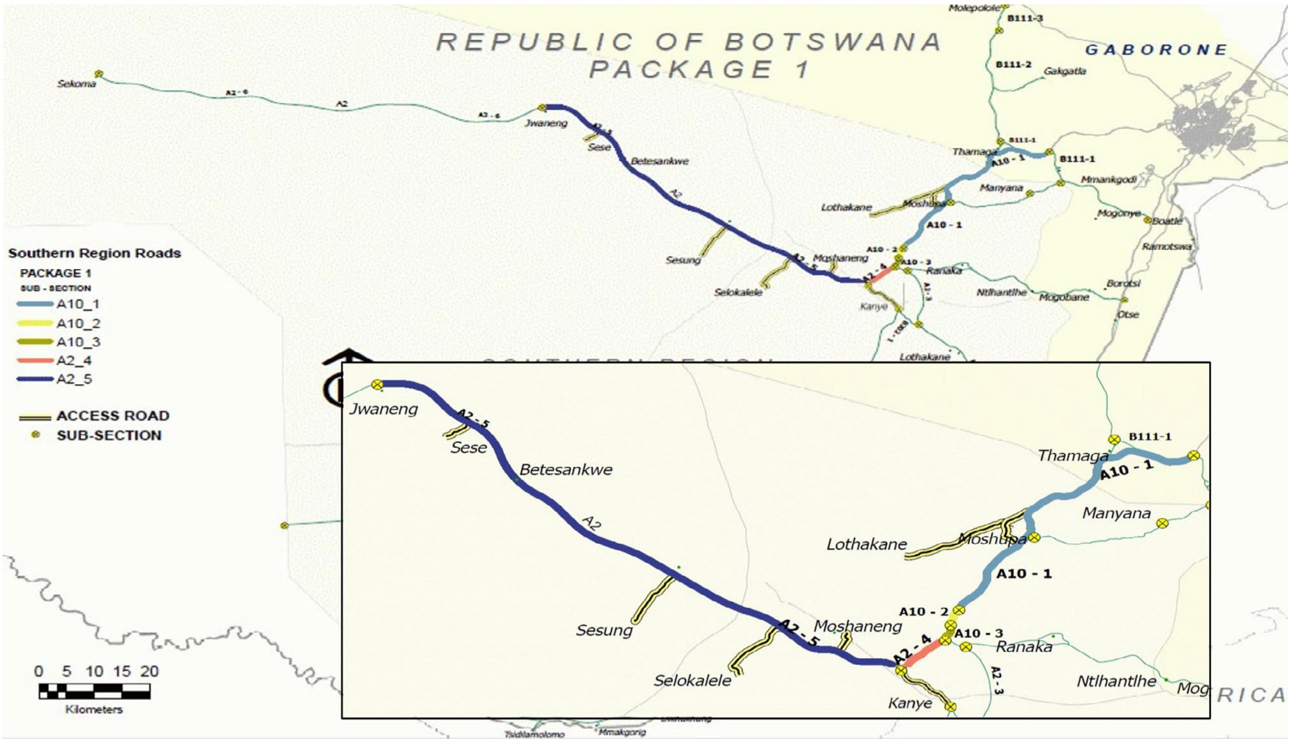
Botswana OPBRC

Botswana's Roads Department began exploring PBC concepts through the World Bank-financed Botswana Integrated Transport Project (BITP). The main reasons for investigating PBCs were as follows:

- PBC was considered a better way of outsourcing compared to traditional methods.
- The Roads Department wanted to avoid reliance on recurrent budget and challenges related to traditional contracting approaches.
- PBC was considered to facilitate timely implementation of maintenance.

With support of the World Bank, the Roads Department initiated a pilot PBC, which commenced in May 2014. The pilot OPBRC was intended to encompass a single district to allow comparison between the pilot OPBRC and districts managed under traditional contracting, but this strategy proved infeasible due to cost and other challenges. The Roads Department eventually offered two separate OPBRCs, which were ultimately won by the same consortium. This case study focuses on the national roads in Lot 1/Package 1 (123.12 km).

FIGURE A4.42: BOTSWANA OPBRC LOT 1



Note: National roads are shown in red, violet, and blue and local/access roads in yellow.
Source: DoR, Botswana.

The Lot 1 contract is a 10-year PBC. It includes rehabilitation of national roads and access roads and routine maintenance only for national roads. Lot 1 was awarded for US$125,498,557 to a joint venture capital association (JVCA). The contract included US$1,194,160 for emergency works and a further US$12,937,000 as a Provisional Sum item.

This case study reviews the main road sections shown in Table A4.15, as there is no post-construction maintenance undertaken on the access roads. The rehabilitation phase of this contract was complete, and the contract was in the maintenance phase in many places at the time of the case study data collection.

TABLE A4.15: OPBRC LOT 1 MAIN ROADS

Road No.	Link Name	Start/End of Section	Section Length (km) (as per contract)	Section Length (km) (after reconciliation)	Surface Type
A2	A2-4	Roundabout (Al O/A2)	6.89	6.82	Paved
	A2-5	Kanye West Junction (A2/B202)	72.71	72.57	Paved
AIO	A 10-1	Junction Al O/B111 direction to Mmankgodi	40.11	40.12	Paved
	Al 0-2	Change 2 lanes/3 lanes	2.05	2.05	Paved
	A 10-3	Change 3 lanes/2 lanes	1.75	1.57	Paved
Total			**123.51**	**123.13**	

The scope of works for Lot 1 includes rehabilitation, improvement, and routine maintenance works. The rehabilitation and improvement works were due to be completed by July 2017 but have been delayed for various reasons. The programmed date for completion of rehabilitation was extended to May 2019. This extension was not applied to the overall contract, which is under review.

All rehabilitation, maintenance, and emergency works within the road corridor are undertaken by the OPBRC contractor consortium. The OPBRC includes four separable portions:

- Reconstruction/rehabilitation
- Periodic maintenance
- Reactive maintenance
- Access road reconstruction.

Rehabilitation and improvement works include subgrade, subbase, base course construction with a DST and AC surfacing. Other features of the contract include the following:

- Rehabilitation payment is made following completion of each 5 km section. Routine maintenance is paid through performance-based monthly quarterly maintenance payments, with deductions for failure to meet performance targets.
- 60 percent of roads within Lot 1 received periodic maintenance, as directed by the client.
- Service levels are grouped into management performance measures, road user and comfort performance measures, and road durability performance measures.
- The contract terms enable the contractor to subcontract up to 30 percent of the reconstruction/rehabilitation work. The contractor is required to undertake 100 percent of the maintenance portion of the contract.
- Maintenance standards included in the OPBRC are the same as used for traditional contracts, with the addition of roughness (IRI) and deflection (FWD) requirements.
- Each month, the monitoring consultant audits a 40 percent network sample. Informally 100 percent of the network is inspected as auditors drive the network throughout the month. Any issues identified at any time are enforceable in the contract.
- Under the OPBRC, 10 percent of the contract value had been established as Provisional Sums.

Botswana Traditional Maintenance Contract

The traditional contracting approach in Botswana is implemented through annual maintenance contracts. Since there are extensive delays, annual maintenance contracts are often not awarded in time to satisfy maintenance needs. In these cases, road maintenance falls back to Force Account contracting, but the Roads Department's capacity to implement works under Force Account is severely overstretched, and maintenance is often delayed.

The traditional road network selected for comparison for this case study is maintained under a series of annually awarded contracts using local contractors and BoQ rates. Contract lengths for the four contract areas included in this case study are relatively short, ranging from 23 to 40 km. They are located on the A1 Road in South-East District. The total length of the four contracts is 128 km.

The scope of works for routine maintenance comprises:

- Bush clearing;
- Fence and gate repairs for animal control;
- Cleaning and maintenance of rest areas, bus stops, and laybys;
- Litter control and removal;
- Removal of obstacles, dead animals, abandoned vehicles, scrap, anthills, and illegal signs;
- Bituminous paved road maintenance including rutting and depression repairs, pothole patching, edge damage, and surfacing failures;
- Maintenance of drainage facilities, including culvert headwall, wingwall and marker post repainting, culvert repairs, and marker post reflector replacement;
- Maintenance of miscellaneous structures; and
- Road furniture, signs, and traffic markings maintenance and replacement.

FIGURE A4.43: LOCATION OF TRADITIONAL INPUT MAINTENANCE CONTRACT

Source: OPUS 2019.

Separate annual contracts are awarded for periodic maintenance, including asphalt resurfacing and DST. In addition to the annual and periodic maintenance contracts, the Roads Department operates a modest Force Account operation to cover periods where annual contracts are not in place.

A road inspector from the Roads Department is assigned to each road contract and is responsible for programming the maintenance activities. The inspector assigns defects for the contractor to rectify. Further inspections are undertaken to verify the competed work before payment is made.

Awarding traditional maintenance contracts (approximately 600 per year nationally) in a timely manner has become a significant issue in recent years. Consequently, the Roads Department has not been spending its annual budget. This is believed to be contributing to a reduction in road conditions and hence overall performance for the traditional network. This issue extends to periodic maintenance contracts but to a lesser degree.

The Procurement Act includes the term 'low-cost procurement'—or essentially lowest price conforming. Contracts can attract between 60 and 200 bidders—typically, more than 100 each time. This level of competition is believed to be driving costs down to unsustainable levels where quality is being compromised. In addition, if a tender does not conform, the Roads Department is required to work with the tendering organization until the tender conforms or the organization withdraws—adding significant time and effort to the tendering process.

The Roads Department identified two strategies to mitigate these challenges. First, it sought to reduce dependence on 'low-cost procurement'. This, however, led to disputed contract awards and time-consuming and costly court challenges. Second, it intended to extend contracts to cover a two-year period—retaining contractors on the ground longer and providing more cover for emergency events.

Delays to contract awards result in essential maintenance falling back to Force Account arrangements which are insufficiently resourced, and roads consequently receive minimal maintenance.

It can take 5 to 10 months to prepare and award a traditional maintenance contract:

- 3-month prep phase -> Open tender
- 1-month evaluation
- 1-month adjudication -> Award
- 10-day cooling-off period.

There is one government materials laboratory in Botswana.

TABLE A4.16: CONTRACT DATA SUMMARY — BOTSWANA OPBRC AND TRADITIONAL MAINTENANCE CONTRACTS

OPBRC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehabilitation Works		
US$153,069/km	US$280,350/km	PBC rehabilitation designs based on widening and overlay
Item 2: Periodic Maintenance Works		
US$129,539/km (AC overlay)	US$66,825/km (DST)	
Item 3: Routine Maintenance Works		
US$10,513/km/year Rehabilitation costs are not fully recovered in the rehabilitation phase and are paid during the maintenance phase.	US$8,190/km/year	Both the PBC and traditional maintenance contract use similar specifications.
Item 4: Emergency Works Expenditure — Average Annual		
Lot 1: US$970/km/year Moshupa bridge repairs and river protection works to be completed as emergency works, along with pavement damage from vehicle accident and flood-damaged culvert replacement	Data not available	Values equate to the contract allowance only.
Item 5: Contract Administration — Procurement		
Consultant = 370 FTE months for both OPBRCs for development and bidding. 10-year contract = 37 FTE months per year = 0.14 FTE months/km/year	Four annual contracts bid and evaluated taking 5 FTEs × 5 months = 100 FTE months per year = 3.6 FTE months/km/year	The annual procurement of the traditional contracts appears administratively demanding and time-consuming with each contract taking around five months to prepare, bid, and award.

TABLE A4.16: CONTRACT DATA SUMMARY — BOTSWANA OPBRC AND TRADITIONAL MAINTENANCE CONTRACTS, CONTINUED

OPBRC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 6: Contract Monitoring/ Supervision/ Administration		
US$25,938/km (US$2,594/km/year) or 2.95% of the combined contractor's prices for both lots)	US$1,500/km/year or 18.25% of the average contract price	OPBRC administration costs for monitoring and supervision consultant only. Traditional contract costs for the contractor's overheads, facilities, and vehicle running only. Excludes cost of Road Department personnel.
Item 7: Non-pavement Maintenance Works		
All included within the OPBRC scope of works	As itemized above	
Item 8: Resilience		
(see commentary)	(see commentary)	OPBRC drainage appeared to be of a higher standard than the traditional network, contributing to overall network resilience.
Item 9: Additional Nonfinancial Benefits		
a. Increased certainty on financial expenditure b. Transfer of risk to the contractor for quality and performance, which resulted in increased quality of workmanship during the PBM period c. Routine maintenance payments based upon service-level compliance, which resulted in consistent service levels along the project road d. Increased data capture and availability around road assets, work completed, and condition/level of service		

Quality Differences

Since road condition data could not be obtained for both networks, comparison of the network condition relied on visual inspection of a portion of each network undertaken during case study visits. Despite the same maintenance standards being employed in both types of contracts, the limited visual inspection determind the OPBRC network was in a better condition than the traditional network. The OPBRC network had fewer potholes, better signage, and overall better road conditions. Drainage and fencing to prevent domestic farm animals from wandering into the roadways were also in a better condition on the OPBRC network. On its own initiative, the OPBRC contractor also started a community awareness program to manage the risk posed by wandering farm animals crossing the road.

Despite this, OPBRC implementation faced numerous challenges, including quality defects and severe implementation delays. For instance, some sections of the road did not achieve the performance for roughness (IRI) and strength testing (FWD).

Interventions undertaken to correct pavement defects were of a significantly higher standard on the OPBRC network than on the traditional road network (Figure A4.44). The case study team was told that treatment selection and timing are often poor in the traditional network.

Table A4.17 presents the condition data, including CI,[42] for the traditional road network for 2016, which were the most recent data available at the time of case study data collection. CI represents an overall condition index score for each section.

FIGURE A4.44: PAVEMENT DEFECT ON ROAD MAINTAINED UNDER TRADITIONAL MAINTENANCE CONTRACT

Source: OPUS 2019.

Value-for-Money Discussion

The OPBRC contract terms offered better value for money for the Roads Department by extending the contractor's liability for outcomes and the quality of repairs. This offered additional value to the Roads Department because defects did arise that required repairs. Particularly at the start of the contract period, the contractor had a strong incentive to ensure quality repairs. Under the traditional contracts, when repairs failed, the contractor could only be required to reinstate the repair within the relatively short liability period.

The OPBRC also allowed for more timely repairs, particularly as the traditional contract tendering process suffers from severe delays. The OPBRC was already in place and funded, and the contractor did not need to be instructed before needed repairs commenced. Under the traditional contract approach, the Roads Department is often unable to intervene in a timely manner due to budget constraints and Government procurement bureaucracy. Delays in preparing maintenance contracts overload the agency's Force Account capabilities, resulting in delays that, in some instances, will require more significant and more costly repairs. Consequently, the overall condition of the tradition-ally managed road network is declining.

Contract Administration, Resilience, and Other Observations

Tendering

Actual costs of tendering the two contracts were not available to the case study team. It is clear that the cost of procuring the Lot 1 OPBRC was relatively high due to the need to gather data and setperformance standards, but the Roads Department staff felt that the longer contract term led to significant savings of cost and effort over the life of the contract. This conclusion is convincing given the extensive delays and challenges experienced in tendering traditional contracts in Botswana at the time of the case study and because traditional maintenance contracts were tendered annually or biennially.

While the rollout of the OPBRC approach was delayed significantly, and this has affected perceptions of the OPBRC model in the country, traditional contracts in Botswana also experienced significant procurement delays during the case study period as noted above.

42 CI scores can be interpreted using the following qualitative classification: 85–100 = Good; 70–85 = Satisfactory; 55–70 = Fair; 40–55 = Poor; 25–40 = Very Poor; 10–25 = Serious; 0–10 = Failed.

TABLE A4.17: TRADITIONAL CONTRACT CONDITION DATA (2016)

From (km)	To (km)	Length (km)	AADT	IRI (m/km)	Rut (mm)	Cracks All (%)	Cracks Wide (%)	CI (%)
A1/1P — B202/1 in Ramatlabama to 0574 to Ngwatsau Kgotla								
0.00	10.00	10.00	793	2.8	8	2	1	58
A1/1P — B101/1 to Rakhuna to Pitsane Patlakwe								
10.00	18.89	8.89	796	3.5	9	1	1	52
A1/1P — B101/1 and B101/2 Pitsane to 1030 to Digawana								
18.89	28.00	9.11	770	3.3	8	1	1	54
A1/1P — 1030 to Digawana to B102/1 to Lorwana								
28.00	38.00	10.00	1,357	2.9	8	2	2	56
A1/1P — B102/1 to Lorwana to Gaborone Depot Boundary								
38.00	45.98	7.98	2,070	3.3	7	2	1	55
A1/2N — A29/1 Lobatse North Roundabout to End Dual								
6.49	7.22	0.73	2,516	3.7	9	0	0	53
A1/2N — A1/2 Begin Dual to A1/3 and A101/1 Kgale Mall Roundabout								
69.53	70.75	1.22	2,423	3.7	9	1	1	50
A1/2P — A1/ and A2/1 Roundabout to A1/ and A2/1 Roundabout								
0.00	4.26	4.26	4,245	2.0	4	7	6	60
A1/2P — A129/1 Lobatse Central to A29/1 Lobatse North Roundabout								
4.26	6.00	1.74	2,516	3.3	8	10	7	40
A1/2P — A29/1 Lobatse North Roundabout to End Dual								
6.00	7.22	1.22	2,467	3.0	6	0	0	64
A1/2P — End Dual to 1504 Otse South								
7.22	11.00	3.78	2,423	2.4	4	5	3	63
A1/2P — End Dual to 1504 Otse South								
11.00	21.00	10.00	2,423	2.6	5	2	1	65
A1/2P — End Dual to 1504 Otse South								
21.00	31.00	10.00	2,591	2.5	6	2	2	64
A1/2P — 1021 Mokgosi to 1500 to Land Ponds								
31.00	41.00	10.00	2,983	2.4	6	4	2	63
A1/2P — 1503/1506 to 1038 to Maseseru								
41.00	49.76	8.76	2,670	2.6	7	4	2	58
A1/2P — A11/1 and B111/1 at Boatle to 1035 Notwane Siding								
49.76	59.38	9.62	5,612	2.2	4	7	2	65
A1/2P — 1035 Notwane Siding to 1502 Mmokolodi Kgotla								
59.38	68.10	8.72	6,653	2.0	3	7	0	71
A1/2P — 1053 Kgale Siding to A1/2 Begin Dual								
68.10	70.71	2.61	5,203	2.5	5	1	0	69

Contract Administration

The Lot 1 OPBRC faced numerous implementation challenges. Completion of the rehabilitation phase was significantly delayed. Most of the delays arose from the contractor's inexperience or mismanagement, including misunderstanding of how to best respond to the OPBRC contract incentives. Issues that arose during the contract include the following:

- Nobody from the contractor's bid team transferred into delivery of the project, and the project team appeared to not fully understand the OPBRC. Staff turnover during implementation exacerbated this challenge.
- The contractor mismanaged the advance payment by initiating work on large parts of the network simultaneously. As payment was contingent on completion of 5 km sections, this strategy resulted in cash flow problems. These were later compounded by parent company financial problems.
- The contractor's designers did not appreciate the difference between the OPBRC model and traditional approaches and did not attempt to innovate in their approach.
- The contractor has not always met the contract performance requirements for IRI (IRI > 3.0 (average for each 100 m section) and FWD (deflection > 0.7 mm) and failed to apply chip seal properly; rectification of the latter required installation of AC.
- At times, the contractor did not seem to appreciate the need to maintain the road following rehabilitation.
- Implementation of the RAP was delayed significantly.
- The contractor did not act quickly enough to identify material sources and secure the required permits, particularly given the strict requirements in Botswana.
- The joint venture relied heavily on subcontracting but did not establish good subcontracting arrangements and delayed payments to subcontracts.

To its credit, the Roads Department invested significant time and effort supporting the OPBRC contractor. Despite this additional effort, the Roads Department staff still reported several perceived advantages of the OPBRC over traditional contracts in terms of the effort required for contract management:

- The OPBRC was also perceived to offer greater clarity about the intended results and payment terms. Performance standards are well-defined and must be met; it was therefore found to be easier to identify when work was not being completed.
- Compared to the OPBRC, the traditional contract required considerably more inspection/supervision, including to initiate repairs and then confirm they were concluded.
- Claims often arose under traditional contracts because of the way they were procured, resulting in the need to modify the BoQ.
- Use of a risk matrix under the OPBRC meant that the division of risks between the parties was much more clearly articulated. This helped clarify the role of each party.
- The Roads Department has established a work plan approval process for rehabilitation and periodic works under traditional contracts. One of the significant challenges faced by these contracts is that the plan can be substantially amended during this process, but this is not the case under the OPBRC.

A key observation of the Roads Department was that OPBRCs could be undertaken with the same number or even fewer professional staff, but staff from both the road agency and contractor required different skills.

Emergency Works

There were two instances in which emergency works were required in Lot 1. These were significantly easier to undertake under the OPBRC model than the traditional approach as provision was made for emergency works in the contract. Emergency works have so far included a 62-ton load dropping on the road and a flash flood in which two culverts that were under repair were washed away.

The OPBRC approach has proved more agile in Botswana. A dedicated allowance for emergency works up to the Provisional Sum amount made it easier and faster to implement the required repairs following these events. The government used these funds to pay for the emergency works, including installation of a box culvert and a bridge to replace the assets lost to the flash flood. In contrast, the procurement and budget constraints under the traditional approach almost always introduce uncertainty about the timing of reinstatement.

TABLE A4.18: CASE STUDY 5: BOTSWANA OPBRC AND TRADITIONAL MAINTENANCE CONTRACT DATA

Name		Description
Surface Type A0.pdf		Full network map
Botswana_Guideline 9 - Traffic Data Collection and Analysis (2004).pdf		Traffic data collection and analysis guide
LEGEND.docx		Road code, road name, and traffic count station
2007-> Count Survey form XXX.xls 2008-> Count Survey form XXX.xls 2011-> Count Survey form XXX.xls 2012-> Count Survey form XXX.xls 2013-> Count Survey form XXX.xls 2015-> Count Survey form XXX.xls	(14) (5) (3) (1) (2) (2)	Manual traffic count survey forms
ASPHALT OVERLAYING OF MAHALAPYE MACHANENG FINAL FINAL.docx		Model traditional contract
LBT SERULE - TONOTA VETTED (00000003).docx		Model contract document
RESEAL OF KAZUNGULA - ZIMBABWE ROAD BORDER ROAD_Final 2018.docx		Model contract document
M&R Ideal Budget Scenario.xls		Full network aggregated IRI, rutting, cracking, and condition index data
Strategic Road Maintenance Needs Analysis Report - Final		
VOLUME 1 OF 5 PART A		OPBRC Contract Document
VOLUME 1OF 5 PART B		OPBRC Contract Document
OPRC Conceptual Design – Various		OPBRC Conceptual Design Report
BW-RoadMaintenanceManualPart_A_B_C_D-2010.pdf		Maintenance Manual
D2 _ 01_1 _ Workshop Training No. 1_Motsu.pdf		PowerPoint presentation on OPBRC
OPRC - Package 1 - Routine maintenance annual deductions Package 1		Annual payment deductions
Traditional Contracts - Book1.xls		Tender totals for a selection of traditional contracts
Traditional Contracts - MAKATI PROJECTS 2014 2019		Tender totals for a selection of traditional contracts
Strategic Road Maintenance Needs Analysis Report - Final		Strategic Road Maintenance Needs Analysis Report (2011)
MPR Package 1 - April 2019		OPBRC Monthly Report
MPR Package 2 - April 2019		OPBRC Monthly Report

Conclusion

The slow progress of the OPBRC rollout (including preparation for the tendering) and rehabilitation works were significant challenges. As noted above, this is partially because the skills required to successfully undertake an OPBRC differ from those required for traditional contracts. Both the contractor and the Roads Department staff recognized that they gained substantial knowledge from the Lot 1 OPBRC pilot.

Roads Department staff recognized that innovation and knowledge sharing across road agencies were strengths of the OPBRC approach, and the OPBRC contractor's staff felt they would be much more likely to successfully implement a future OPBRC based on this experience.

At the time of the case study, delays to rollout and rehabilitation had negatively affected the appetite for the OPBRC approach in Botswana, however. There was a significant risk that further PBCs would not be implemented in the near future, and much of the knowledge gained through this process may be lost.

FIGURE A4.45: EMERGENCY WORK REINSTATEMENT FOLLOWING FLASH FLOOD

Source: OPUS 2019.

Case Study 6: Florida Department of Transport

Florida is the southernmost state in the 48 contiguous United States. It is bordered by the Gulf of Mexico, the states of Alabama (to the northwest) and Georgia (to the north), and the Atlantic Ocean and Straits of Florida to the east and south. Florida is the third most populous state in the United States with approximately 21 million inhabitants and spans a land area of 170,300 km^2. The Miami metropolitan area is the most populous in the state with a population of 6.1 million and accounts for more than one-quarter of the state's economic activity. Tallahassee is the state's capital and has a population of 191,000.

Florida's US$1.0 trillion economy is the fourth largest in the United States. If it were a country, Florida would be the 16th largest economy in the world.

Roads are the primary means of transport in Florida. The state has 1,473 miles (2,371 km) of interstate highways, and 9,934 miles (15,987 km) of non-interstate highways. The other main transport modes are rail and air. Florida has 131 public airports, of which 7 are large and medium hubs.

FDOT is responsible for the state-owned roads in Florida, which includes interstates constructed through the United States Highway Trust Fund. The case study compares maintenance of state highways undertaken through a PBC model known as asset maintenance contracts to comparable road maintenance works procured by FDOT under traditional road maintenance contracts. FDOT is divided into seven districts which are responsible for the state's roads. Districts have full discretion on what model they choose to use for maintenance of individual roads. This affords districts the appropriate degree of autonomy to make delivery model solutions based on industry capacity and capability, internal capacity and capability, asset composition and distribution, and previous local success (or otherwise) of each contract model within the local context implemented.

Contract Details and Characteristics

FDOT Asset Maintenance PBC

Performance-based contracts in Florida are branded as asset maintenance (AM) contracts. Key features of the AM contract[43] are as follows:

- Only routine maintenance activities (work required to maintain assets in a fair to good condition state) are included in these contracts.

43 FDOT has published extensive information on the AM contracting approach at https://www.fdot.gov/maintenance/amcontractdocuments.shtm.

- All major renewal works including periodic maintenance and asset renewals are carried out using other contract mechanisms.
- Routine maintenance includes all maintenance associated with the roadway (that is, routine surface maintenance), roadside (that is, routine shoulder and right-of-way maintenance), traffic services (that is, signs, signals, lighting, and barrier maintenance), vegetation, and drainage (that is, culvert, curb, and gutter and side drain maintenance).
- AM contracts must be for at least seven years (with possibility of renewal) but no longer than 14 years (including renewal).
- Non-routine maintenance works such as emergency response are included in the scope of work, but the risk transfer to the contractor is capped between US$500,000 and US$1 million depending on the contract.

Each district within Florida decides the duration of AM contracts within its control. The length is determined by various factors including the agency's level of trust in the ability and willingness of the contractor to take ownership, whether significant roadway additions to the geographical area are expected during the contract period, whether the project is standard or includes new features, and so on. Historically, AM contracts were around five years' duration.

As of the time of the case study, there were 49 active AM PBCs in the state of Florida, as shown in Table A4.19, with six contractors participating in these contracts. Currently, 9,272 centerline kilo-meters of highways are maintained under AM contracts at a total cost of US$1,082,432,453.

Maintenance delivery under these AM contracts is assessed using FDOT's MRP which has been deployed across the state of Florida and is used by all districts to 'benchmark' the delivery of routine maintenance activities. The benchmark MRP rating makes it easy to compare the level of service delivery achieved across the state and delivery models given that the level of service is clearly understood through the MRP. A target of MRP 80 is used on all non-freeway highways and a target of MRP 90 is used on freeways.

TABLE A4.19: LIST OF PBCS IN FLORIDA (2019)

No.	Contract ID	Vendor Name	Original Contract Amount (US$)
1	BD524	Infrastructure Corp of America	73,073,000.00
2	EIF88	Ferrovial Services Infrastructure, Inc	11,406,300.00
3	EIG23	DBI Services	92,630,736.00
4	EIL59	Ferrovial Services Infrastructure, Inc	9,257,300.00
5	EIM87	DBI Services	10,282,783.00
6	EIN92	Infrastructure Corp of America	82,622,064.00
7	E1032	Jorgensen Contract Services, LLC	5,300,000.00
8	E2Q70	Jorgensen Contract Services, LLC	8,997,000.00
9	E2Q71	Jorgensen Contract Services, LLC	6,897,000.00
10	E2Q74	Infrastructure Corp of America	25,431,000.00
11	E2R38	DBI Services	27,840,432.00
12	E2R43	Jorgensen Contract Services, LLC	6,425,000.00
13	E2R44	Ferrovial Services Infrastructure, Inc	6,514,932.00
14	E2R51	DBI Services	7,100,000.00
15	E2R56	Jorgensen Contract Services, LLC	6,191,000.00
16	E2S59	Jorgensen Contract Services, LLC	3,780,000.00
17	E2V97	Ferrovial Services Infrastructure, Inc	88,902,029.93

TABLE A4.19: LIST OF PBCS IN FLORIDA (2019), CONTINUED

No.	Contract ID	Vendor Name	Original Contract Amount (US$)
18	E2X03	Jorgensen Contract Services, LLC	86,002,000.00
19	E3G97	Ferrovial Services Infrastructure, Inc	37,844,600.00
20	E3M31	Infrastructure Corp of America	24,638,000.00
21	E3040	Ferrovial Services Infrastructure, Inc	30,985,000.00
22	E3P16	Ferrovial Services Infrastructure, Inc	18,224,860.00
23	E3R56	Ferrovial Services Infrastructure, Inc	21,313,001.50
24	E4H52	Ferrovial Services Infrastructure, Inc	87,950,000.00
25	E4L77	DBI Services	10,848,450.00
26	E4N77	Florida Drawbridges, Inc	23,905,000.00
27	E4Q30	Jorgensen Contract Services, LLC	59,842,000.00
28	E4R18	Jorgensen Contract Services, LLC	61,004,848.00
29	E4S94	DBI Services	14,014,170.00
30	E5N05	DBI Services	17,568,440.00
31	E5P62	DBI Services	26,887,000.00
32	E5Q90	DBI Services	28,079,000.00
33	E5T54	DBI Services	36,546,628.00
34	E5U43	Ferrovial Services Infrastructure, Inc	15,018,772.00
35	E5U63	Louis Berger Hawthorne Services	27,458,646.31
36	E6D11	Florida Drawbridges, Inc	23,706,970.00
37	E6147	Infrastructure Corp of America	19,573,764.00
38	E6197	DBI Services	45,987,000.00
39	E7G51	Jorgensen Contract Services, LLC	6,720,000.00
40	E7H52	Infrastructure Corp of America	32,000,000.00
41	E7187	DBI Services	25,511,000.00
42	E7195	Ferrovial Services Infrastructure, Inc	29,678,094.00
43	E7J67	Infrastructure Corp of America	63,232,360.00
44	—	DBI Services	14,909,260.00
45	E8M31	Infrastructure Corp of America	33,265,000.00
46	E8M70	Louis Berger Hawthorne Services	20,896,860.00
47	E8N09	Jorgensen Contract Services, LLC	16,563,300.00
48	E8P46	Jorgensen Contract Services, LLC	18,988,000.00
49	E8Q56	Ferrovial Services Infrastructure, Inc	11,818,997.40

Florida Traditional Contract

Maintenance is also delivered under traditional contracts (measure and value and quantified maintenance) and in-house service delivery (FDOT own forces). Traditional work-directed contracts used by FDOT, by definition, provide maintenance wherever the Department of Transport wishes. Maintenance delivered under these models is also assessed using the MRP.

TABLE A4.20: CONTRACT DATA SUMMARY — FDOT PBC AND TRADITIONAL MAINTENANCE CONTRACTS

OPBRC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 1: Pavement Rehabilitation Works		
Not assessed (see commentary)	Not assessed (see commentary)	Pavement rehabilitation work is not delivered under maintenance—this work is delivered separately under specific pavement rehabilitation contracts and not under the AM contracts.
Item 2: Periodic Maintenance Works		
Not assessed (see commentary)	Not assessed (see commentary)	Like pavement rehabilitation works, this work is delivered under separate contracts, irrespective of the delivery model. Neither the PBC nor traditional routine maintenance contracts included periodic maintenance works.
Item 3: Routine Maintenance Works		
Estimated to be US$6,400 per lane km[44]	Estimated to be approximately US$9,500 per lane km[45]	FDOT was unable to provide the exact lane kilometers of the case study networks, and the unit costs are estimates. Routine maintenance includes surface maintenance and roadside maintenance.
Item 4: Emergency Works Expenditure — Average Annual		
Not assessed. There are no emergency works provisions see commentary)	There are no emergency works provisions. Not assessed (see commentary)	Quantifying emergency works is challenging as it depends on the frequency, severity, and location of hurricanes. There is no difference between the contracts.
Item 5: Contract Administration — Procurement		
Data not available. Not assessed (see Commentary)	Data not available. Not assessed (see Commentary)	The specific cost to bid both types of contracts is unknown and changes depending on the contractor. Anecdotally, one of FDOT's suppliers did qualitatively comment that the 'effort' to bid for the AM contract is less than that of the traditional contract.
Item 6: Contract Monitoring/ Supervision/ Administration		
Data not available. Not assessed (see Commentary)	Data not available. Not assessed (see Commentary)	Qualitative evidence obtained during the interview process suggested that the administration and supervision effort is less for an AM contract than for a traditional contract, but data on actual FTEs required for each contract model were unavailable.

44 Values for AM contracts were derived from assessing the US$ per CL km for each AM contract type, then dividing by the contract duration (seven years) and average number of lanes per CL (assumed to be 3.5 lanes per CL km given the typical four-lane composition of rural arterial and rural limited access highways).

45 Values for non-AM were derived by adjusting the AM values based on the following FDOT data:
47.5 percent of District 2 roadway miles are delivered under PBM type 'asset maintenance' contracts. This consumes 34 percent of the total budget to achieve the same Maintenance Rating Program (MRP) score of 80. About 52.5 percent of District 2 roadway miles are delivered under non-PBM type models, including traditional and insourced models. This consumes 66 percent of the total budget to achieve the same MRP score of 80.

TABLE A4.20: CONTRACT DATA SUMMARY — FDOT PBC AND TRADITIONAL MAINTENANCE CONTRACTS, CONTINUED

OPBRC Values (2019)	Traditional Contract Values (2019)	Commentary
Item 7: Non-pavement Maintenance Works		
Non-pavement maintenance scope of work is identical for both contract types (see Commentary).	Non-pavement maintenance scope of work is identical for both contract types (see Commentary).	Non-pavement maintenance scope of work includes roadside (unpaved shoulder, front slope, slope pavement, sidewalk, fence), traffic services (raised pavement markers, striping, pavement symbols, guardrail, signage delineators, lighting), drainage (side/cross drains, roadside/median ditch, outfall ditch, inlets, miscellaneous structures, roadway sweeping), and vegetation/aesthetic (roadside mowing, slope mowing, landscaping, tree trimming, curb/sidewalk edge, litter removal, turf condition)
Item 8: Resilience		
No discernable differences were observed. Not assessed (see Commentary)	Data not available. Not assessed (see Commentary)	There are no distinguishable resiliency benefit differences between contract models.
Item 9: Additional Nonfinancial Benefits		
a. Reduction in FDOT FTEs required to deliver maintenance allows FDOT staff to remain focused on governance, strategy, and asset management initiatives b. Increased data capture and availability around road assets and condition c. Increased certainty on financial expenditure d. Transfer of risk on quality and performance to the contractor.	a. Simple maintenance contract which is easy to procure and administer	

Quality Differences

The MRP recorded negligible differences in the quality of outcomes provided by the two contract models. In the case of AM contracts, challenges remain in the areas of drainage and the National Pollutant Discharge Elimination System (NPDES). Any discernible quality will be driven by the differing service levels of each highway type—that is, non-freeway highways require an MRP score of 80 while interstate freeway require an MRP score of 90.

The following are additional quality outcomes delivered through the AM contracts:

- The contractor may perform at a higher level to ensure that s/he meets an MRP of 80.
- The contractor may offer, in the proposal, outcomes that exceed the minimum criteria stipulated in the contract scope.

Value-for-Money Discussion

Although the scope of the two contracting approaches is similar and the quality outcomes are comparable, it was not possible to compare value for money of the AM and traditional contracts as the case study could not obtain confirmation of the number of lane kilometers for the roads that constitute each comparison network. As noted in Table A4.20, it is therefore not clear whether the AM model has achieved actual efficiencies.

The case study also did not gain insights into the individual district's decision-making about the choice of contracting approach. The factors affecting these decisions could be of interest for understanding the track record of the two contracting approaches.

There are nonetheless certain advantages to the AM contracting approach:

- FDOT has greater influence over quality of workmanship and responsiveness in the AM contracts due to the ability to make deductions should either metric be compromised.
- In areas where district resources are limited and where AM contracts are used, FDOT staff can focus on more urgent activities and divest the responsibility of inspections and defect management to their service providers.

Contract Administration, Resilience, and Other Observations

Tendering

FDOT was unable to confirm differences in the financial costs to bid the different contract modalities, noting that it depended on the choice of contractor. One of FDOT's staff did mention, anecdotally, that tendering AM contracts requires less effort.

Contract Management

It was acknowledged during the interview process that relationship management is key when it comes to AM contracts. This meant both FDOT and its service providers needed to actively focus on maintaining healthy relationships at each management level within the contract, which ultimately resulted in stronger, more collaborative, and trusting partnerships.

Even though maintenance within FDOT is funded 'off the top' (that is, maintenance of existing assets is prioritized over building new assets) and this policy is unlikely to change any time soon, the regular lump-sum payments required for the AM contract model make it difficult for funds to be reallocated to other FDOT activities. This guarantees a minimum funding level for at least the duration of the AM contract.

There have also been challenges for FDOT in adapting to the PBC compared to the traditional contract. These challenges include:

- Reduction in the number of in-house personnel;
- Staff's difficulty in accepting/understanding the performance-based model; and
- Staff's difficulty in responding to local pressing demands for immediate action, for example, littering, mowing, and graffiti.

Summary

The AM PBC contracting approach differs from other PBCs in this study in that the scope is limited to maintenance. While the AM and traditional contracts are largely comparable in terms of scope and quality outcomes and represent a large enough sample of contracts to provide meaningful comparisons for the context, unit cost differences could not be confirmed. There is also uncertainty about the factors affecting districts' decisions on the choice of contracting model. The case study may not have fully captured potential findings in terms of the benefits or disbenefits of the AM model.

It is presumed that contractors have established and utilize good quality assurance processes during initial construction/rehabilitation, and this has made the AM contract model more viable.

TABLE A4.21: CASE STUDY 6: FLORIDA DEPARTMENT OF TRANSPORTATION CONTRACT DATA

Document	Overview	Commentary
Questionnaire response	Formal response to original outreach questionnaire including detail on network configuration, administration, budgets, contracts, and service levels	Provided electronically via email in PDF format
2018 Asset Maintenance Scope of Services	Asset Maintenance Contract Scope of Services Template defining contract requirements for the maintenance of roadways, structures, and facilities	Provided electronically via email in MS Word format
Asset Maintenance Contractor Performance Evaluation Report (AMPER)	Excel spreadsheet used to collate and analyze performance data to benchmark and compare contractor performance	Provided electronically onsite in MS Excel format
Maintenance Rating Program (MRP) Manual	Manual defining the service levels to be achieved to meet the maintenance requirements defined in the AM contract	Provided electronically via email in PDF format
General	Guidelines, policies, procedures, and other contract documents as defined on the FDOT maintenance website	Provided electronically via website link

APPENDIX 5
Characteristics of PBCs

TABLE A5.1: SUMMARY OF PBC CONTRACT CHARACTERISTICS

Country/ Source	Scope				Contract Type	Length (km)	Contract Duration (years)	Financing
	Design Responsi-bility	Work Types	Intervention Time	Residual Life at Handover (years)				
Georgia[1]	Contractor	Rehabilitation	Rehabilitation within 18 months after the start of the contract	20	PBC	17.4	20	IBRD
Georgia[2]	Contractor	Rehabilitation + Maintenance + Emergency	Rehabilitation within 24 months after the start of the contract	—	PBC	117	5	IBRD/IDA
Liberia[3]	Contractor	Rehabilitation + Periodic + Routine + Management and Operation	Rehabilitation within 25 months after the start of the contract	10	PBC	57	10	IDA
Liberia[4]	Contractor	Rehabilitation + Periodic + Routine	Rehabilitation within 24 months after the start of the contract	8	PBC	68.6	10	IDA
Thailand[5]	Indepen-dent Consultant	Improvement + Periodic + Routine		—		300	3	IBRD
Egypt[6]	Contractor	Rehabilitation + Periodic + Routine + Improvement	Rehabilitation within 12 months after the start of the contract	—	PBC	58	5	PPIAF
Yemen[7]	Contractor	Periodic + Routine + Emergency	—	—	PBC	417	3	

Skill Set		Payments and Incentives				Max Expenditure on Rehabilitation		
Internal Quality Control	Appointment of Project Manager Year	Payment Structure	Advance Payment	Incentive/ Bonus Payments	VOP Provisions		Risk Matrix	Traffic/Overloading Risks
✓	Externally appointed	Rehabilitation/ maintenance/ road management works paid by fixed lump sum	✓	X	X		✓	—
✓	Externally appointed	Rehabilitation/ maintenance works paid by fixed lump sum Emergency paid by BoQ	✓	X	✓	80%	—	—
✓	Externally appointed	Rehabilitation works paid by lump sum based on set milestones Maintenance paid by fixed lump sum	✓	✓	✓		✓	Contractor compensated if axle loads/ traffic volumes exceed 15% of estimated values
✓	Externally appointed	Rehabilitation works paid by lump sum based on set milestones Maintenance paid by fixed lump sum.	✓	✓	✓	52.1%	✓	Contractor compensated if axle loads/ traffic volumes exceed 15% of estimated values
✓	Externally appointed	—	X	X	—	✓	✓	—
✓	Externally appointed	Rehabilitation/improvement works paid by lump sum based on set milestones/outputs Maintenance paid by fixed lump sum	X	X	✓	✓	✓	—
✓	Externally appointed	Periodic works paid by lump sum based on set milestones/outputs Maintenance paid by fixed lump sum	X	X	—		—	—

TABLE A5.1: SUMMARY OF PBC CONTRACT CHARACTERISTICS, CONTINUED

Country/ Source	Scope				Contract Type	Length (km)	Contract Duration (years)	Financing
	Design Responsi-bility	Work Types	Intervention Time	Residual Life at Handover (years)				
Bangladesh[8]	Contractor	Repair + Maintenance + Emergency	Repairs to be done within 6 months after the start of the contract	—	Hybrid PBC		5	IDA + NG
Bangladesh[9]	Contractor	Repair + Maintenance + Emergency	Repairs to be done within 6 months after the starts of the contract	—	Hybrid PBC	24.2	5	NG
China[10]	Contractor	Repair + Maintenance + Emergency	Repairs to be done within 18 months after the start of the contract	—	Hybrid PBC	57	5	ADB + NG
India[11]	Contractor	Rehabilitation + Improvement + Resurfacing + Routine + Emergency	Improvement to be done within 36 months after the start of the contract	5	PBC	204	10	IBRD
Tonga[12]	Contractor	Routine only. Periodic main-tenance sepa-rate contract	—	—			1	PRIF
Papua New Guinea[13]	Contractor	Restoration + Maintenance + Emergency	Restoration to be done within 12 months after the start of the contract	—	Hybrid PBC	31.8	3	NG
Papua New Guinea[14]	Contractor	Rehabilitation + Improvement + Maintenance	Improvement to be done within 18 months after the start of the contract	—	Hybrid PBC	112	3.7	IBRD/IDA
Tajikistan[15]	Contractor	Periodic + Routine + Winter Main-tenance + Emergency	—	—	Hybrid PBC	73	3	ADB + NG

Source: 1. Roads Department of the Ministry of Regional Development and Infrastructure of Georgia (2011); 2. Roads Department of the Ministry of Regional Development and Infrastructure of Georgia (2015); 3. Republic of Liberia - MPW (2011); 4. Republic of Liberia - MPW (2012); 5. RFP for Highway Management Project: Loan Number 4721-TH. (2005); 6. Procurement of OPRC: Specifications for OPRC in Egypt; 7. Republic of Yemen: Ministry of Public Works and Highways (2013); 8. Chief Engineer, Bangladesh (2011); 9. Government of the Peoples Republic of Bangladesh: Local Government

Skill Set		Payments and Incentives				Max Expenditure on Rehabilitation		
Internal Quality Control	Appointment of Project Manager Year	Payment Structure	Advance Payment	Incentive/ Bonus Payments	VOP Provisions		Risk Matrix	Traffic/Overloading Risks
✓	Internally appointed	Repair/emergency works paid by BoQ Maintenance paid by fixed lump-sum payments	✓	X	✓ Emergency works only	✓	—	—
✓	Internally appointed	Repair/emergency works paid by BoQ Maintenance paid by fixed lump-sum payments	X	X	✓ Emergency works only		—	—
✓	Externally appointed	Repair/emergency works paid by BoQ Maintenance paid by fixed lump-sum payments	✓	✓	✓ Emergency + maintenance works after 18 months		✓	—
✓	Internally appointed	Rehabilitation/ improvement/ resurfacing/routine works paid by fixed lump-sum payments. Emergency works paid by BoQ	✓	X	✓		✓	Contractor compensated if axle loads/ traffic volumes exceed 15% of estimated values
✓	Internally appointed	—	X	X	—		—	—
✓	Internally appointed	Restoration/emergency works paid by BoQ Maintenance paid by fixed lump-sum payments	X	✓	✓ Applicable after 18 months	✓	—	—
✓	Internally appointed	Rehabilitation/improvement works paid by BoQ Maintenance paid by fixed lump-sum payments	✓	X	✓ Applicable after 18 months	85%	✓	—
✓	Externally appointed	Periodic/winter/ emergency works paid by BoQ Routine paid by fixed lump-sum payments	✓	X	X			—

Engineering Department Second Rural Transport Improvement Project (2015); 10. Yunnan Highway Administration Bureau (2012); 11. Government of Punjab Public Works Department (2011); 12. Ministry of Infrastructure - Kingdom of Tonga (2012); 13. Independent State of Papua New Guinea - Bidding Document (2014); 14. Department of Works: Road Maintenance and Rehabilitation Project II (2016); 15. Ministry of Transport of the Republic of Tajikistan (2012).
Note: P = Data available; X = Data not available; NG = National government.

APPENDIX 6
Lifecycle Costs Analysis of Road Investment and Operation and Maintenance Strategies[46]

1. Introduction

It is widely believed that PBCs can promote the optimum long-term road investment and O&M strategies. This is because PBCs create incentives for contractors to maintain road assets in good condition throughout the contract duration and keeping roads in good condition can minimize lifecycle economic costs for both the road agencies and road users. However, this hypothesis has not been well tested by quantitative analysis with real-world data, especially data from developing countries.

This appendix analyzes possible economic benefits inherent in the PBC methodology by comparing various O&M scenarios and thereby showing that well-designed PBCs can contribute to achieve the optimum O&M strategies in terms of lifecycle costs. To achieve this aim, the study conducted the following tasks:

1. Identify and define the most common road investment and O&M scenarios based on the data obtained through case studies in Chapter 3.
2. Undertake LCCA of the various road investment and O&M scenarios using the HDM-4 simulation model.
3. Assess and compare the economic efficiency of a range of road investment and O&M scenarios.

2. Review of Lifecycle Analysis of Road Investment

With the rising cost of road construction, maintenance, and rehabilitation over the past years, road agencies have increasingly recognized the need to undertake long-term economic assessment to inform investment decisions (Babashamsi et al. 2016). Long-term economic analysis of road investment decisions, known as lifecycle costs analysis, allows comparison of the long-term economic cost and benefits of different investment options (AASHTO 1986). LCCA is relevant for optimizing pavement design and management in an environment of inadequate road financing and increasing demand for better infrastructure management across the globe (Babashamsi et al. 2016).

The concept of lifecycle cost/benefit analysis was first developed by AASHTO in 1960 in a book titled the Red Book (Babashamsi et al. 2016).[47] The method involves assessing the initial costs and discounted future costs over the entire life of the project (Kane 1996). According to Donahue (2014), this entails (a) selecting an analysis period; (b) selecting a discount rate; (c) estimating initial agency costs; (d) estimating user costs such as vehicle operating costs and the costs of delays and collisions; (e) estimating future agency costs, for example, maintenance costs and rehabilitation costs; (f) estimating residual value; and, finally, (g) comparing the alternatives.

46 All figures in this appendix are from World Bank analysis.

47 Not to be confused with the FIDIC 'Red Book' SBD for civil works.

Three approaches may often be considered in evaluating LCCA: (a) the maximization of benefits for a given investment level, (b) the minimization of costs to meet a desired strategy, or (c) a combination of the two approaches (Babashamsi et al. 2016). This analysis combines the first two approaches while identifying the best investment strategies.

One of the most common LCCA evaluation tools is the HDM-4 model, which was initially developed by the World Bank. The HDM-4 analytical framework predicated upon the concept of pavement lifecycle analysis (typically 15 to 40 years), which is applied to predict road deterioration, the effects of road works, the effects on road users, and socioeconomic and environmental effects (Odoki and Kerali, 2009. HDM-4 has evolved over the past 35 years to become the de facto standard tool used worldwide for assessing the impact of various road construction and maintenance interventions. This is due to its internationally accepted analytical framework, the transparency in its analysis, and its ability to be calibrated to reflect local conditions (Kerali 2001). Therefore, it has also been used in this study.

Most LCCA calculation tools and methodologies yield various economic indicators, such as the NPV, internal rate of return (IRR), and benefit-cost ratio (BCR). The FHWA (1998) recommends the use of NPV as the economic efficiency indicator of choice and this study also uses NPV for comparing options and alternatives.

3. The Analytical Approach

As mentioned above, the technical analysis approach for this study has been premised on the use of the HDM-4 model which is a software developed to appraise both technical and economic aspects of road investment decisions (Kerali and Odoki 2009).

Using the road section data (that is, geometry, pavement type, pavement strength, road condition, climate, drainage, and so on) and the traffic data (for example, traffic composition by vehicle types, traffic volumes, growth rates, speed-flow types, and traffic flow patterns), the model predicts the deterioration of roads over time and the impacts of various improvement and maintenance interventions on road roughness (Harral and Faiz 1988). Also, using the unit cost of multiple work types and the vehicle fleet data (that is, physical characteristics, utilization, loading patterns, vehicle resource costs, time value costs and so on), the model then estimates the total lifecycle RAC arising from the implementation of the defined maintenance and construction policies, and the resultant RUC, which are then discounted to obtain economic indicators such as the NPV and IRR (Harral and Faiz 1988).

The current study has used HDM-4 to evaluate the net benefits of different investment and O&M strategies believed to be inherent to PBC and compare these with a base case of minimum ‘reactive’ maintenance followed by accelerated deterioration and reconstruction. The analysis is, in fact, a simulation of road lifecycle cost, vehicle operating conditions, and the costs for various road investment and maintenance alternatives. The overall savings for road users have been calculated in terms of savings in vehicle operating costs and savings in travel time costs. These benefits have been incorporated in the analysis to identify the optimal combinations of investment and O&M interventions.

4. The Analytical Approach

The analysis focused on case studies from three countries (Argentina, Lao PDR, and Liberia) for which sufficient data (and the HDM-4 data files), including parameters of typical road characteristics, vehicle operation costs, and civil work costs, were available. Three other case studies (New Zealand; Florida, United States; and Botswana) did not yield sufficient data to enable a meaningful analysis of investment and O&M scenarios.

The analysis first evaluated the project information from Argentina, Lao PDR, and Liberia to define a set of 32 different scenarios which could in principle be applied in all three countries. These 32 scenarios were then evaluated for each of the three countries using the country-specific cost input data.

Apart from the case study from Liberia, for which the workspace was reconstructed using information from a feasibility report, data for the other two case studies were available in the form of HDM-4 object file formats, that is, objects.dat and objects.idx. The analysis was thus based on actual aggregate data from the specific countries for homogenous road sections, in terms of physical and engineering characteristics, traffic volumes and composition, and road conditions. As the HDM workspaces were calibrated to the countries, the simulations also utilized the economic and financial parameters from the three case studies.

The accuracy of the analysis outputs is heavily dependent on the accuracy of the data collected in each country. Given the high level of generalization expected to be derived from the study findings, the quality of data used appears acceptable for this level of analysis. The overall confidence level in the data used is categorized by the team as being ‘Medium’.

Based on the year of the data provided (that is, 2018 for Argentina, 2016 for Lao PDR, and 2010 for Liberia), the analysis assumes that there have been no significant changes in unit costs of vehicle resource consumption and road work activities. An increase in vehicle resource consumption unit costs (for example, tire prices, fuel prices, and vehicle prices) often leads to an increase in project benefits, while an increase in unit costs of work activities (for example, construction and maintenance costs) leads to a decline in net project benefits. Unit costs for vehicle resource consumption and road works often increase and decrease in parallel, since they have some common denominators, including the price of crude oil.[48]

The analysis does not assess the RAC related to designing, preparing, procuring, and supervising road works to be incurred by the road agency, due to lack of data for those cost items. Some of the key input data used in this study are presented below.

5. Road Sections

The road section characteristics adopted in the study for each country is as presented in Table A6.1. The modelled road sections each had two lanes and were 10 km long with a 7 m wide carriageway and 1 m shoulders.

TABLE A6.1: ROAD SECTION CHARACTERISTICS

Country	Surface Class	Road Class	Climate	Traffic Flow Pattern
Liberia	Bituminous	Primary	Tropical peri-humid	Interurban
Lao PDR	Bituminous	Primary/trunk	Subtropical humid	Interurban
Argentina	Bituminous	Primary/trunk	Subtropical humid	Commuter

48 Crude oil prices affect fuel and bitumen prices, with fuel being a major component of both vehicle operating costs and road works and bitumen being a major ingredient of road works.

6. Climatic Data

The climate input data for the roads are as summarized in Table A6.2.

TABLE A6.2: CLIMATIC DATA

Parameter	Liberia	Lao PDR	Argentina
Moisture index	100	60	60
Duration of dry season (months)	7	3	3
Mean monthly precipitation (mm)	210	175	500
Mean temperature (°C)	26	18	18
Average temperature range (°C)	5	13	13
Days with temperature > 32°C	90	30	30
Freeze index	0	0	0
Driving on water covered roads (%)	20	0	15

7. Road Works and Unit Costs

The adopted economic unit cost of works is presented in Table A6.3.

TABLE A6.3: ECONOMIC UNIT COST OF WORKS

Intervention	Liberia	Lao PDR	Argentina
Reconstruction with asphalt surfacing (US$/m^2)	72.60	73.40	55.60
Reconstruction with DBST surfacing (US$/m^2)	58.10	58.70	44.50
50 mm asphalt overlaya (US$/m^2)	18.10	18.40	11.60
Reseal with 25 mm DBST (US$/m^2)	8.60	8.40	5.30
Reseal with 13 mm SBST (US$/m^2)	4.30	4.20	2.60
Crack sealing (US$/m^2)	2.21	4.25	2.58
Pothole patching (US$/m^2)	25.10	8.51	27.30
Edge repair (US$/m^2)	26.50	5.32	38.00
Routine miscellaneous (US$/km/year)	2,250.00	1,712.00	2,853.00

Note: Exchange rates: US$1 = ARS 38 (Argentina); US$1 = LAK 8,179.55 (Lao PDR).SBST = Single bituminous surface treatment.a. Unit cost for 25 mm, 30 mm, 40 mm, 65 mm, and 80 mm estimated from ratio of overlay thickness with respect to 50 mm overlay unit cost.

8. Traffic Mix

Distribution of traffic by vehicle class for the various sample countries is shown in Table A6.4.

TABLE A6.4: VEHICLE COMPOSITION

Liberia		Lao PDR		Argentina	
Vehicle Type	%	Vehicle Type	%	Vehicle Type	%
Medium/heavy bus	5	Hand tractor	0.3	Articulated truck	24
Articulated	1	Articulated	1	Medium truck	6
Heavy truck	2	Van (4WDs)	7	Medium bus	3
Medium truck	5	Medium truck	3	Medium car	67
Small truck	11	Tuk-tuk	1		
Light good vehicle	36	Motorcycle	47		
Car	41	Car	25		
		Small bus	2		
		Large/medium bus	1		
		Light truck	10		
		Heavy truck	3		

Note: 4WD = Four-wheel drive.

Table A6.5 presents the proportion of heavy vehicles in the traffic mix for each country based on Table A6.4.

TABLE A6.5: PROPORTION OF HEAVY VEHICLES

Country	Proportion of Heavy Vehicles (%)
Liberia	8
Lao PDR	6
Argentina	30

9. Traffic Growth Rates

For traffic forecasting, the growth rates presented in Table A6.6 were used for the analysis.

TABLE A6.6: TRAFFIC GROWTH RATES

Country	Annual Rate (%)	Remarks
Liberia	5 to 35 (average 14.4)	Varies by year
Lao PDR	–2.5 to 11 (average 5.1)	Varies by year and by vehicle type
Argentina	3	Constant throughout

10. Other Analysis Parameters

Other analysis parameters are as shown in Table A6.7.

TABLE A6.7: ANALYSIS COMPONENTS

	Liberia	Lao PDR	Argentina
Discount rate		6%	
Analysis period		20 years	
Standard conversion factor (SCF)	0.90	0.87	0.71

11. Vehicle Fleet Data

Tables A6.8 and A6.9 show summaries of the adopted basic and economic vehicle fleet details for each country.

TABLE A6.8: BASIC VEHICLE FLEET CHARACTERISTICS (US$)

Country	Name	Base Type	PCSE	No. of Wheels	No. of Axles	Tire Base Recaps
Lao PDR	Hand tractor	Motorcycle	0.5	2	2	1.3
	HT >5 axle	Heavy truck	1.8	18	5	1.3
	Van	4WD	1.0	4	2	1.3
	Medium truck	Medium truck	1.4	6	2	1.3
	Tuk-tuk	Small car	0.7	3	2	1.3
	Motorcycle	Motorcycle	0.5	2	2	1.3
	Car	Medium car	1.0	4	2	1.3
	Small bus	Light bus	1.0	4	2	1.3
	Large and medium bus	Heavy bus	1.6	6	2	1.3
	Light truck	Light truck	1.3	6	2	1.3
	Heavy truck	Medium truck	1.6	10	3	1.3
Argentina	Camion Pesado	Articulated truck	1.8	18	5	1.0
	Camion Liviano	Medium truck	1.4	6	3	1.0
	Omnibus	Medium bus	1.6	8	3	1.0
	Automovil	Medium car	1.0	4	2	0.0
Liberia	Medium/heavy bus	Medium bus	1.5	6	2	1.3
	Articulated	Articulated truck	1.8	18	5	1.3
	Heavy truck	Heavy truck	1.6	10	3	1.3
	Medium truck	Medium truck	1.4	6	2	1.3
	Small truck	Light truck	1.3	6	2	1.3
	Good vehicle	Light goods	1.0	4	2	1.3
	Car	Medium car	1.0	4	2	1.3

Note: ESALF = Equivalent standard axle load factor; PCSE = Passenger car space equivalent.

Tire Retread Cost (%)	Annual km	Annual Work Hours	Average Life	Private Use (%)	Passengers	Work Related Trips (%)	ESALF	Operating Weight (t)
15	6,000	200	10	20	3	75	0.00	1.5
15	50,000	1,300	10	0	2	0	4.50	27.0
15	25,000	625	10	20	1	0	0.01	2.3
15	40,000	1,00	12	0	2	0	2.00	14.0
15	33,000	1,100	15	10	6	25	0.00	0.6
15	8,000	300	8	75	1	75	0.00	0.2
15	15,000	375	12	100	3	75	0.00	1.4
15	75,000	1,900	10	0	9	75	0.01	2.1
15	50,000	1,150	10	0	40	75	0.80	10.6
15	30,000	800	10	0	2	0	0.20	6.2
15	45,000	1,200	10	0	2	0	3.50	20.0
30	100,000	2,000	14	0	1	100	3.80	30.6
30	60,000	2,000	14	0	1	100	0.79	12.0
30	100,000	2,000	8	0	32	75	1.49	12.0
30	20,000	400	12	100	1	75	0.00	1.,2
15	80,000	2,300	3	0	50	75	0.74	10.9
15	70,000	2,200	8	0	0	0	6.30	38.0
15	65,000	2,160	8	0	0	0	3.22	18.5
15	65,000	2,160	8	0	0	0	1.78	11.8
15	65,000	2,160	8	0	0	0	0.60	5.6
15	54,000	1,500	5	0	8	0	0.01	2.6
15	30,000	300	6	100	5	75	0.00	1.7

TABLE A6.9: ECONOMIC VEHICLE FLEET CHARACTERISTICS (US$)

Country	Name	Base Type	New Vehicle	Replace Tire	Fuel (per liter)
Lao PDR	Hand tractor	Motorcycle	1,103	34	0.8
	HT >5 axle	Heavy truck	86,809	254	0.8
	Van	4WD	30,406	59	0.8
	Medium truck	Medium truck	19,098	169	0.8
	Tuk-tuk	Small car	1,811	47	0.8
	Motorcycle	Motorcycle	739	8	0.8
	Car	Medium car	13,477	47	0.8
	Small bus	Light bus	27,872	59	0.8
	Large and medium bus	Heavy bus	63,441	93	0.8
	Light truck	Light truck	17,362	59	0.8
	Heavy truck	Medium truck	66,554	178	0.8
Argentina	Camion Pesado	Articulated truck	54,707	309	0.4
	Camion Liviano	Medium truck	29,177	262	0.4
	Omnibus	Medium bus	119,808	306	0.4
	Automovil	Medium car	9,519	82	0.4
Liberia	Medium/heavy bus	Medium bus	55,450	70	0.4
	Articulated	Articulated truck	125,964	225	0.4
	Heavy truck	Heavy truck	91,666	225	0.4
	Medium truck	Medium truck	51,932	154	0.4
	Small truck	Light truck	19,364	106	0.4
	Good vehicle	Light goods	26,666	70	0.3
	Car	Medium car	22,841	39	0.3

Lubricating Oil (per liter)	Maintenance Labor (per hour)	Crew Wages (per hour)	Annual Overhead	Annual Interest (%)	Passenger Work Time (per hour)	Passenger Nonwork (per hour)	Cargo Holding (per hour)
2.4	2.4	0.0	46	12	1.1	0.3	0.6
2.4	2.7	15.6	1,379	12	1.1	0.3	2.9
2.4	2.4	1.6	552	12	1.8	0.5	0.0
2.4	2.7	3.1	37	12	1.1	0.3	2.5
2.4	1.8	1.0	28	12	1.1	0.3	0.0
2.4	2.4	0.0	46	12	1.1	0.3	0.0
2.4	2.4	1.6	322	12	1.8	0.5	0.0
2.4	2.7	2.1	460	12	1.3	0.4	0.0
2.4	2.7	7.8	919	12	1.3	0.4	0.0
2.4	2.7	2.3	276	12	1.1	0.3	0.6
2.4	2.7	15.6	919	12	1.1	0.3	2.9
1.7	5.0	14.2	2,492	12	3.6	1.1	0.0
1.7	5.0	11.2	2,332	12	3.6	1.1	0.0
1.7	5.0	19.3	6,600	12	3.6	1.1	0.0
5.7	5.0	10.1	1,566	12	3.6	1.1	0.0
1.8	8.0	3.4	1,311	12	0.1	0.1	0.0
1.8	8.0	4.2	1,953	12	0.0	0.0	0.0
1.8	8.0	4.2	1,822	12	0.0	0.0	0.0
1.8	2.2	3.4	2,459	12	0.0	0.0	0.0
1.8	2.2	3.4	1,093	12	0.0	0.0	0.0
1.8	2.2	2.7	789	12	0.2	0.1	0.0
1.8	224.0	0.0	364	12	0.6	0.2	0.0

12. Road Intervention Scenarios

A total of 32 different investment and O&M scenarios for paved roads have been defined and used in the LCCA. The scenarios represent varying levels of initial construction and varying maintenance interventions and intervals. In addition, the 32 scenarios were applied to three different 'starting road conditions', namely good, fair, and poor road conditions at the beginning of the simulation period, with assumed IRI values of 3.0 m/km for roads in good condition, 4.0 m/km for roads in fair condition, and 6.0 m/km for roads in poor condition. The starting IRI values were selected following the most common conditions in general.

The impact of varying traffic levels on the various O&M scenarios has also been assessed. The traffic bands included an AADT of 750, 3,000, and 7,500 vehicles per day for low-, medium-, and high-traffic bands, respectively.

The study approach involved comparing the impacts of these 32 scenarios against a base case intended to represent reactive maintenance practices that are typical in many developing countries for roads or road networks that are not covered by PBCs. The base case assumes that only routine maintenance works are carried out[49] when certain condition criteria are triggered, for example, pothole patching when more than five potholes are present per km or road. This reactive maintenance approach results in gradually worsening road roughness, which cannot be avoided through routine maintenance only, and a corresponding gradual increase in annual routine maintenance costs.

The LCCA simulations carried out for this research cover a 20-year analysis period during which the investment costs, maintenance costs, and RUC were computed, discounted at 6 percent to the present value, and compared to the 'base case'. It is noted that while a 6 percent discount rate may not be appropriate for all countries, different discount rates do not affect the comparative analysis and ranking of scenarios. They do, however, affect the absolute values of the NPV and IRR, which are however not relevant under this study.[50]

The various pavement defects in HDM-4 are expressed in terms of IRI, which is a measure of the quality of the riding surface. Roughness is expressed in the model as a function of age, strength, traffic loading, potholes, cracking, raveling, rutting, and environment.

The base case and the various road investment and O&M scenarios are presented in Table A6.10. They involve a mix of heavy/light rehabilitation and intensive/low maintenance regimes. Each option consists of a set of activities as detailed in Table A6.10 and developed as follows:

- The reconstruction works are segregated by surfacing type, that is, asphalt surfacing or surface dressing. The thicknesses ranged from 25 mm (D) to 100 mm (A).
- The periodic maintenance involved either overlays or surface dressing. These works were triggered at various IRI values ranging from 4 m/km (corresponding to options 1 and 2) to 6 m/km (corresponding to options 4 through 8), with thicknesses also varying between 13 mm to 80 mm.
- Patching was triggered in the model at the occurrence of 1, 5, 10, or 15 potholes per km with 50 percent, 75 percent, or 100 percent of the potholes being repaired after a time lapse of 2, 3, or 12 months.
- Crack sealing was scheduled in the model to be undertaken when wide structural cracking exceeded 10 percent, 20 percent, or 50 percent of the carriageway surface, with 50 percent, 75 percent, or 100 percent of these distresses being repaired during a given maintenance operation.

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49 It is understood that the base case scenario cannot be continued indefinitely, because road roughness will eventually become so high as to make pavement rehabilitation or reconstruction necessary.

50 The absolute values of the NPV and IRR are not only relevant but indeed essential in economic feasibility studies for specific investment projects. Certain threshold values for the IRR are applied by governments and IFIs to avoid 'bad' investments that do not generate sufficient benefits for society as a whole.

- Edge repairs were scheduled in the model to be undertaken when edge breaks exceeded 1, 5, 10, or 15 m^2/km, with 50 percent, 75 percent, or 100 percent of the edge breaks being repaired during a given maintenance operation.
- Routine maintenance activities were scheduled to be undertaken annually for all the scenarios.

For instance, option A1 involves (a) overlaying the road using 50 mm AC when roughness exceeds IRI value 4.0 m/km and the mean rut depth is less than 20 mm, (b) patching of all potholes within two weeks of their occurrence when the number of potholes exceeds 1/km, (c) sealing of all cracks when wide structural cracks damage more than 10 percent of the road surface, (d) repair of all edge breaks when damaged areas exceed 1 m^2/km of the road surface, and (e) annual routine maintenance.

Figure A6.1 shows the average roughness progression for typical scenarios and is broadly representative of the results. The average roughness progression graphs summarize the predicted road condition over the 20-year life cycle for the base case and for eight road investment and O&M scenarios involving higher-quality initial construction ('A' scenarios). The graphs highlight not only the nonlinear deterioration behavior of roads with bituminous pavements but also the harmful impact of delaying necessary maintenance interventions on the future rate of pavement deterioration. Notably, as shown in Figure A6.1, the only scenarios that triggered reconstruction were those with longer maintenance intervals. The findings show that for scenarios where overlay is triggered at around IRI of 4.0 m/km, 5.0 m/km, and 6.0 m/km, the average annual roughness over the analysis period remains close to these thresholds. As expected, they also revealed that heavy traffic triggers work much earlier than light traffic.

TABLE A6.10: ROAD O&M OPTIONS AND INTERVENTION CRITERIA

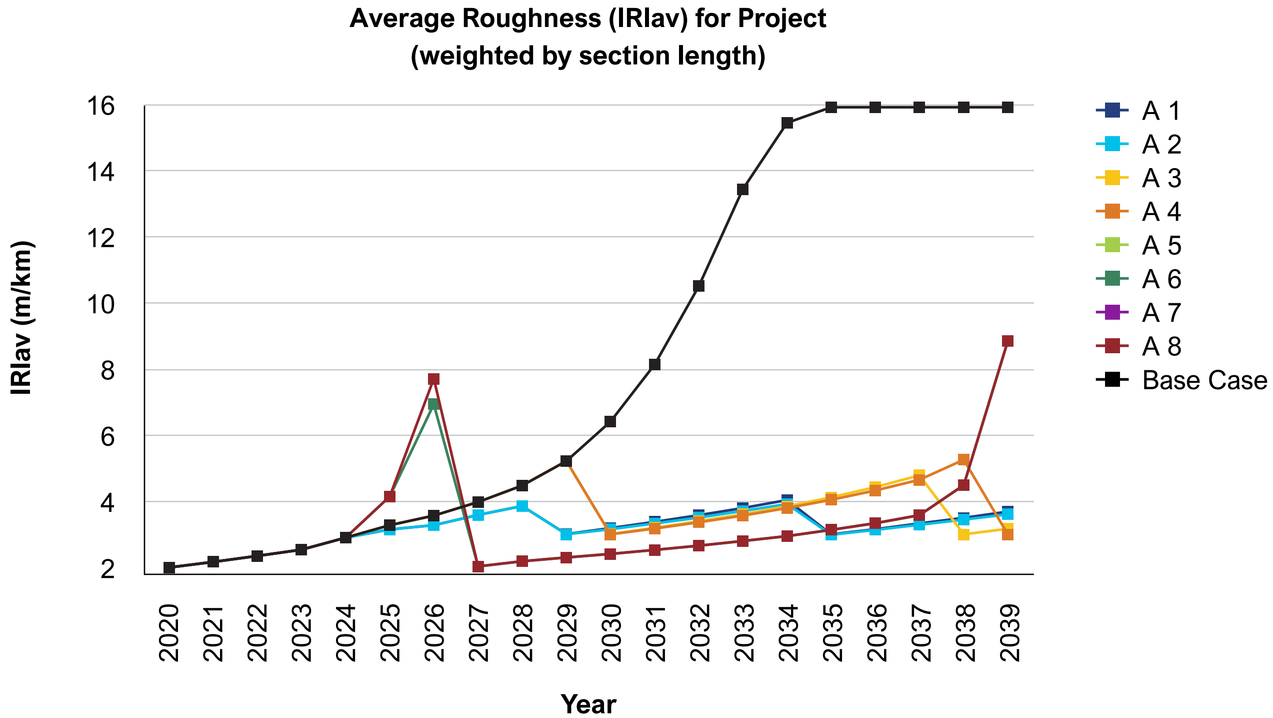
Option	Reconstruction[1]	Asphalt Overlay/Surface Dressing[2]	Patching[3]
Base Case	—	—	Potholes ≥ 5 per km; 75% of all potholes repaired; TLF = 3 months
A1	100 mm thick asphalt mix on granular base (AMGB)	50 mm overlay at IRI of 4.0 m/km	Potholes ≥ 1 per km; 100% of all potholes repaired; TLF = 2 weeks
A2		80 mm overlay at IRI of 4.0 m/km	
A3		50 mm overlay at IRI of 5.0 m/km	Potholes ≥ 5 per km; 75% of all potholes repaired; TLF = 3 months
A4		65 mm overlay at IRI of 5.0 m/km	
A5		30 mm overlay at IRI of 6.0 m/km	Potholes ≥ 10 per km; 50% of all potholes repaired; TLF = 12 months
A6		40 mm overlay at IRI of 6.0 m/km	
A7		25 mm overlay at IRI of 6.0 m/km	Potholes ≥ 15 per km; 25% of all potholes repaired; TLF = 12 months
A8		25 mm DBST at IRI of 6.0 m/km	
B1	50 mm thick asphalt mix on granular base (AMGB)	50 mm overlay at IRI of 4.0 m/km	Potholes ≥ 1 per km; 100% of all potholes repaired; TLF = 2 weeks
B2		80 mm overlay at IRI of 4.0 m/km	
B3		50 mm overlay at IRI of 5.0 m/km	Potholes ≥ 5 per km; 75% of all potholes repaired; TLF=3 months
B4		65 mm overlay at IRI of 5.0 m/km	
B5		30 mm overlay at IRI of 6.0 m/km	Potholes ≥ 10 per km; 50% of all potholes repaired; TLF = 12 months
B6		40 mm overlay at IRI of 6.0 m/km	
B7		25 mm overlay at IRI of 6.0 m/km	Potholes ≥ 15 per km; 50% of all potholes repaired; TLF = 12 months
B8		25 mm DBST at IRI of 6.0 m/km	
C1	35 mm thick asphalt mix on granular base (AMGB)	50 mm overlay at IRI of 4.0 m/km	Potholes ≥ 1 per km; 100% of all potholes repaired; TLF = 2 weeks
C2		80 mm overlay at IRI of 4.0 m/km	
C3		50 mm overlay at IRI of 5.0 m/km	Potholes ≥ 5 per km; 75% of all potholes repaired; TLF = 3 months
C4		65 mm overlay at IRI of 5.0 m/km	
C5		30 mm overlay at IRI of 6.0 m/km	Potholes ≥ 10 per km; 50% of all potholes repaired; TLF = 12 months
C6		40 mm overlay at IRI of 6.0 m/km	
C7		25 mm overlay at IRI of 6.0 m/km	Potholes ≥ 15 per km; 50% of all potholes repaired; TLF = 12 months
C8		25 mm DBST at IRI of 6.0 m/km	
D1	25 mm thick DBST surfacing on granular base (STGB)	25 mm DBST at IRI of 4.0 m/km	Potholes ≥ 1 per km; 100% of all potholes repaired; TLF = 2 weeks
D2		13 mm SBST at IRI of 4.0 m/km	
D3		25 mm DBST at IRI of 5.0 m/km	Potholes ≥ 5 per km; 75% of all potholes repaired; TLF = 3 months
D4		13 mm SBST at IRI of 5.0 m/km	
D5		25 mm DBST at IRI of 6.0 m/km	Potholes ≥ 10 per km; 50% of all potholes repaired; TLF = 12 months
D6		13 mm SBST at IRI of 6.0 m/km	
D7		25 mm DBST at IRI of 7.0 m/km	Potholes ≥ 15 per km; 50% of all potholes repaired; TLF = 12 months
D8		13 mm SBST at IRI of 7.0 m/km	

Notes: 1. Applicable when IRI value ≥ 7 m/km and mean rut depth ≥ 20 mm.
2. Applicable only when mean rut depth ≤ 20 mm.

Crack Sealing	Edge Repair	Routine Miscellaneous[4]
Wide structural cracking ≥ 20%; 75% of all distresses repaired	Edge breaks ≥ 5 m^2/km; 75% of all edge breaks repaired	Interval ≥ 1 year(s)
Wide structural cracking ≥ 10%; 100% of all distresses repaired	Edge breaks ≥ 1 m^2/km; 100% of all edge breaks repaired	
Wide structural cracking ≥ 20%; 75% of all distresses repaired	Edge breaks ≥ 5 m^2/km; 75% of all edge breaks repaired	
Wide structural cracking ≥ 50%; 50% of all distresses repaired	Edge breaks ≥ 10 m^2/km; 50% of all edge breaks repaired	
Wide structural cracking ≥ 75%; 25% of all distresses repaired	Edge breaks ≥ 15 m^2/km; 25% of all edge breaks repaired	
Wide structural cracking ≥ 10%; 100% of all distresses repaired	Edge breaks ≥ 1 m^2/km; 100% of all edge breaks repaired	
Wide structural cracking ≥ 20%; 75% of all distresses repaired	Edge breaks ≥ 5 m^2/km; 75% of all edge breaks repaired	
Wide structural cracking ≥ 50%; 50% of all distresses repaired	Edge breaks ≥ 10 m^2/km; 50% of all edge breaks repaired	
Wide structural cracking ≥ 50%; 25% of all distresses repaired	Edge breaks ≥ 15 m^2/km; 25% of all edge breaks repaired	
Wide structural cracking ≥ 10%; 100% of all distresses repaired	Edge breaks ≥ 1 m^2/km; 100% of all edge breaks repaired	
Wide structural cracking ≥ 20%; 75% of all distresses repaired	Edge breaks ≥ 5 m^2/km; 75% of all edge breaks repaired	
Wide structural cracking ≥ 50%; 50% of all distresses repaired	Edge breaks ≥ 10 m^2/km; 50% of all edge breaks repaired	
Wide structural cracking ≥ 50%; 25% of all distresses repaired	Edge breaks ≥ 15 m^2/km; 25% of all edge breaks repaired	
Wide structural cracking ≥ 10%; 100% of all distresses repaired	Edge breaks ≥ 1 m^2/km; 100% of all edge breaks repaired	
Wide structural cracking ≥ 20%; 75% of all distresses repaired	Edge breaks ≥ 5 m^2/km; 75% of all edge breaks repaired	
Wide structural cracking ≥ 50%; 50% of all distresses repaired	Edge breaks ≥ 10 m^2/km; 50% of all edge breaks repaired	
Wide structural cracking ≥ 50%; 25% of all distresses repaired	Edge breaks ≥ 15 m^2/km; 25% of all edge breaks repaired	

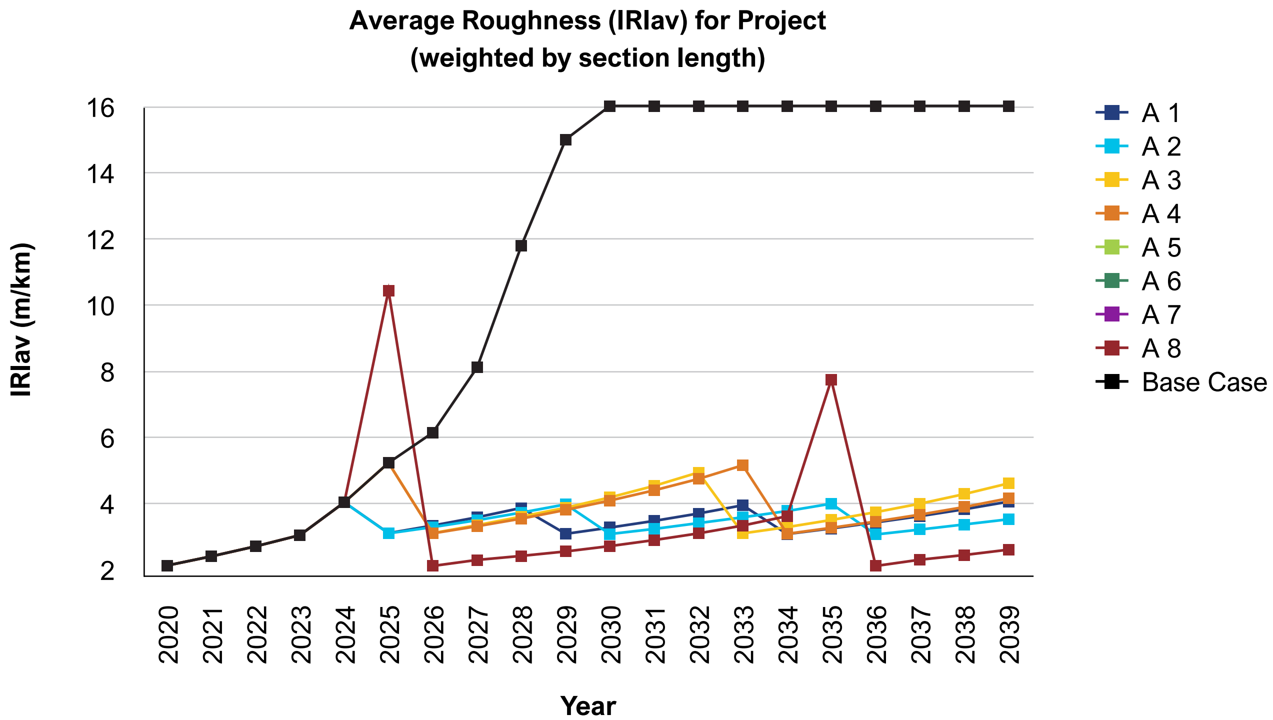
Notes: 3. TLF = Time-lapse factor. Refers to time delay before patching of potholes.
4. All scenarios include annual routine miscellaneous works.

FIGURE A6.1: AVERAGE ROUGHNESS PROGRESSION FOR ROADS IN GOOD CONDITION IN ARGENTINA — A: AADT = 3,000



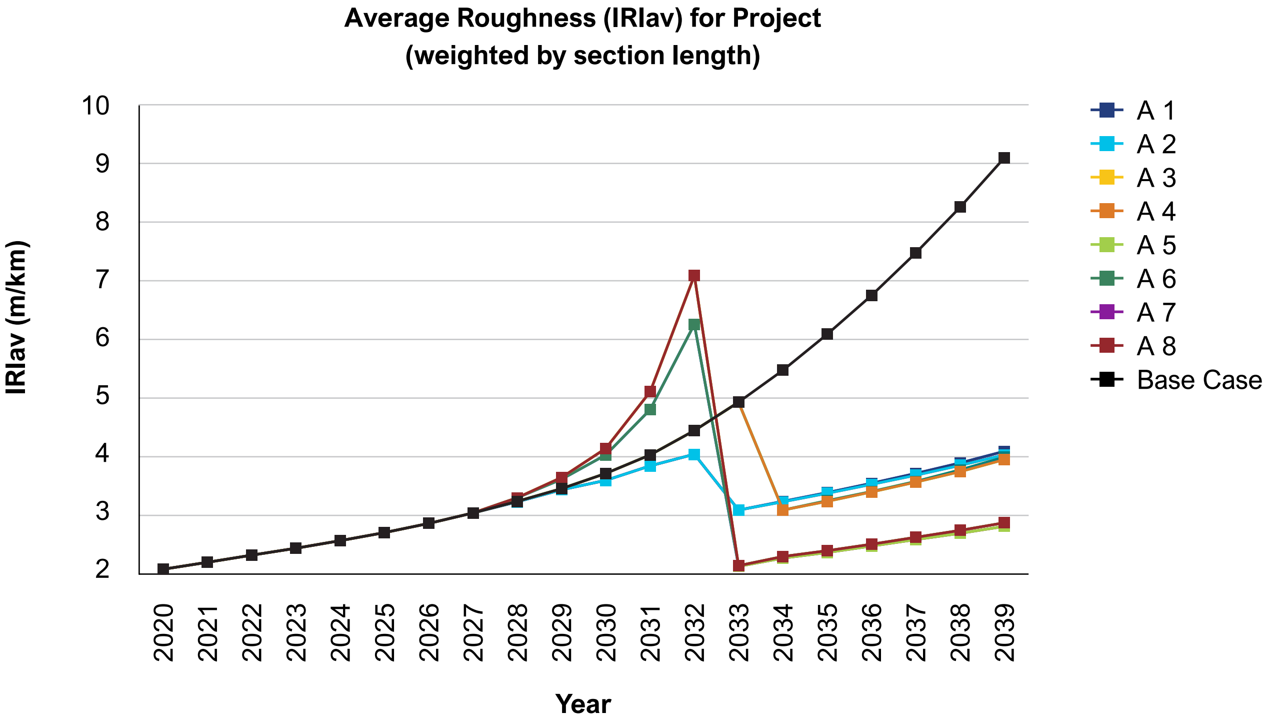
Source: World Bank

FIGURE A6.1: AVERAGE ROUGHNESS PROGRESSION FOR ROADS IN GOOD CONDITION IN ARGENTINA — B: AADT = 7,500



Source: World Bank

FIGURE A6.1: AVERAGE ROUGHNESS PROGRESSION FOR ROADS IN GOOD CONDITION IN ARGENTINA — C: AADT = 750



Source: World Bank

It is important to note that the base case was not necessarily the 'worst case' scenario in terms of roughness developing. A7, for instance, has works intervention trigger criteria which are higher (or worse) than those for the base case.

13. Comparison of NPVs

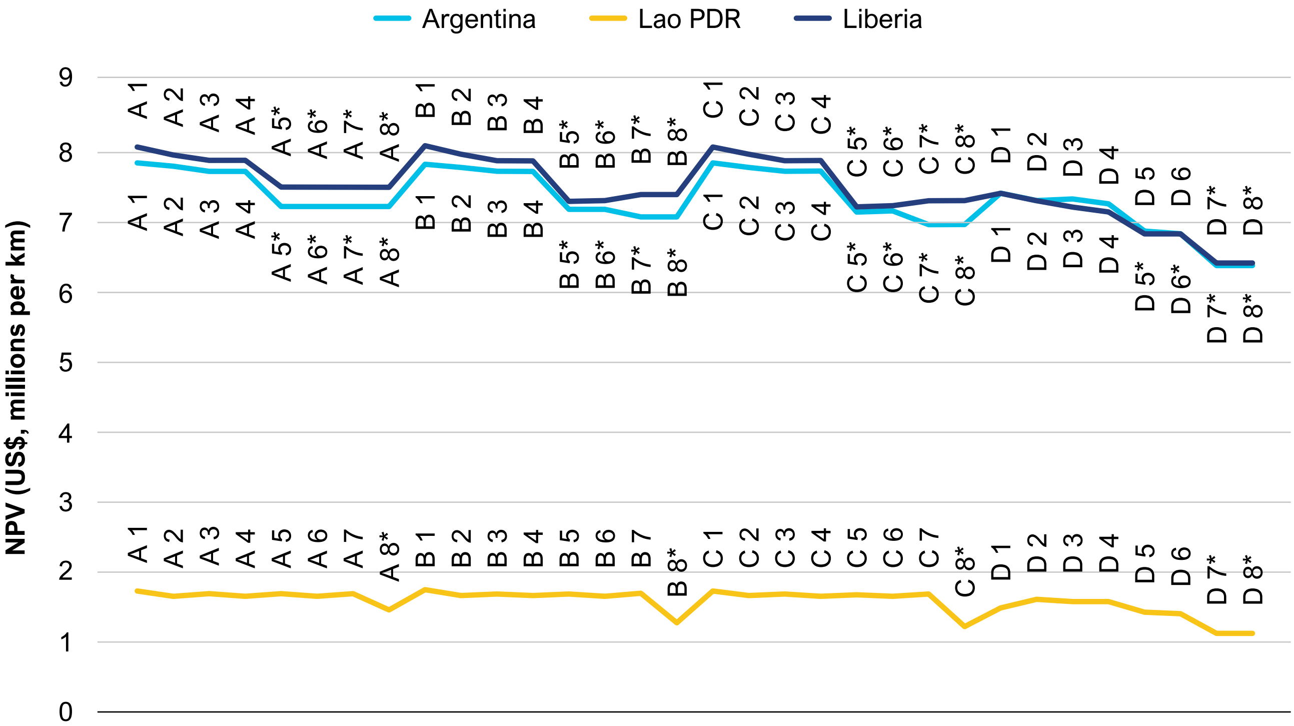
The NPV for each option has been calculated through HDM-4[51] and plotted. The results are grouped by traffic bands with alternatives that trigger major reconstruction works marked with an asterisk.[52]

Most high-trafficked roads trigger a 50 mm overlay at IRI of 4.0 m/km (Options A1, B1, and C1) as shown in Figure A6.2.

51 As noted above, the discount rate of 6 percent has been applied to all the scenarios as the current exercise focuses on ranking options rather than assessing feasibility.

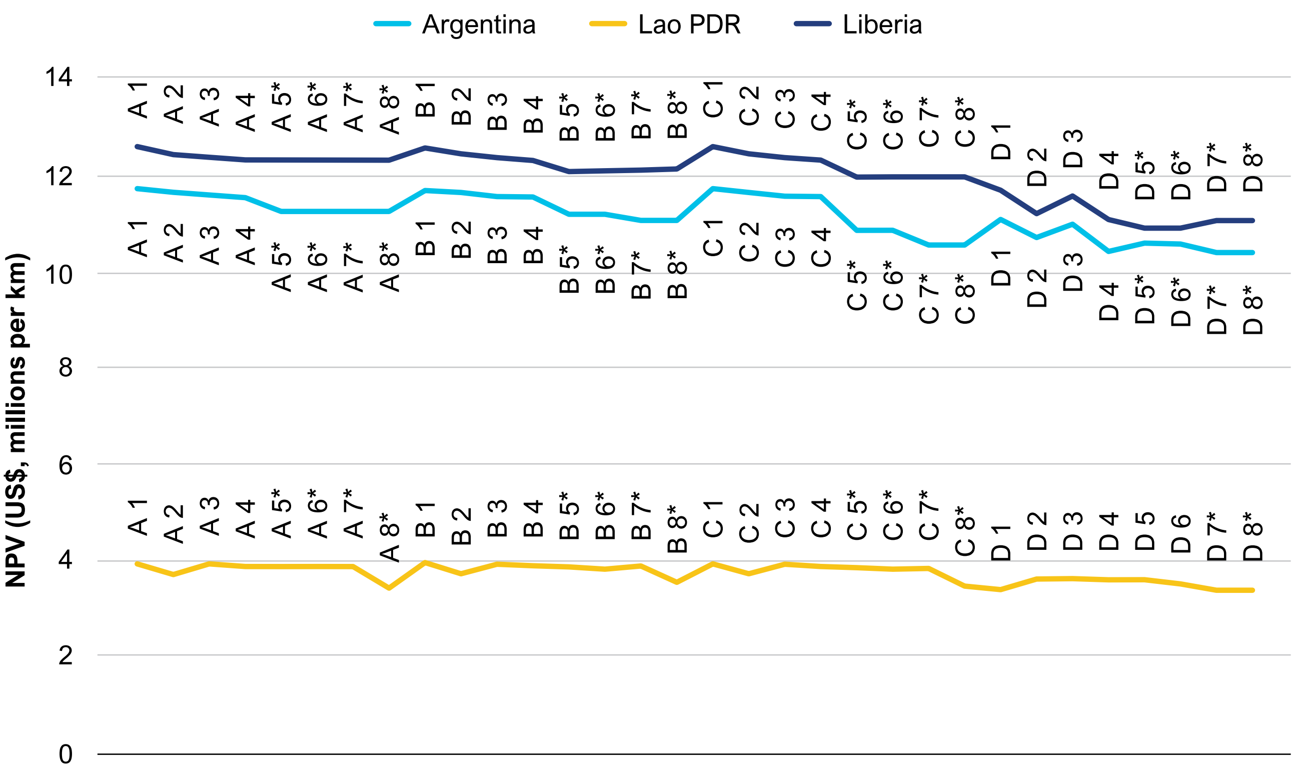
52 For instance, Option A1 would mean only periodic and routine maintenance works are triggered during the analysis period while Option A1* would imply that reconstruction works are triggered besides the periodic and routine maintenance works.

FIGURE A6.2: NPV OF ROAD O&M ALTERNATIVES (AADT = 7,500)
A. GOOD CONDITION



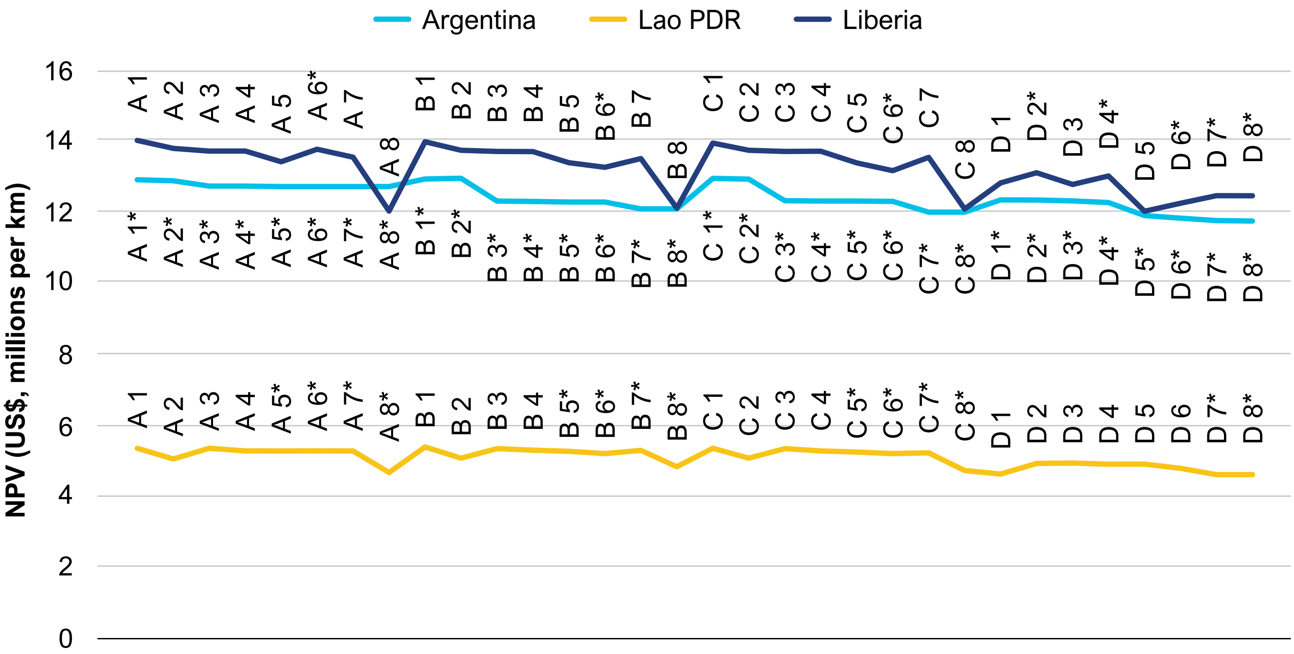
Source: World Bank

FIGURE A6.2: NPV OF ROAD O&M ALTERNATIVES (AADT = 7,500)
B. FAIR CONDITION



Source: World Bank

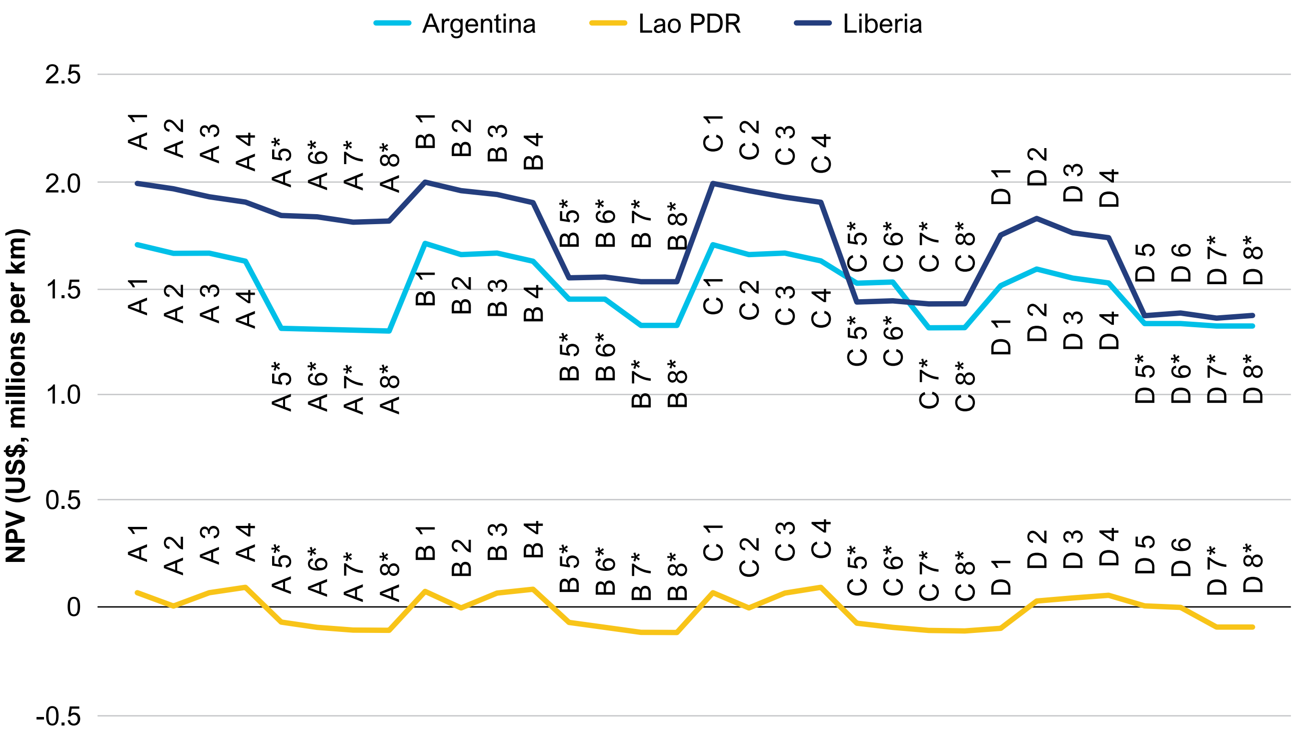
FIGURE A6.2: NPV OF ROAD O&M ALTERNATIVES (AADT = 7,500)
C. POOR CONDITION



Source: World Bank

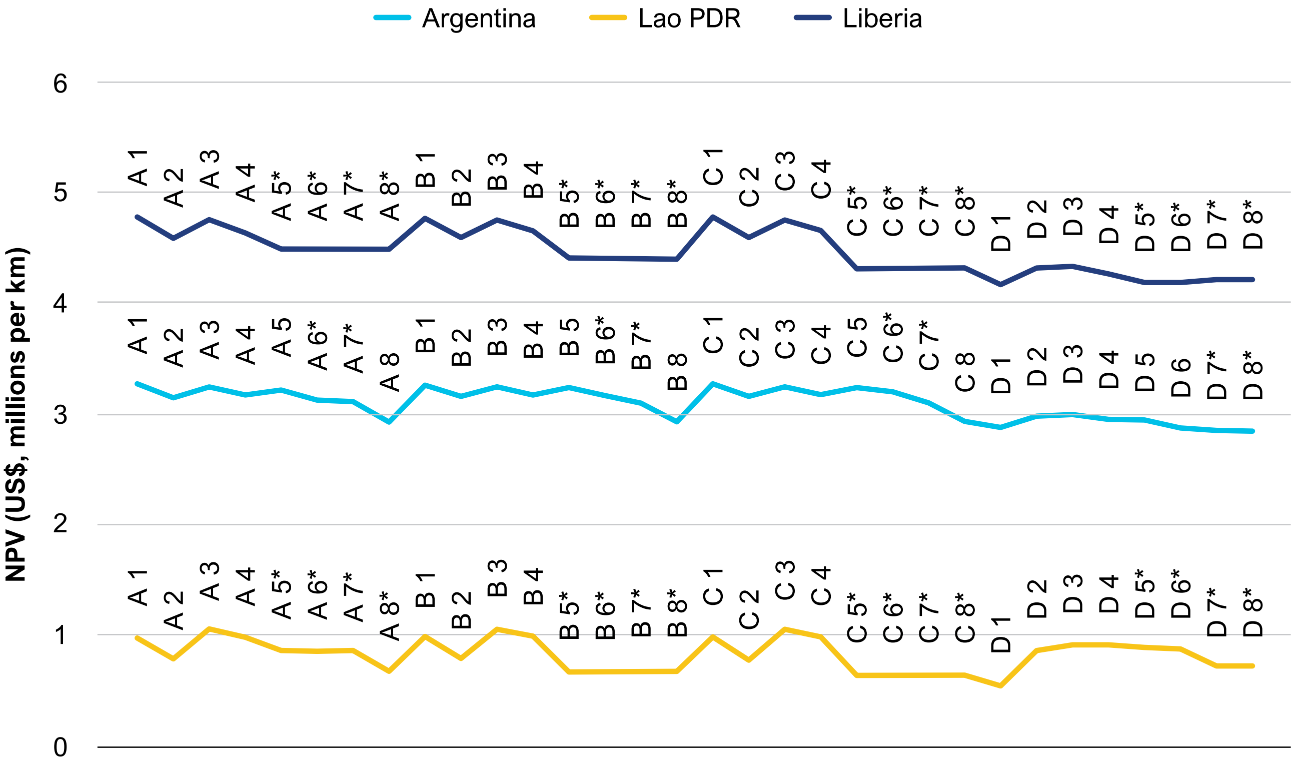
In contrast, most medium-trafficked roads trigger 50 mm overlay at IRI of 5.0 m/km (Options A3, B3, and C3) as shown in Figure A6.3.

FIGURE A6.3: NPV OF ROAD O&M ALTERNATIVES (AADT = 3,000)
A. GOOD CONDITION (AADT=3,000)



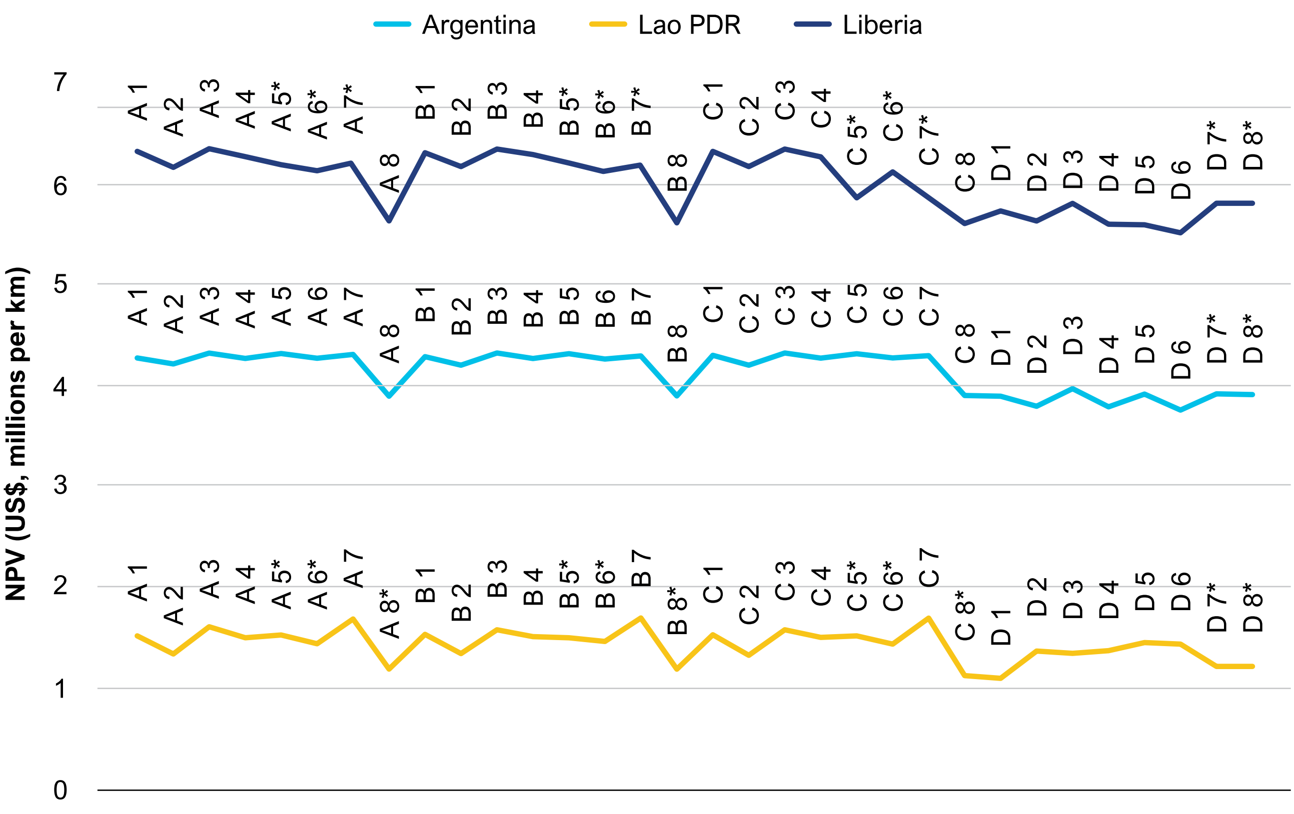
Source: World Bank

FIGURE A6.3: NPV OF ROAD O&M ALTERNATIVES (AADT = 3,000)
B. FAIR CONDITION (AADT=3,000)



Source: World Bank

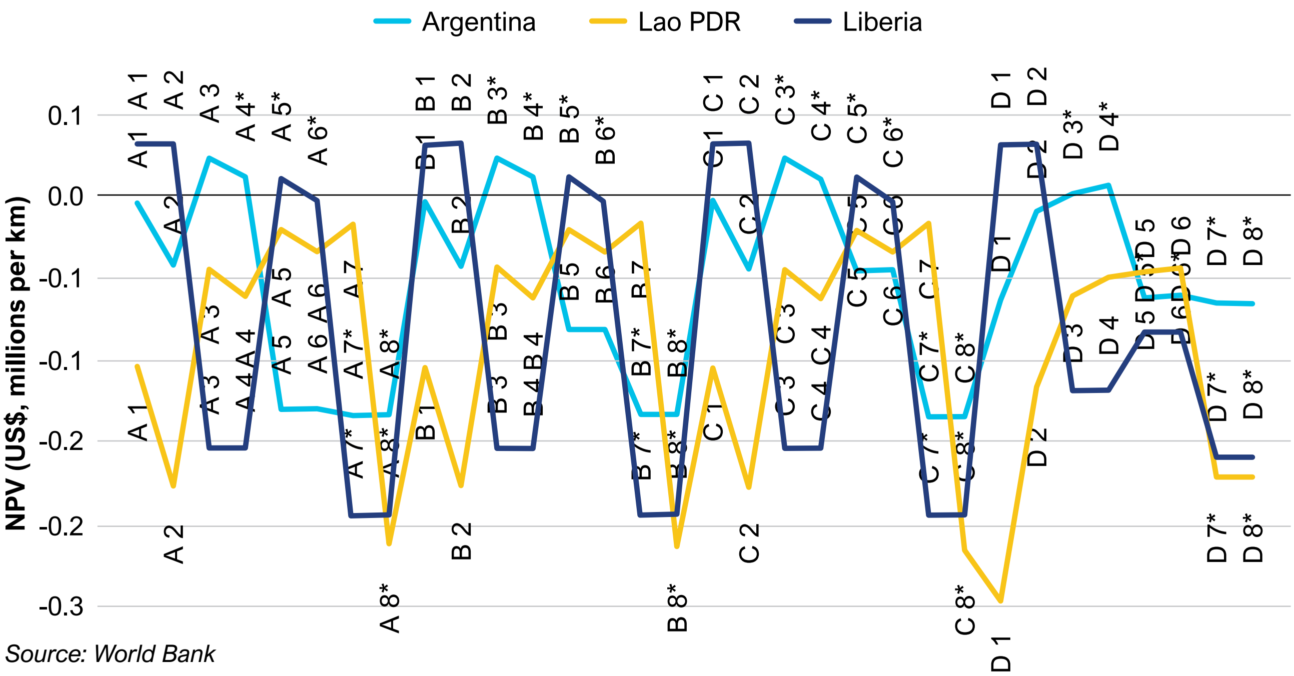
FIGURE A6.3: NPV OF ROAD O&M ALTERNATIVES (AADT = 3,000)
C. POOR CONDITION (AADT=3,000)



Source: World Bank

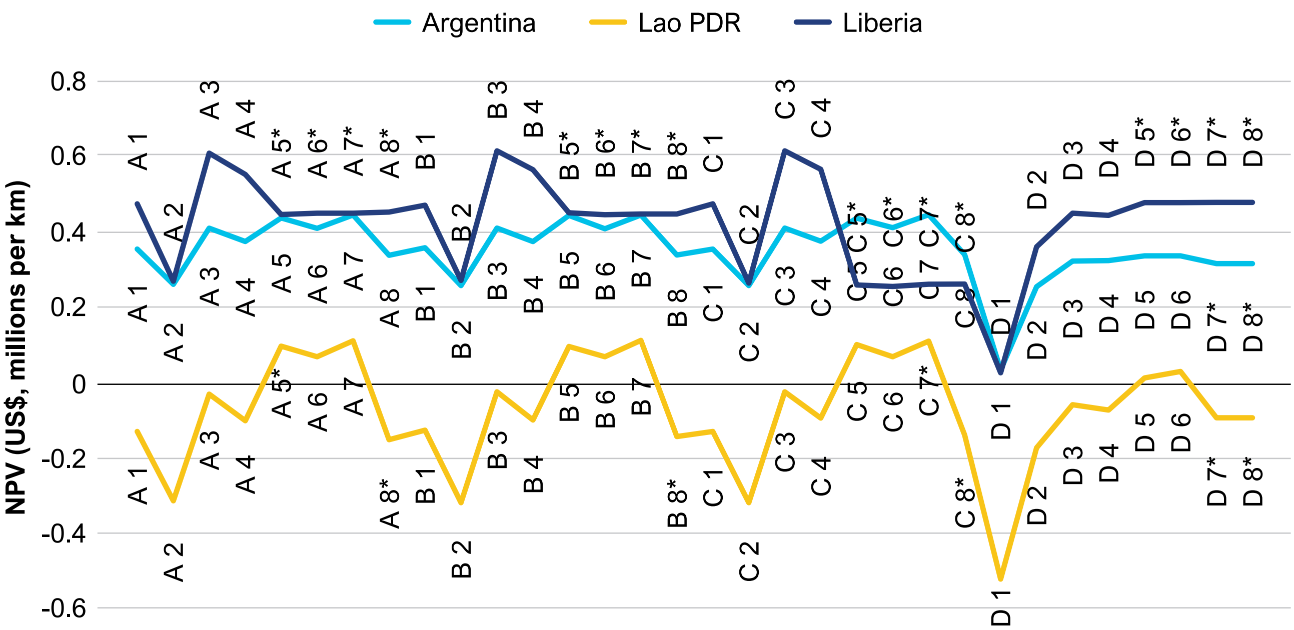
Meanwhile, most low-trafficked roads trigger 30 mm overlay at IRI of 6.0 m/km (Options A5, B5, and C5) as shown in Figure A6.4.

FIGURE A6.4: NPV OF ROAD O&M ALTERNATIVES (AADT = 750)
A. GOOD CONDITION (AADT=750)



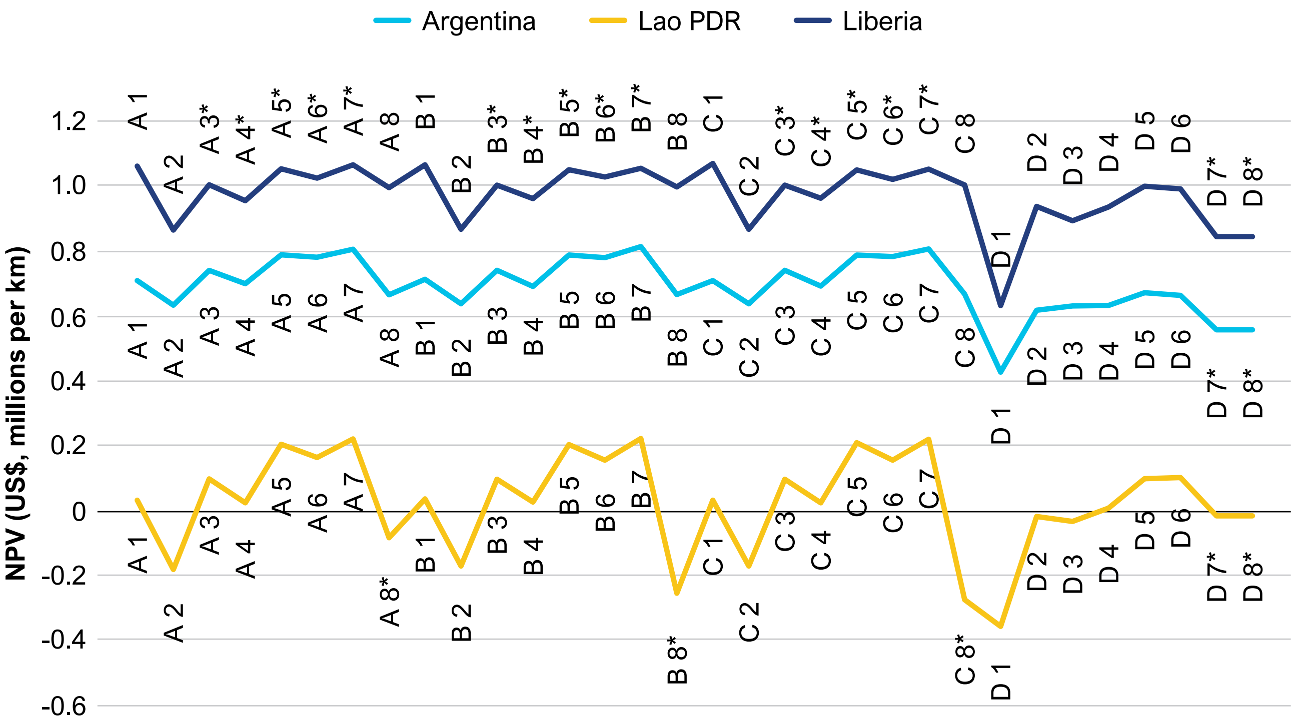
Source: World Bank

FIGURE A6.4: NPV OF ROAD O&M ALTERNATIVES (AADT = 750)
B. FAIR CONDITION (AADT = 750)



Source: World Bank

FIGURE A6.4: NPV OF ROAD O&M ALTERNATIVES (AADT = 750)
C. POOR CONDITION (AADT = 750)



Source: World Bank

The following broad conclusions can be drawn from these findings:

- Generally, intensive reconstruction, rehabilitation, and routine maintenance yield better NPVs than the minimum rehabilitation and maintenance strategies. Also, depending on traffic volumes, heavier reconstruction (Group A) could provide a slightly better NPV. On the contrary, lighter reconstruction (Group D) provided the lowest NPV among all four options.
- Generally, early routine maintenance yields better results than delayed maintenance. By comparing NPVs within the same scenario group, scenarios with lower IRI thresholds (earlier intervention) provide better results than ones with higher IRI criteria in general.
- Increasing the AADT to 7,500 vehicles per day translates to increased total net benefits, with the highest increase in roads which initially are in poor condition and the least in roads which initially are in good condition. The reverse is true when the AADT is reduced to 750 vehicles per day. This is to be expected as the benefits will increase with more vehicle use.

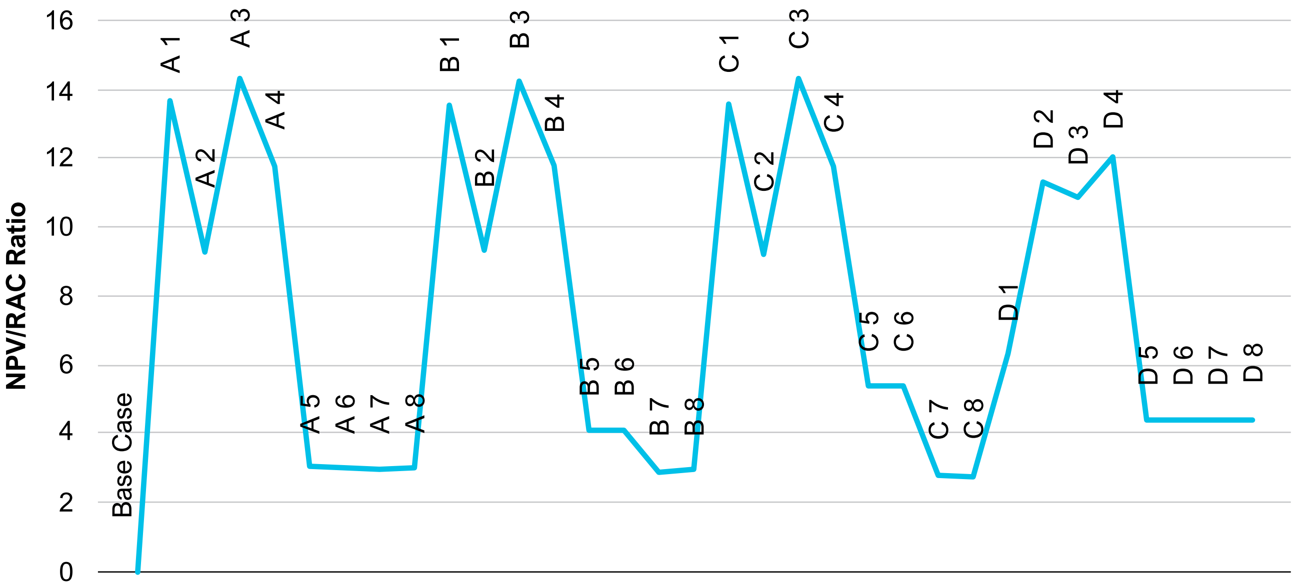
The road O&M alternative analysis also shows, not surprisingly, that investing in roads which are initially in poor condition yields higher net benefits than investing in roads which are initially in good condition. This may be attributed to the greater vehicle operating cost and travel time savings to be realized when roads in poor condition are improved.

Another critical finding to note is that the scenarios yielding the best returns rarely triggered reconstruction works for the various case studies, thereby highlighting the importance of timely maintenance interventions to avoid major works, as shown in Figures A6.2 to A6.4.

14. NPV versus Present Value of RAC

Plotting the ratio of the NPV to present value of RAC allows comparison of the efficiency of the individual investment options (Figure A6.5) and identification of the most efficient option. As the total number of kilometers is fixed, the option with the highest ratio has the highest marginal benefits and greatest net benefits.

FIGURE A6.5: NPV/RAC RATIO OF O&M ALTERNATIVES IN GOOD CONDITION (ARGENTINA; AADT=3,000)

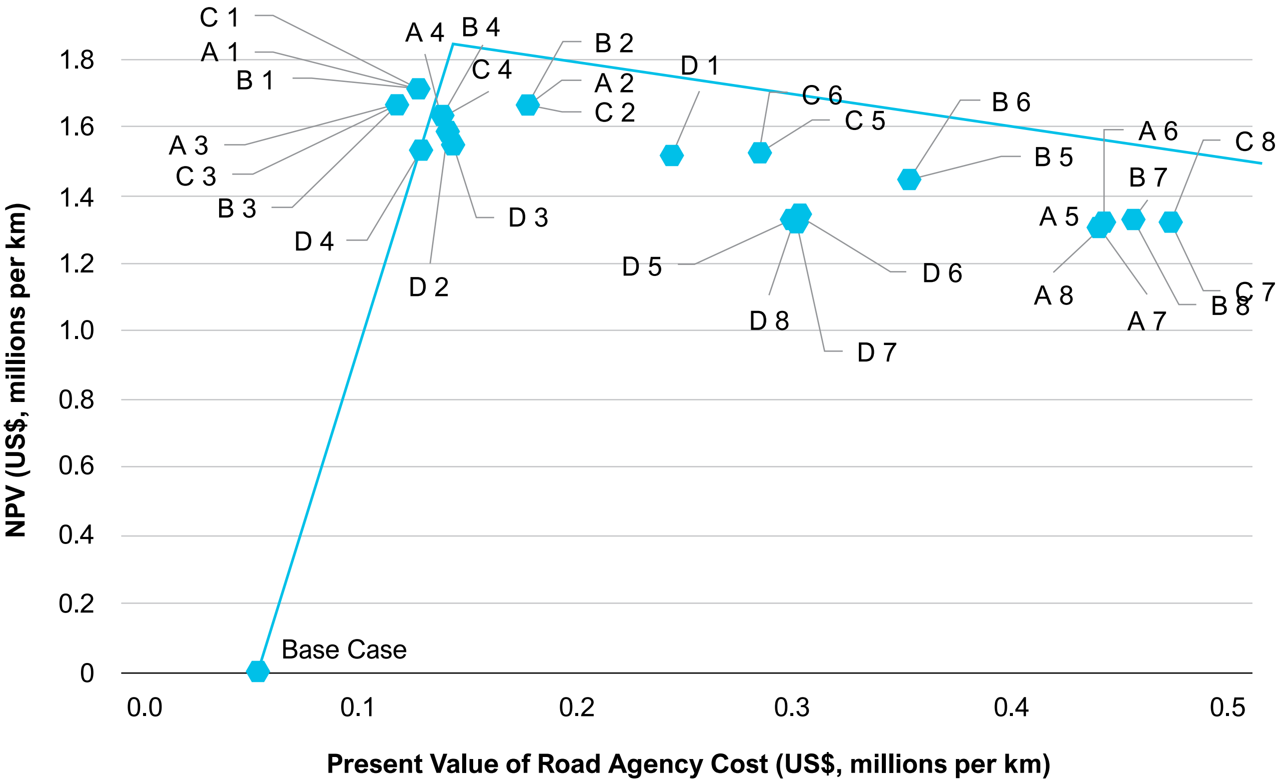


Source: World Bank

Plotting the per km NPV against RAC (Figure A6.6) likewise enables identification of the most efficient O&M scenario while also more readily revealing underlying patterns. A positive correlation implies that greater expenditure leads to greater returns. The most efficient combination shall always lie on the outer boundaries of the positively sloped section(s) of such a graph (Harral and Faiz 1988). More important to note is the inflection point, which represents the maximum NPV at the lowest possible RAC. Usually, the points to the right of this inflection point represent options with increasing RAC and decreasing NPV. This analysis helps identify which interventions can bring about the greatest economic benefits under budget constraints.

For instance, for roads in good condition in Argentina with an AADT of 3,000 vehicles (Figure A6.6), all the alternatives to the right of A4, B4, and C4 are characterized by declining marginal returns and increasing RAC. The declining returns show that deferring maintenance yields poor returns. In this example, O&M scenarios A3, B3, and C3 yield the best returns for every dollar invested and would be the preferred options as they have the highest NPV/RAC ratios (Figure A6.5). Moreover, clustering of scenarios with more intensive maintenance programs (1 through 4) in the upper-left region and less intensive maintenance programs (5 through 8) in the right-hand side demonstrates that all the scenarios involving more proactive maintenance performed better than scenarios involving less maintenance, regardless of the treatment chosen for reconstruction/rehabilitation (additional NPV versus RAC results are presented at the end of this Appendix).

FIGURE A6.6: NPV VERSUS RAC OF O&M ALTERNATIVES IN GOOD CONDITION (ARGENTINA; AADT=3,000))

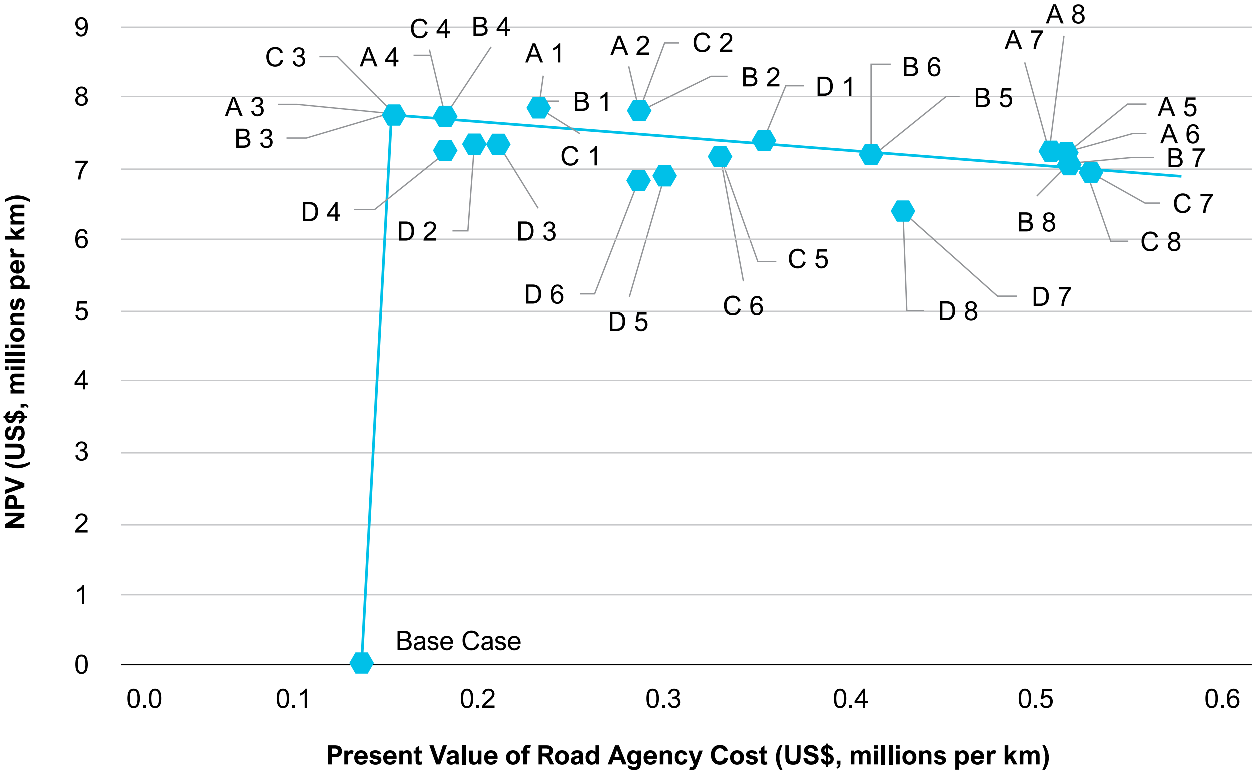


Source: World Bank

A comparison of NPV and RAC graphs may also be used to assess how the economic efficiency of the various work types varies by traffic band and initial road condition. This is well illustrated by comparing Figures A6.6 and A6.7. In Figure A6, for an AADT of 3,000 vehicles, D2, D3, and D4 are almost lying on the outer boundary of the positively sloped section while in Figure A6.7, for an AADT of 7,500 vehicles, D2, D3, and D4 are located along the negatively sloped section of the graph. This shift highlights decreasing economic efficiency of the thinner overlays and longer periodic maintenance intervals on higher traffic roads.

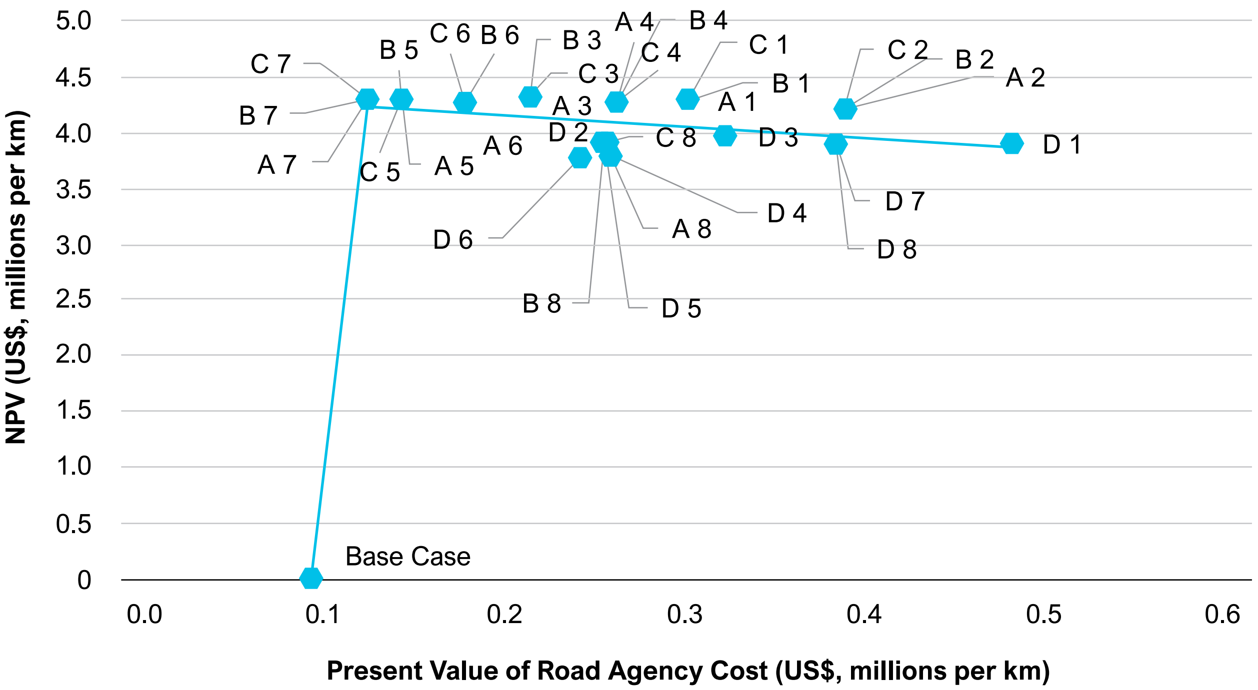
As shown in Figure A6.8, the benefits due to investment and maintenance for roads initially in poor condition (NPV of US$4.3 million per km) are higher than those derived from roads in good condition with similar traffic (NPV of US$1.7 million per km) (see Figure A6.6).

FIGURE A6.7: NPV VERSUS RAC OF O&M ALTERNATIVES IN GOOD CONDITION (ARGENTINA; AADT=7,500)



Source: World Bank

FIGURE A6.8: NPV VERSUS RAC OF LCCA ALTERNATIVES IN POOR CONDITION (ARGENTINA; AADT=3,000)



Source: World Bank

15. Conclusions

The analysis allows for the ranking of investment and O&M scenarios. However, it needs to be kept in mind that (a) the results for some of the scenarios are only marginally different and (b) for those scenarios, data accuracy may not be good enough to establish a clear ranking. For this reason, the study team has identified groups of "most advantageous" scenarios, instead of one single "best" scenario. The groups of "most advantageous" scenarios for each of the three countries were defined on the basis of the three main criteria:

- NPV
- Minimization of RUC and RAC, that is, RUC-RAC relationship
- Maximization of NPV and minimization of RAC, that is, NPV-RAC relationships.

Based on these findings, the generalized descriptions of the optimal combinations of investment and O&M policies are presented in Table A6.11, with more details listed in Table A6.12. It must be pointed out that each road is subject to specific climatic conditions, traffic characteristics, constraints related to material availability in the vicinity of the road, and so on. These conditions, along with budget constraints and availability of contractors, need to be accounted for through feasibility studies carried out to select the 'best' option for a particular road. For example, while a pavement overlay of 30 mm thickness may be optimal, a contractor who has the technical capacity and equipment needed to apply such a thin overlay may not be available. For this reason, further judgement and knowledge of the local construction market and other variables must be considered when developing work plans.

Although the findings of this study are specific to the three countries for which data were available and used by the study team, some generalized conclusions may be drawn that are valid for most countries:

1. Investment in long-term road asset management strategies involving periodic maintenance works yields better returns than carrying out routine maintenance only (as modelled for the base case).
2. Regardless of the initial road condition, implementing an intensive maintenance regime generally yields better lifecycle costs (i.e., savings) than a low-intensity maintenance regime. Intensive regimes involve early and frequent interventions while the IRIs are still low and the road has not deteriorated adversely, for instance, overlaying a road at IRI of 4.0 m/km as opposed to 6 m/km, patching at 1 pothole per km as opposed to 10 potholes per km, or sealing cracks at 10 percent wide structural cracking as opposed to at 50 percent wide structural cracking.
3. Heavy investment for full-depth pavement reconstruction is mainly triggered for poor roads with high traffic volumes. In most of the other cases, regular overlays (sometimes combined with surface milling) appear to be sufficient in most cases to maintain reasonable pavement roughness. Also, generally, light reconstruction involving 25 mm DBST yielded lower NPVs than heavy reconstruction involving AC.
4. As traffic volumes decrease, triggers for pavement interventions may be 'relaxed' without a significant loss in net benefits. For instance, it was observed that it may make economic sense to allow low-traffic roads to deteriorate to a poor condition before intervening through periodic maintenance measures. On the contrary, for middle- to high-volume roads, early and frequent maintenance interventions tend to provide better benefits as revealed by the higher NPV-RAC ratios.
5. When prioritizing investments under budget constraints, heavy investments in highly trafficked roads that are initially in poor condition yield better benefits than investments in roads that are still in good condition.
6. Introduction of PBCs could promote Point 2 as PBCs generally require an intensive maintenance regime to keep the required service levels and performance of road conditions such as IRI, particularly early and frequent intervention while the IRI is still low. Furthermore, PBCs could achieve lower lifecycle costs for middle- to high-volume roads as noted in Point 4, as contractors will optimize maintenance frequency based on real road conditions. However, it would be important to apply proper rehabilitation and reconstruction approaches when PBCs are designed.

TABLE A6.11: GENERALIZED INVESTMENT AND O&M OPTIONS THAT WERE ANALYZED

AADT	Initial Condition	Description of the Investment and O&M Options
7,500	Good	Patching of 75% potholes when the number of potholes exceeds 5 per km; sealing of 75% cracks when wide structural cracks exceed 20% of carriageway surface; repair of 75% road edges when edge breaks exceed 5 m^2/km; and 50 mm thick overlay when roughness exceeds IRI of 5.0 m/km. No reconstruction is required.
	Fair	Patching of 75% potholes when the number of potholes exceeds 5 per km; sealing of 75% cracks when wide structural cracks exceed 20% of carriageway surface; repair of 75% road edges when edge breaks exceed 5 m^2/km; and 50 mm thick overlay when roughness exceeds IRI of 5.0 m/km. No reconstruction is required.
	Poor	Immediate reconstruction of the pavement using asphalt surfacing. Patching of all potholes when the number of potholes exceeds 1 per km; sealing of all cracks when wide structural cracks exceed 10% of carriageway surface; repair of all road edges when edge breaks exceed 1 m^2/km; and 50 mm thick overlay when roughness exceeds IRI of 4.0 m/km.
3,000	Good	Patching of 75% potholes when the number of potholes exceeds 5 per km; sealing of 75% cracks when wide structural cracks exceed 20% of carriageway surface; repair of 75% road edges when edge breaks exceed 5 m^2/km; and 50 mm thick overlay when roughness exceeds IRI of 5.0 m/km. No reconstruction is required.
	Fair	Patching of 75% potholes when the number of potholes exceeds 5 per km; sealing of 75% cracks when wide structural cracks exceed 20% of carriageway surface; repair of 75% road edges when edge breaks exceed 5 m^2/km; and 50 mm thick overlay when roughness exceeds IRI of 5.0 m/km. No reconstruction is required.
	Poor	Patching of 75% potholes when the number of potholes exceeds 5 per km; sealing of 75% cracks when wide structural cracks exceed 20% of carriageway surface; repair of 75% road edges when edge breaks exceed 5 m^2/km; and 50 mm thick overlay when roughness exceeds IRI of 5.0 m/km. No reconstruction is required.
750	Good	Patching of 50% potholes when the number of potholes exceeds 10 per km; sealing of 50% cracks when wide structural cracks exceed 50% of carriageway surface; repair of 50% road edges when edge breaks exceed 10 m^2/km; and 30-mm-thick overlay when roughness exceeds IRI of 6.0 m/km. No reconstruction is required.
	Fair	Patching of 25% potholes when the number of potholes exceeds 15 per km; sealing of 25% cracks when wide structural cracks exceed 75% of carriageway surface; repair of 50% road edges when edge breaks exceed 10 m^2/km; and 25 mm thick overlay when roughness exceeds IRI of 6.0 m/km. No reconstruction is required.
	Poor	Patching of 25% potholes when the number of potholes exceeds 15 per km; sealing of 25% cracks when wide structural cracks exceed 75% of carriageway surface; repair of 50% road edges when edge breaks exceed 10 m^2/km; and 25 mm thick overlay when roughness exceeds IRI of 6.0 m/km. No reconstruction is required.

TABLE A6.12: TOP THREE RANKED SUITABLE INVESTMENT AND O&M OPTIONS (FOR EACH OF THE THREE COUNTRIES ANALYZED)

Criteria	Country	High Traffic (ADDT = 7,500)		
		Good	Fair	Poor
NPV	Argentina	A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1, A2, B2, C2, A7, A8, A5, A6
	Lao PDR	A1, B1, C1; A3, B3, C3; A7, B7, C7	A3, B3, C3; A1, B1, C1; A4, B4, C4	A1, B1, C1; A3, B3, C3; A4, B4, C4
	Liberia	A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A2, B2, C2; A3, B3, C3
RUC-RAC	Argentina	A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A2, B2, C2; A3, B3, C3	B1, C1, B2, A1, C2, A2; A7, A8
	Lao PDR	A1, B1, C1; A3, B3, C3; A7, B7, C7	A3, B3, C3; A1, B1, C1; A4, B4, C4	A1, B1, C1; A3, B3, C3; A4, B4, C4
	Liberia	A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A2, B2, C2; A6; A4, B4, C4
NPV-RAC	Argentina	A3, B3, C3; A4, B4, C4; D4, D2, D3	A3, B3, C3; A4, B4, C4; D4, D2; A1, B1, C1	C1, B1, D4, D2, D3, C2, B2, A1
	Lao PDR	A7, B7, C7; A5, B5, C5; A6, B6, C6	A3, B3, C3; D6, D5; A4, B4, C4	A3, B3, C3; D6, A7, B7, D5
	Liberia	A3, B3, C3; D4, D2; A4, B4, C4	A3, B3, C3; D4, D2; A4, B4, C4	A7, B7, C7; A5, B5, C5; A3, B3, C3

Medium Traffic (AADT = 3,000)			Low Traffic (AADT = 750)		
Good	Fair	Poor	Good	Fair	Poor
A1, B1, C1; A3, B3, C3; A2, B2, C2	A1, B1, C1; A3, B3, C3; A5, B5, C5	A5, B5, C5; A3, B3, C3; A7, B7, C7	A3, B3, C3; A4, B4, C4; D4, D3, C1	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6
A4, B4, C4; A1, B1, C1; A3, B3, C3	A3, B3, C3; A4, B4, C4; A1, B1, C1	A7, B7, C7; A3, B3, C3; A1, B1, C1	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6
A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A3, B3, C3; A4, B4, C4	A3, B3, C3; A1, B1, C1; A4, B4, C4	A1, B1, C1, A2, B2, C2, D1, D2; A5, B5, C5	A3, B3, C3; A4, B4, C4; D5, D6, D7, D8	A1, B1, C1; A7, B7, C7; A5, B5, C5
A1, B1, C1; A3, B3, C3; A2, B2, C2	A1, B1, C1; A3, B3, C3; A5, B5, C5	A5, B5, C5; A3, B3, C3; A7, B7, C7	A3, B3, C3; A4, B4, C4; D4, D3; A1, B1, C1	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6
A4, B4, C4; A1, B1, C1; A3, B3, C3	A3, B3, C3; A4, B4, C4; A1, B1, C1	A7, B7, C7; A3, B3, C3; A1, B1, C1	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6
A1, B1, C1; A2, B2, C2; A3, B3, C3	A1, B1, C1; A3, B3, C3; A4, B4, C4	A3, B3, C3; A1, B1, C1; A4, B4, C4	A1, B1, C1, A2, B2, C2, D1, D2; A5, B5, C5	A3, B3, C3; A4, B4, C4; D5, D6, D7, D8	A1, B1, C1; A7, B7, C7; A5, B5, C5
A3, B3, C3; A1, B1, C1; A4, B4, C4, D4	A5, B5, C5; A3, B3, C3; D6, A8, B8, C8	A7, B7, C7; A5, B5, C5; A6, B6, C6	A3, B3, C3; A4, B4, C4; D4, D3; A1, B1, C1	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6
A4, B4, C4; A3, B3, C3; A1, B1, C1	A3, B3, C3; A4, B4, C4; D4, D3; A1, B1, C1	A7, B7, C7; A3, B3, C3; D6, D5, A5	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6	A7, B7, C7; A5, B5, C5; A6, B6, C6
A3, B3, C3; D2, D4; A4, B4, C4	A3, B3, C3; A4, B4, C4; D4; A1, B1, C1	A3, B3, C3; A4, B4, C4; D6; A7, B7, B8	A1, B1, C1, A2, B2, C2; A5, B5, C5	A3, B3, C3; A4, B4, C4; D7, D8, D5, D6	D6; A8, B8, C8; D5; A7, B7, C7

16. Detailed Results of the Investment and O&M Scenario Simulations

FIGURE A6.9: RUC VERSUS RAC ARGENTINA: GOOD CONDITION (AADT = 7,500)

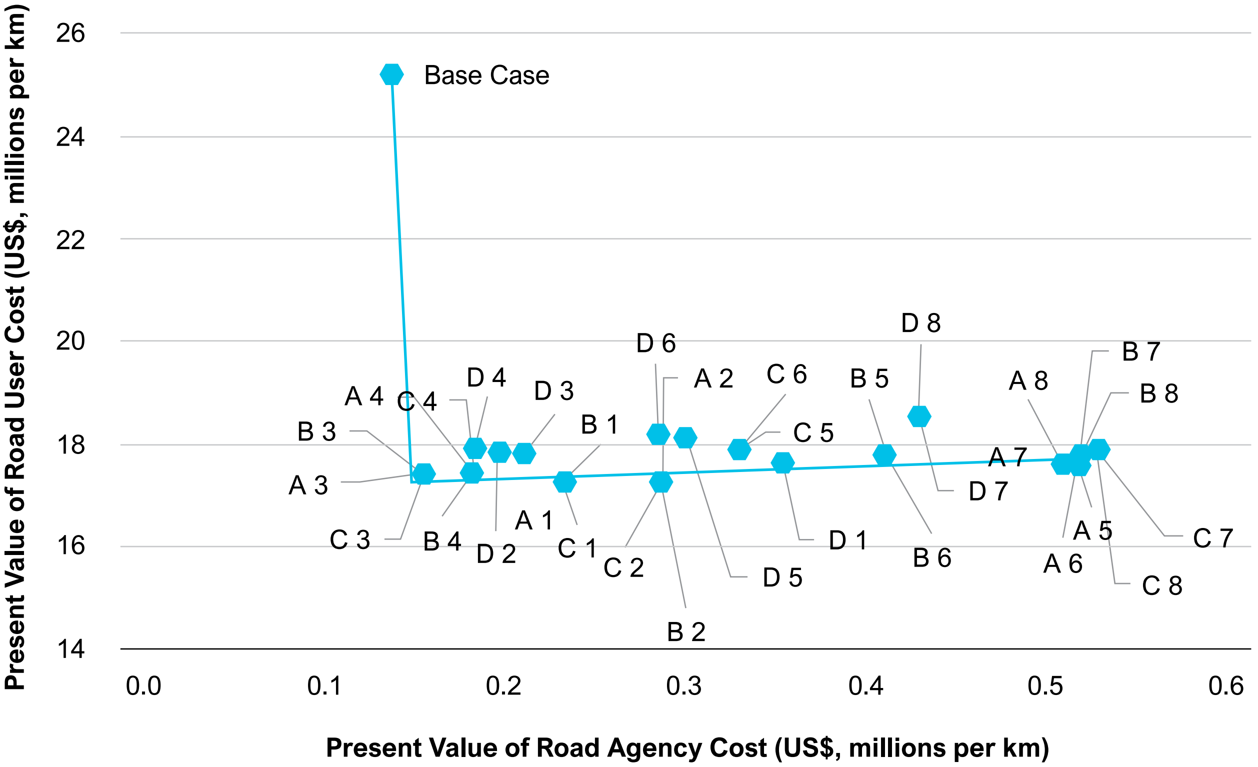


FIGURE A6.10: RUC VERSUS RAC: ARGENTINA: FAIR CONDITION (AADT = 7,500)

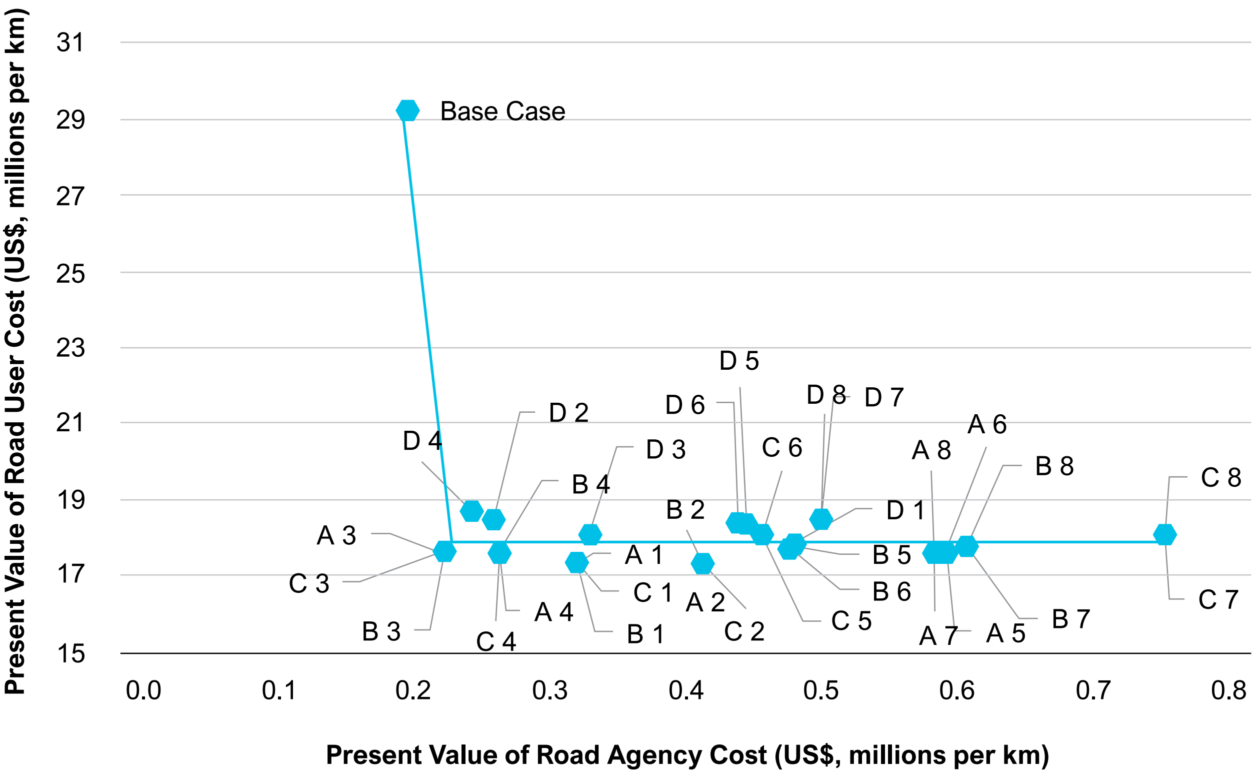


FIGURE A6.11: RUC VERSUS RAC ARGENTINA: POOR CONDITION (AADT = 7,500)

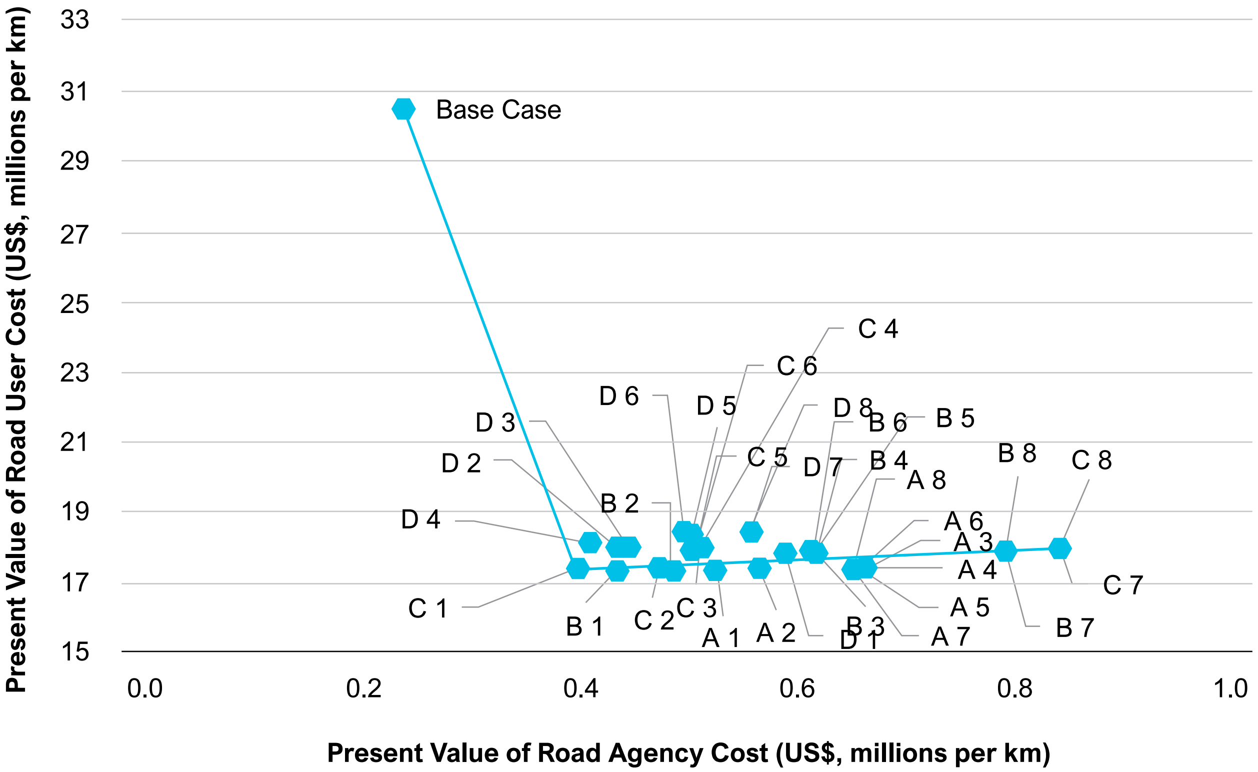


FIGURE A6.12: RUC VERSUS RAC ARGENTINA: GOOD CONDITION (AADT = 3,000)

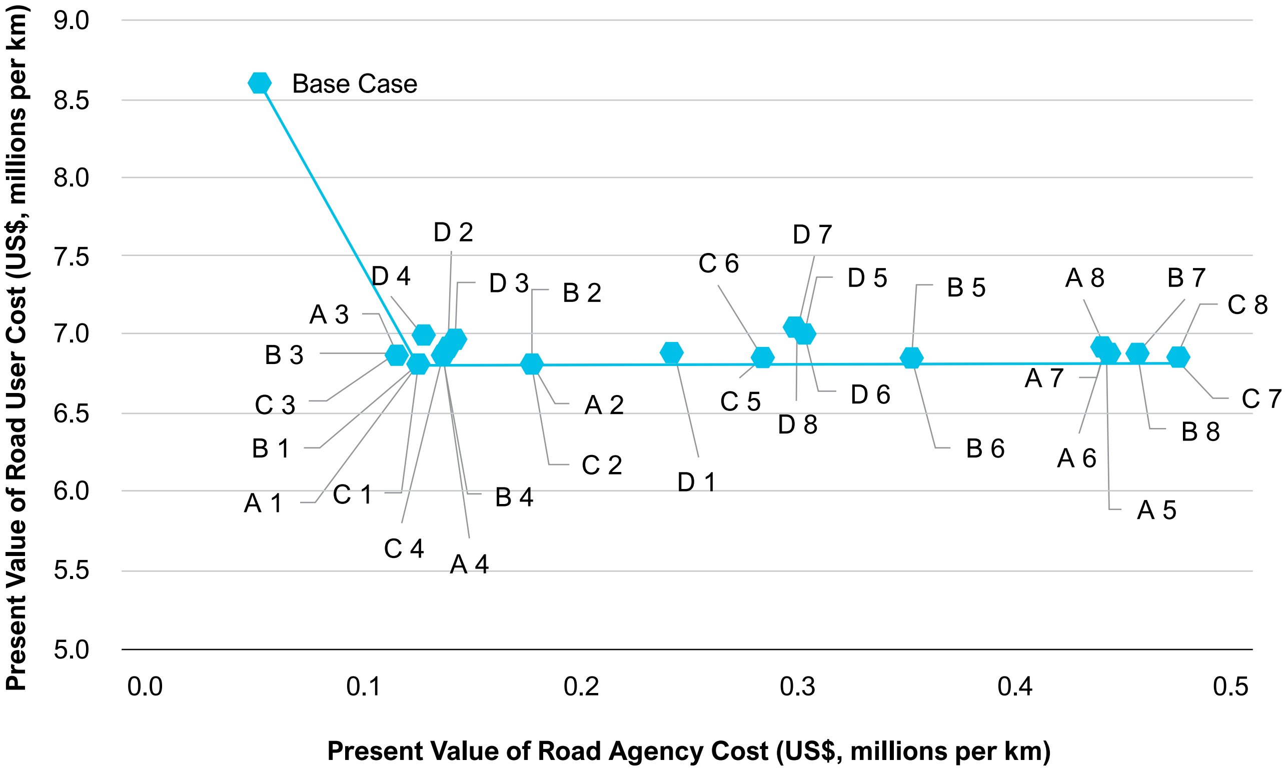


FIGURE A6.13: RUC VERSUS RAC ARGENTINA FAIR CONDITION (AADT = 3,000)

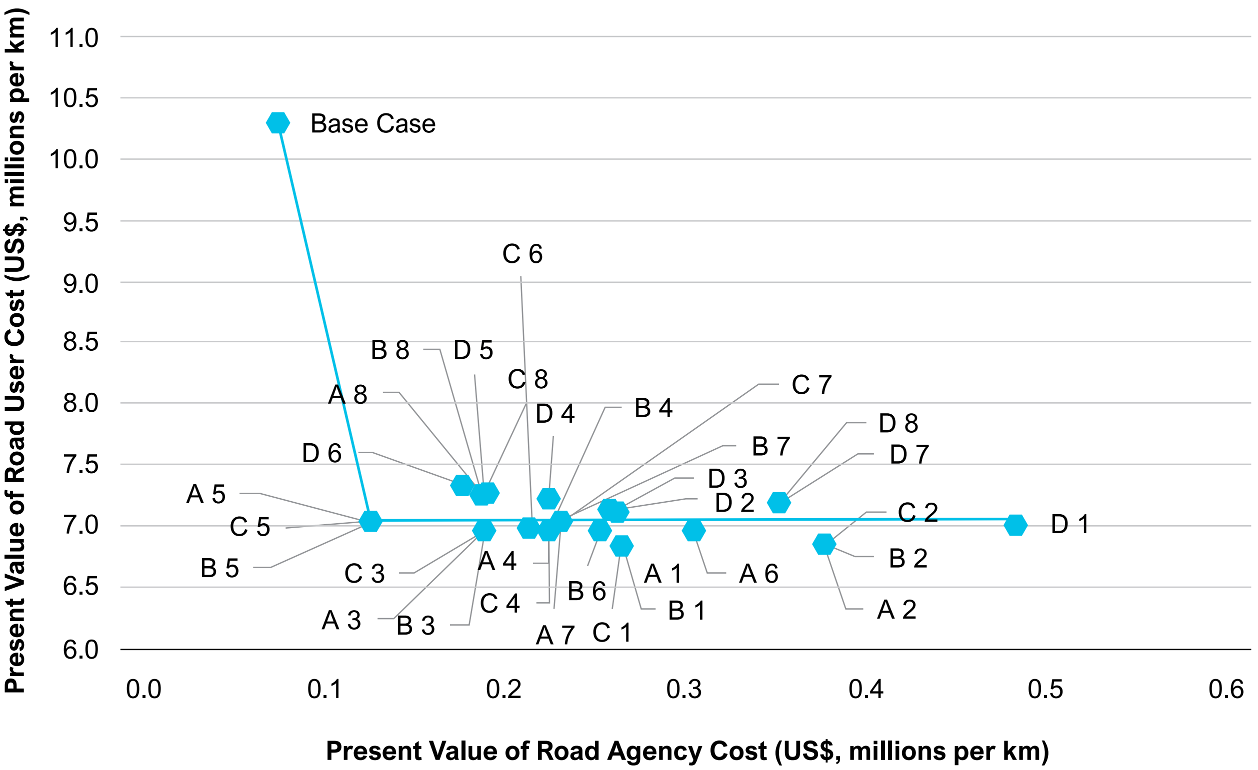


FIGURE A6.14: RUC VERSUS RAC ARGENTINA: POOR CONDITION (AADT = 3,000)

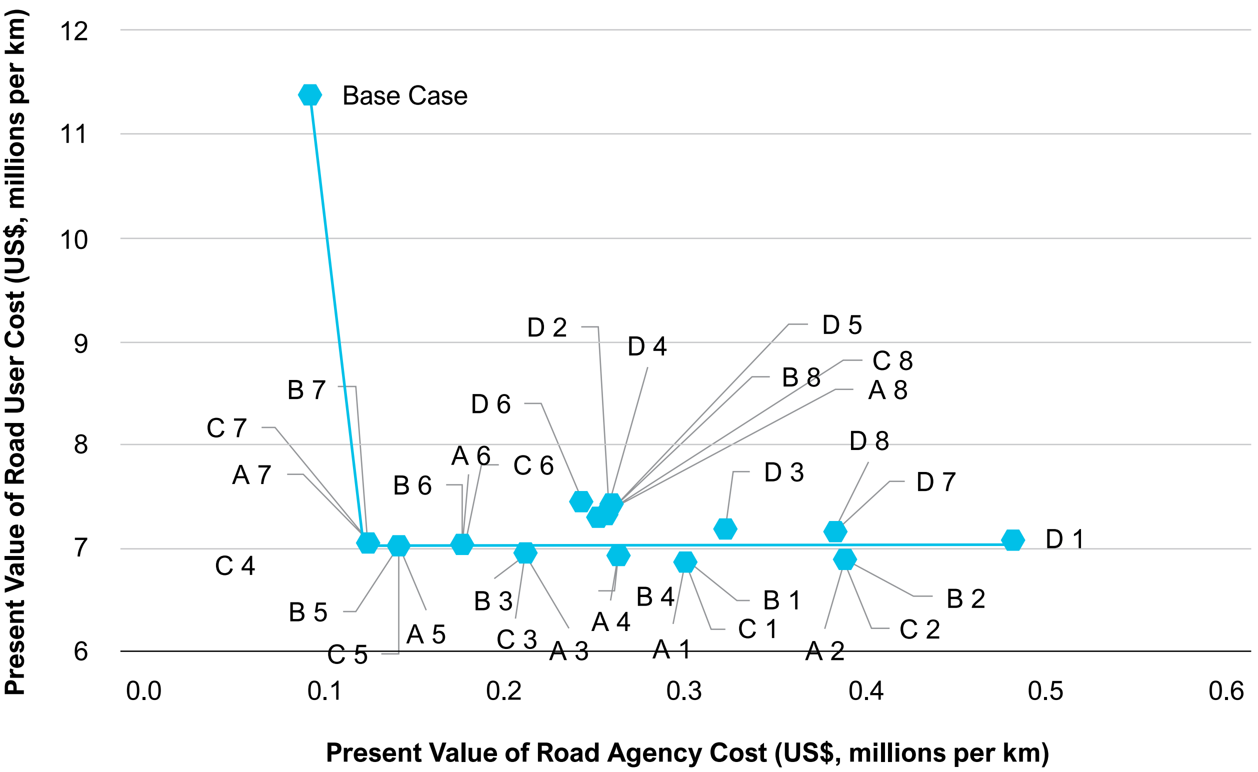


FIGURE A6.15: RUC VERSUS RAC ARGENTINA: GOOD CONDITION (AADT = 750)

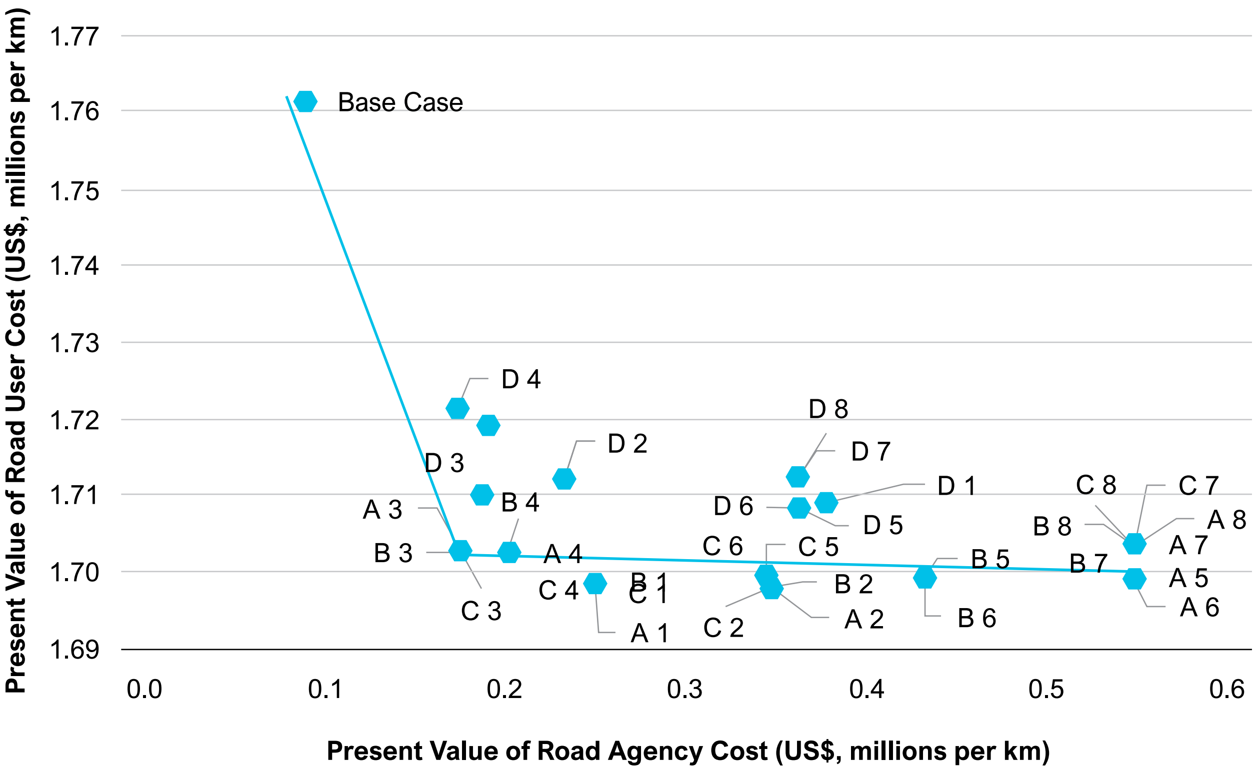


FIGURE A6.16: RUC VERSUS RAC ARGENTINA: FAIR CONDITION (AADT = 750)

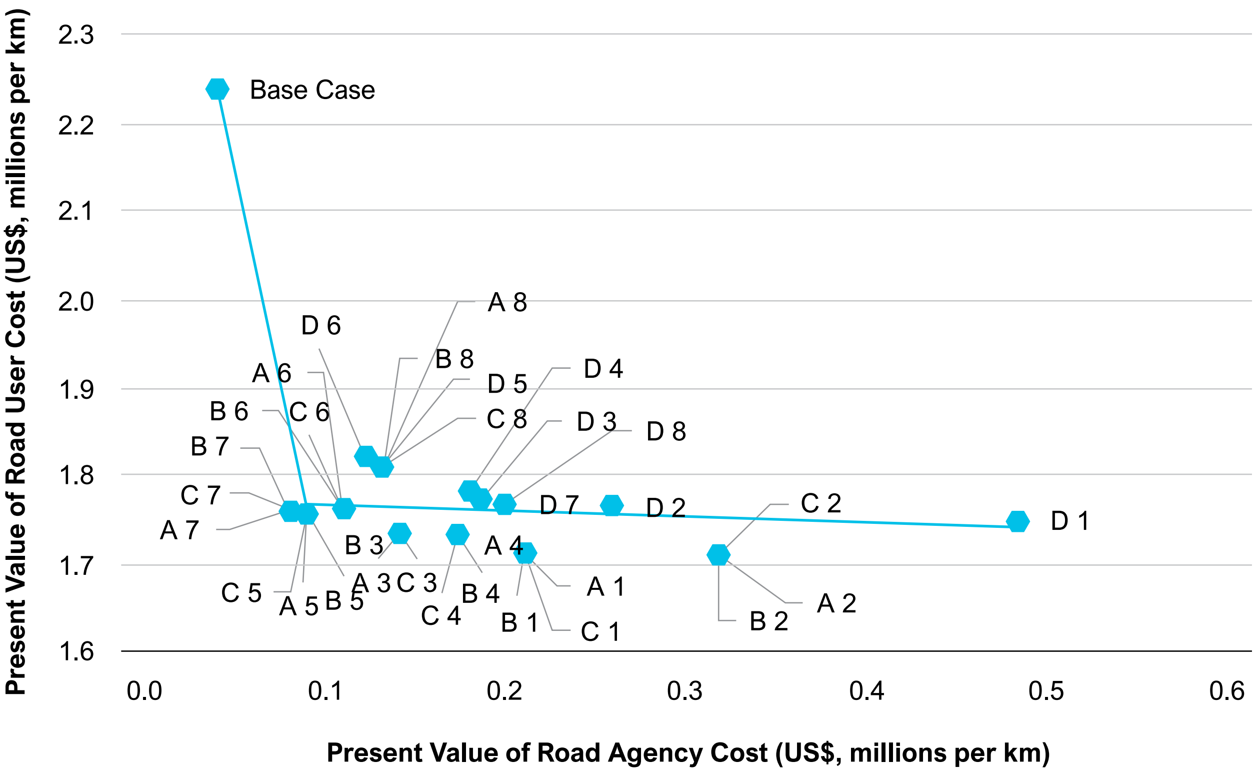


FIGURE A6.17: RUC VERSUS RAC ARGENTINA: POOR CONDITION (AADT = 750)

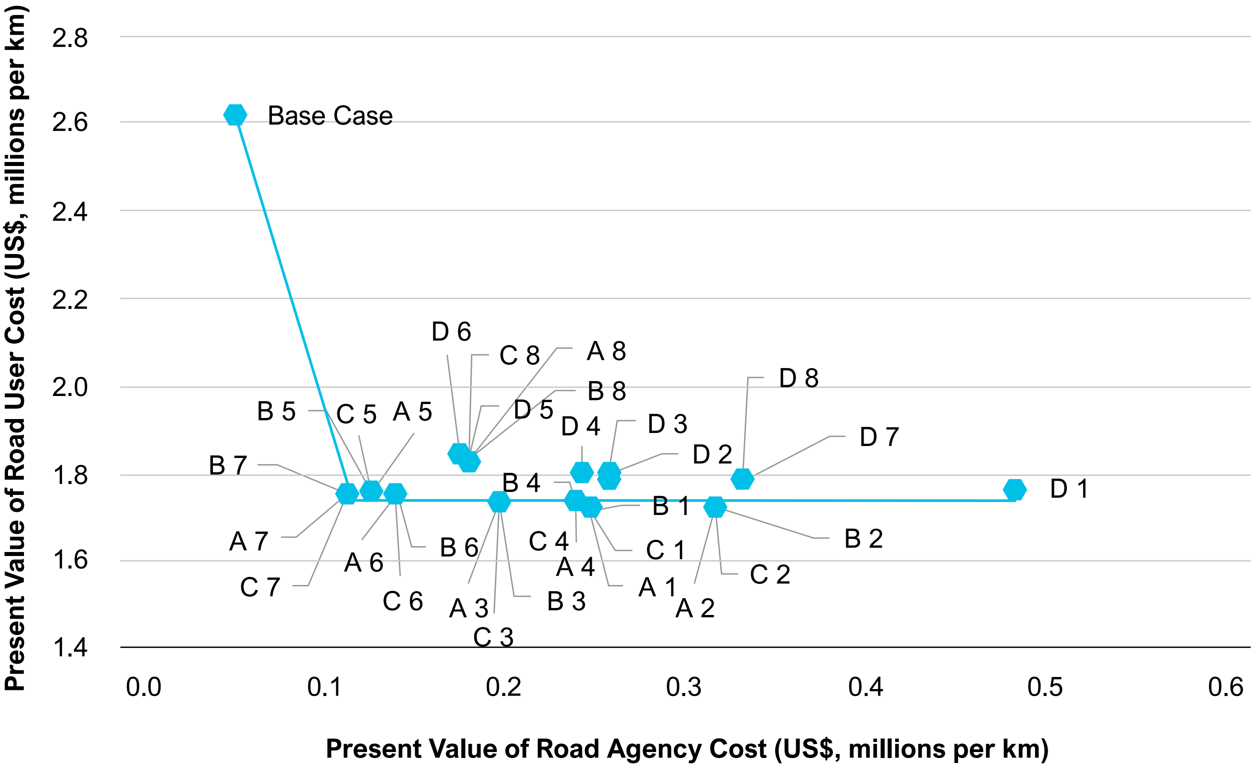


FIGURE A6.18: RUC VERSUS RAC LAO PDR: GOOD CONDITION (AADT = 7,500)

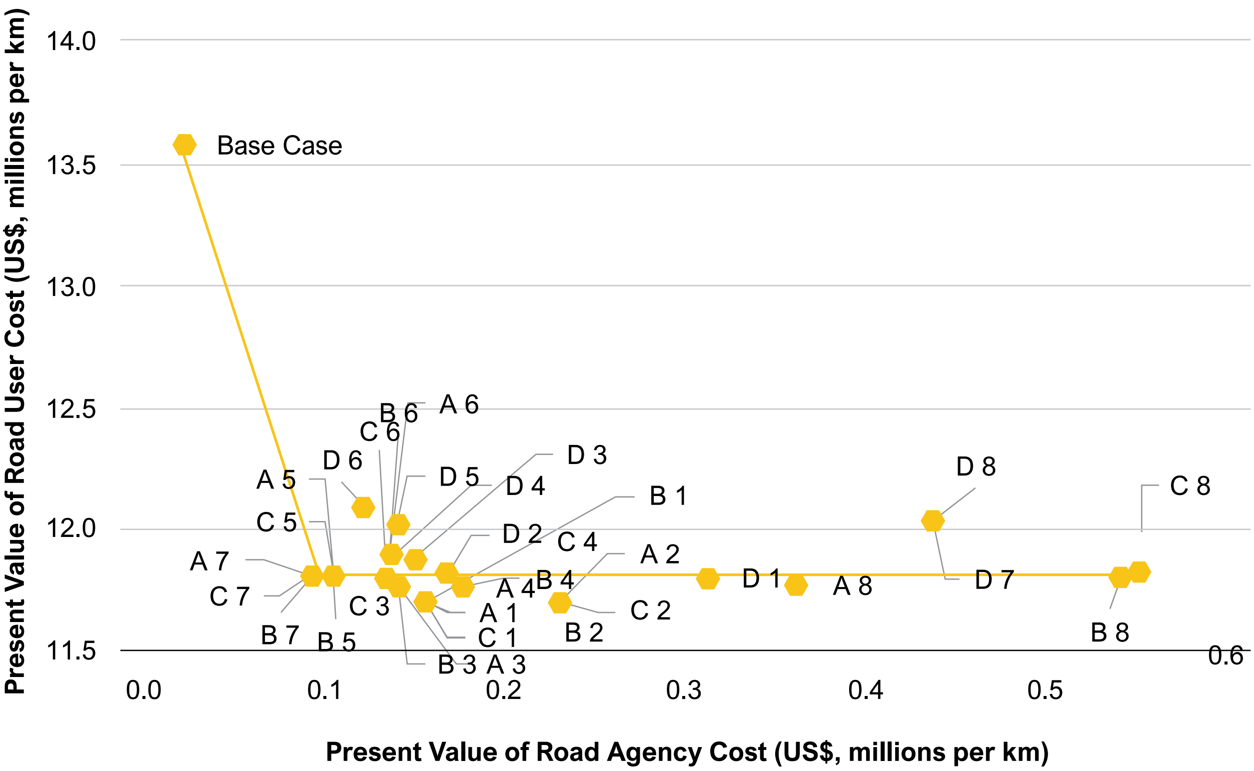


FIGURE A6.19: RUC VERSUS RAC LAO PDR: FAIR CONDITION (AADT = 7,500)

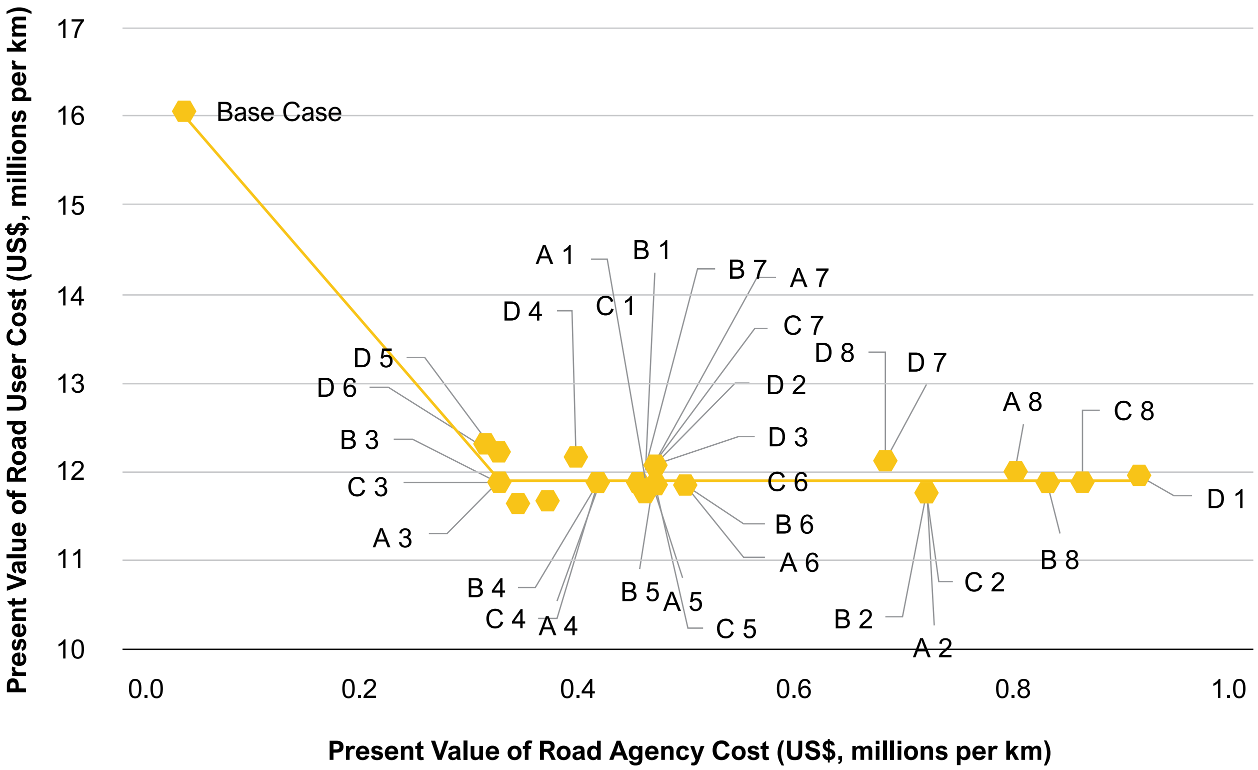


FIGURE A6.20: RUC VERSUS RAC LAO PDR: POOR CONDITION (AADT = 7,500)

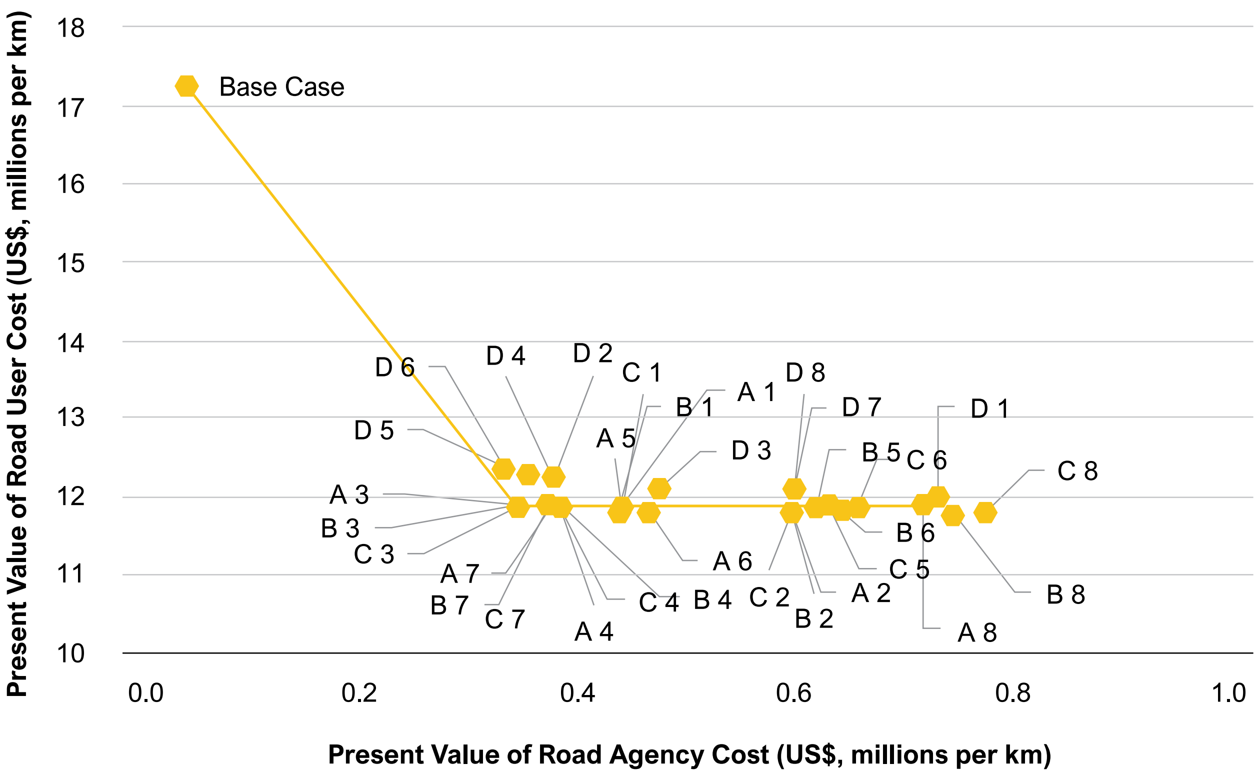


FIGURE A6.21: RUC VERSUS RAC LAO PDR: GOOD CONDITION (AADT = 3,000)

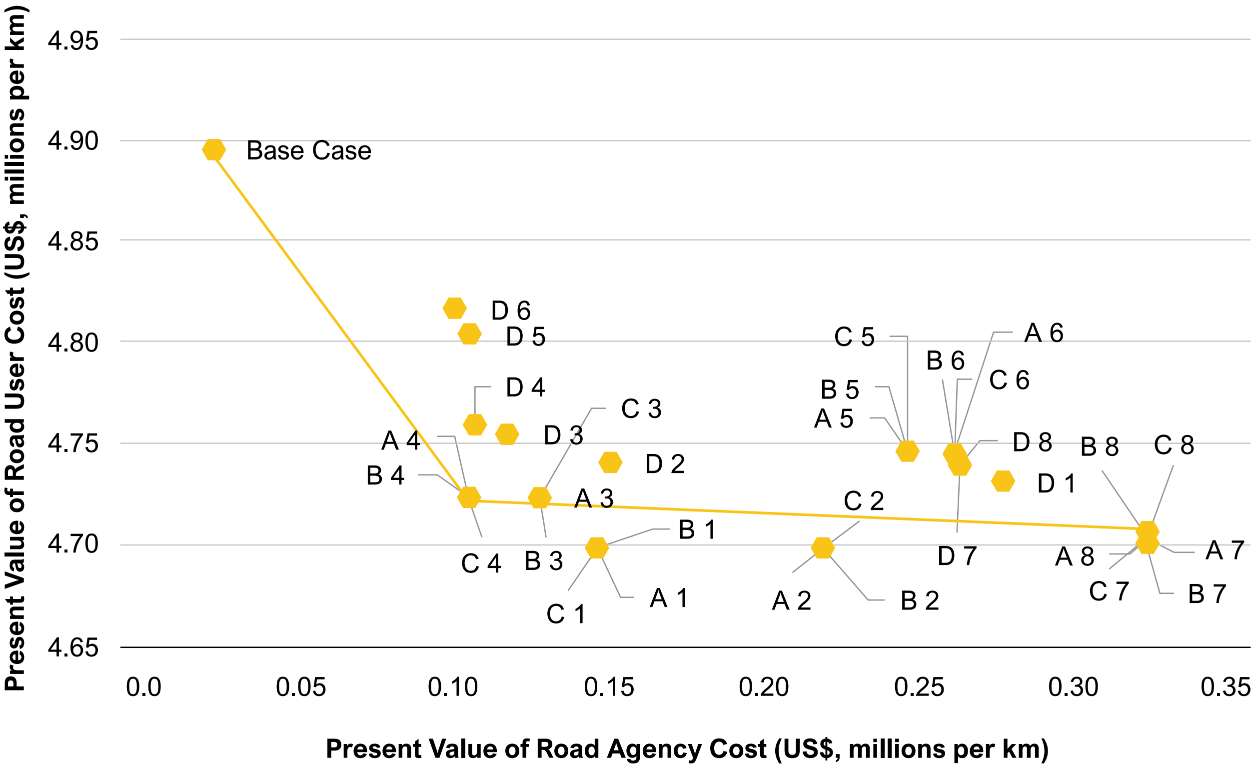


FIGURE A6.22: RUC VERSUS RAC LAO PDR: FAIR CONDITION (AADT = 3,000)

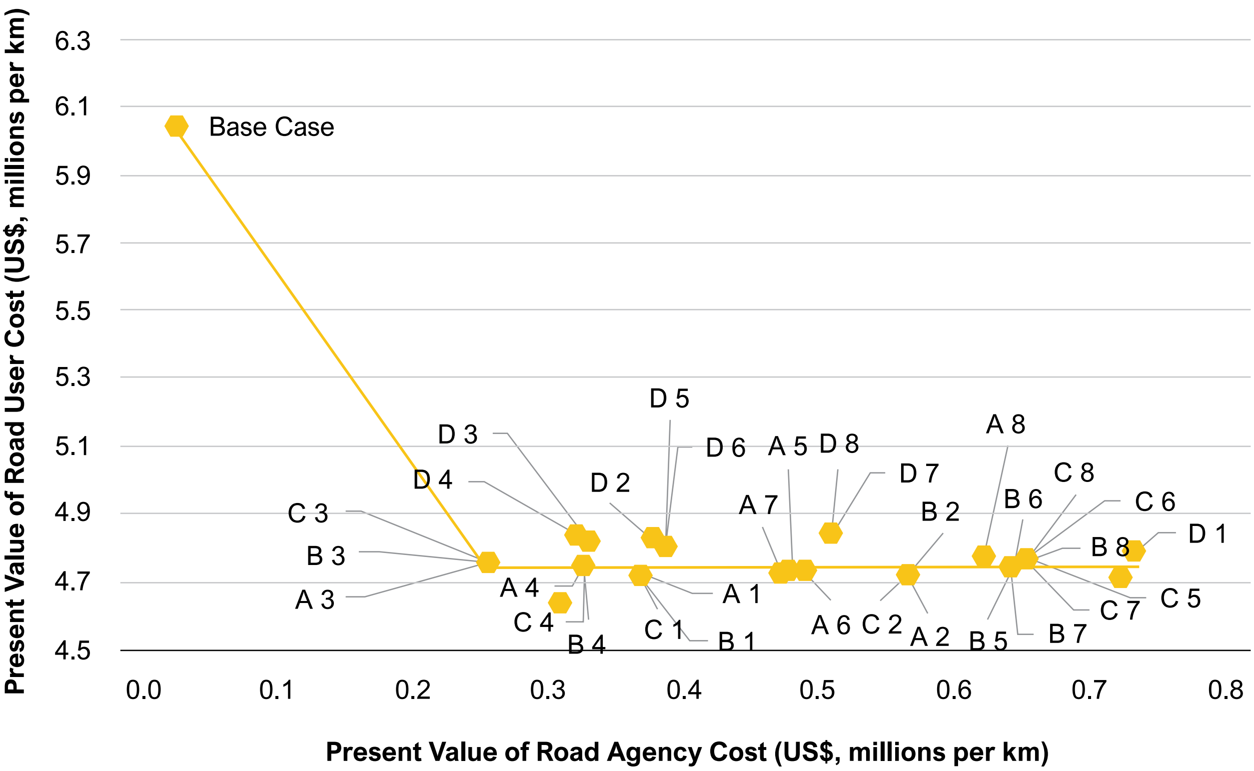


FIGURE A6.23: RUC VERSUS RAC LAO PDR: POOR CONDITION (AADT = 3,000)

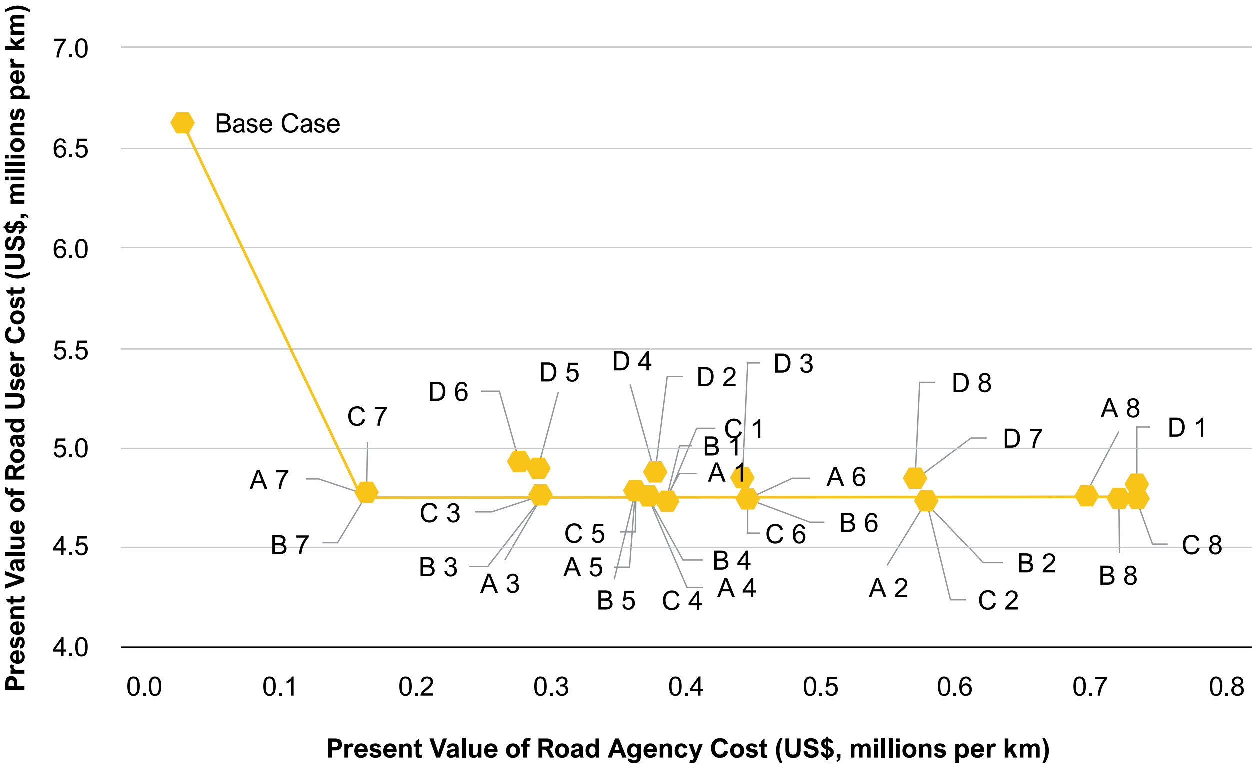


FIGURE A6.24: RUC VERSUS RAC LAO PDR: GOOD CONDITION (AADT = 750)

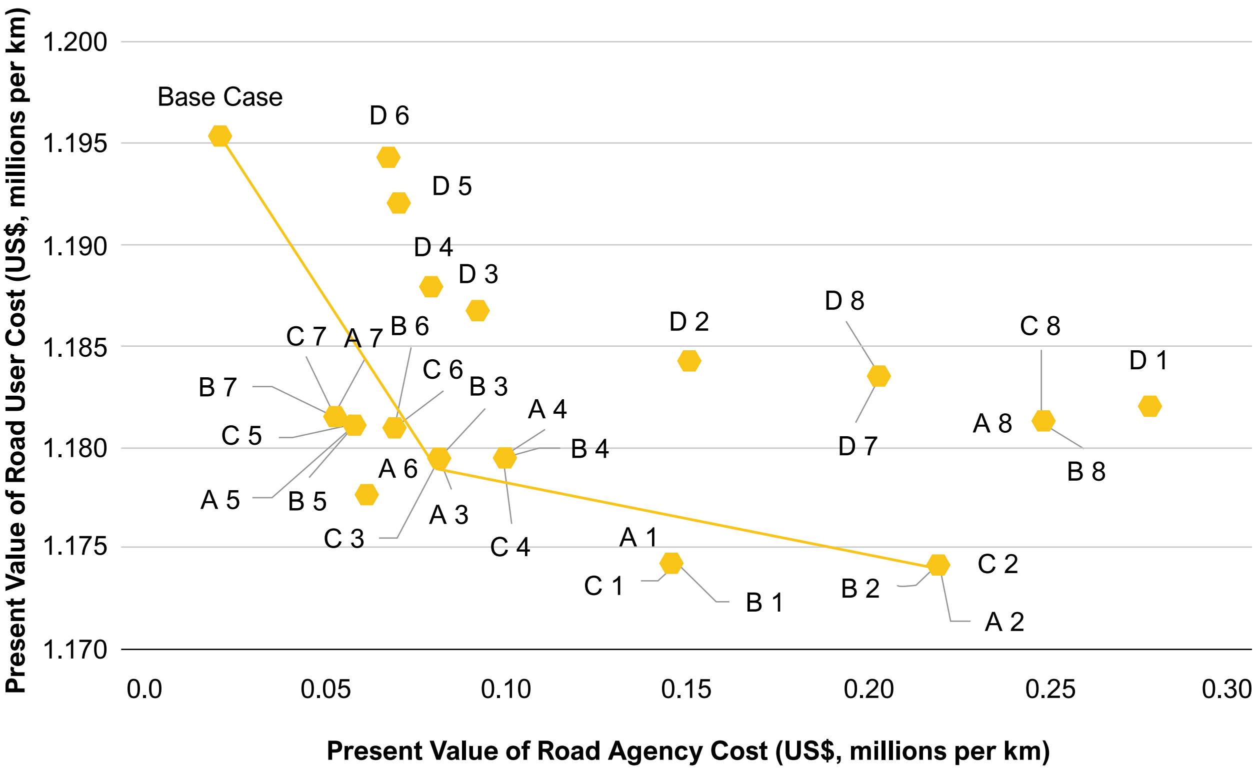


FIGURE A6.25: RUC VERSUS RAC LAO PDR: FAIR CONDITION (AADT = 750)

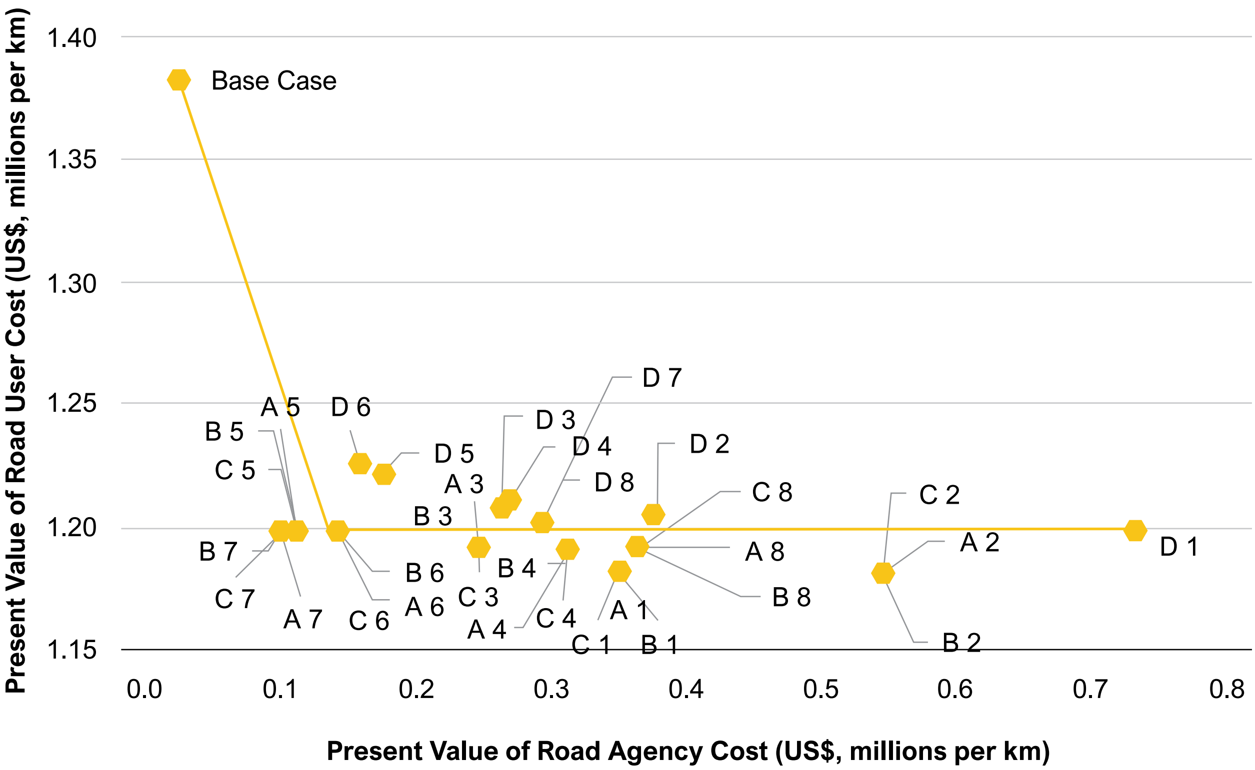


FIGURE A6.26: RUC VERSUS RAC LAO PDR: POOR CONDITION (AADT = 750)

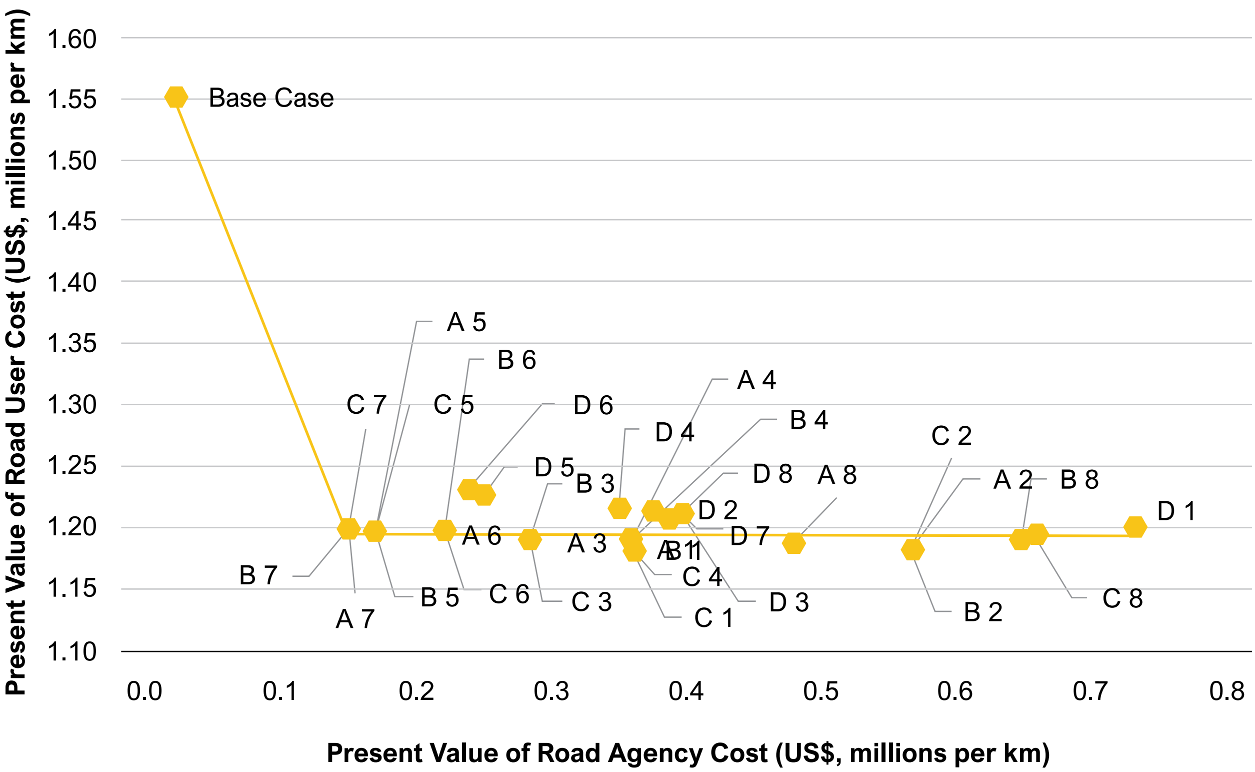


FIGURE A6.27: RUC VERSUS RAC LAO PDR: GOOD CONDITION (AADT = 7,500)

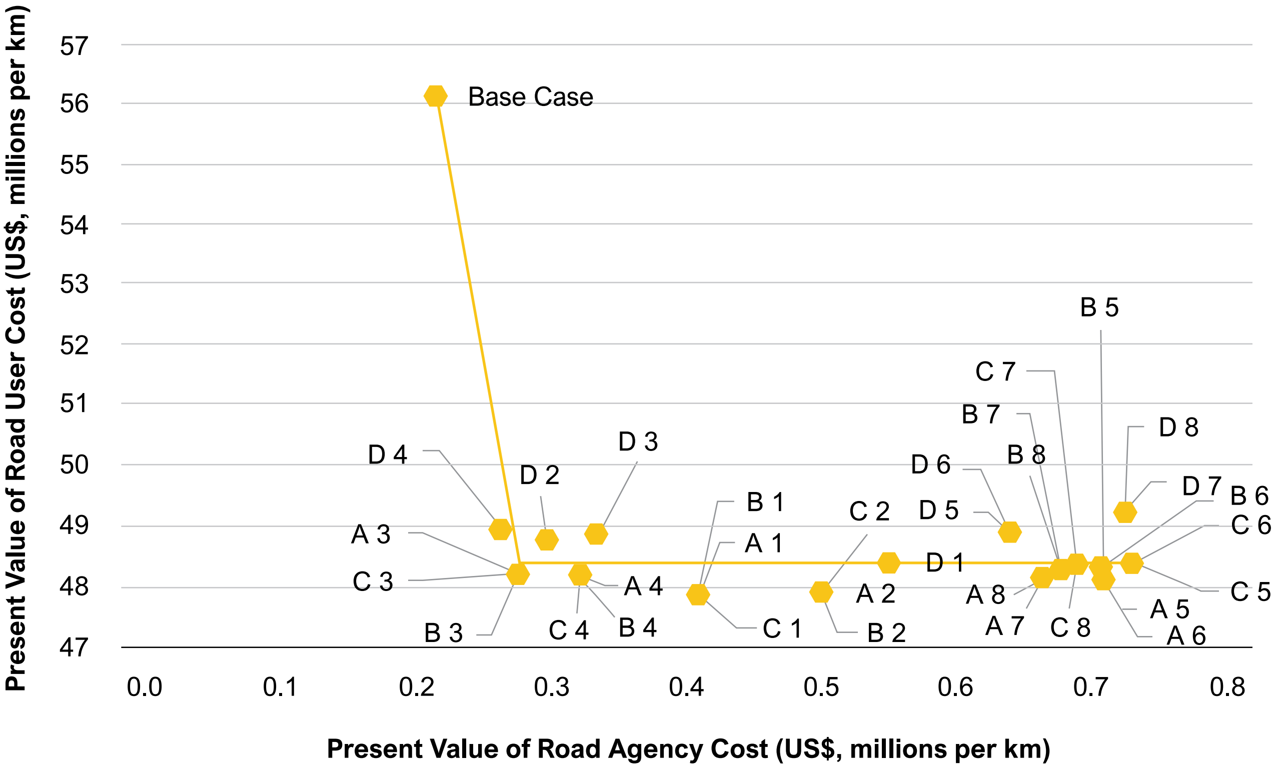


FIGURE A6.28: RUC VERSUS RAC LAO PDR: FAIR CONDITION (AADT = 7,500)

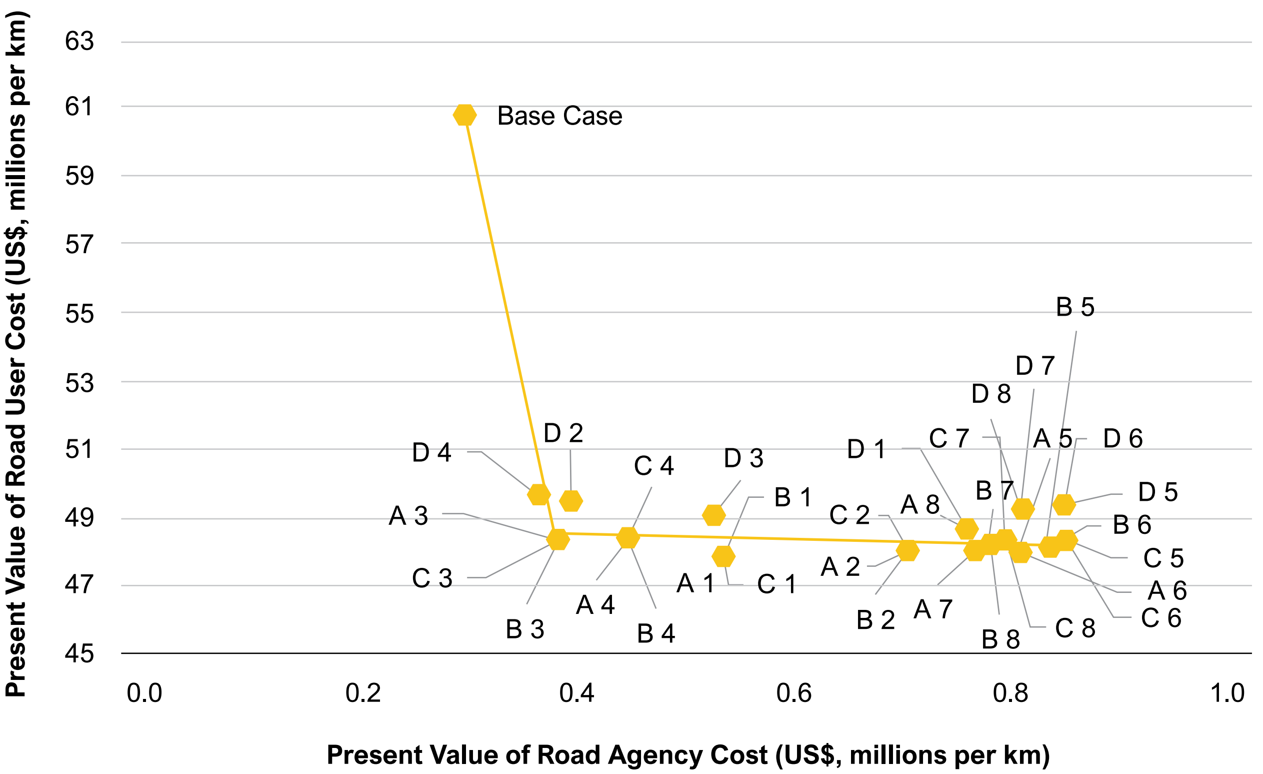


FIGURE A6.29: RUC VERSUS RAC LAO PDR: POOR CONDITION (AADT = 7,500)

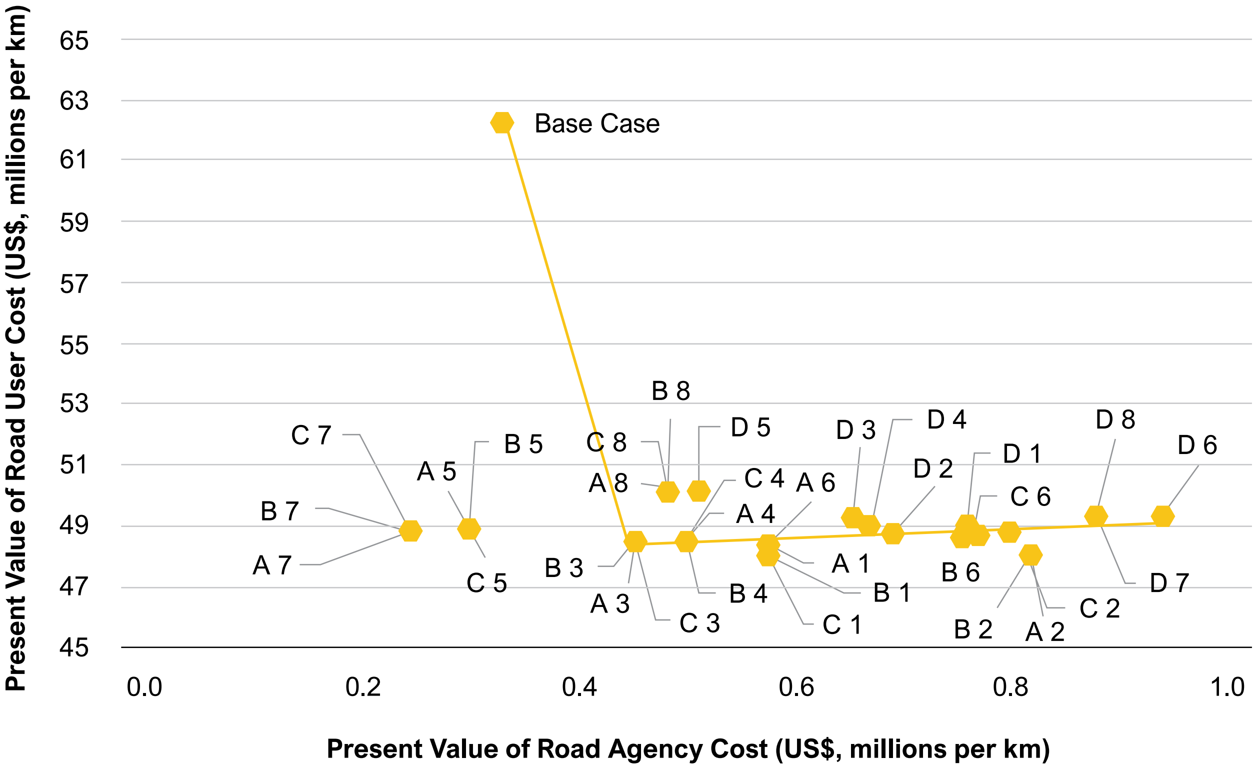


FIGURE A6.30: RUC VERSUS RAC LIBERIA: GOOD CONDITION (AADT = 3,000)

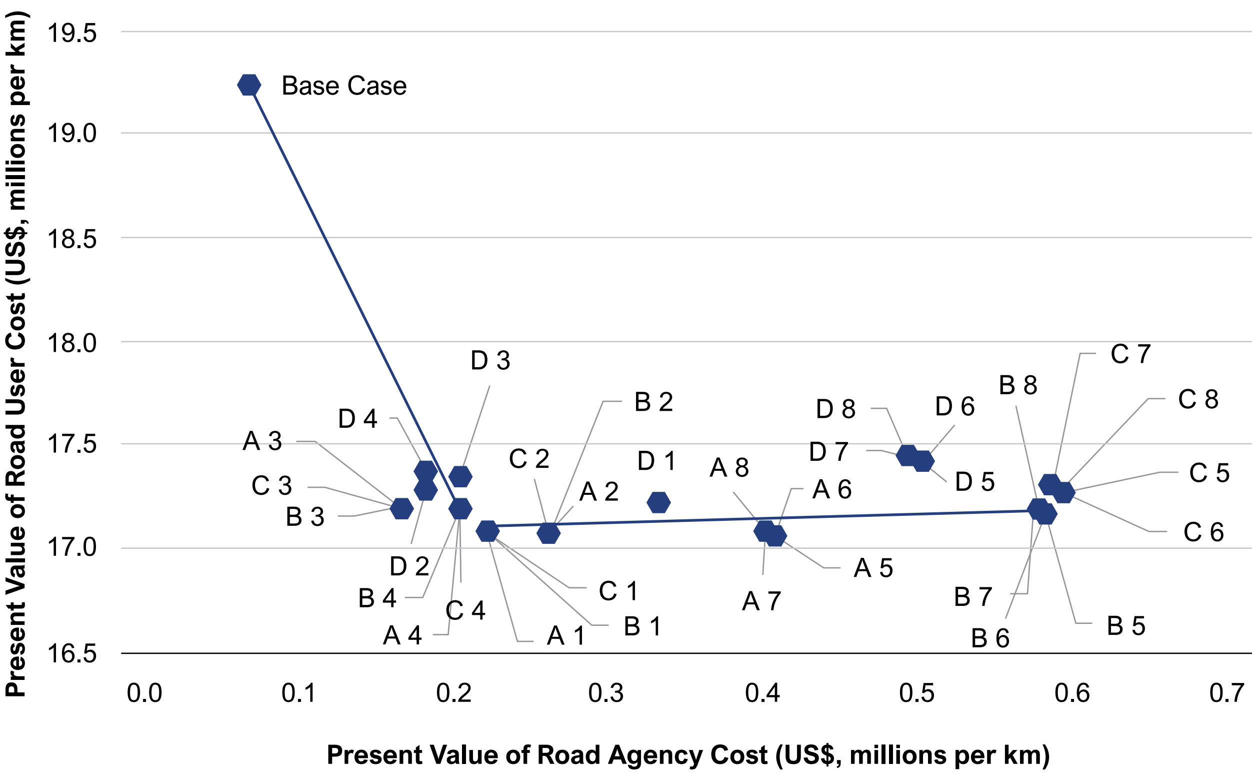


FIGURE A6.31: RUC VERSUS RAC LIBERIA: FAIR CONDITION (AADT = 3,000)

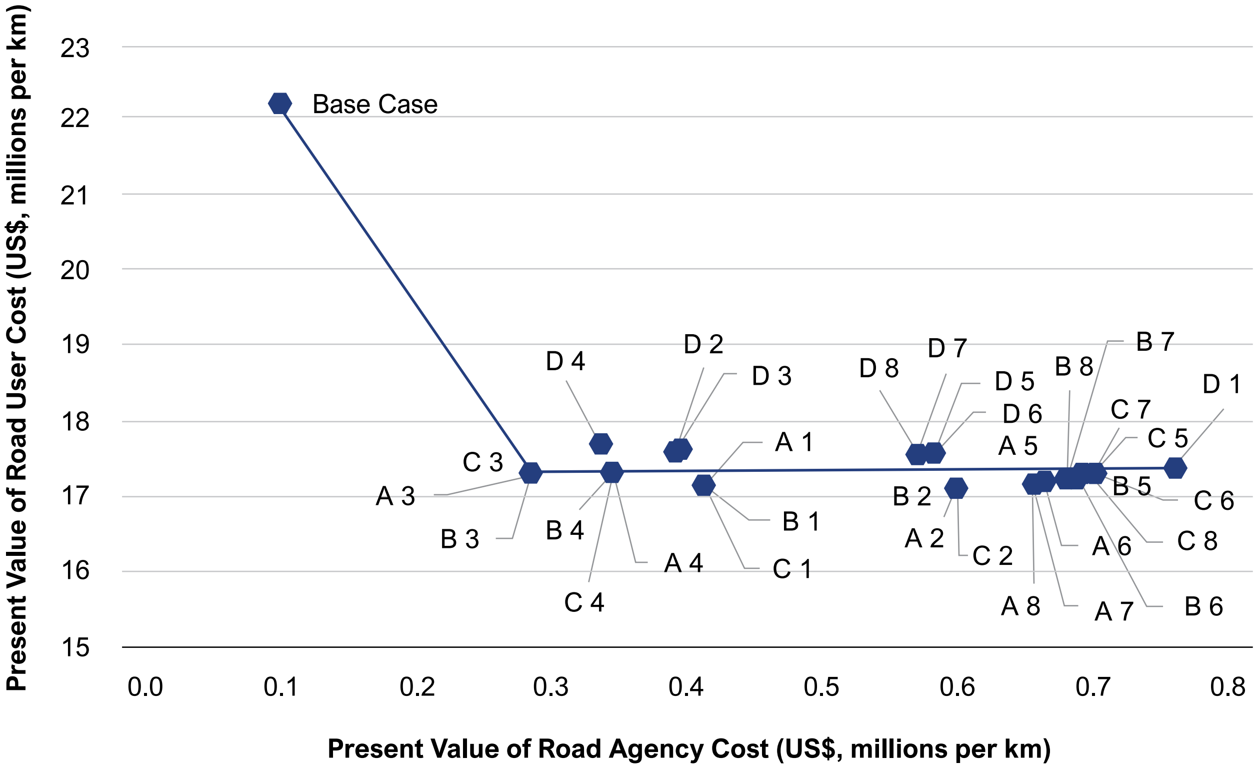


FIGURE A6.32: RUC VERSUS RAC LIBERIA: POOR CONDITION (AADT = 3,000)

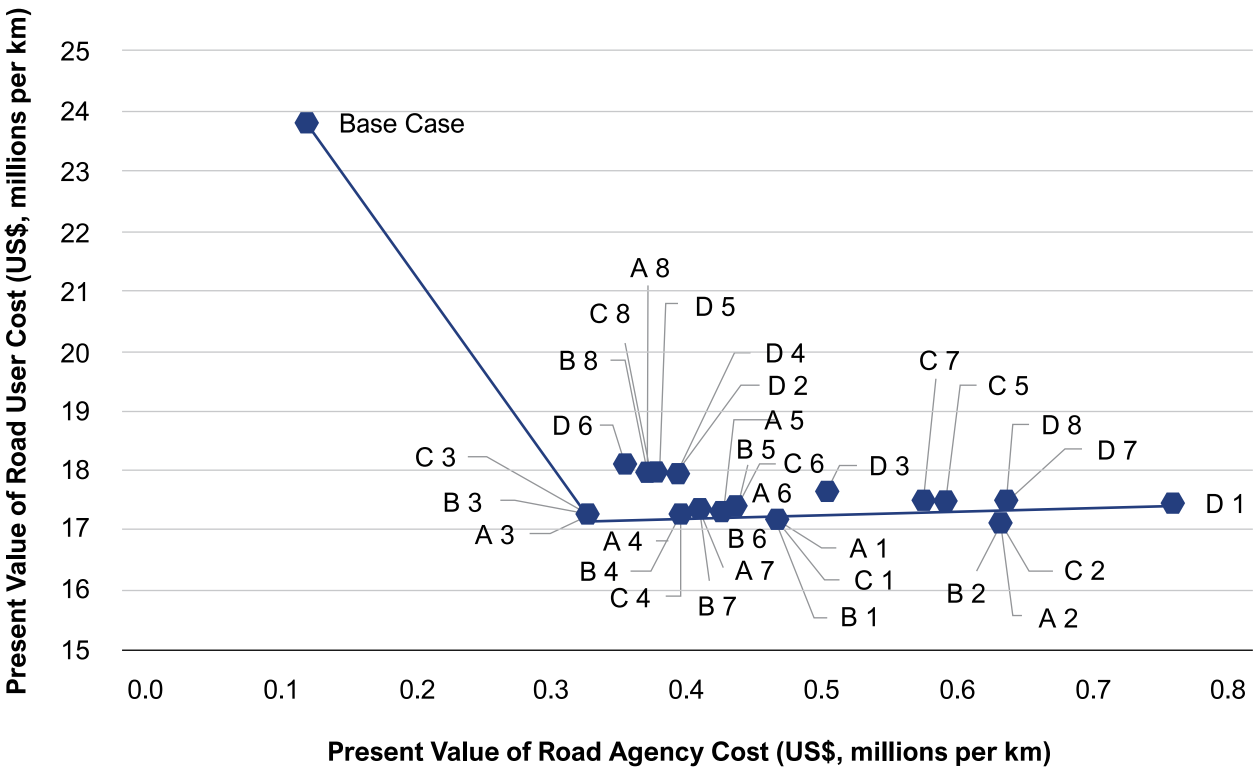


FIGURE A6.33: RUC VERSUS RAC LIBERIA: GOOD CONDITION (AADT = 750)

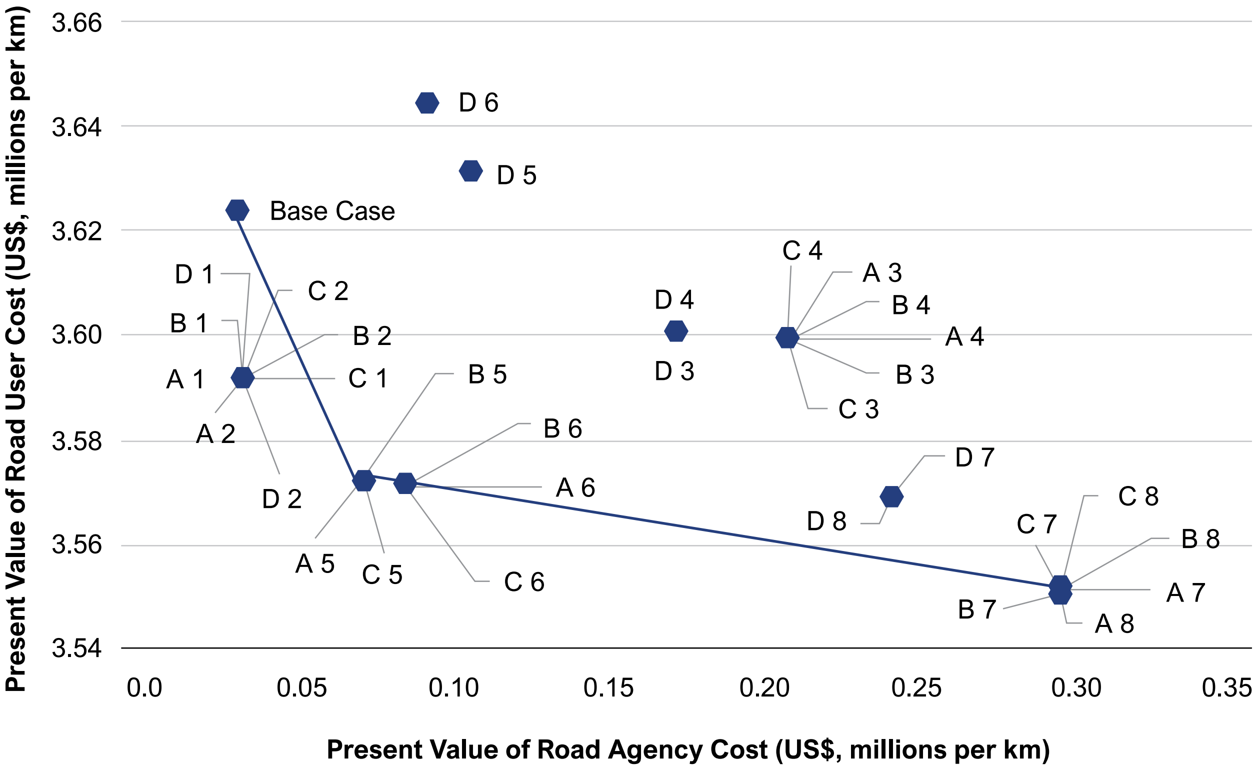


FIGURE A6.34: RUC VERSUS RAC LIBERIA: FAIR CONDITION (AADT = 750)

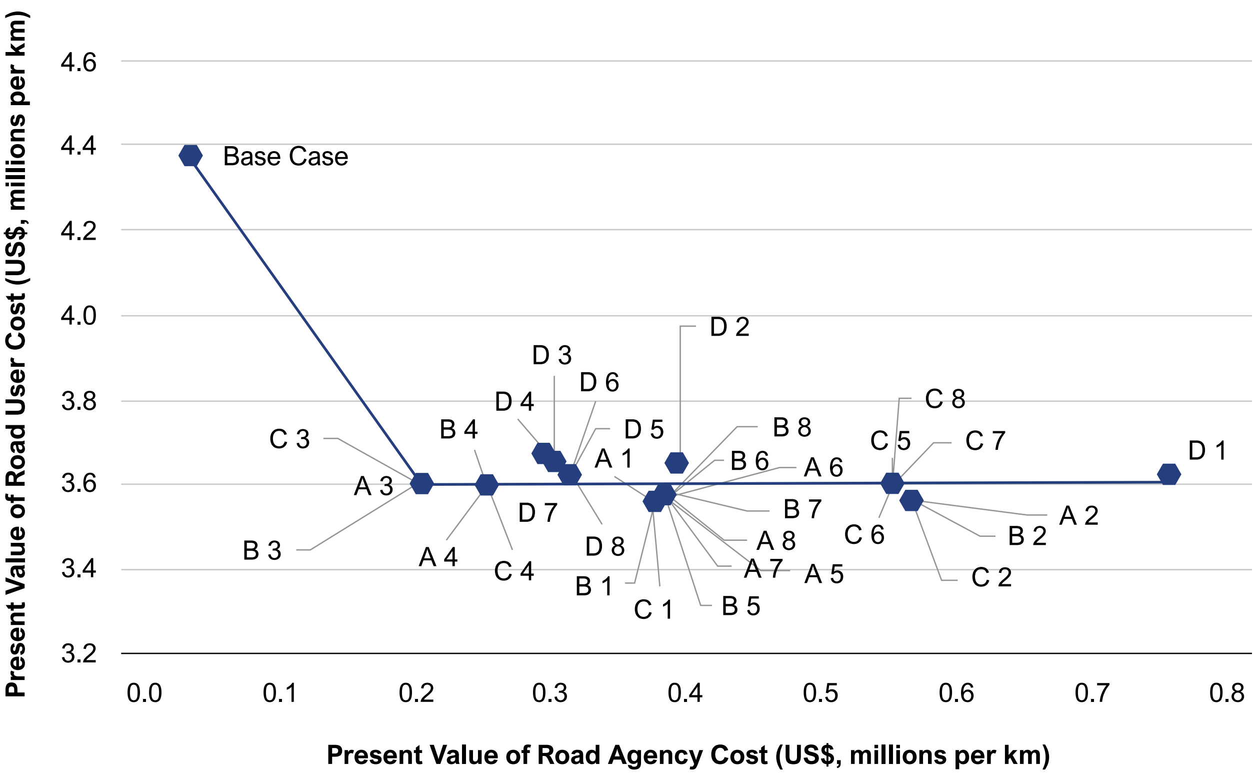


FIGURE A6.35: RUC VERSUS RAC LIBERIA: POOR CONDITION (AADT = 750)

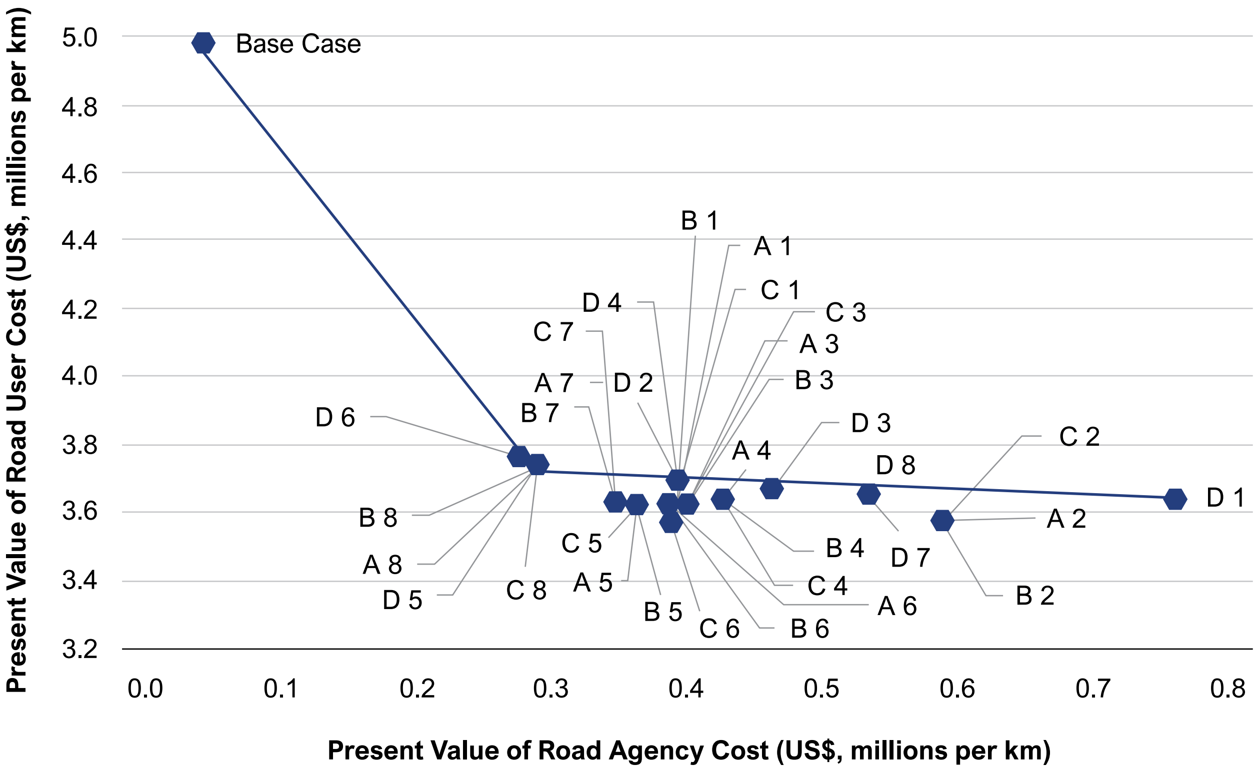


FIGURE A6.36: NPV VERSUS RAC FOR ARGENTINA: GOOD CONDITION (AADT = 7,500)

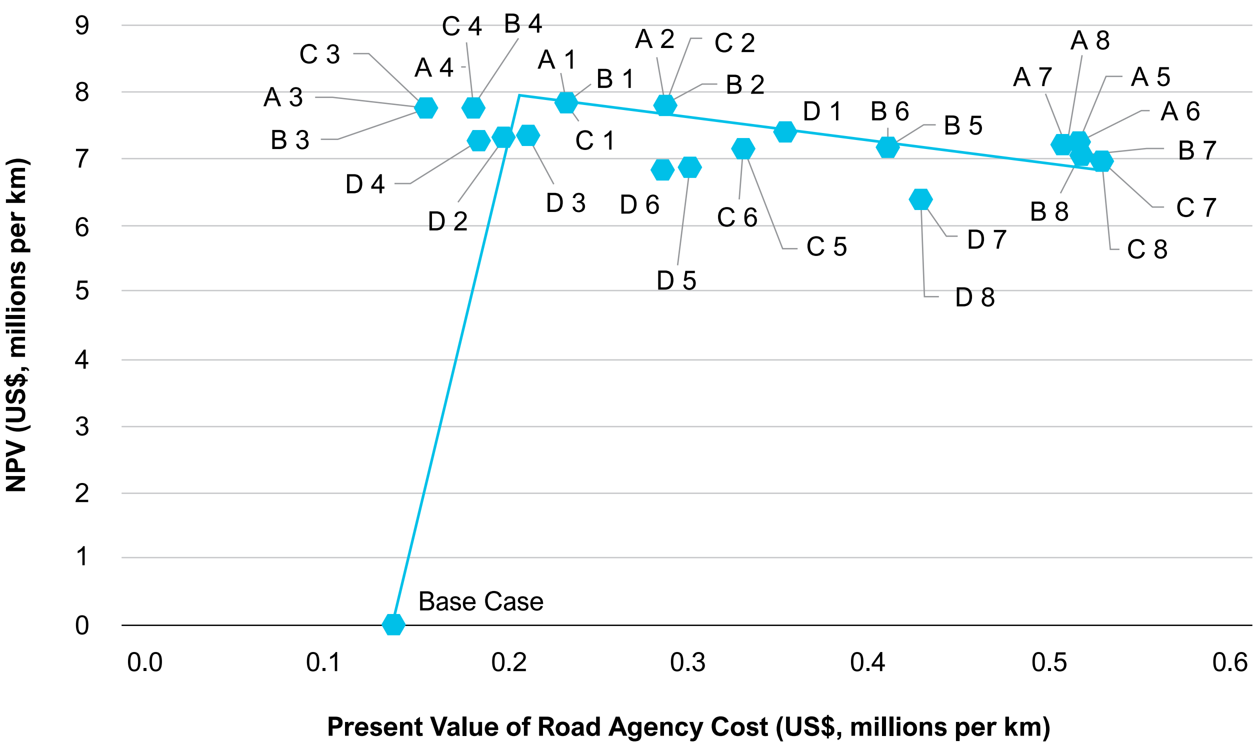


FIGURE A6.37: NPV VERSUS RAC ARGENTINA: FAIR CONDITION (AADT = 7,500)

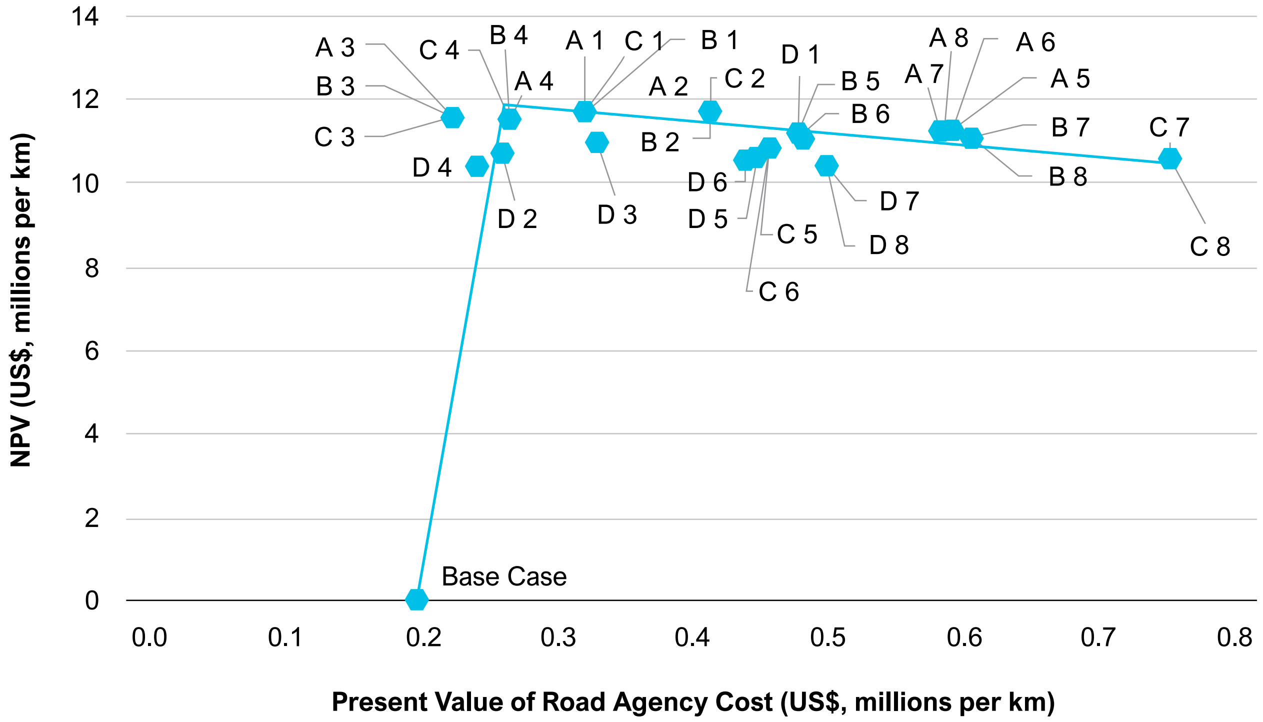


FIGURE A6.38: NPV VERSUS RAC ARGENTINA: POOR CONDITION (AADT = 7,500)

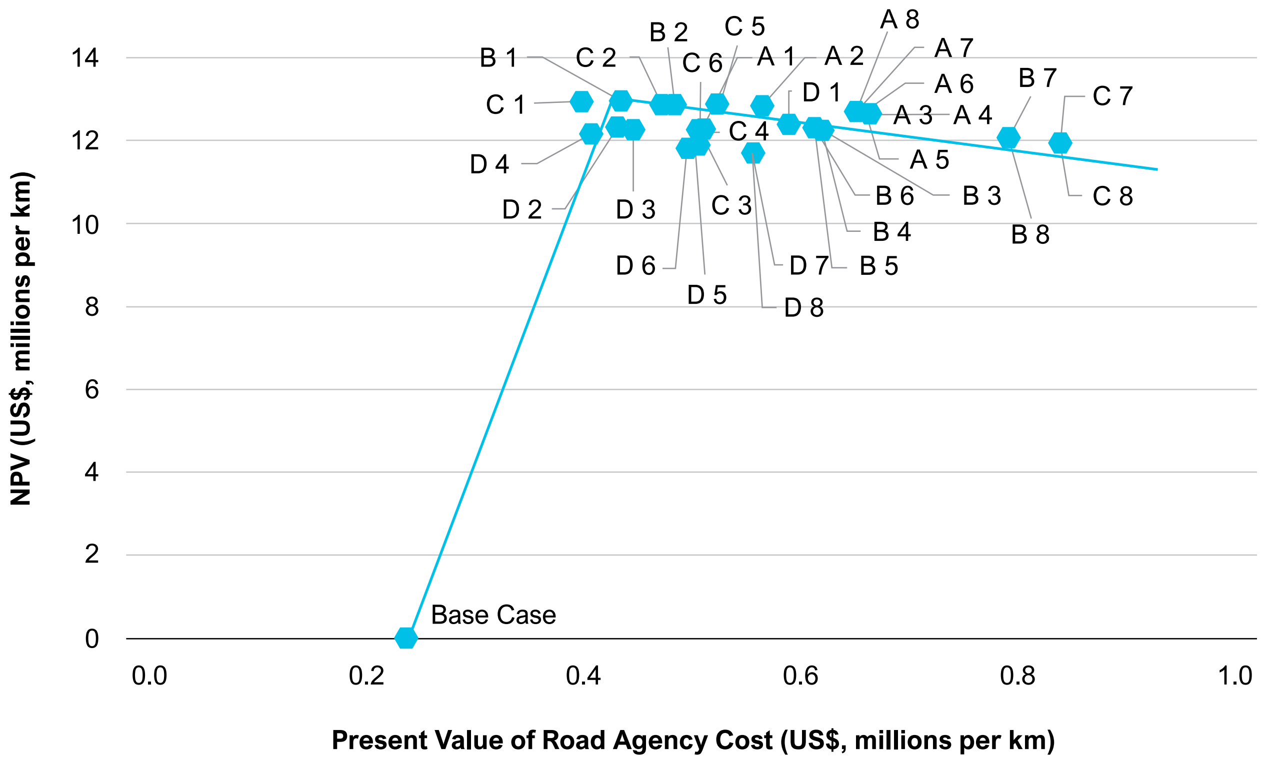


FIGURE A6.39: NPV VERSUS RAC ARGENTINA: GOOD CONDITION (AADT = 3,000)

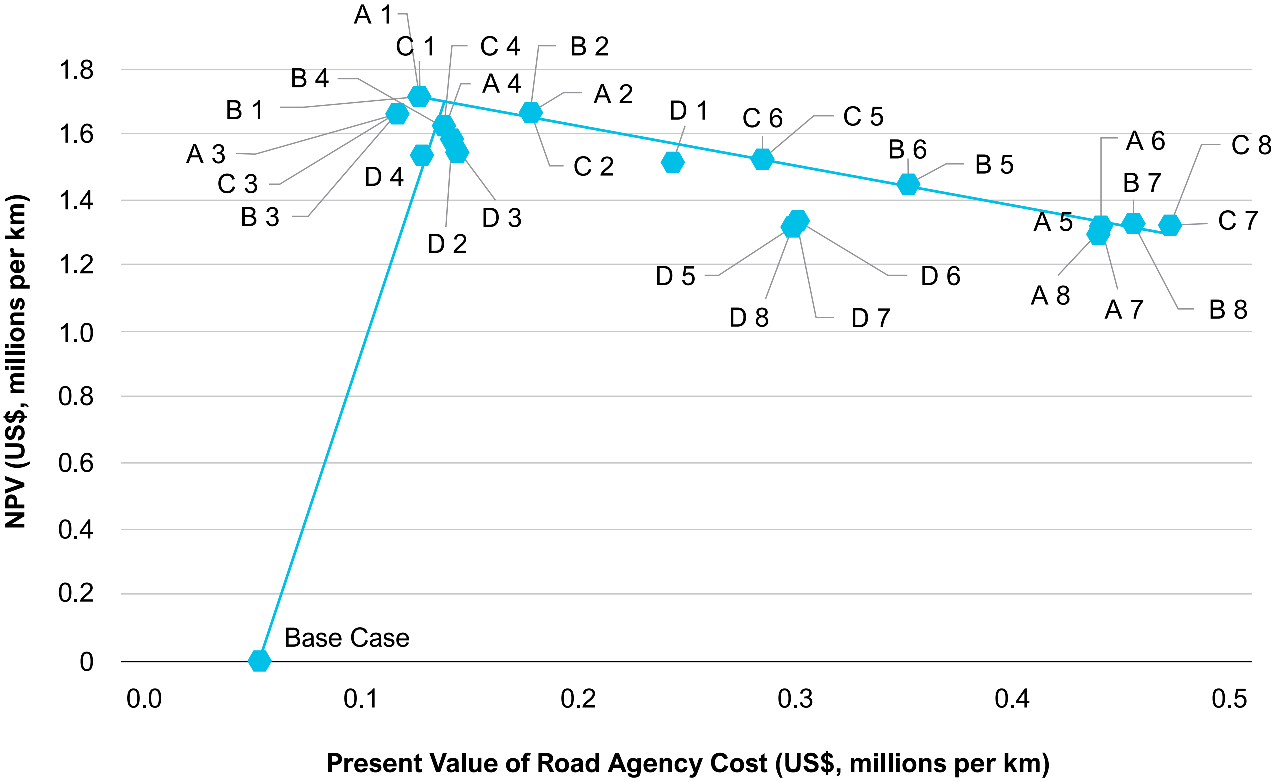


FIGURE A6.40: NPV VERSUS RAC ARGENTINA: FAIR CONDITION (AADT = 3,000)

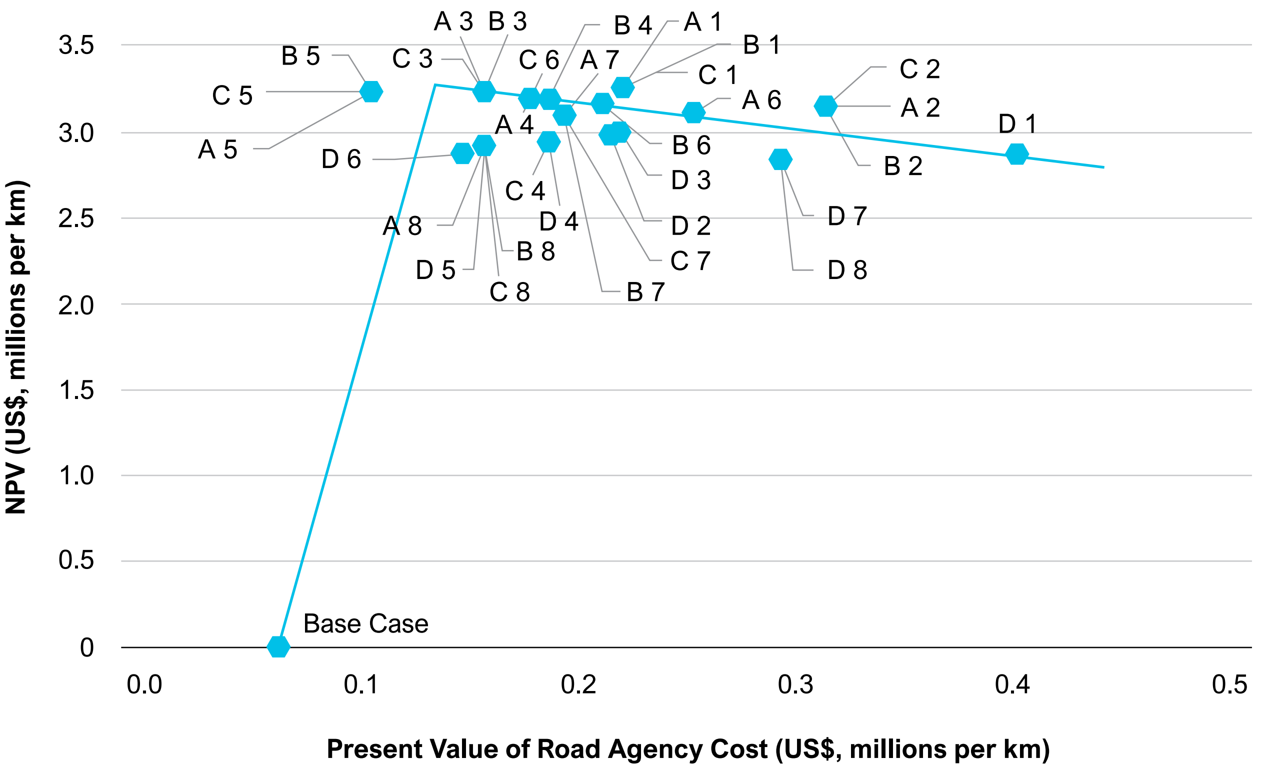


FIGURE A6.41: NPV VERSUS RAC ARGENTINA: POOR CONDITION (AADT = 3,000)

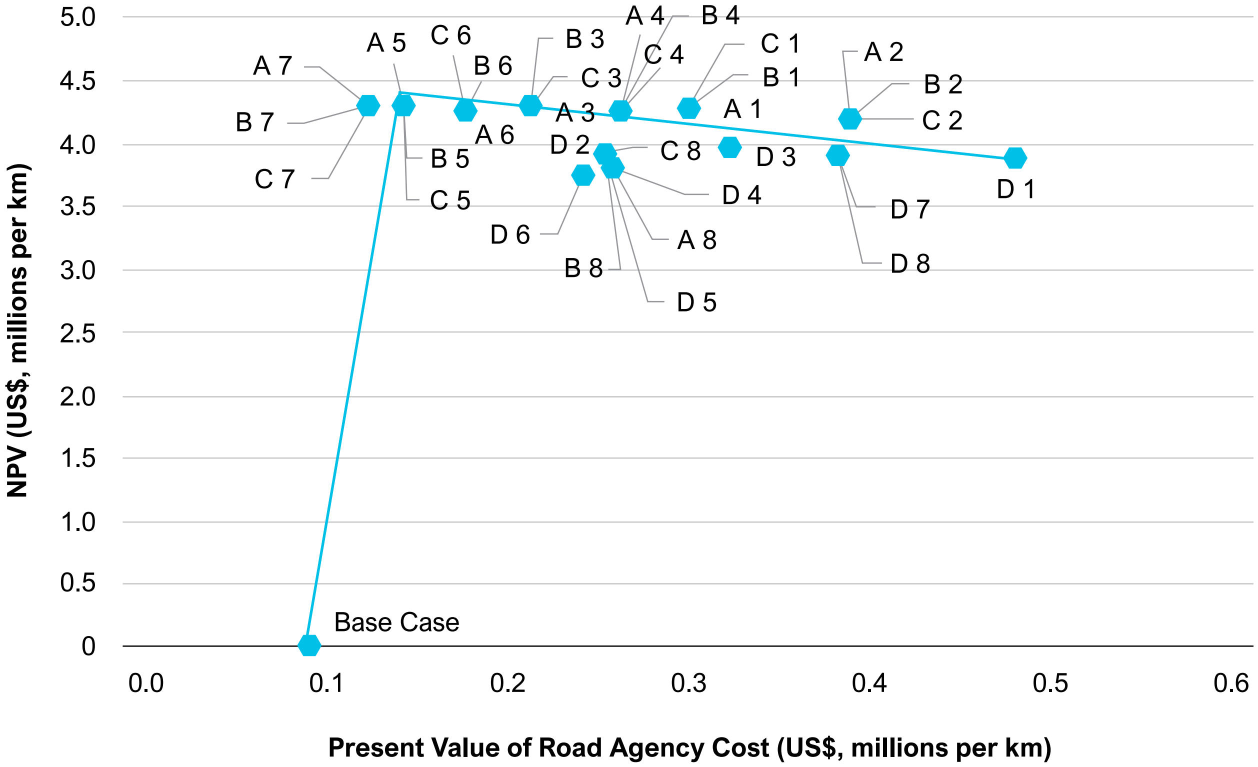


FIGURE A6.42: NPV VERSUS RAC ARGENTINA: GOOD CONDITION (AADT = 750)

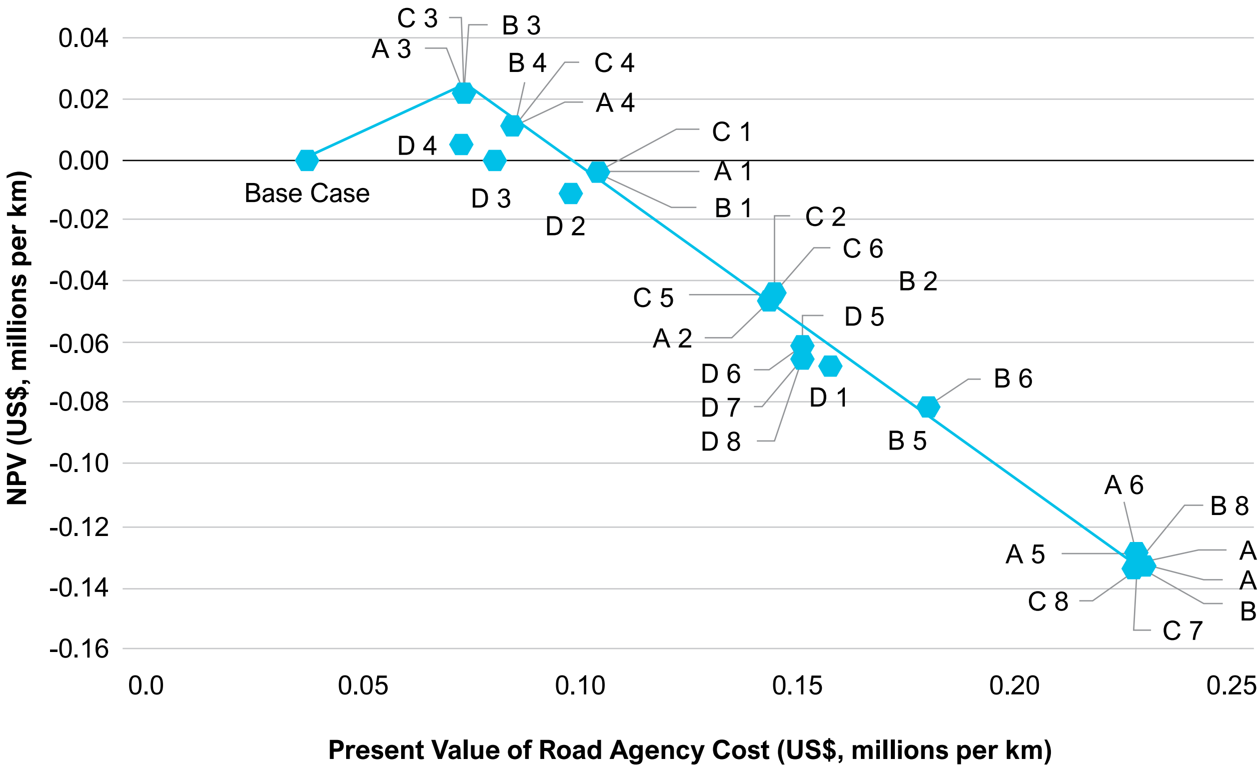


FIGURE A6.43: NPV VERSUS RAC ARGENTINA: FAIR CONDITION (AADT = 750)

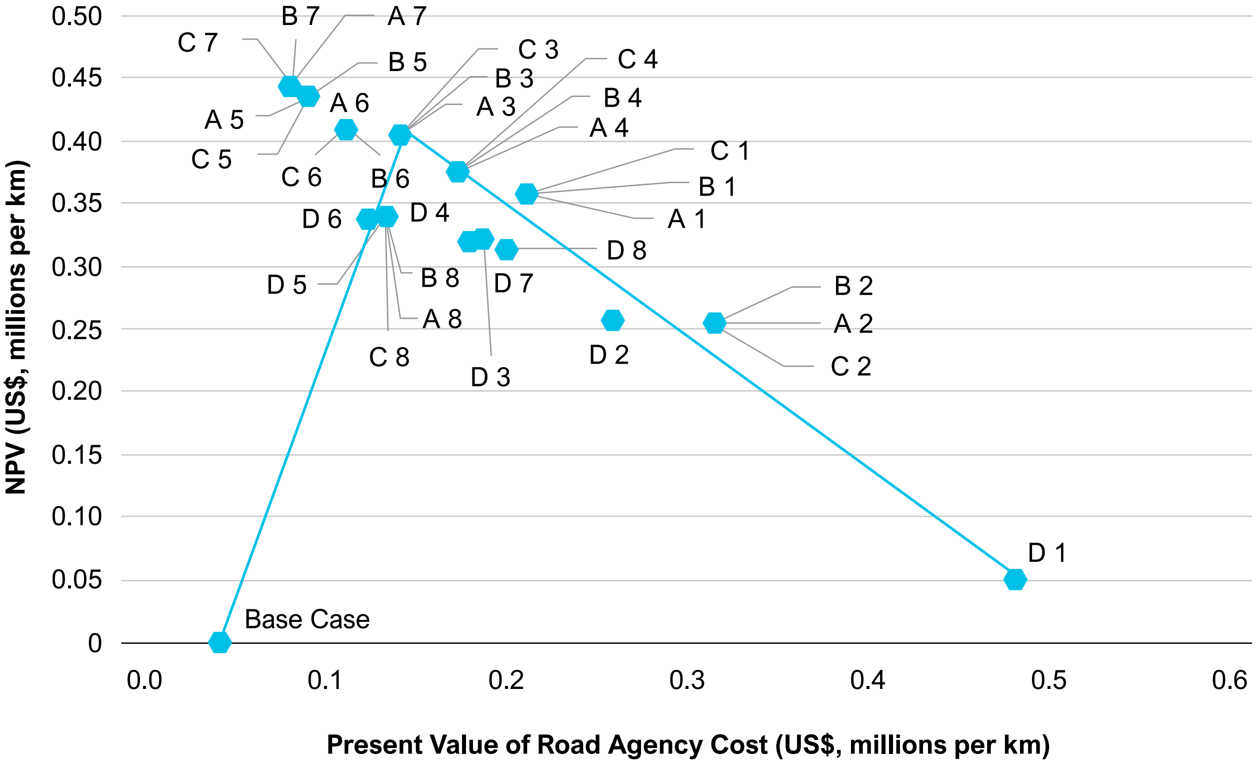


FIGURE A6.44: NPV VERSUS RAC ARGENTINA: POOR CONDITION (AADT = 750)

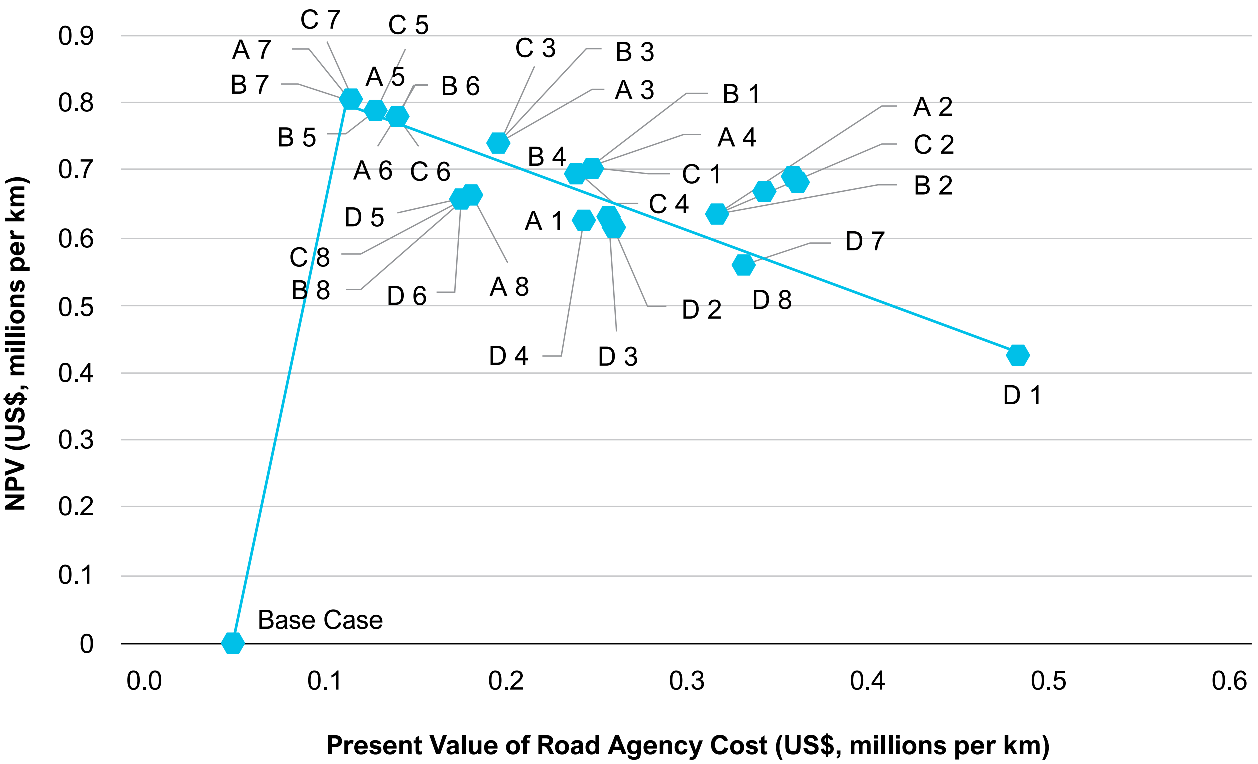


FIGURE A6.45: NPV VERSUS RAC LAO PDR: GOOD CONDITION (AADT = 7,500)

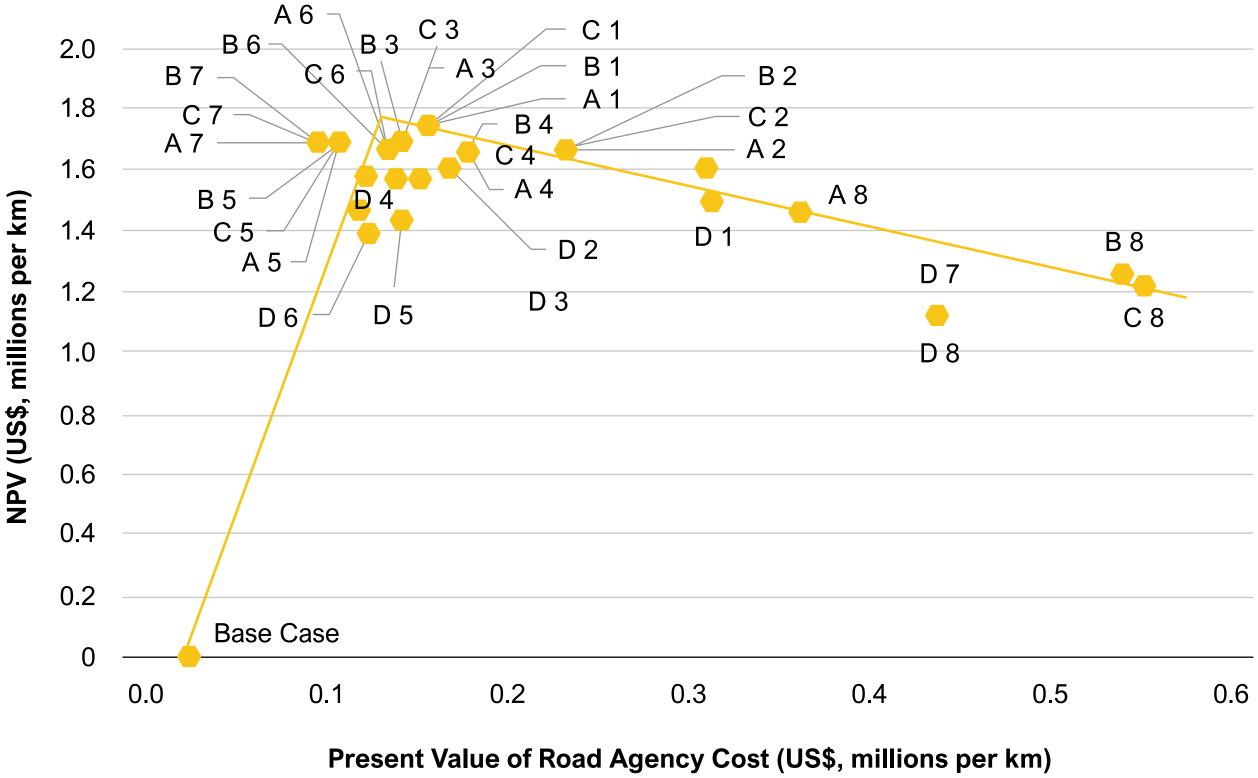


FIGURE A6.46: NPV VERSUS RAC LAO PDR: FAIR CONDITION (AADT = 7,500)

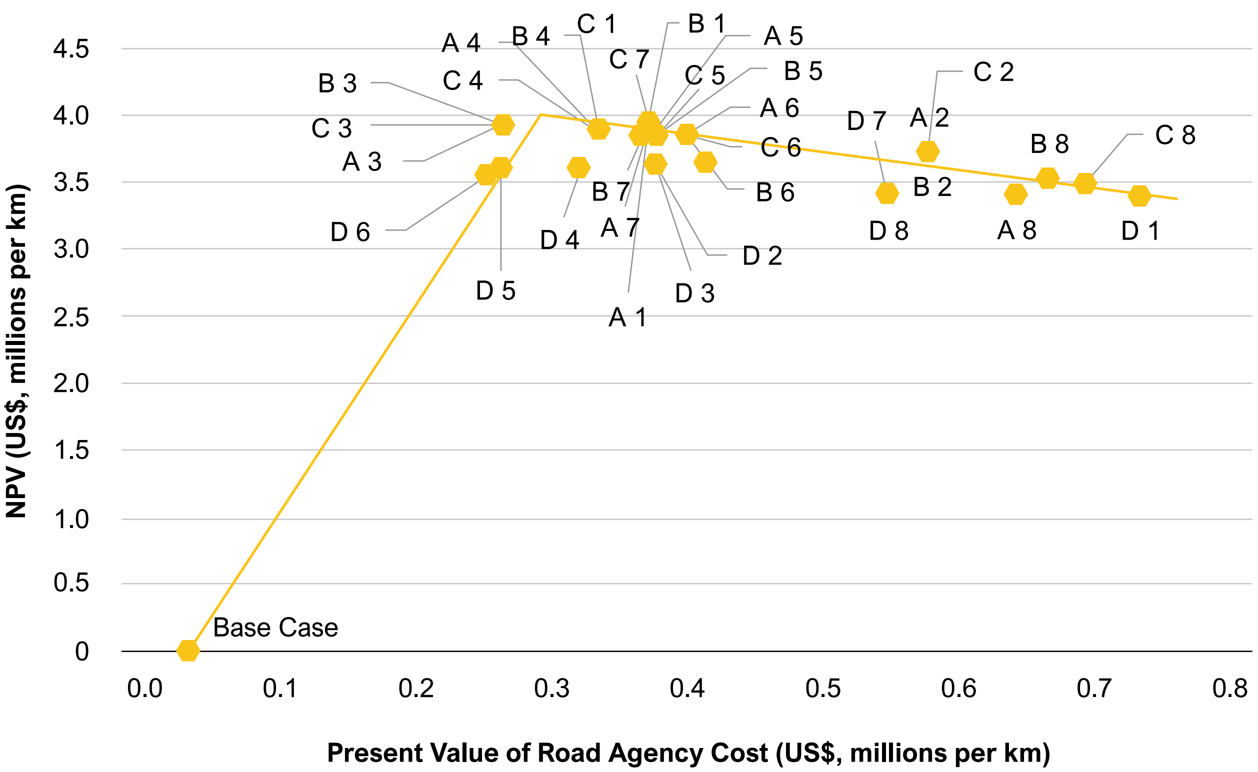


FIGURE A6.47: NPV VERSUS RAC LAO PDR: POOR CONDITION (AADT = 7,500)

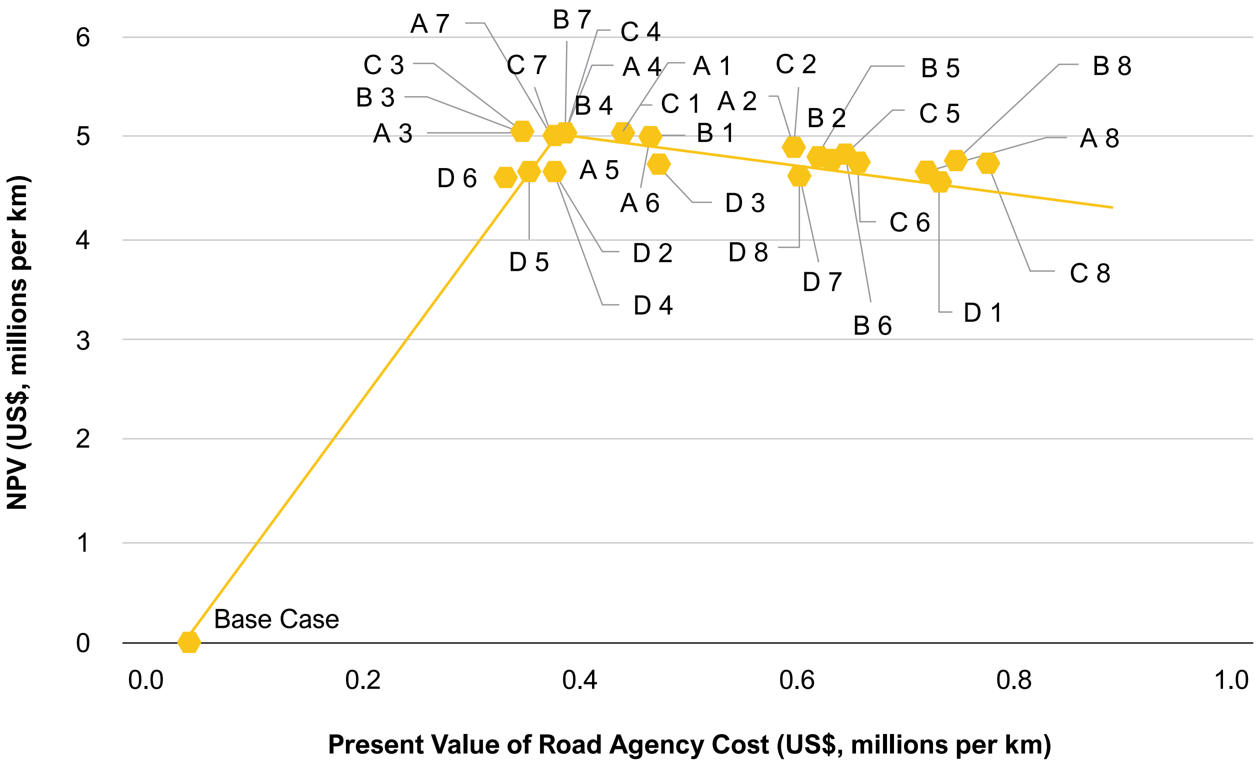


FIGURE A6.48: NPV VERSUS RAC LAO PDR: GOOD CONDITION (AADT = 3,000)

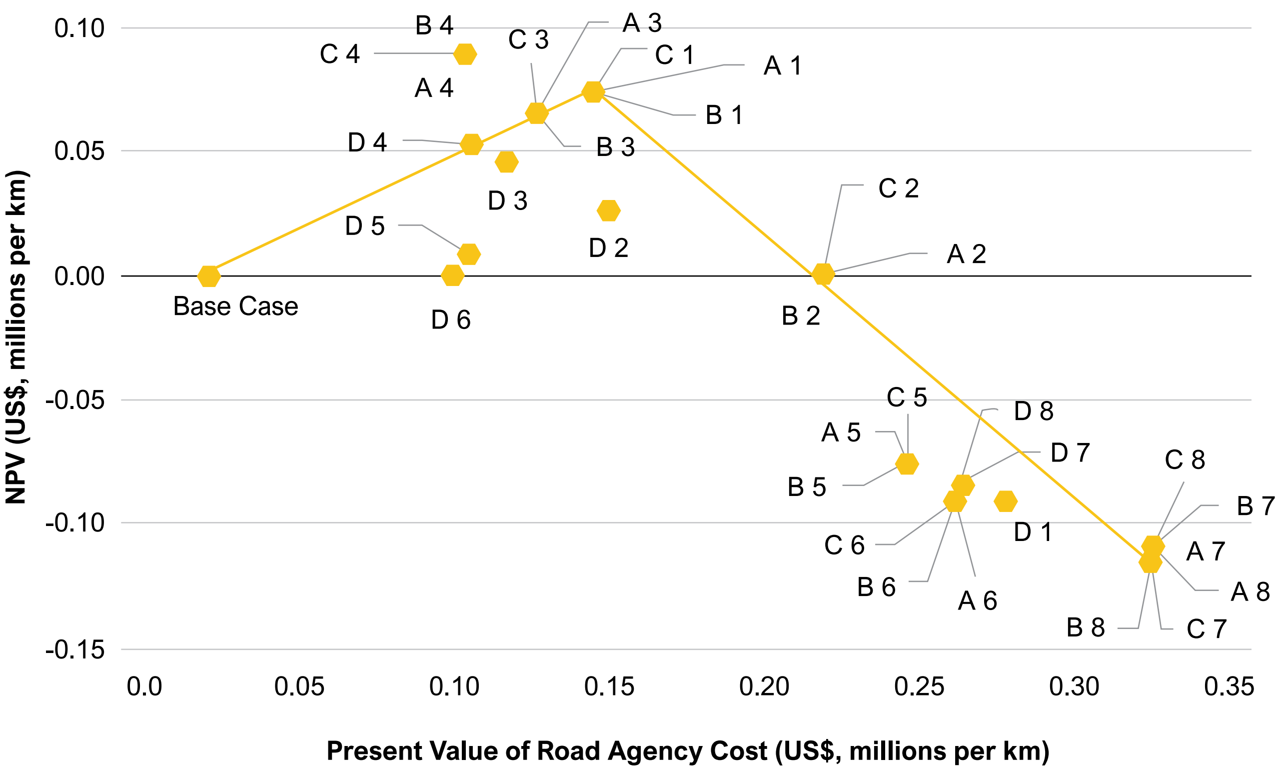


FIGURE A6.49: NPV VERSUS RAC LAO PDR: FAIR CONDITION (AADT = 3,000)

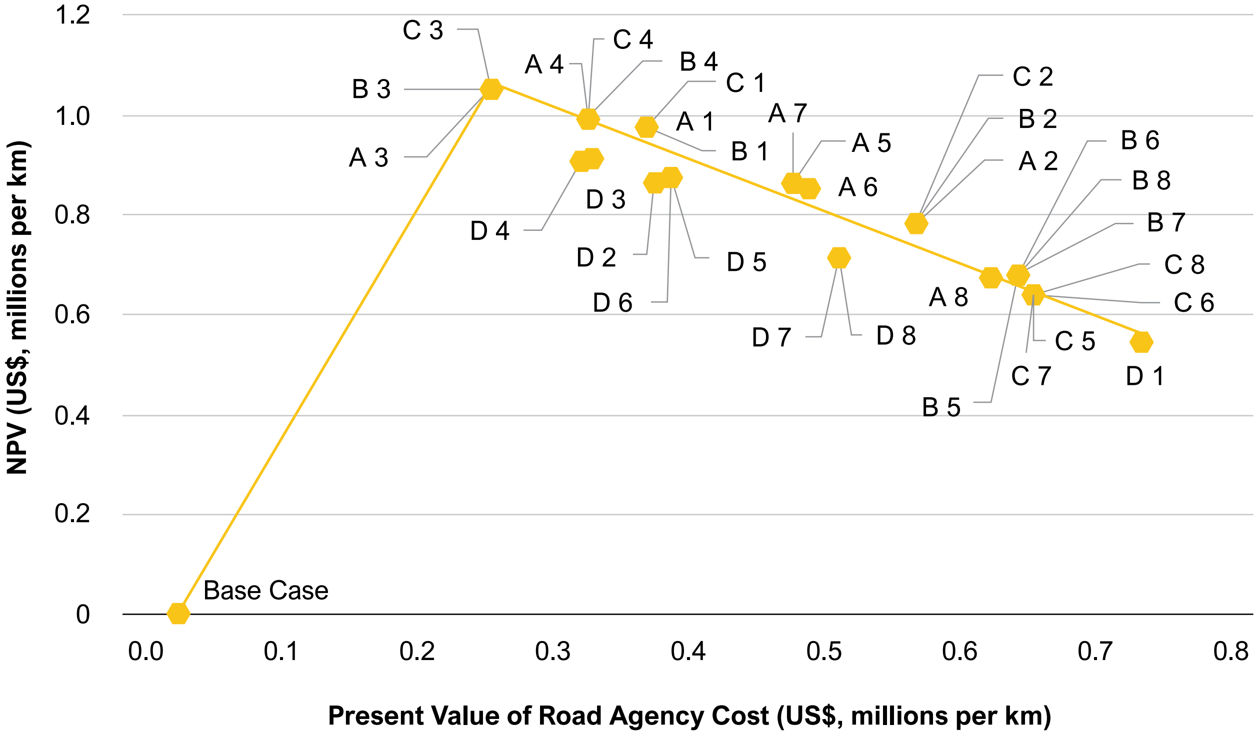


FIGURE A6.50: NPV VERSUS RAC LAO PDR: POOR CONDITION (AADT = 3,000)

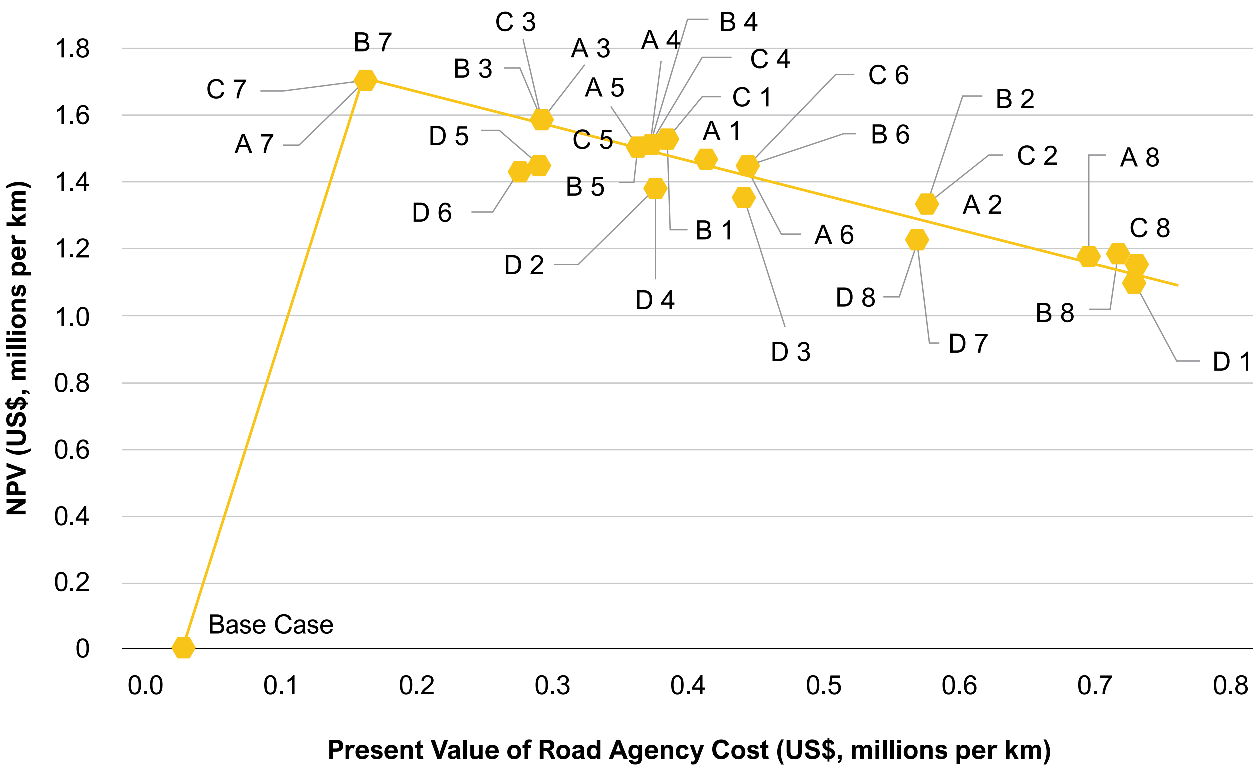


FIGURE A6.51: NPV VERSUS RAC LAO PDR: GOOD CONDITION (AADT = 750)

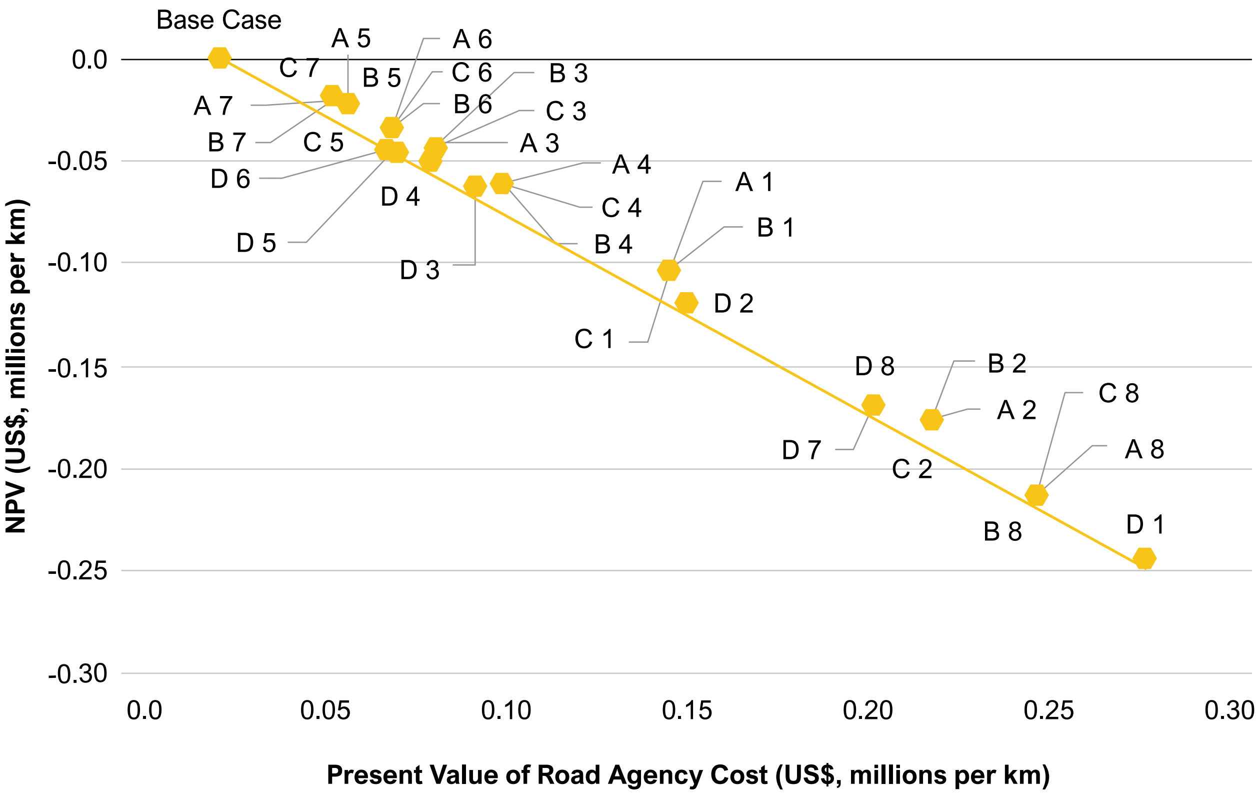


FIGURE A6.52: NPV VERSUS RAC LAO PDR: FAIR CONDITION (AADT = 750)

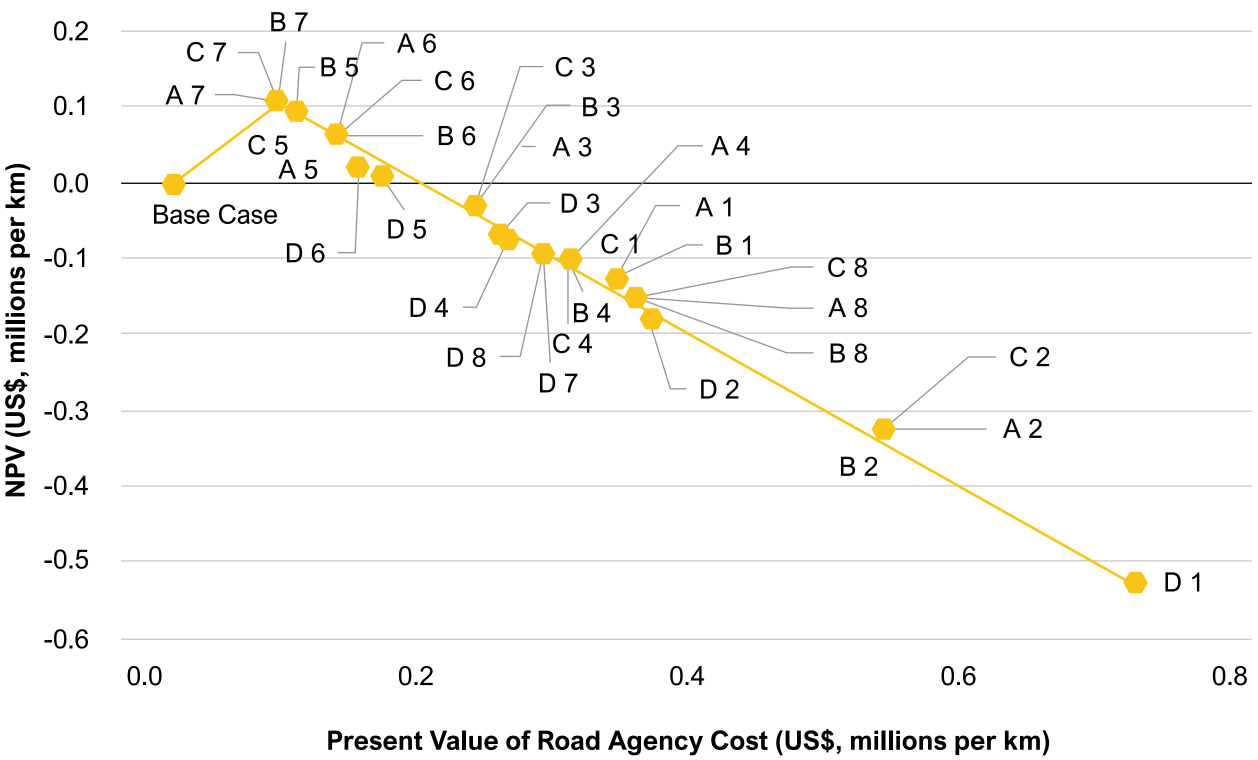


FIGURE A6.53: NPV VERSUS RAC LAO PDR: POOR CONDITION (AADT = 750)

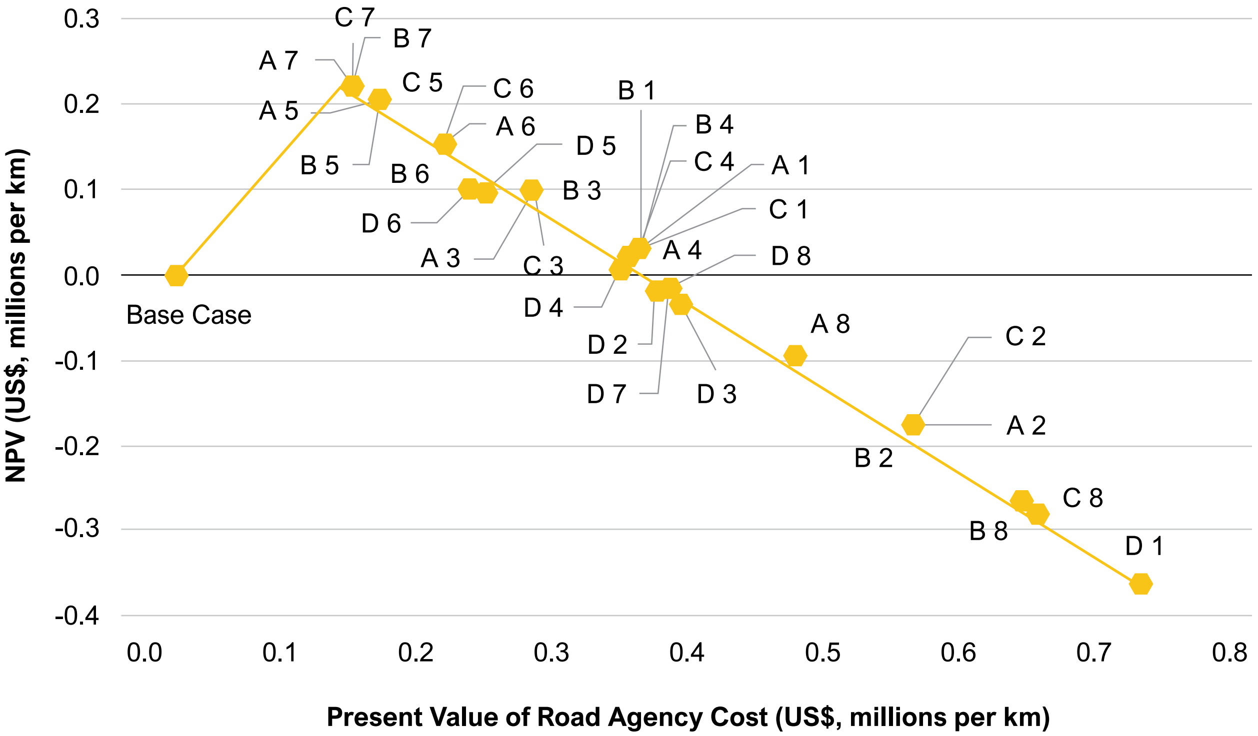


FIGURE A6.54: NPV VERSUS RAC LIBERIA: GOOD CONDITION (AADT = 7,500)

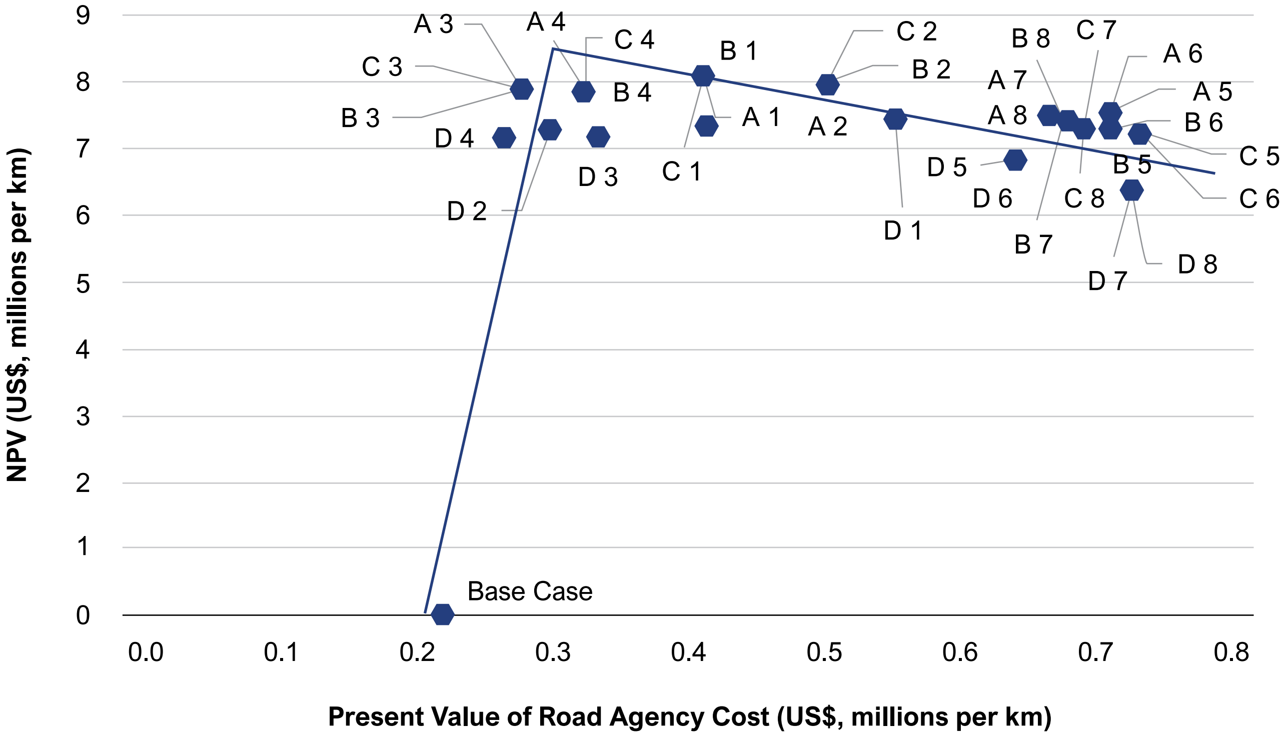


FIGURE A6.55: NPV VERSUS RAC LIBERIA: FAIR CONDITION (AADT = 7,500)

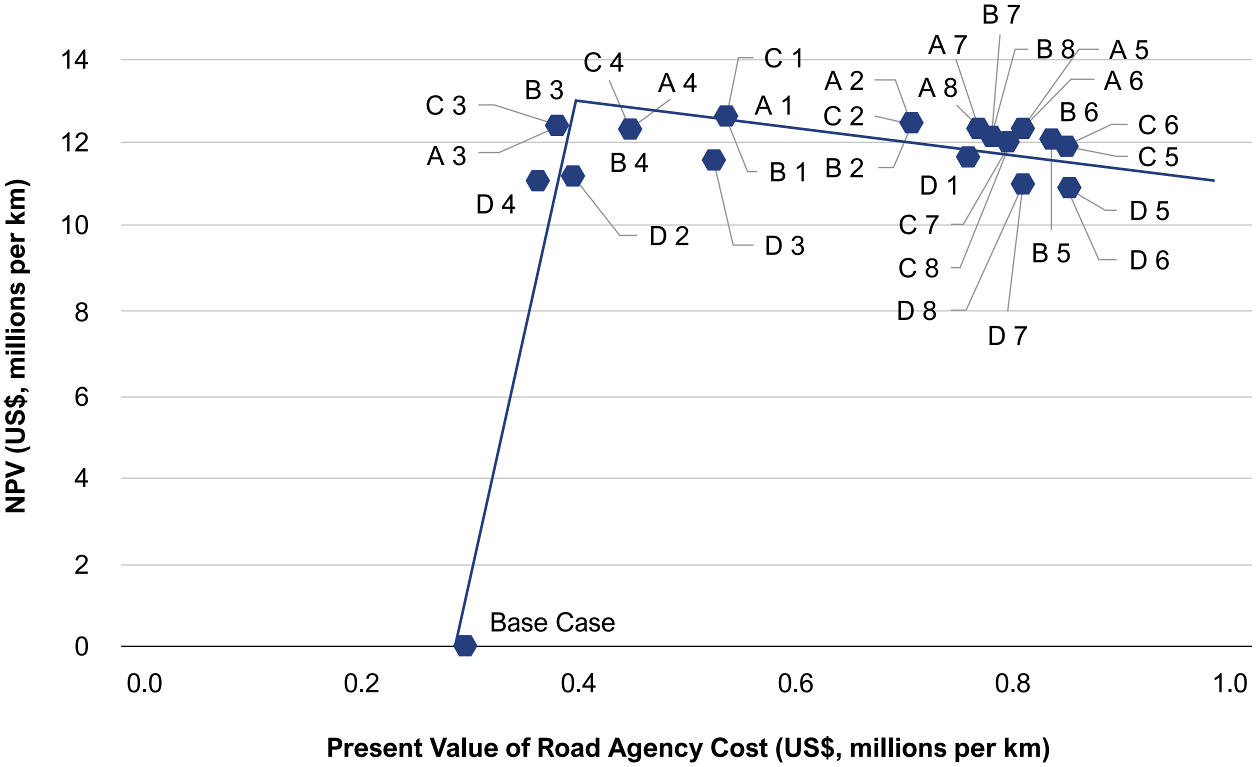


FIGURE A6.56: NPV VERSUS RAC LIBERIA: POOR CONDITION (AADT = 7,500)

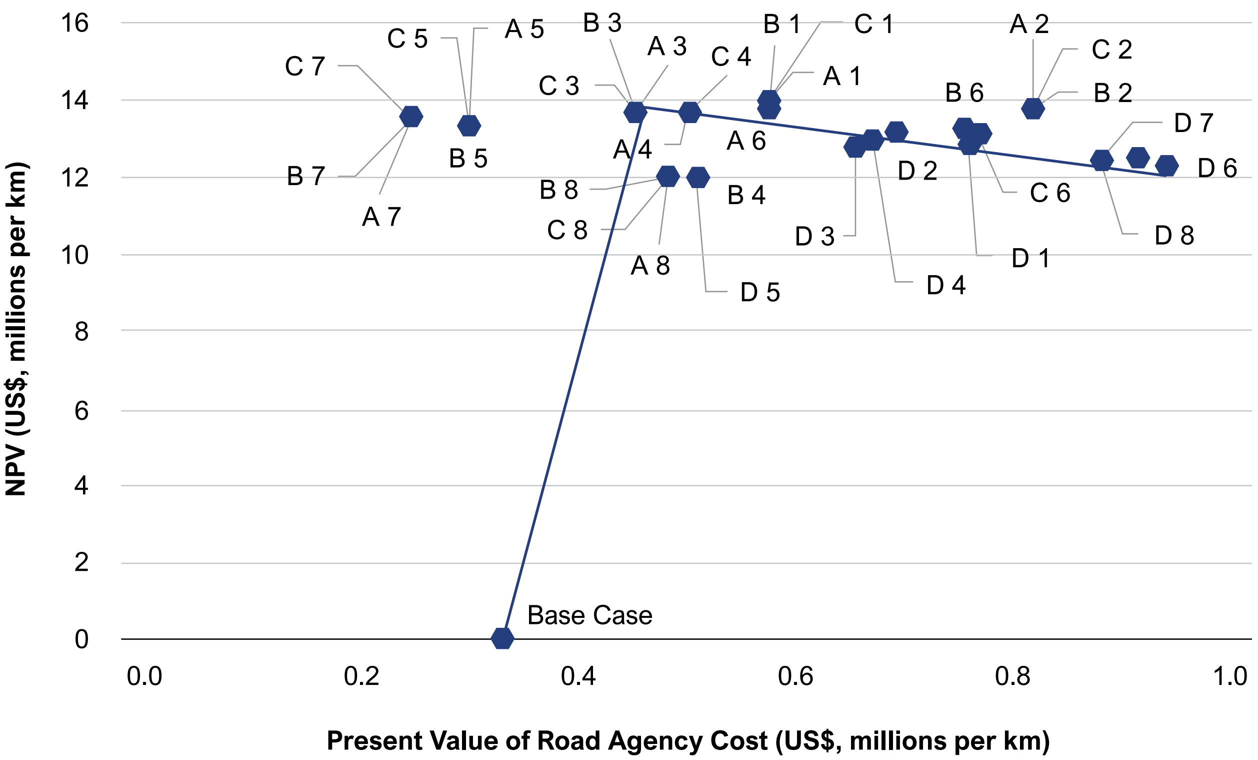


FIGURE A6.57: NPV VERSUS RAC LIBERIA: GOOD CONDITION (AADT = 3,000)

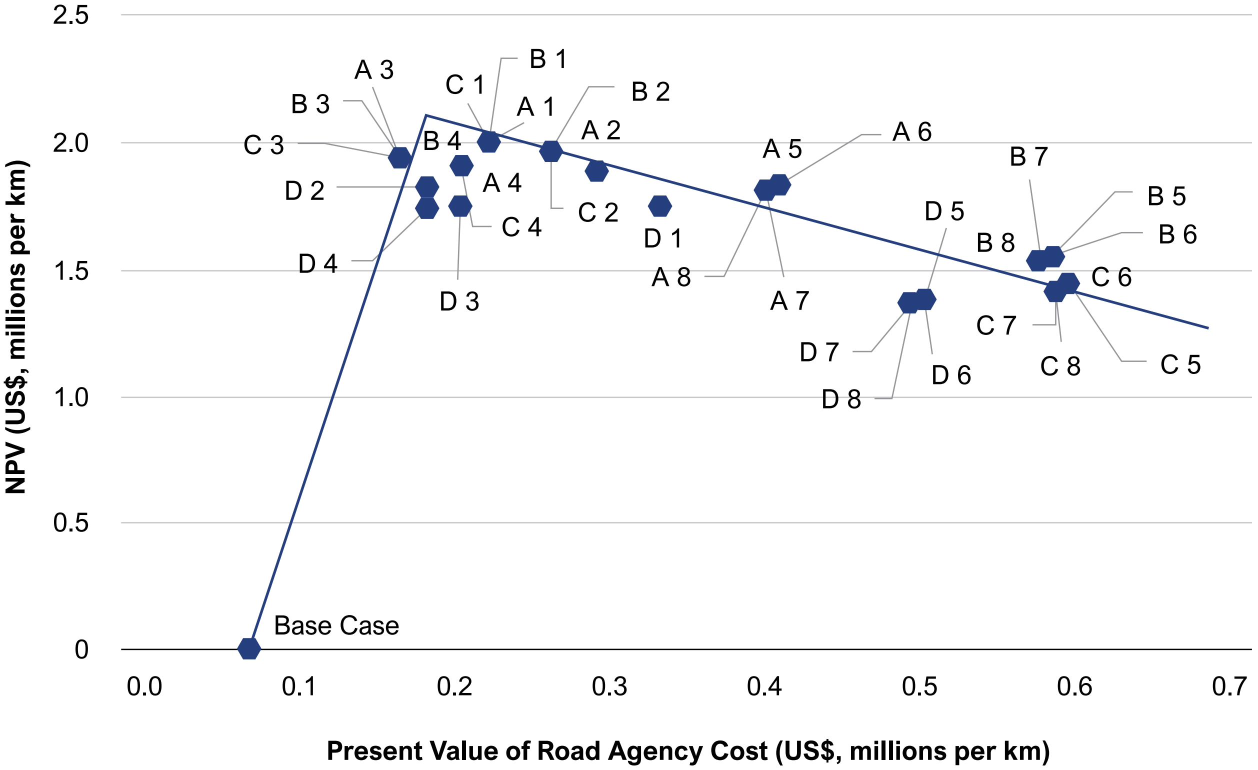


FIGURE A6.58: NPV VERSUS RAC LIBERIA: FAIR CONDITION (AADT=3,000)

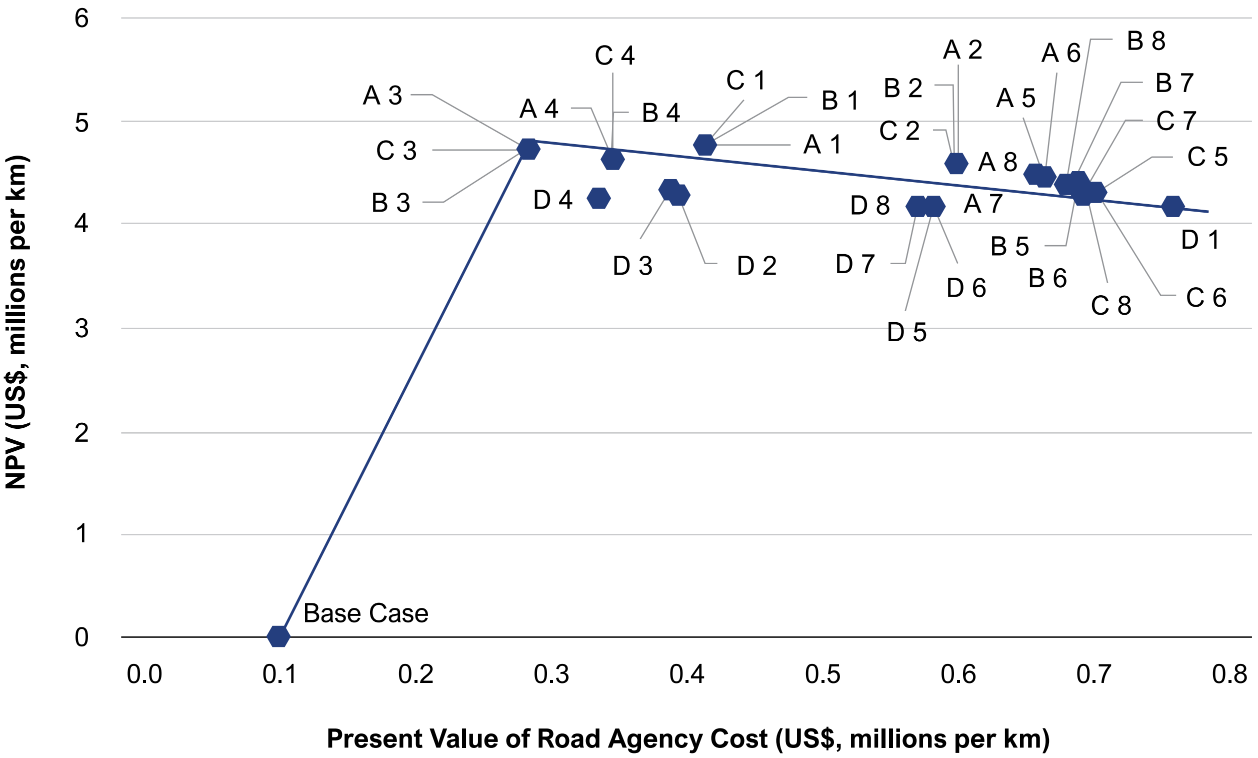


FIGURE A6.59: NPV VERSUS RAC LIBERIA: POOR CONDITION (AADT = 3,000)

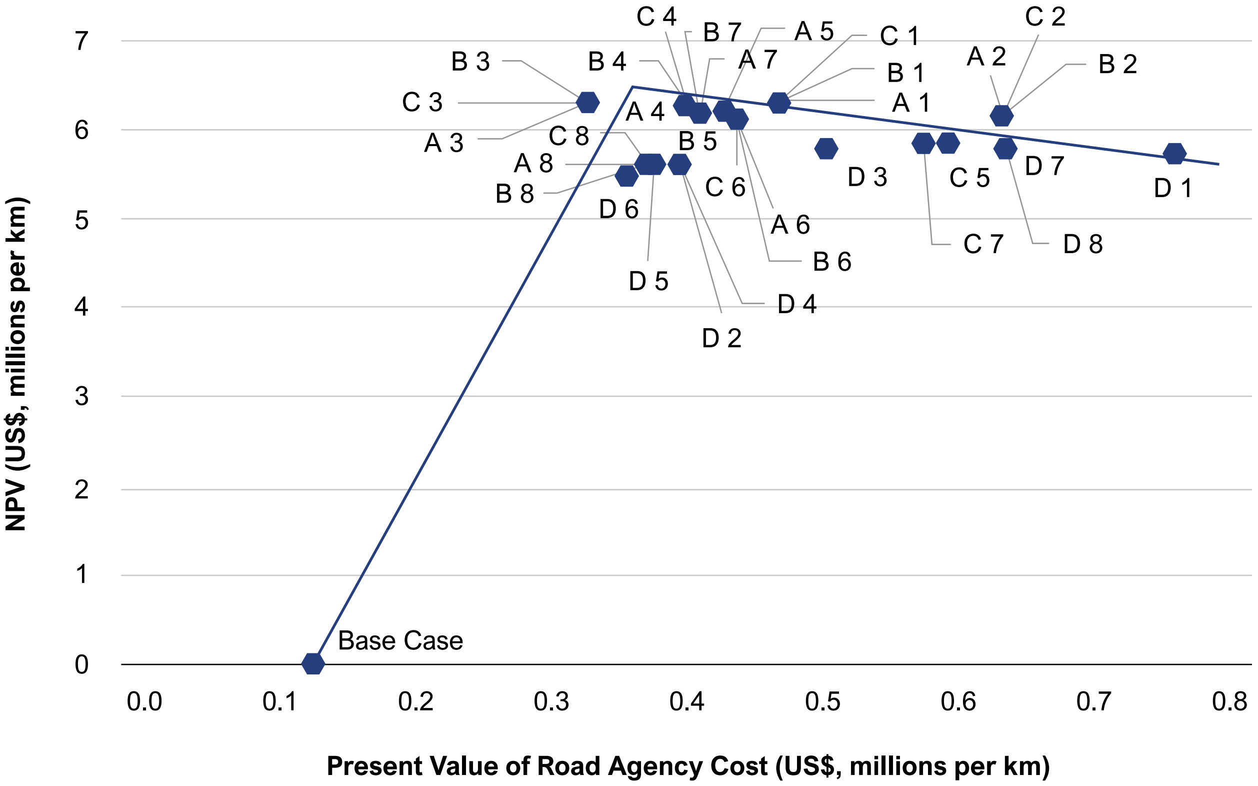


FIGURE A6.60: NPV VERSUS RAC LIBERIA: GOOD CONDITION (AADT = 750)

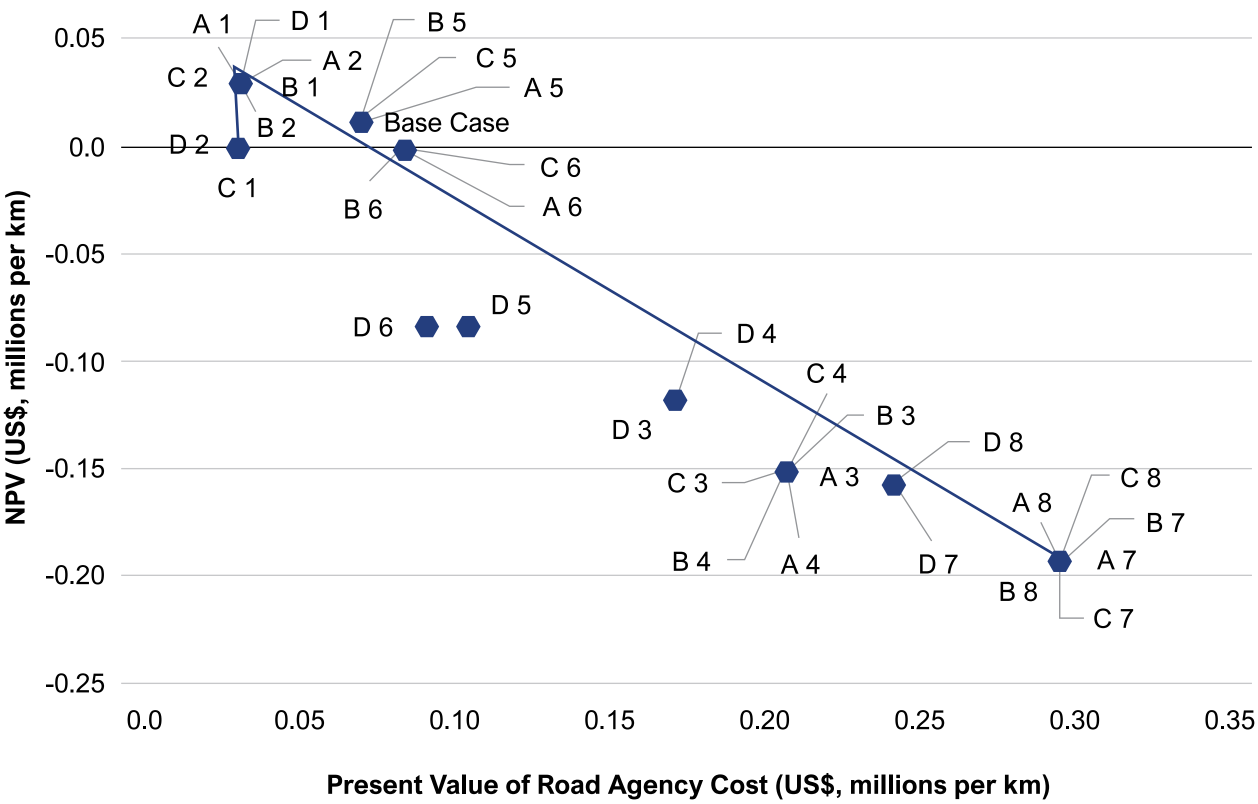


FIGURE A6.61: NPV VERSUS RAC LIBERIA: FAIR CONDITION (AADT=750)

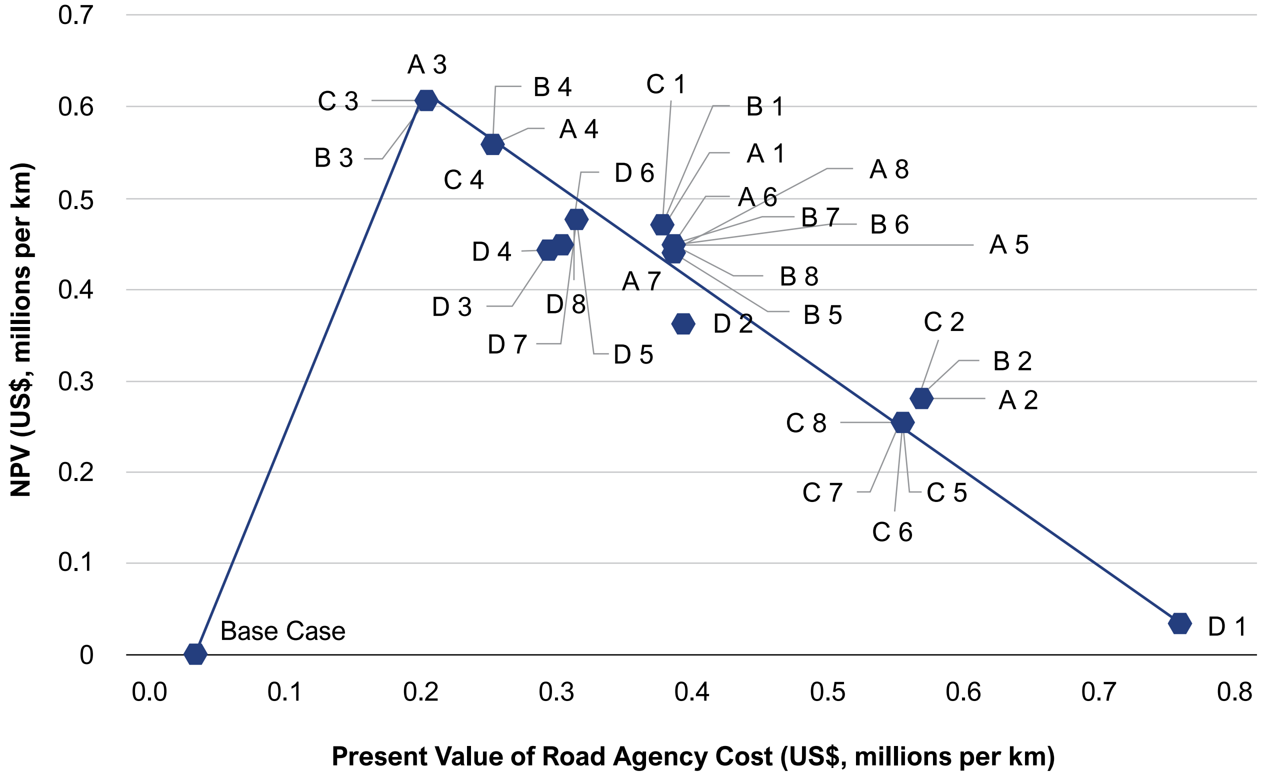
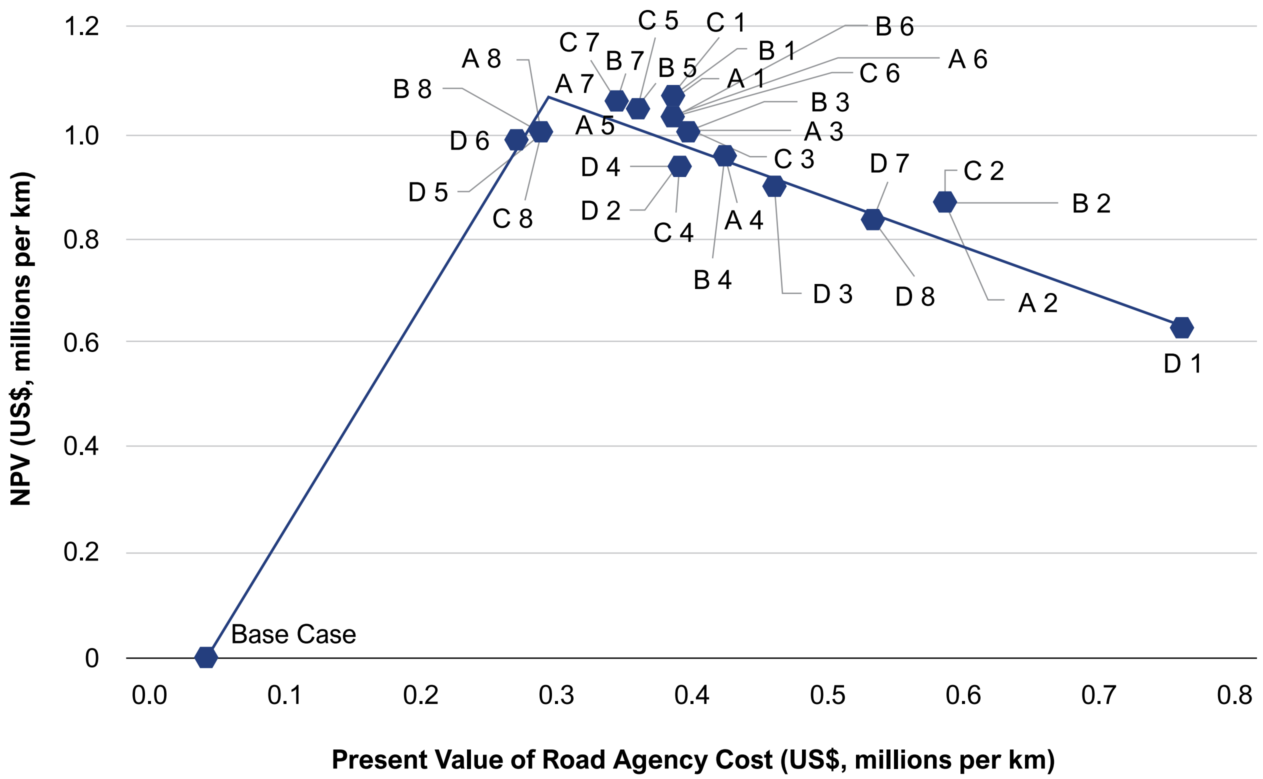


FIGURE A6.62: NPV VERSUS RAC LIBERIA: POOR CONDITION (AADT = 750)



APPENDIX 7
References

AASHTO (American Association of State and Territorial Highway Officials). 1986. *Guide for Design of Pavement Structures*. Washington, DC: AASHTO.

Babashamsi, Peyman, Nur Izzi Md Yusoff, Halil Ceylan, Nor Ghani Md Nor, Hashem Salarzadeh Jenatabadi. 2016. "Evaluation of Pavement Life-Cycle Cost Analysis: Review and Analysis." *International Journal of Pavement Research and Technology* 9: 241–254.

Donahue, J. 2014. "Life-Cycle Cost Analysis: A Tool for Better Pavement Investment and Engineering Decisions." Municipal Streets Seminar. November 12, 2014. Ames-Iowa.

FHWA. 1998. *Life-Cycle Cost Analysis in Pavement Design - In Search of Better Investment Decisions - Errata: Life-Cycle Cost Analysis in Pavement Design*. Publication No. FHWA-SA-98-079.

Harral, Clell G., and Asif Faiz. 1988. *Road Deterioration in Developing Countries: Causes and Remedies*. International Bank for Reconstruction and Development/World Bank. Washington, DC: World Bank.

Heller, P. 2005. "Understanding Fiscal Space." IMF Policy Discussion Paper 04/05, International Monetary Fund, Washington, DC.

Iimi, Atsushi, and Kulwinder Rao. 2018. Spatial Analysis of Liberia's Transport Connectivity and Potential Growth. International Development in Focus. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/29803.

Kerali, H. R., and J. B. Odoki. 2009. *The Role of HDM-4 in Road Management: HDM-4 Training Course*. September 2009. UK: University of Birmingham.

Kerali, H. R. 2001. "The Role of HDM-4 in Road Management." In *Proceedings of the First Road Transportation Technology Transfer Conference in Africa*. Ministry of Works, Tanzania, pp. 320–333.

Kane, A.R. 1996. *National Highway System Designation Act: Life-Cycle Cost Analysis Requirements*. Washington, DC: Federal Highway Administration.

OPUS International Consultants, Ltd., "Assessing Economic Efficiency of Long-Term Road Asset Management Strategies Interim Report #2 " (unpublished manuscript, February 28, 2022), typescript.

Pakkala, Pekka. 2005. "Performance-based contracts—International Experiences." Proc., TRB Workshop on "Performance-based Contracting," Finnish Road Administration, Washington, DC.

Pakkala, Pekka A., W. M. de Jong, and Juha Aijo. 2007. *International Overview of Innovative Contracting Practices for Roads*. Helsinki: Finnish Road Administration.

Porter, Tony, Ian Greenwood, Theuns Henning, and Katsuya Abe. 2014. "Delivering Good Asset Management in the Road Sector Through Performance Based Contracting." Transport Notes TRN—46, World Bank, Washington, DC.

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