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Rethinking Infrastructure Delivery: Case Study of a Green, Inclusive, and Cost-effective Road Program in Nicaragua

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Safe, Clean, Affordable TRANSPORT

RETHINKING INFRASTRUCTURE DELIVERY:

CASE STUDY OF A GREEN, INCLUSIVE, AND COST-EFFECTIVE ROAD PROGRAM IN NICARAGUA

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ABREVIATIONS AND ACRONYMS

AADT	Average Annual Daily Traffic
AF	Additional Financing (formal World Bank additions to existing agreements)
ALBA	Bolivarian Alliance for the Americas (Alianza Bolivariana para los pueblos de nuestra) *)America)*
ANE	National Road Administration, Mozambique (*Administracao Nacional de Estradas*)
BCIE	Central American Bank for Economic Integration (*Banco Centroamericano de Integración Económica*)
CBR	California Bearing Ratio
COERCO	Corporation of Regional Highway Construction Agencies (Corporación de Empresas Regionales de la Construcción)
DANIDA	Danish International Development Agency
DoLIDAR	Department of Local Infrastructure Development and Agricultural Roads, Nepal
ECA	Europe and Central Asia
EIRR	Economic Internal Rate of Return
ESAL	Equivalent Standard Axle Load
FM	Financial Management
FOMAV	Road Maintenance Fund, Nicaragua (*Fondo de Mantenimiento Vial*)
GDP	Gross Domestic Product
GIG	Green and Inclusive Growth
GHG	Greenhouse Gas emissions
HDM-4	Highway Design and Management Model
IDA	International Development Association
IDB	Interamerican Development Bank
IRI	International Roughness Index
JICA	Japanese International Cooperation Agency
LAC	Latin America and the Caribbean
LCCA	Life-Cycle Cost Analysis
MCA	Community Modules for Adoquines (*Modulos Comunitarios de Adoquinado*)

MHCP	Ministry of Finance and Public Credit (*Ministerio de Hacienda y Crédito Público*)
MTI	Ministry of Transport and Infrastructure (*Ministerio de Transporte e Infraestructura*)
NCRHP	National Cooperative Highway Research Program
NPV	Net Present Value
OECD	Organization for Economic Corporation and Development
RAAN	North-Atlantic Autonomous Region (Región Autónoma del Atlántico Norte)
RAAS	South-Atlantic Autonomous Region (Región Autonoma del Atlántico Sur)
RED	Road Economic Decision model
ROCKS	Road Costs Knowledge System, World Bank
RRIIP	Rural Roads Infrastructure Improvement Project
SADC	Southern Africa Development Community
SATCC	Southern Africa Transport and Communications Commission
SEACAP	South East Asia Community Access Program
SSATP	Sub-Saharan Africa Transport Policy Program
TRL	Transport Research Laboratory
UCP	Project Coordination Unit (*Unidad Coordinadora del Proyecto*)
WB	World Bank

PAPER STRUCTURE AND AUDIENCE

This paper is organized as follows:

Chapter 1 begins with a presentation of the community development adoquine modules (*modulos comunitarios de adoquinado,* or MCA for their acronym in Spanish) model. A summary review of the Nicaragua road sector follows and describes the general challenges and efforts that the Government of Nicaragua has faced and worked on over the years. An overview of the Government of Nicaragua-World Bank partnership follows, describing the joint cooperation in the road sector over the past four decades. More specifically, the Fourth Roads Rehabilitation and Maintenance Project (Fourth Roads Project), financed in the past six years of engagement is highlighted, and forms the bulk of the basis for the current paper. The initial content is presented in order to anchor the reader on the specific country, sector and program context.

Chapter 2 provides a synopsis on what is environmentally green about the MCA model.

Chapter 3 draws on the experiences with the MCAs.to describe how infrastructure can be delivered in an inclusive way.

Chapter 4 presents the cost-effectiveness attributes of the model.

Chapter 5 offers words of caution, with a review of the key challenges with the model.

Chapter 6 summarizes the factors that would determine the transferability of the model, including key prerequisites for its use, and the conditions that would increase the chances of its successful application.

Chapter 7 concludes the paper. It provides summary recommendations to inform policy dialogue for those contemplating similar country development programs, whether on their own, in conjunction with the Bank, or under other development partnerships.

The intended audience of this paper includes practitioners in development organizations, and road sector counterparts in different countries implementing rural road programs. It is hoped that the lessons learned could inform current and future policy decisions and help address practical rural road infrastructure delivery challenges not only in Nicaragua but worldwide in greener, more inclusive, and more cost-effective ways.

1 INTRODUCTION

1.1 PRESENTING THE MCA MODEL

This paper presents a development case study on alternative thinking in rural infrastructure delivery. Delivery in this case is achieved in a manner that advances the green growth, social inclusion and cost-effectiveness agendas. The need for green and inclusive approaches in reaching development goals cannot be overstated. At the same time, the use of public funds should ensure value for money and stretch government resources as far as they can go. Inclusion refers to the empowerment of all citizens to participate in, and benefit from the development process, removing barriers against those who are often excluded. The use of a community development approach is presented in this paper to demonstrate how this has been achieved on large scale and in a cost-effective way without compromising quality or timing. Heightened roles and responsibilities are conferred to the local target authorities and populations in this infrastructure delivery approach, and this experience is presented as a best practice that could be emulated in similar development work. On the technical front, most road infrastructure delivery in many countries is heavily mechanized and undertaken using default asphalt surfacing. This paper presents the adoption of an alternative and green paving material that is also cost-effective at the secondary rural road level.

While general context information is presented on the Government of Nicaragua's road sector and on other World Bank transport efforts over the years, this paper focuses on the past six years of engagement in a specific road program financed by the Government of Nicaragua and the World Bank relating to works undertaken with the MCA model: the Fourth Roads Rehabilitation and Maintenance Project (henceforth to be referred to as the Fourth Roads Project, including its additional financing, henceforth to be referred to as AF). The discussion is focused on two key elements: technology adopted (adoquines) and method of delivery (MCAs). Adoquines refer to precast concrete paving blocks. See Box 1 for definitions and explanation of how the model works).

Box 1: MCA Model

MCAs are local entities formed under the leadership of local mayors. Each MCA has a board of five directors, one of them serving as president and the MCA's legal representative. The MCA is charged with performing a specific road upgrading project. MCAs join together and use economies of scale to contract with an earthworks contractor and an adoquines supplier. Individually, each MCA hires its own local labor in order to construct a specified stretch of road. The MCA personnel receive technical support and training from the centralized Ministry of Transport and Infrastructure (MTI) from inception and have an MTI supervisor and promoter accompanying them throughout the implementation process. (See more details in Chapter 4). Adoquines are concrete-like paving blocks that are precast in an offsite factory. The raw materials are cement, fine aggregates, coarse aggregates, filler, and water. Other additives and pigments may be added for extra strength or color but must comply with set specifications. The adoquines can be made in different shapes and sizes and used for a variety of applications. In many countries, they are used primarily in urban streets, sidewalks, cycle lanes, parking stations, and industrial and residential compounds. One critical differentiator in their laying is that it relies on manual labor rather than on heavy or sophisticated mechanical equipment. The adoquines used for vehicular traffic in Nicaragua in the program described in this paper are hexagonal in shape and 10 centimeters thick (specifications require 8 centimeters minimum). After fabrication, the adoquines are transported to the project site to be laid as the final surface course of the newly paved road (over a sand bed and cement stabilized road base) and confined on both sides by a concrete cordon. The adoquines are laid to interlock with each other with only a minor gap between them (less than 5 millimeters). Annexes 3 and 4 provide more technical details on adoquines).

The use of labor-based construction methods and alternative road surfacing materials is not new; (See Box 2 for World Bank research history on the use of labor-based construction in the road sector. This paper presents the Nicaragua MCA road program as an engaging developmental experience in five key, differentiating ways:

- It challenges business-as-usual choices on pavement surface type (usually defaulted to asphalt) and contracting modalities (traditional contractor) by customizing a solution suited to the country context;
- It makes extensive use of locally sourced and environmentally friendly road surfacing elements that lend themselves to labor-based construction methods and that afford lower subsequent maintenance costs;
- It adopts the use of the adoquines on long stretches of rural roads, and does *not* limit it to the traditional use in urbanized streets;
- It extends the application of the labor-based model to paved roads, and does *not* limit it to the historical roles on unpaved roads, without compromising quality or undermining project budgets, and;
- It enables widespread integration of local authorities and populations in the road prioritization and construction phases with heightened administration and management responsibilities to engender ownership of the roads and to create opportunity, capability, and empowerment.

Box 2: Brief History on the Use of Labor-Based Construction Methods in the Road Sector

The most powerful arguments for labor-based road construction are the benefits it brings to local people in terms of economic opportunity, employment, and ownership. DoLIDAR research work in Nepal found that in addition to giving local people an opportunity to learn new skills and earn a wage during the time that they are employed, knock-on effects arise when some workers set up businesses for themselves by using their earning proceeds, something that they otherwise would not have undertaken. McCutcheon (2008) finds that these methods and the subsequent infrastructure delivered through them have a positive impact on poverty alleviation. He notes that per unit of expenditure, labor-intensive methods generate significantly more productive employment opportunities than conventional capital-intensive methods without compromising time, cost, or quality. The World Bank and the International Labor Organization (ILO) were among the premier international development organization to promote the use of labor-based construction in the sector. Stock and de Veen (1996) note that resistance to adoption of these methods was high, with many developing countries maintaining a capital-intensive bias even though these countries were labor-abundant and capital-scarce. World Bank research work four decades ago (World Bank 1971, 1974) found that "it is technically feasible to substitute labor for equipment for all but about 10 to 20 percent of total road construction cost. This work also determined that "labor-intensive methods are technically feasible for a wide range of construction activities, and can generally produce the same quality of product as equipment-intensive methods." One of this work's main recommendations was that "wherever the basic wage is less than about US$4 per day in 1982 prices, and labor is available in adequate quantities, the alternative of using labor-intensive techniques should be seriously considered." It is important to note that the historical approach has been the involvement of labor-based approaches for gravel road rehabilitation and for routine maintenance purposes. Stock and de Veen (1996) note that these methods not only produce gravel roads of equal quality to those produced using labor-based methods but that they also generate rural employment in a cost-effective manner. Stock and de Veen also find that labor-based methods create around 15 times more employment per kilometer than equipment-based methods. Further, they also find that these methods combine the employment benefits of public works with the efficiency benefits of private sector delivery. One key recommendation from their work is the need to use the most effective combination of labor and equipment for gravel road rehabilitation. The current work demonstrates how this message was taken to heart and extended to paved (adoquine) roads.

1.2 NICARAGUA ROAD SECTOR CONTEXT

Despite concerted efforts, and some promising results in the fight against poverty, Nicaragua remains one of the poorest countries in its region. On the infrastructure front, the Global Competitiveness Report 2013–14 (Schwab 2013) places the country at 105 out of 148 countries with a score of 3.14 out of a possible 7. This is an improvement over 2012–13's miserly score of 2.97.

According to the MTI, Nicaragua's road infrastructure stock totals some 23,647 kilometers, of which only 3,151 kilometers (13 percent) is paved The adoquine roads amount to some 800 kilometers (a quarter of the paved road network). Of these, about 620 kilometers have been financed under Government of Nicaragua–World Bank cooperation. It is estimated that about one-third of the population has access to a paved road. MTI data also indicates deficiencies in the condition of the core road network. Of the 8,142-kilometer core, only 42 percent of roads are in good or fair condition. (If local roads are included, this falls to less than 25 percent). These infrastructure quality deficiencies seriously restrict mobility and overall network connectivity while posing adverse development risks for the country's economy in terms of high costs of transport, losses in productivity, and diminished competitive advantage in the region. The insufficiency of other transport modes, primarily water and air transport systems, makes the road network vital to the country's overall economic development.

Moreover, with about two-thirds of the poor living in the rural areas, and agricultural and livestock activities contributing 30 percent of the country's gross domestic product (GDP), the need to provide better, more reliable roads to improve economic outcomes has been a pressing imperative for quite some time. The rural roads complement the national trunk roads to form an integrated road network that allows for the efficient movement of goods and people within the country, and it is thus the backbone of key productive economic activity.

In summary, the main issues facing the road sector in Nicaragua are (i) infrastructural deficiencies in the form of an underdeveloped road network; (ii) an inefficient customs and logistics system in general (road transport services challenges, warehousing challenges, customs challenges); (iii) an unfunded maintenance mandate that is made even more burdensome by the transit of overloaded vehicles without adequate cost-recovery mechanisms; and (iv) the increasingly frequent occurrence of natural disasters that cause significant damage to road and bridge infrastructure, leaving some areas of the country with limited or no connectivity when they occur and with huge and unplanned for repair bills. The Government has been working vigorously on all fronts to confront these challenges, both with its own resources and in collaboration with multilateral organizations; bilateral organizations and private partners including: the Bolivarian Alliance for the Americas (ALBA for its acronym in Spanish); the Central American Bank for Economic Integration (BCIE for its acronym in Spanish); the Interamerican Development Bank (IDB); the Danish International Development Agency (DANIDA); The European Commission (EC); the Japanese International Cooperation Agency (JICA); and the World Bank through the International Development Association (IDA), among others.

Efforts toward addressing road infrastructural bottlenecks are derived from the Government's National Human Development Plan. The main entities spearheading efforts in the sector are the MTI and the road maintenance fund (FOMAV). The rural road infrastructure is being improved to contribute to economic development and poverty reduction, with a strong focus on undertaking works in the productive regions of the country. The road improvements have had significant impacts on the economic welfare of the beneficiaries—rural populations (poor and non-poor), agricultural producers, and transporters. The evidence base for this is documented in separate project impact evaluation reports (Roughton International 2012; Jimenez 2013).

1.3 THE NICARAGUA–WORLD BANK PARTNERSHIP IN THE ROAD SECTOR

The Bank has a long history of successful engagement in the country on roads projects since the early 1990s. It has worked in conjunction with the Government of Nicaragua (through MTI and FOMAV) to finance projects that made significant contributions to both the country's broader poverty reduction strategy and to general economic development by: (a) contributing to the removal of infrastructure bottlenecks, and (b) improving the institutional capabilities of the main entities responsible for administration and management of the sector (MTI and FOMAV). The focus on infrastructure aligns with one of the key pillars in the World Bank Group Country Partnership Strategy (FY2013–2017) (see World Bank 2012b) and is also in line with the WBG's twin goals of ending poverty and promoting shared prosperity. (See also annex 1).

The current World Bank portfolio includes the two latest in a series of five operations (see Box 3). The Fourth Roads Rehabilitation and Maintenance Project finances the rehabilitation of national roads (asphalt), periodic maintenance on national roads (asphalt overlay), and the paving of secondary (collector) roads to adoquines or concrete standards. The latter is the main focus of this report.

Box 3: Summary Information on Ongoing World Bank–Government of Nicaragua Road Projects

Fourth Roads Rehabilitation and Maintenance Project (including Additional Financing)

1. Direct beneficiaries: approximately 386,980 people identified for original project, of which 195,425 (51 percent) are female. There are additional beneficiaries for road sections under the additional financing.
2. Community participation in road construction with over 8,000 short term jobs created, engenderment of an entrepreneurial spirit, enhancement of technical skills, and ownership of the roads. Other jobs under other private contracts yield total employment prospects of almost 18,000 jobs.
3. Geographical area of intervention: Boaco, Carazo, Chinandega, Esteli, León, Madriz, Managua, Masaya, RAAS, and Rivas
4. Road rehabilitation and improvement:
   - 58 kilometers of roads rehabilitated
   - 355 kilometers of road paved with adoquines
5. Cooperation with FOMAV on road maintenance
   - 84 kilometers of roads with periodic maintenance
   - 40 microenterprises formed for routine road maintenance of 2,480 kilometers
6. Benefits for country competitiveness and export promotion in productive zones of country (main agricultural products: coffee, beef, milk, beans, and sugar cane) with faster and more reliable delivery and product delivery in better condition (critical for cattle and motion-damage-sensitive agricultural produce)
7. Improved connectivity and access to the infrastructure-deficient Atlantic region with a new road section, Nueva Guinea to Naciones Unidas, with a length of 24 kilometers
8. Improved capacity in road asset management, social and environmental management, and design and supervision of road projects

Rural Roads Infrastructure Improvement Project (expected results)

7. Direct beneficiaries: 74,445 people, of which 37,595 (50.5 percent) are female
8. Geographical area of intervention: Granada, Leon, Managua, Matagalpa, and Rivas
9. Rural improvement
   - 88 kilometers of road paved with adoquines
10. Cooperation with FOMAV on road maintenance
    - 40 kilometers of roads with periodic maintenance
11. Improving connectivity and access to the Atlantic region, Rio Blanco to Mulukuku, 10 kilometers
12. Improved institutional capacity of MTI in road asset management, disaster risk management, road safety, and axle load control

To stretch resources further, in kilometers and in social impact, the Government has combined a road-building technique (using adoquines) with an extended version of the community-driven development approach to implement larger scale projects: MCAs. The MCAs have taken on the responsibility of paving unconventionally long sections (on one specific stretch, MCAs built 27 kilometers of road) with significantly lower than traditional costs, without compromising quality, and while also engendering ownership of the roads. There is also substantial gender and youth participation in the MCA approach, helping to address recurring development challenges and in some limited way contributing to the alleviation of unemployment concerns. Box 4 summarizes the Nicaraguan history with the use of adoquines.

Box 4: Nicaragua's History with the Use of Adoquines

Nicaragua has a rich history of engagement in the road sector with the use of different pavement types and contracting modalities. Cantarero and Mendez (2007) note that the use of adoquines runs back more than four decades to the year 1972 with the construction of the 32-kilometer stretch of the road Empalme Santa Rita–Empalme Masachapa. This road was designed, built, and supervised under force account by the then Ministry of Public Works (the current MTI). To this day this stretch is still in use and in fairly good condition, acting as the main communication road to the municipalities of El Carmen and Masachapa, located in the Pacific coast areas (with a vibrant tourism industry and active sugar cane production).

The main benefits arising out of road sector engagements in Nicaragua include the following:[1]

- **Wider economic benefits to agricultural producers and transporters:** These include important economic benefits (for example, lower vehicle operating costs and reduced travel times) with improved access to markets for agricultural and livestock producers, transporters, and exporters in different departments of the country. The benefits arise from the improvements in connectivity and reliability of the road network in the productive zones of the country as well as on the national trunk road network.

- **Localized economic benefits for local populations:** Contributions to improved standards of living of the local beneficiaries are due to the elimination of dust during the dry season and mud during the rainy season, reduction of vehicle operating costs, reductions in travel times, and more reliable and more

[1] As mentioned before, the justifications for these points are documented in the project impact evaluation reports (Roughton 2012; Jimenez 2013). Annex 1, "Why Invest in Rural Road Infrastructure?" also provides supporting evidence.

comfortable commutes to access education, health, markets, jobs, and administrative services. The use of the MCA model has led to the generation of short-term employment opportunities, skills building, and the engendering of a sense of community and ownership of the roads, leading to better sustainability of the investments.

- **Ancillary local economic benefits:** Local economy benefits arise from a boost to local adoquine manufacturers, other materials providers, transportation companies, and earthworks contractors. Other benefits are attributable to improvements in tourism, improved land values, and attraction of new businesses and professionals to the rural areas.
- **Improvements in institutional capabilities:** Important efforts are made in strengthening the planning, construction, and maintenance capabilities of both MTI and FOMAV by building experience in the management of assets (conducting road inventories, traffic surveys, economic prioritization models, and technical courses, and financing equipment purchases); road maintenance (microenterprise model); and disaster risk management planning and execution.
- **Road agency and municipality cost-saving benefits:** The switch to more durable pavement options and funding of maintenance to preserve and restore road conditions results in longer term savings for the road agency and municipalities in their management and financing of the road network.
- **Leveraging of resources:** The program has facilitated successful engagement with other financing institutions and thus leveraged Bank resources in the country. For example, the US$39 million AF to the Rural Road Infrastructure Improvement Project and the US$35 million Rural Road Infrastructure Improvement Project (RRIIP) Bank financing (total US$74 million Bank financing) have been accompanied by BCIE with two projects to the tune of US$95 million in leveraged funds.

Table 1 provides a summary of the adoquine road program engagement only. Roads surfaced with other surfacing (concrete, asphalt) are not included in this table. At the time of the writing of this paper, the RRIIP had only recently started, while the Fourth Roads Project is nearing completion.

Table 1: Government of Nicaragua-World Bank Project Road Lengths (1996–2012)

	First project	Second project	Third project	Fourth project	AF fourth project	Total
Total roads rehabilitated/received periodic maintenance/paved*	**65 km**	**90 km**	**204 km**	**281 km**	**204 km**	**844 km**
Adoquine roads (all modalities)	0 km	70 km	203 km	198 km	158 km	**629km**
Adoquine roads (MCAs only)	0 km	0 km	0 km	121 km	133 km	**254 km**

Source: UCP-WB/MTI and World Bank.
Note: km = kilometers, AF = additional financing.
* Does not include road lengths with routine maintenance only, and also does not include Rural Roads Infrastructure Improvement Project.

This paper describes only the works executed through the Fourth Roads Project (including its AF). Through this project, a total of 38 road sections were paved with adoquines by 272 MCAs for a total length of about 254 kilometers.
(See distribution by modality in Table 2). Annex 3 provides more details on the road sections constructed with the MCA modality under the project.

It is important to note two main points. First, under the MCA modality, there is still substantial participation of the private sector in the delivery of the infrastructure: the manufacture and transport of the adoquines and earthworks construction. The main difference is that the MCAs and local administration authorities are in charge of the process and that the MCAs contract their own labor to carry out the adoquine paving process and other ancillary works. Second, the force account modality—the Corporation of Regional Highway Construction Agencies (*Corporación de Empresas Regionales de la Construcción*, or COERCO), a semiautonomous state corporation of regional construction firms—is not the typical force account mechanism. In the COERCO case, the corporation operates on commercial principles, and under the law has some form of autonomy from other state organs. It is not just a collection of districts or departments with equipment.

Table 2: MCA Adoquine Distribution by Contracting Modality

Modality	Adoquines (All)	Adoquines (MCA)	Adoquines (private contractor)	Adoquines (force account-COERCO)
Fourth Project	198 km	121km	55 km	22 km
AF Fourth Project	158 km	133 km	18 km	6 km
Total	**356 km**	**254 km**	**74 km**	**28 km**
Percentage	100%	72%	21%	7%

Note: km = kilometers.

As per Table 2, in the Fourth Roads Project the adoquine roads have been built by private companies, using force account and through the MCAs, with the majority under the MCAs modality (72 percent). The latter is a contract modality whose main objective is to use local labor, both skilled and semi-skilled, for the adoquine road construction. The major earthworks are contracted to the private sector, as is the supply and provision of the main construction elements themselves (adoquines). The contracts of the MCA have been successful on both the quality and cost fronts, with fast execution and disbursements. As such, the Government of Nicaragua is actively promoting these contracts for projects financed by the World Bank as well as other financing organizations, such as BCIE.

2 PAVEMENT CHOICES

2.1 GENERAL CONSIDERATIONS

The successful provision of a low-volume sealed road requires ingenuity, imagination and innovation. It entails "working with nature" and using locally available, nonstandard materials and other resources in an optimal and environmentally sustainable manner. It will rely on planning, design, construction and maintenance techniques that maximize the involvement of local communities and contractors.
— *Guideline: Low-Volume Sealed Roads* (SATCC 2003)

This quote from the Southern African Transport and Communications Commission is as relevant today as when it was first published. Pavement-type selection is one of the challenging decisions that road administrators face. They must balance issues of short- and long-term performance with initial and long-term costs as well as highway user impacts. For any given project, the selected pavement type is expected to provide the maximum utility value for taxpayers and road users over a predetermined design and analysis period. The traveling public generally does not express strong feelings on the type of pavement constructed, as long as reasonable levels of service, safety, and ride quality are provided (NCRHP 2011). Therefore, in making the decision to pave a road, a number of surfacing options have to be explored. The typical options range from the do-nothing option of leaving the road unpaved (earth or gravel) to surfacing options including new gravel layer, surface dressing, otta seals,[2] asphalt, concrete, coarse naturally occurring stones (*empedrado* for their name in Spanish), or use of paving blocks (adoquines or similar). While there are advantages and disadvantages to each option, a number of factors determine the ultimate choice.

The typical questions that have to be asked and analyzed in determining the chosen pavement surface and consequent design choices are as follows:

- What is the functional classification of the road?
- What are the projected opening-day and projected design-life traffic levels on the road?
- What are the heavy-goods vehicle axle-loading realities and projections?
- What is the structural capacity and design life offered by the chosen surface solution?
- What riding conditions does the chosen surface solution offer?
- How green is the chosen surface solution?
- What are the climatic conditions in the road area?
- How vulnerable is the area to natural disasters?
- What type of terrain does the road traverse?

[2] Otta seals are 16 millimeter to 32 millimeter thick bituminous surfacings constituting an admixture of graded aggregates, ranging from natural gravel to crushed rock, combined with low viscosity binders with or without a sand seal cover.

- Are there sections with steep longitudinal gradients?
- What is the quality of existing road bed (subgrade) materials?
- What is the adequacy of current drainage systems?
- How far/remote is the road from a major urban center?
- What is the availability of road construction materials (type, quality, and haulage distance)?
- Can local people be involved heavily in the construction process?
- What are the mechanical needs for delivering the infrastructure solution?
- What are the technical capabilities needed to deliver the solution, and do they exist locally or need to be sourced nationally?
- What quality control system is proposed?
- What are the provisions for road safety (during construction but also during operation and maintenance)?
- What is the current maintenance regime and proposed maintenance strategy for this or similar roads?

The green question is only one of a number of considerations but nevertheless one that is very important as it relates to many other questions in the list. The pavement type selected for the rural roads analyzed in this paper is adoquines, and it does exhibit some green credentials. The term *green* is used in the context of road construction materials that are clean, resilient (durable), and friendly to the environment.

In some countries like Vietnam, extensive studies have been done to trial different road surfacing types on different rural roads in different regions to gauge performance. The range of surfaces tested included emulsion surface treatments, otta seals, surface dressing, dense bitumen macadam, lime stabilized and cement stabilized options, non-reinforced concrete, concrete blocks (adoquines), clay bricks, and mortared macadam (Intech, TRL, and TDSI 2009).

The first decision must be to choose whether to pave the road or use gravel. Box 5 provides a synthesis of cases in which the gravel consideration is not recommended.

Box 5: When Not to Use Gravel as a Final Surfacing Course

- **Gravel quality is poor:** Gravel should comply with grading and plasticity requirements and not break down under traffic, otherwise it will be lost from the surface at a high rate. Natural gravel quality varies substantially within each pit location and with depth. Great care is essential to ensure that only suitable material is selected, and that mixing of marginal/unsuitable material is avoided
- **Compaction and thickness cannot be ensured:** Un-compacted surface gravel will be less durable. Supervision arrangements should ensure that the full specified compacted thickness is placed.
- **Haul distances are long:** If haul distances are longer than 10 kilometers, then other surface types may be cheaper in life-cost terms. Hauling gravel for construction and periodic maintenance causes damage or further maintenance liabilities to the haul routes
- **Rainfall is very high:** Gravel loss is related to rainfall and may be excessive with intense storms or where annual precipitation is greater than 2,000 millimeters.
- **There are dry season dust problems:** Long dry seasons can allow the binding fines to be removed from the surface by traffic or wind. This is particularly problematic where communities live beside the road or their crops and property are regularly coated in dust. Inhalation of road dust is unhealthy, and there are also safety issues related to visibility.
- **Traffic levels are high:** Gravel loss is related to traffic flows. It is unlikely that a gravel surface will be cost-effective at traffic flows of more than 200 motor vehicles (two or more axles) per day.
- **There are longitudinal gradients:** Gravel should not be used in low rainfall situations (less than 1,000 millimeters per year) on longitudinal road gradients of more than 6 percent. In medium rainfall areas (1,000–2,000 millimeters per year), gravel loss by erosion will be high on gradients of more than 4 percent.
- **Adequate maintenance cannot be provided:** Gravel is a high maintenance surface requiring both routine reshaping/grading and expensive periodic regravelling. It is hard to maintain to adequate levels in many emerging and developing nations due to funding and operational constraints.
- **Subgrade is weak or soaked (flood risk):** Weak subgrades (in-situ foundations) require additional thickness of residual gravel to prevent traffic punching through to the subgrade. Flooding can seriously damage gravel surfaces,
- **Gravel deposits are limited/environmentally sensitive:** Gravel is a natural and finite resource, usually occurring in limited quantities. Once deposits are used up, subsequent periodic regravelling will involve longer hauls and higher maintenance costs.

Source: Intech Associates, TRL, and Transport Development Strategy Institute, *Vietnam Rural Transport Project 2: Rural Road Surfacing Research; SEACAP 1 Final Report*, vol. 1 (Hanoi: Vietnam Ministry of Transport, 2009).

In the Nicaragua adoquine roads program, a blend of the factors described above, combined with the experience with the use of adoquines, has driven many program choices for this surfacing option. It is important to note that the considerations are tailored to a particular context (lower service level secondary and tertiary roads). Box 6 provides a simple synthesis of the considerations relevant to using or not using adoquines.

Box 6: When to Use and When Not to Use Adoquines

Adoquines are *not* a preferred surfacing option on higher level service roads, e.g., roads functionally classified as *national roads*. They are preferred for use in urban streets and parking lots or on lower functional category roads: secondary roads and possibly tertiary roads if justified economically. Table 3 shows the criteria used to define low level service roads and high level service roads. Adoquines are also not recommended in the following circumstances: (i) areas of very high rainfall (more than 2,500 millimeters) unless special drainage measures are adopted; (ii) countries with high cement and therefore high adoquine costs (i.e., where adoquine costs are greater than 60 percent of the total road construction costs); (iii) sites where transport costs from adoquine factory to site are excessive (more than 15 percent of total road construction costs); and (iv) pronounced slopes (greater 10 percent grade) unless special measures like construction of transverse concrete beams are incorporated into the design.

Table 3: Classifying Low-Service- and High-Service-Level Roads

Parameter	Low-service-level road	High-service-level road
Functional category	Secondary road, tertiary road	Primary/trunk/national road
Speed	Design speed: 30 to 60 kilometers per hour (kph)	Design speed greater than 60 kph
Target IRI levels	Between 4.0 and 6.0 (some/higher tolerance for vibration/surface irregularity)	Between 2.5 and 4.0 (Limited/no tolerance for vibration/surface irregularity)
Noise levels	Some/higher tolerance for noise	Limited/no tolerance for noise

Note: IRI = International Roughness Index.

There is a greater emphasis on speed and comfort on higher level service, but as one goes down the road hierarchical chain, focus turns to the greater need for connectivity and access. For these reasons, adoquine pavement surfacing is more suited to lower-service-level and lower functional classification roads or alternatively for urbanized environments where low speeds are deliberately desired for safety purposes. The technical characteristics of the adoquines used in Nicaragua, and the issues related to the major fabrication of the same, are presented in annexes 4, 5, and 6.

It is important to clarify one major point on the technical characteristics of adoquines. While adoquines are better suited for low service level roads, this does not mean that they cannot handle the typically heavy goods traffic common on these types of roads. Shackel (n.d.) documents in the literature review establish the following points: (i) An increase in block thickness within the range 60 to 100 millimeters is beneficial to pavement performance; and (ii) under trafficking, block pavements tend to develop interlock, which manifests as increases in the load-spreading ability of the blocks and reduces the rate of accumulation of deformation. The literature notes that once interlock has developed, the adoquine blocks act as a structural layer rather than merely as a wearing course. This is supported by the experience in Nicaragua: for example, in some streets of Managua, heavy goods vehicles have been running over adoquine paved roads for over three decades with limited pavement-damaging effects. The strength of the adoquine roads is not inhibited in anyway by the adoquines themselves but rather by the strength of the underlying base, sub-base, and subgrade materials. (See more detailed discussion in section 4.3).

More important, adoquines have been chosen because they are locally manufactured, are a green and sustainable solution, lend themselves easily to labor-based construction for final laying, and are an economically viable alternative.

The surface dressing option (chip seal option) is also used in many countries on rural roads. It is a cheaper option than asphalt, concrete, or adoquines and a viable one too but also has some shortcomings: (i) it is not a structurally robust pavement solution, since it operates more as a wearing course than a structural layer and hence would need frequent periodic renewals, pothole patching, and fixing depending on traffic and climate, and (ii) it does not address the need for community participation and involvement as quality delivery would necessitate a mechanized approach. It remains an attractive choice on rural roads where these two issues are not considered the driving factors for rural roads delivery. Joshi and Jha (2012) note that otta seals experience in Nepal over a decade of implementation as an option for low volume sealed roads has had ambiguous results. They do not rule it out totally, and provide a number of possible reasons as to why it has not been as successful as planned.

2.2 ARE ADOQUINES GREEN?

In the lifetime of the pavement, adoquines are considered a particularly green and attractive surfacing option for the reasons that follow. It is worth noting that the benefits over gravel options in many cases can also be achieved with asphalt, concrete, surface dressing, or other paved options but that adoquines have special benefits over asphalt in some cases.

- Adoquines eliminate dust nuisance (in comparison to earth or gravel option), which leads to benefits in health (less spread of airborne diseases, fewer respiratory problems), and produce savings in cleaning costs.
- Adoquines eliminate the need for continuous borrow pit materials exploitation (in comparison to the earth or gravel option).
- Adoquines eliminate the continuous pollution of streams and rivers from washed away earth and gravel materials.
- Adoquines are easily reusable and recyclable and require less onerous periodic maintenance. By comparison, with low to moderate traffic volumes and/or in areas with heavy rainfall, gravel roads undergo a continual process of washing away, which necessitates the extraction of new borrow pit materials on a regular basis (which is clearly not sustainable for the environment). Also, fixing potholes or failed sections on adoquine roads is much easier than on asphalt or concrete. Adoquines are simply removed, the affected area is re-stabilized with cement and re-compacted, and a new sand bed is placed with the adoquines following on top. For asphalt, pothole repairs require asphalt cutting and replacement of base layers but also the mixing of small quantities of quality asphalt, which is hard to achieve if there is no asphalt plant in the vicinity of affected roads, unless cold mix options are chosen. Afterward concrete repair, the joints between the newly formed pavement and the existing pavement, if not properly sealed, become a source of continuous maintenance pressure. Concrete pothole repairs may also

require cutting and replacement of failing sections or overlaying them with new concrete or asphalt.

- Adoquines are more resistant to the weather and traffic than asphalt or gravel. Both asphalt and gravel degrade relatively more rapidly (with accelerated oxidation and disintegration, respectively) than adoquines or concrete.

- Adoquines can be prepared in the factory at ambient temperatures, avoiding the need for extensive heat sources required for mixing, preparing, and spreading hot mix asphalt. It is clear that adoquines provide an opportunity to reduce energy use in the road materials manufacturing process. Hot mix asphalt (which is used on a large scale in road construction in many countries) requires high energy inputs for preparation, and in the spreading operation, asphalt needs to be heated to between 140 and 170 degrees centigrade and transported to the laying site carefully so that it can be laid at about 100 to 120 degrees centigrade. In a review of the literature, the closest study on environmental energy comparisons for manufacture focuses on asphalt versus concrete for work undertaken in Canada by the Athena Sustainable Materials Institute in 2006. Given that adoquines are close cousins to concrete, the results of this study are reproduced here to give a measure of the environmental comparisons. The study found that the embodied primary energy required to construct, maintain, and rehabilitate a highway is three times higher for asphalt designs than for its typical concrete equivalent (with almost 21,000 Gigajoules of energy for the concrete pavement compared to more 63,000 Gigajoules for the asphalt pavement for a four-lane, one km highway section).[3] Some of these advantages are reduced for adoquines in terms of transport costs because adoquines are manufactured off-site and have to be transported over medium to long distances to final road placement sites while concrete can be manufactured and placed in situ. A study into the full whole life cycle energy needs of different pavement surface materials would be a critical step in making greener decisions in road infrastructure delivery.

It is also worth noting that while the concrete alternative is the closest to the adoquine option, costs for the former have proven to be much higher in practice in Nicaragua. It is also clear that going for the concrete option would necessitate an alternative delivery model to the current MCA approach. This is in part due to the fact that in-situ concrete production and paving would entail greater quality risks that would not be easily appropriated to MCAs. Also, quality finishes may also call for a more mechanically intensive approach (e.g., use of concrete pavers) in the concrete option. Nevertheless, it remains an option to be explored, especially if less thick and less costly concrete pavements can be designed with the right quality assurance.

[3] *Embodied primary energy* refers to all the energy required to bring a material to its final product state, including transportation. It is composed of the primary energy (energy resources required by processes, including energy input used to extract the energy resources) and feedstock energy (gross combustion heat for any material input).

3 INCLUSIVE DELIVERY

3.1 GENERAL CONSIDERATIONS

Too often, services fail poor people: in access, in quantity, in quality. But the fact that there are strong examples where services do work means governments and citizens can do better. How? By putting poor people at the center of service provision: by enabling them to monitor and discipline service providers, by amplifying their voice in policymaking, and by strengthening the incentives for providers to serve the poor.
—*World Development Report 2004* (World Bank 2004)

The key to the development of successful services is often a focus on *social inclusion*, which the same World Bank report defines as “the process of improving the ability, opportunity and dignity of people, disadvantaged on the basis of their identity, to take part in society.” In this paper, the term relates to the use of local authorities and populations in the prioritization, construction, and maintenance phases of road systems.

As noted by Bardhan and Mookherjee (2003) in their review of the literature, the problems of accountability associated with traditional modes of delivery involving centralized bureaucracies include cost padding, service diversion, limited responsiveness to local needs, limited access, and high prices charged especially to the poor. Many developing countries have thus begun to experiment with initiatives to increase accountability of service providers by providing greater control rights to citizen groups. These include decentralization of service delivery to local governments, community participation, direct transfers to households, and contracting out delivery to private providers and nongovernmental organizations (NGOs).

In the Nicaragua adoquine road program, social inclusion aspects revolve around the direct and extensive involvement and empowerment of the usually ignored end beneficiaries (local mayors, local populations) working together with the centralized MTI to achieve specific project development goals. The MCAs have been a powerful tool for community involvement and empowerment.

Construction of the adoquine roads using the MCA model provides a number of direct benefits, which can be summarized as follows.

1. The use of local people under the MCA model generates short-term employment opportunities in the road construction process for local workers.
2. The use of local people under the MCA model creates an entrepreneurial spirit and builds technical capacity at the local level, with the possibility of local residents gaining new skills.
3. The use of local people under the MCA model engenders a sense of local ownership. The participation of and oversight by local mayors and residents not only has benefits during the construction phase but can help engender sustainability during the operation and maintenance phase.

4. The use of predominantly local labor and limited use of heavy machinery results in lower construction costs compared to other, equipment-heavy construction alternatives.
5. The use of local people under the MCA model provides incentives for cost control, since the local people do not have their overriding interest aligned with the making of profit.
6. The use of local people under the MCA model provides opportunity for mainstreaming gender into the adoquine construction process in a way that is not possible under traditional road construction contracting.

3.2 DEFINING MCAS

The MCAs represent a community development approach for the construction of the adoquine roads under a collaborative arrangement between a central ministry of transport, local mayors, and selected local participants living in the vicinity of those roads. The MCAs are legally constituted and accredited by the municipal authorities, which are co-responsible for work execution. The Nicaraguan MTI and the World Bank started to implement this modality in 2004 through a pilot project with 32 MCAs contracted to pave 28 kilometers of roads with adoquines.

MCAs under the Fourth Roads Project have paved a total of over 250 kilometers. The length paved for individual road sections ranges from 1 to 27 kilometers with an average paved road section length of 7 kilometers. Execution with the model is particularly fast once drainage and earthworks are completed, with a typical implementation time of six months for a 5-kilometer section. Details of roads paved with adoquines under the project are listed in annex 3. There are no noted challenges with paving long lengths, and the only restricting factor is the functional classification of the road and extent of earthworks. All roads paved with adoquines under the project fall into the secondary/collector road classification.

A summary description of how the MCA approach works in the program is presented in Box 7.

Box 7: How the MCAs Approach Works in the Program

First, the local authorities, in consultation with MTI, agree on the priority roads to be evaluated at the national level for priority intervention. Once roads have been approved into the project, a legally binding agreement is signed between MTI and the local mayor describing the works to be undertaken and the modality to be followed in executing the works. Afterward, the municipal authorities organize a meeting to call on community members that meet the qualifications for particular posts to present themselves for grouping into MCAs. The MCAs then duly undertake work in conjunction with the local mayors as well as MTI. The ministry provides a promoter to carry out training of MCAs as well as a supervisor who accompanies the MCAs throughout project implementation. Each individual MCA attends to a road project with a maximum length of 3 kilometers (originally 1.5 kilometers but ramped up to reduce administrative burden). Project size for each MAC was established to mitigate fiduciary concerns, with each MCA having a contractual ceiling of US$500,000. Also, the municipal authorities are jointly responsible with the MCAs for the implementation of the works undertaken by the MCAs under their jurisdiction. As such, the contract awarded to each MCA is signed jointly by MTI, as the contracting party, and the mayor and the president of the MCA on the other hand (as the contracted party). The MCAs in turn undertake their own contracting. For local labor, they can contract workers directly or use subcontractors. However for earthworks and for the supply of adoquines, MCAs working on the same road stretch jointly procure these services to benefit from economies of scale, contract prices, and administrative effort. For these group MCA contracts, the mayor(s) and presidents of all the contracting MCAs are the contracting party and the earthworks contractor or adoquines supplier is the contracted party. The contracting of the earthworks contractors and the adoquines suppliers follow national competitive bidding procedures (contract amounts less than US$1.5 million) to ensure transparency and competition. Any minor works (less than US$25,000) are contracted on a shopping basis.

3.3 ORGANIZATION AND FUNCTIONING OF THE MCAS

The stated objectives of the MCA include the following:

- To promote development at the local level in different social sectors.
- To strengthen the organization and self-management of the group
- To develop projects with a social impact quickly and with tangible benefits
- To support the municipal administration for the benefit of the community
- To create temporary employment taking advantage of available local labor

The guidelines for the functioning of the MCA are described in the *Operational Manual of the IV Roads Rehabilitation and Maintenance Project of the MTI-World Bank* MCA Annex. The main contents of these guidelines are the following:

- Structure of the MCA
- Contracting steps
- Standards and procedures for financial management and reporting.
- Guidelines for procurement procedures
- Internal regulations of the MCA
- Functions of the board of directors and accountant of the MCA

Structure and Set-Up

Contractual commitments between the MTI and the Municipality are set out through a signed agreement, wherein the responsibilities of each of the parties (MTI and municipality) are defined, including an emphasis on the economic contribution expected of the municipality to carry out the work.

The MCA, in coordination with MTI and the municipalities, is in charge of directing, managing, and executing the adoquine pavement projects described in the agreement and in the contract signed between MTI and the mayor's office and the MCA legal representative. The same states that the MCAs are responsible for execution, supervision, contracting, and procurement of goods and services for the following pavement works:

- Earthwork
- Pavement structure
- Minor drainage works

- Signage (vertical and horizontal)
- Environmental and social activities

The MCA module structure is based on the intensive use of local labor. The MCAs are set up in a consultative and participative process at the local level with the coordination of MTI and the local mayor. The criteria for selection and participation is clearly spelt out and adhered to in order to afford fair and equal opportunity. MCA management and administration is carried out by a board of directors as follows:

- One president: A civil engineer, or a student in the last two years of a civil engineering university degree program. The president is the legal representative of the MCA and the resident engineer of the adoquine pavement project.
- One secretary: A foreman with experience, a qualified worker with experience in related works, or a student in the technical career of master builder. The secretary shall be responsible for leading and monitoring the construction work and control the minutes of the meetings held by the MCA.
- One treasurer: A graduate from economic sciences (business administration, economics, banking and finances). The treasurer should have at least two years professional accounting experience. The treasurer also controls the financial movements and warehousing and inventory.
- Two members: High school graduates. These board members are responsible for warehouse functions and field oversight.
- The board of directors, which is mandated to have the support of one accountant, who is not part of the board. The selection criterion for this post is for a graduate with a degree in accounting with minimum one to years' experience in this field.

Once the MCAs have been formed, the accreditation and legalization processes are started, based on the legal framework found in Law 475 – Law for Citizens Participation. This process requires:

- That the Municipal Council issue a resolution and a certification of the MCA; and
- The registration of the MCA by the secretary of the Municipal Council in the Book of Municipal Organizations.

Strengthening of the MCA

The Project Coordination Unit of the World Bank and MTI (UCP-WB-MTI), in coordination with the MTI General Directorate of Financial Administration, is responsible for supporting the MCA and mayoral office personnel involved in the project so that during project execution the personnel carry out their work efficiently, transparently, and in an orderly manner.

Once the MCA is contracted, the UCP carries out training for the board of directors, the MCA accountant, and mayoral office personnel involved in the project. The training is divided into three basic areas: (i) organizational aspects, (ii) physical implementation aspects, and (iii) financial management aspects.

MCA Monitoring

The UCP-WB-MTI supervisors and project liaison monitor the MCA's physical and financial execution to ensure quality and compliance with established norms.

MCA Implementation

MCA implementation begins with signing of the contract among MTI, the mayor, and the MCA legal representative. Following contract signature, the specific project enters two distinct phases.

- **Preconstruction phase**. In this phase, the following activities are undertaken:
  - Possession of construction site
  - Preconstruction meeting and definition of work plan
  - Process to obtain legal tax identification number, carried out by the MCA legal representative with the support of the MTI project liaison
  - Initial payment by MTI of 20 percent after twenty working days from the date of contract signature and emission of the tax identification number. This money is meant to be used exclusively for eligible expenditures including mobilization, laboratory services, surveying services, and nominal salaries, and the MCAs have to provide the requisite backup financial documentation (copies of invoices, receipts, subcontracts, or other documents as per the operations manual).
  - Bank account opened by the Legal Representative, reception of the first disbursement, with the support of the MTI liaison.
- **Construction phase**: In this phase, the following activities are undertaken:
  - The MTI supervisory works engineer issues the order to start work.
  - The process of contracting earthwork and supply of adoquines at the site is begun. This process is done through national competitive bidding with the participation of private contractors and suppliers respectively.
  - Hiring process of needed intensive labor begins: This is done through two methods:
    - *Direct contracting*: In this method the contracted staff is included in the MCA's field payroll with a monthly payment of the minimum wage of construction (approximately C$5,000 per month, equivalent to about US$200). Once included in the payroll, workers are entitled to social benefits such as medical insurance, vacation, bonuses, and proportional severance pay. Payment of wages is also calculated depending on the activity hired, measured by advancement or by task.
    - *Subcontracting*: In this case the contractual relationship is through the subcontractor who is responsible for recruiting, social security enrollment, and paying workers' salaries and benefits. MCA responsibility lies in overseeing the subcontractor's compliance with labor laws and regulations.
  - Payment based on work advances, carried out by MTI through monthly disbursements against the contract signed by MTI, mayoral office, and the MCA. Any initial down payments are recovered continuously from the payment certificates. Also, an extra 5 percent of each payment certificate is withheld as a reserve for defects. This money is reimbursed 70 percent at the time of the taking over of the road, and the remaining 30 percent is returned at the end of the defects liability period (45 days).

MCA Obligations Close-Out

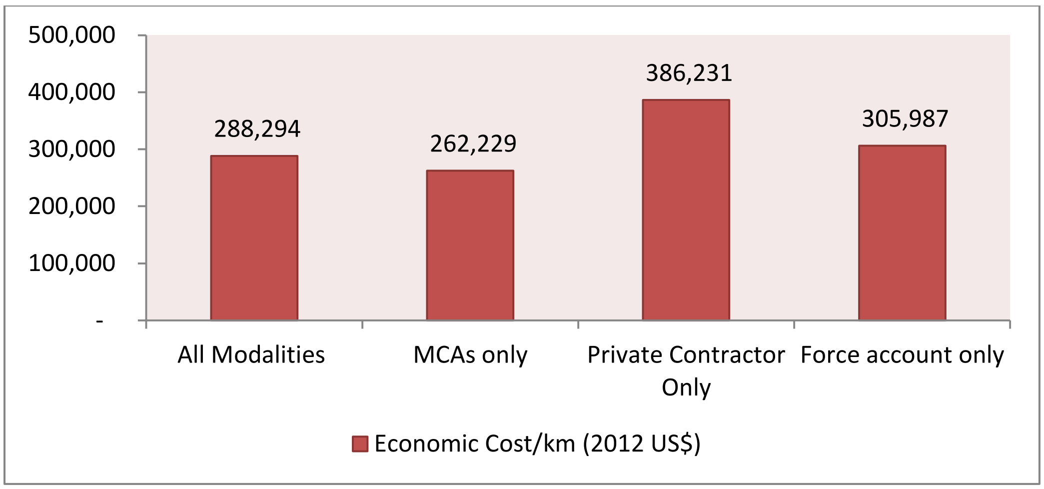
The MCA works are concluded when the MTI works supervisor emits the Final Reception Act (Defects Liability Certificate). This is issued when the contractor has complied with all clauses established in the MCA contract and all civil, tax, merchant, labor, and other obligations acquired by the MCA have been satisfactorily met.

The work supervisor emits the Defects Liability Certificate 45 days after the emission of the Provisional Works Document (Taking-Over Certificate). This 45-day period is the defects liability period in which to terminate all pending obligations and carry out any repairs or defects on the road. At the same time, the MCA will deliver all the tools and items acquired as part of the project, such as pertinent construction documents, to the mayoral office once all contractual obligations have been met.

3.4 COST OF PAVING WITH THE MCAS

Figure 1 shows a historical comparison of the costs of paving a road with adoquines in the Nicaragua roads project depending on the modality of construction. All costs have been adjusted to 2012 US dollar prices.

Figure 1: Cost of Adoquine Paving Using Different MCA Modalities



At an average economic cost of about US$262,000 per kilometer, the MCA modality works out to be the cheapest way to construct the adoquine roads. Not surprisingly, the modality with private contractors at an average economic cost of US$386,000 per kilometer (47 percent more expensive than the MCA cost) works out to be the most expensive. The force account option falls midway between the two. This may be surprising given that traditionally a force account arrangement is more costly than outsourcing works to the private sector. The difference arises from the fact that the force account in Nicaragua is provided by COERCO, which is well organized throughout the Nicaragua region and operates on commercial principles.

On a cautionary basis, these results should not be interpreted unreasonably. It is obvious that the private contractors have higher overhead costs to factor into their costing including all nominal salaries and benefits of staff, other administrative and home office support overheads, and margin for profit to stay in business. These overheads do not feature in the cost structure for the MCAs, except insofar as the MCAs need to provide compensation and other mandatory legal benefits for workers during the project implementation phase. According to MTI, one other mitigating circumstance in cost reduction through MCAs is the saving in the waste/loss factor for handling of the adoquines, with private contractors operating at 7 percent while MCAs operate at only 1 percent. The present discussion is useful only to document that paving with MCAs is an economically viable alternative. Project experience in Nicaragua has also shown that with the right due diligence in place, quality and pace of execution are not compromised by opting for the MCA alternative.

3.5 EMPLOYMENT OPPORTUNITIES UNDER THE MCAS

Unemployment is a serious and growing problem in many developing countries. Paid work has the potential to provide people with a route out of poverty. Even when temporary, the opportunity for employment may provide workers with a boost that takes them out of their previous unfavorable economic condition, leaving them with new skills, new self-belief, and possibilities of further opportunity. The construction and maintenance of road infrastructure has long been viewed as one of the most promising sectors for large-scale pro-poor job creation. The International Labour Organization uses the term *employment-intensive* for such scenarios, which it defines as the optimal use of labor to reach maximum effect on employment, while paying due regard to cost and quality issues. Employment-intensive construction and maintenance offers the opportunity for the absorption of low or semi-skilled individuals, and bring into the employment fold normally employment-marginalized groups like women and youth.

Through the Fourth Roads Project (and its AF), 8,922 temporary jobs were created during the period 2007 to 2012 under the MCA model. Table 4 shows only the direct jobs created for MCA board directors and direct workers for the MCA model. If the whole project employment numbers are to be taken into consideration, the results would need to incorporate the employment supported for private contractors on asphalt rehabilitation and periodic maintenance road contracts, private contractors on adoquine roads, workers supported under the force account, private earthworks contractors, adoquine manufacturers, other suppliers, and transporters. If these numbers are taken into consideration, the number of jobs created is estimated to be almost doubled (about 18,000 total direct jobs created).

Table 4: Employment in MCA Adoquine Contracts (Fourth Roads Project and Its Additional Financing)

Project	No. MCAs	Board men		Board women		Total employed men	Total employed women	Total employed	Total employed % women
		No	%	No	%	No.	No.	No.	
Fourth Roads	120	400	71%	160	29%	2,792	327	3,119	10%
AF (IV)	152	489	64%	273	36%	4,946	857	5,803	15%
Total	272	889	67%	433	33%	7,738	1,184	8,922	13%

Note: AF = Additional Financing.

The total amount of money spent on the MCA roads only in the Fourth Roads Project and its AF is about US$49 million. With this information, and assuming a conservative 10,000 jobs created for the MCA model in total (including ancillary jobs on earthworks contracts, adoquine suppliers, and transporters), the employment generation effect of the MCA model works out at 204 direct jobs per US$1 million of investment or 68 annualized direct jobs per US$1 million investment. This is in line with the findings of Tuck, Schwartz, and Andres (2009), which noted that about 40 jobs are created per US$1 million for infrastructure capital investment projects. However, as expected, it is short of the estimated 200 to 500 annualized direct jobs created for every US$1 million spent in rural road maintenance projects.

Since the employment drastically falls upon road construction completion, the sustainability of the employment effects can be sustained in one of three ways: (i) workers use the skills gained to obtain similar construction work in the project area or other locality; (ii) workers gain entrepreneurial spirit and skills and invest earnings in new business or opportunity, either individually or as part of a group; and (iii) workers get assimilated into routine maintenance microenterprises since the roads will need to be maintained after the road construction. The last option is currently being explored by the maintenance agency FOMAV in Nicaragua.

3.6 MAINSTREAMING GENDER IN THE MCAS

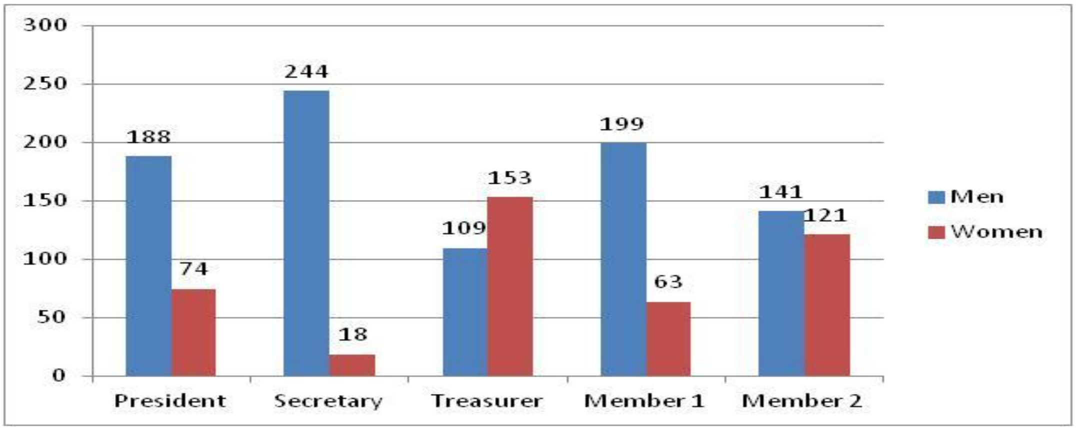
In Nicaragua, management and labor in the infrastructure construction sector have historically been predominantly a male domain with men particularly taking up the bulk of the labor provision. This trend has been changing in recent years as women graduate with civil engineering degrees and related qualifications. However, cultural barriers still prevent the full incorporation of women in this sector, specifically in labor-intensive activities.

It is obvious that there are a number of gender-related issues and impacts surrounding rural road projects. For one, the peculiarity of rural contexts lends itself to a situation where women may not have a strong voice, especially in male-dominated cultures (Caballero and Alcahausi 2007). Also, women have an unnecessarily heavier transport burden than men, and are more likely than men to travel for health and education purposes. They spend considerable time waiting for transportation and are unduly affected by delays or costs in accessing emergency, obstetric, and postnatal care (World Bank 2010a). Being thus affected by transport decisions and policy, women have an integral role to play in rural infrastructure development. For the adoquine roads projects, their participation to date has been integral to ongoing and completed project successes.

MTI has made significant efforts to provide equal opportunity for women in this field. This can be evidenced by the fact that women are often recruited to be the presidents of the MCAs, supervise the works, work as the treasurers, act as traffic controllers, work as pavement joint fillers, and, in a few cases, place the adoquines. Also, as Table 4 shows, women's participation in total has been increasing from the 10 percent in the original Fourth Roads Project to 15 percent in the AF (to September 2012), where 20 percent of the labor force was women.

On an even more positive note, over the course of the Fourth Roads Project, 33 percent of the overall board positions for the MCAs—including both principal office holders and members—were filled by women. (See distribution by role in Figure 2.)

Figure 2: MCA Board of Directors Positions by Gender



Source: Information provided by UCP and MTI.

For the board of directors, the post of president was split, with 72 percent men and 28 percent women. Men occupied 93 percent of board secretary positions; the secretaries act as the site foremen of the construction work, a job historically dominated by men. A majority—58 percent—of treasurers have been women. It is heartening to note that such a high percentage of the sensitive treasurer positions have been occupied by women in the absence of any quotas or mandates. For the post of board member one, responsible for field oversight, the predominance is again men, with 76 percent. In the case of board member two, who acts as the stock keeper, occupancy is more balanced, with 46 percent women.

Under the auspices of RRIIP, actions are being undertaken on the following gender-related themes of interest:

- Gender impact evaluation: this reviews the impact that women have had on project design, implementation, and success (quality, cost, time).
- Gender user satisfaction surveys: these will solicit the views of women in implemented projects to learn how they have benefited from project initiatives.
- Gender monitoring: progress on women's integration into projects is monitored and evaluated and deliberate efforts are made to increase this percentage.

Through financing made available by the Umbrella Facility for Gender Equality, work is to be undertaken to measure the impact of project road interventions on gender agency, and how this can inform future policy and design both in the sector and in other countries.

3.7 MCA BENEFICIARIES EXPERIENCES AND PERCEPTIONS

A focus group was organized to document the experiences and perceptions of beneficiaries for projects carried out under the MCA modality. It was directed to members of the board of directors of various MCA and includes interviews with members of the UCP of the MTI-WB project as well as information collated from field visits. The focus group was carried out on Wednesday, November 14, 2012, in MTI facilities. A total of 41 members of the boards of directors of the MCAs participated from the following sample road sections: Telpaneca–Quibuto; Camoapa–Boaco; Santa Lucia–Boaco; Santa Cruz–Balgue; Moyogalpa–La Flor; Cuyalí–Abisinia, and Cuyalí–Las Cruces.

The participants in the focus group and the personnel interviewed have a positive perception of the projects executed under the MCA modality. The main positive aspects mentioned by the participants include the following:

- Knowledge transfer (The majority of MCA contracts were awarded to a recent engineering graduate or to university seniors who gained new skills and knowledge that will serve them in the working world.)
- Creation of direct and indirect employment, including inclusion of youth in formal labor
- Capacity building in entrepreneurship and leadership skills (More specifically, the presidents, and other members of the board of directors develop an interdisciplinary profile that allows them to enter into the labor market with an added value or create their own business.)
- High local population participation and engagement in the execution of the works

Opinion of the Beneficiaries about the MCA Modality

In order to gather information on beneficiaries, various adoquine roads were visited. During the visit to the road section Telpaneca–Quibuto, there were positive opinions of the target population and the municipal authorities with regard to the adoquine MCA model. Among the key benefits noted by the beneficiaries are the resolution of transportation issues and the generation of both direct and indirect employment.

The visit to Telpaneca–Quibuto coincided with the inauguration of this road section, in which the mayors of Telpaneca and San Juan del Río Coco Laguna participated, as did the population of the neighboring communities: Los Lirios and El Pericón y Apaguique. During the inauguration, satisfaction with the construction of the project road was expressed by members of the community.

In a visit to the road sections of La Subasta–Camoapa, San Benito–Urban Area Camoapa, and Rancho Rojo–La Calamidad (road section one), a meeting was held with municipal councilors, who expressed their satisfaction with the adoquine program. These officials were of the view that the MCAs should be used to execute urban projects that the Camoapa Municipality is planning (MCAs should be constituted as microenterprises). They also highlighted the importance of the adoquine road sections that have benefited the population of Camoapa's estimated

53,000 inhabitants. In particular, one beneficiary noted, "Agricultural production has increased because various roads now join the productive areas of the livestock sector, considerably reducing transport times to the two important milk collectors in Masiguito and San Francisco."

In separate user satisfaction work, a resident and beneficiary of one of the adoquine pavement roads put the impacts more clearly on herself and on others related to her with the following words: "I'm glad I got to see this project come to fruition. I normally travel with fear on the bike with my husband, since the road gets very slippery with the rain. However, now that you are working on the road, things are improving….My grandchildren go to school. However, when the road is impassable, the bus cannot pick them up, and they have to walk the long distance to school. Things will get better when the road is improved. It will also be good to improve the quality of service of buses when the road is completed".

3.8 SUSTAINABILITY OF THE MCAS

One of the main issues of concern with the MCAs is the sustainability of the model once construction works have been completed. While participants in the MCAs gain new skills that they can then transfer to new jobs or use to seek new opportunities, one obvious opportunity exists in the fact that the completed roads need to be maintained. The roads fall under the remit of the maintenance agency FOMAV, which has a model for using local persons under a microenterprise model. Current efforts are under way to pilot the formation of MCAs in one road stretch into microenterprises so that the same MCAs that constructed the road can take care of the maintenance afterward.

4 COST-EFFECTIVE DELIVERY

4.1 GENERAL CONSIDERATIONS

The term *cost-effective* is self-explanatory insofar as it relates to the prudent and economic use of scarce resources in a manner that offers value for money or "bang-for-the-buck." This is best evaluated not just on initial construction costs but rather on the totality of life-cycle costs, including construction and maintenance costs compared against the benefits that the investment brings.

4.2 ECONOMIC BENEFITS

The first notable benefits of the MCA program are economic, in the sense of whole life-cycle costs savings of scarce financial resources. Adoquines in road construction are more cost-effective than alternative surfacing options like asphalt and concrete on a whole life-cycle basis for the traffic levels considered on the secondary rural roads (with opening year traffic volumes in the range of 150 to 800 vehicles per day).

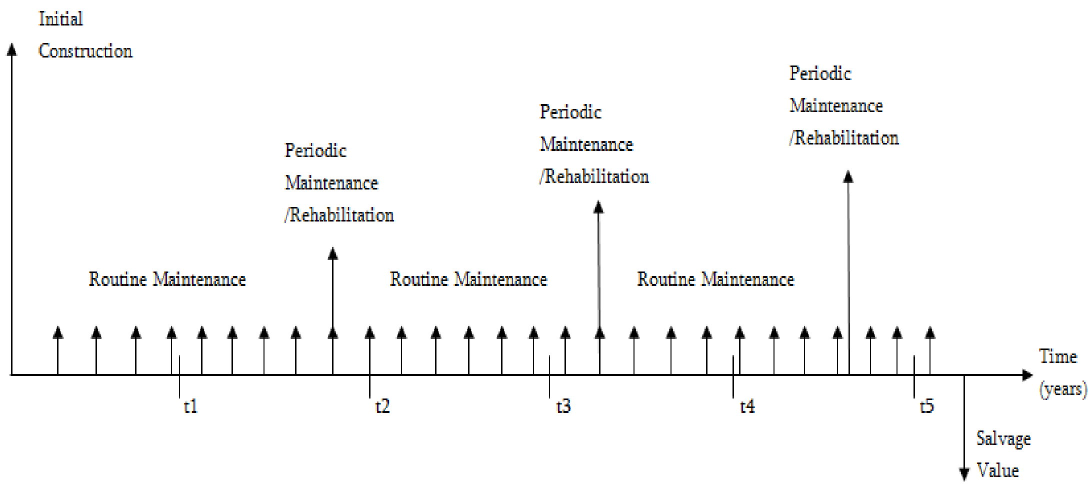
To test this hypothesis, two approaches have been adopted. The first approach carries out a life-cycle cost analysis (LCCA). Under LCCA, the direct agency costs for initial construction and future maintenance and rehabilitation activities of each proposed alternative are estimated and converted into a single discounted life-cycle cost (at net present value). The second approach does a cost-benefit analysis with a traditional road economic evaluation model suited for rural roads, known as the Road Economic Decision (RED) model. The Highway Design and Management model (HDM-4) is not used because it is not particularly suited to economic evaluations of low volume roads as discussed next. RED is a consumer surplus model designed to help evaluate investments in low volume roads. The RED model aims at improving the decision-making process for the development and maintenance of low-volume roads. The model performs an economic evaluation of road investments options using the consumer surplus approach and is customized to the characteristics of low volume roads such as (i) the high uncertainty of the assessment of the model inputs, particularly the traffic and condition of unpaved roads; (ii) the need to reduce input data requirements; (iii) the importance of vehicle speeds for model validation; (iv) the need for a comprehensive analysis of generated and induced traffic; and (v) the need to clearly define all accrued benefits that are very important for low volume roads but not necessarily critical for high volume roads.[4]

Approach 1: LCCA Model

The LCCA is best reflected using an expenditure-stream diagram (see Figure 3). *Salvage* value refers to the estimated value of the pavement asset at the end of the analysis period. For purposes of simplicity, and to err on the conservative side, this value is taken to be zero in this LCCA analysis. An analysis period of 30 years and a 12 percent discount rate have been adopted.

[4] For more information about RED, see Rodrigo S. Archondo-Callao, "Roads Economic Decision Model (RED) for Economic Evaluation of Low Volume Roads," *Africa Transport Technical Note* no. 18. Washington, DC: World Bank.

Figure 3: Life-Cycle Cost Analysis Expenditure Stream



Construction costs: Construction costs are derived from those managed by the MTI Costs Office as well as from the historical database of cost information from the World Bank and government-financed projects over the years (see Table 5). All costs are standardized at 2012 prices. The costs align closely with those observed under the project and in similar works in Nicaragua and the Central American region. They also correlate well with the construction costs from Archondo-Callao and James (2009). The study made an economic comparison for different types of pavement types: earth, gravel, adoquines, and asphalt. The results of the quoted study indicated the construction cost of adoquines to be 40 percent higher than that of gravel, 87 percent higher than for earth pavements, but 67 percent lower in comparison to asphalt. This current study indicates the construction cost of adoquines to be 75 percent higher than that of gravel, 133 percent higher than for earth pavements, but 11 percent lower than for asphalt pavements.[5]

Adoquine construction costs are reduced in part in comparison to asphalt or concrete due to the fact that they do not need expensive or sophisticated equipment in their placement, thus reducing the cost of capital. This has to be offset against the fact that adoquines are prefabricated, and hence there are costs associated with transportation, especially if the manufacturing plants are far away from the final road placement sites. The full analysis of costs is presented further in following sections.

Maintenance costs: Maintenance costs are divided into (i) annual routine maintenance costs (small-scale, routine measures to ensure transitability and safety and to prevent premature road deterioration, e.g., cleaning of side drains, culverts, cutting of grass, minor patches, and pothole repairs), and (ii) annualized periodic maintenance costs (more large-scale interventions undertaken at longer intervals with specialized equipment to ensure pavement strength attributes, including repairs of failed sections and overlays).

[5] In the current study, the asphalt pavement considered has a 5-centimeter surfacing thickness compared to the 10 centimeters of adoquines. If a 10 centimeter asphalt pavement were to be considered, the asphalt pavement would be much more expensive than the adoquines.

The routine maintenance costs with microenterprises in Nicaragua are for very basic routine activities (working out at about US$1000 per kilometer). This does not include routine maintenance activities like maintaining of vertical signs and road marking, repairs to structures, slope stabilization, major cleanups, or even limited pavement repairs. For more comprehensive routine maintenance costs, the 2000 World Bank Road Costs Knowledge System ROCKS database costs for the Latin America and Caribbean region are updated to 2012 US dollar values. This results in estimated routine maintenance costs of US$3,614 per kilometer for gravel roads and US$4,627 per kilometer for asphalt roads.[6] The routine maintenance costs for asphalt are taken as being typical for paved roads and applied to concrete and adoquines as well.

Periodic maintenance varies significantly for different pavements, given different deterioration performances. It is also highly dependent on the maintenance regime adopted by the maintenance authorities. Some authorities are more proactive and carry out regular periodic maintenance (intensive periodic maintenance strategy), while others are more passive and carry out periodic maintenance quite infrequently, and in many cases when rehabilitation or reconstruction is what is needed (non-intensive periodic maintenance strategy). The latter strategy, while neither optimal nor desired, is common in many developing countries. The analysis evaluates the two divergent periodic maintenance strategies as follows:

1. **Intensive periodic maintenance strategy** (assuming high overload traffic and unfavorable climatic conditions): For the adoquines, cement re-stabilization and replacement of about 10 percent of typical road section every five years; for the asphalt, a 5-centimeter thick overlay every eight years and a 5-centimeter asphalt overlay for the concrete pavement every 12 years. For gravel, the adopted regime is regravelling every 4 years and re-grading every year.

2. **Non-intensive periodic maintenance strategy** (assuming low overload traffic and favorable climatic conditions): For the adoquines, cement re-stabilization and replacement of about 10 percent of typical road section every 10 years; for the asphalt, a 5-centimeter overlay every 15 years and a 5-centimeter asphalt overlay for the concrete pavement every 25 years. For gravel, the intensive regime efforts described previously are halved. The non-intensive periodic maintenance strategy is what is closer to the typical maintenance practices in many developing countries irrespective of traffic or climatic conditions.

The results are presented in Table 5. As discussed previously, surface dressing is another possible alternative, but this has not been analyzed as there is not a robust database/experience for this option in the program. More detailed analyses on this and other options can be found from work done in Vietnam under the South East Asia Community Access Program (SEACAP) studies (Intech, TRL, and TDSI 2009); Department of Local Infrastructure Development and Agricultural Roads, Nepal (DoLIDAR) research work in Nepal; and research work by the Transport Research Laboratory (TRL) in different countries in Africa.

[6] These estimates are deemed reasonable for the Nicaraguan context being evaluated, comparing them with the available literature on maintenance costs. See for example *City of Milton Transportation Plan Pavement Management Evaluation and Recommendations*; Jahren et al. 2005; Zimmerman and Wolters 2004; and Spencer 2008.

Table 5: Construction and Maintenance Costs (2012 US$)

Pavement type	Construction cost/km (2012 US$)	Annual routine maintenance cost/km (2012 US$)	Annualized periodic maintenance cost/km (2012 US$)		Total Life-cycle costs/km (25 years) (2012 US$)	
			Intensive scenario	Non-intensive scenario	Intensive scenario	Non-intensive scenario
Adoquines	350,000*	4,627	6,323	3,162	612,799	536,918
Concrete	505,000**	4,627	7,989	3,835	807,766	708,067
Asphalt	390,000***	4,627	11,983	6,391	788,631	654,420
Gravel	130,000	3,614	29,359	12,421	921,344	569,038

Sources: MTI Costs Office report; World Bank 2011a (rural infrastructure Project Appraisal Document); FOMAV unit rates, and World Bank Road Costs Knowledge System (ROCKS) (database), Washington, DC.
ROCKS database.
Notes: km = kilometer. For adoquines, the construction cost per kilometer adopted is the one used in the preparation of the Rural Roads Infrastructure improvement project. The analysis on historical costs with MCAs indicates values between US$250,000 and US$300,000 per kilometer (see section 4 of this paper).
** For concrete, the construction cost per kilometer is high because of the higher design standard attached to the roads surfaced with concrete.
*** For asphalt, the surfacing course is 5 centimeters thick. If a thicker asphalt surfacing and/or base are adopted, costs would increase significantly.

The LCCA results in 2012 US$ are also shown graphically in Figures 4 and 5.

Figure 4: Whole Life-Cycle Costs 2012 (US$/km): Intensive Maintenance Scenario

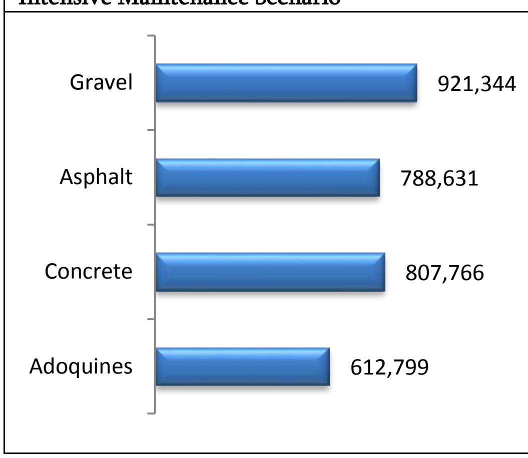
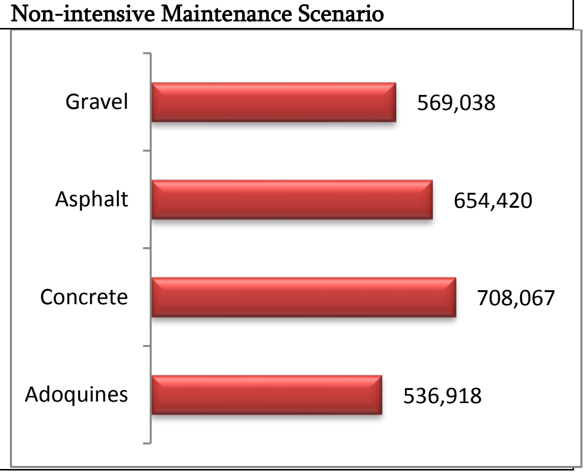


Figure 5: Whole Life-Cycle Costs (2012 US$/km): Non-intensive Maintenance Scenario



Note: km = kilometer.

For both maintenance scenarios, the adoquine option is evaluated to be the least expensive paved option based on whole life-cycle costs. This is driven in large part from the adoquine option starting out at a more attractive construction-costs comparison in the analysis undertaken but also from a less demanding maintenance profile. The gravel option comes in a close second in the non-intensive maintenance scenario. However, with the gravel option, the road conditions would actually be worse than for all the paved options, varying depending on the traffic and climatic realties. The next logical step is to carry out an evaluation that analyzes both the costs and benefits and not only the whole life-cycle costs.

Approach 2: RED model

Four traffic profiles are tested (average annual daily traffic, or AADT, of 100, 200, and 500 trips) with heavy vehicle concentration of 20 percent. A 10-kilometer road section is adopted for the model runs. The 500 AADT is on the higher side of traditional traffic volumes of rural roads but has been included to test model boundary performance. The geographic profile adopted is with a climate profile of 50 percent wet season and 50 percent dry season in rolling terrain. An analysis period of 20 years and a 12 percent discount rate have been adopted. The vehicle operating costs for the Nicaragua context were first calibrated using the RED model's HDM-4 vehicle operating costs module and then transposed into the main module for analysis.

Economic evaluation results: Using the RED model and the characteristics indicated previously, the results shown in Table 6 have been attained. It is worth noting that these results do not include any socioeconomic benefits that are not calculated by the RED model—such benefits might include increases in land values, attraction of new business opportunities, lower input and output prices, and so forth—but rather capture the basic vehicle operating cost and travel time savings for road users and agency cost savings from reduced maintenance burdens.

Table 6: RED Model Economic Evaluation Results

AADT	Result	Adoquines	Asphalt	Concrete
100	NPV (US$ mil)	$2.56	$2.28	$1.13
	EIRR	22%	20%	15%
200	NPV (US$ mil)	$7.32	$7.41	$5.98
	EIRR	36%	34%	27%
500	NPV (US$ mil)	$21.59	$22.78	$20.53
	EIRR	77%	74%	56%

Note: AADT = average annual daily traffic, NPV = net present value, EIRR = economic internal rate of return.

These results are also presented graphically in Figures 6, 7, and 8.

Figure 6: RED Results, 100 AADT

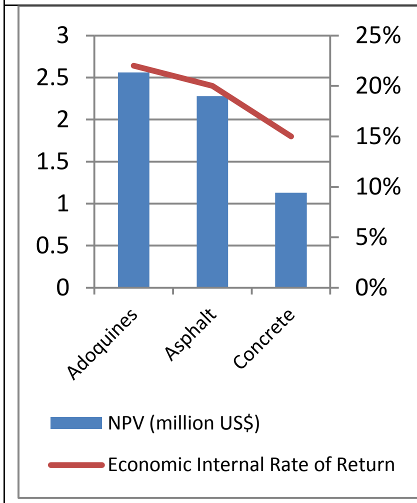


Figure 7: RED Results, 200 AADT

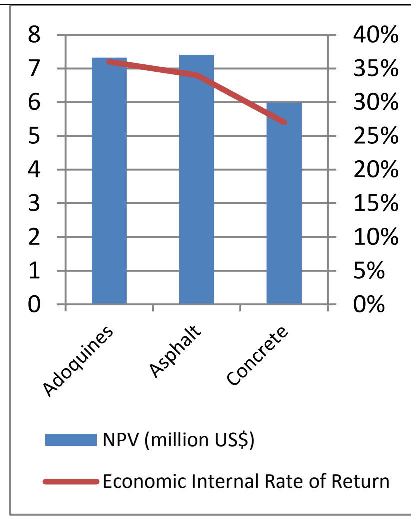
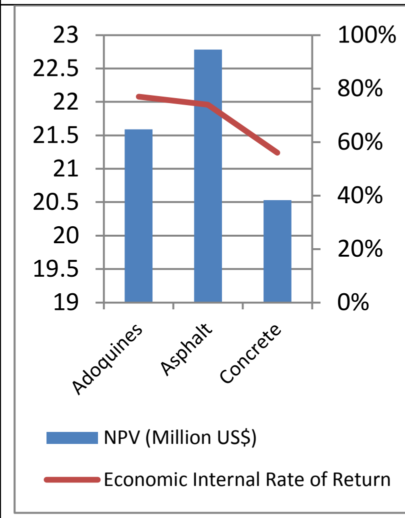


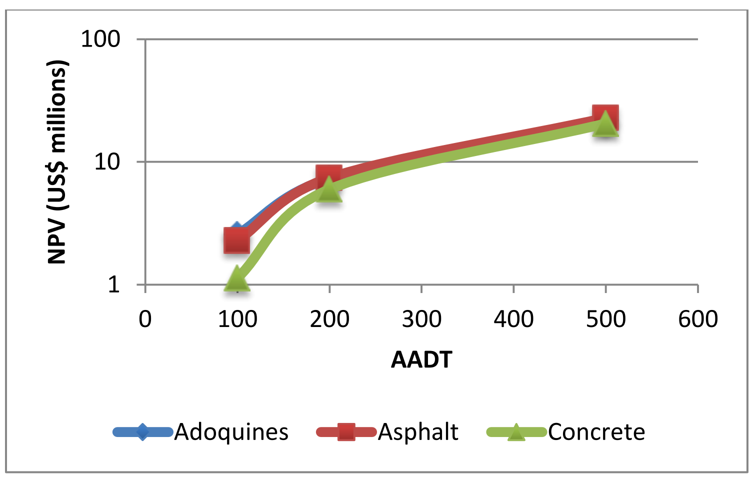
Figure 8: RED Results, 500 AADT



Note: AADT = average annual daily traffic, NPV = net present value, EIRR = economic internal rate of return.

The NPV differences are not that pronounced at the 500 AADT level. A separate graph is plotted of NPV against AADT to check the validity of this assertion and to confirm the convergence of results as traffic volumes rise. See Figure 9.

Figure 9: NPV versus AADT for Different Surfacing Materials



Note: AADT = average annual daily traffic, NPV = net present value.

All pavement solutions yield positive NPV for the chosen variables. However, the concrete option is only marginal at the lower bound of traffic. Adoquines prove to be the preferred option for all evaluated traffic ranges based on the internal rate of return. On NPV considerations, asphalt performs best as traffic volumes go beyond 200 AADT. One possible explanation is that with the climb to higher traffic volumes, the model places a greater emphasis on the International Roughness Index (IRI) and higher speeds (for which adoquine roads do not fare as well as asphalt). On a more cautionary interpretation of the results, the concrete evaluation should be taken in the context that the initial construction costs are relatively much higher because of the chosen design in the Nicaraguan roads analyzed (17 centimeters of concrete pavement). If a 10 centimeter concrete pavement were analyzed instead (same thickness as the adoquine blocks), the results would change, with the concrete option expected to become the best performer of all. Concrete pavements tend to perform better than either adoquines or asphalt pavements in areas with very high amounts of rainfall or on roads that carry significant volumes of heavy goods traffic (especially international routes).

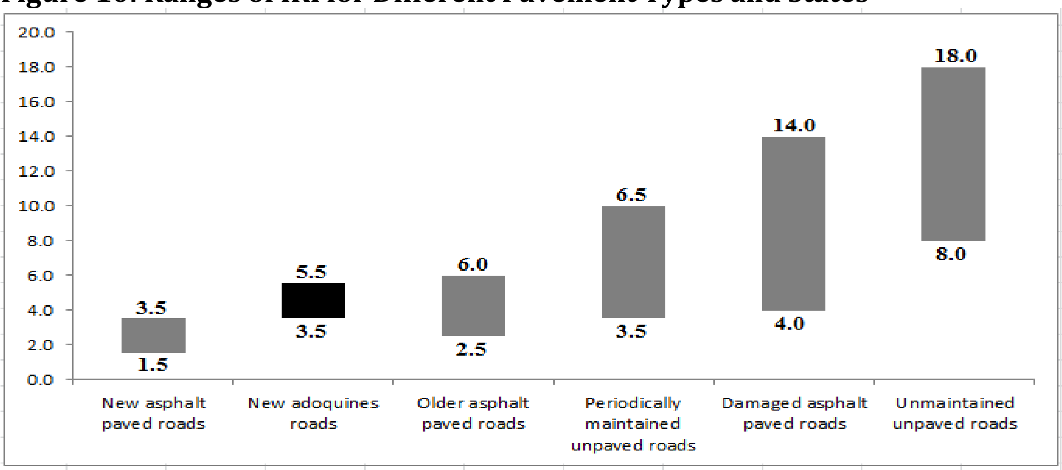
4.3 EXTENDED LEVELS OF SERVICE BENEFITS

Adoquine pavements (much like concrete pavements) maintain a reasonable level of service over time in low maintenance regimes (which are typical in many countries) and thus bring more sustained transport and road benefits to users and road agencies in such environments

Adoquines are more durable and resistant in nature to the actions of weather and traffic than some other road surfacing alternatives like asphalt and gravel (for example, adoquine roads still in fair condition on Managua streets after 40 years of heavy use and limited replacement). When laid over well-stabilized bases, the adoquines themselves, by virtue of their stiffness (elastic modulus), are more suited to carrying heavier loads without the risk of rutting common with asphalt pavements.[7] As opposed to asphalt or gravel, no additional layers are required to maintain a good level of service. To reach the desired levels of service sustained for longer times during the life of the road, many authorities in Europe are opting for thick, multilayered asphalt pavements designed to last 40 years; they have higher initial construction costs, and lower maintenance costs.

Figure 10 shows typical levels of service for different pavement types and conditions. The levels of service are presented in units of the IRI. As noted before, the surface dressing option has not been analyzed in this paper.

Figure 10: Ranges of IRI for Different Pavement Types and States



Note: IRI = International Roughness Index.

From inception, the roads go through five distinct life phases:

[7] Typical concrete elastic modulus values are between 20,000 to 40,000 MPa, while typical asphalt elastic modulus values are between 3,000 and 14,000 MPa. This is not to be confused with compressive strength, where typical values for concrete, for example, are 28 MPa. The formula that relates the elastic modulus to the compressive strength is given by Elastic Modulus = 22,000(compressive strength/10)$^{1/3}$ with units in MPa. In the Nicaragua project, the required compressive strength of adoquines is 24 MPa.

- **Phase 1: Design Phase.** Road planning with design of both geometric and pavement layers to physically perform their intended functions: normally following officially designated technical guides/standards

- **Phase 2: Construction Phase.** The physical act of building the road to the set design standards

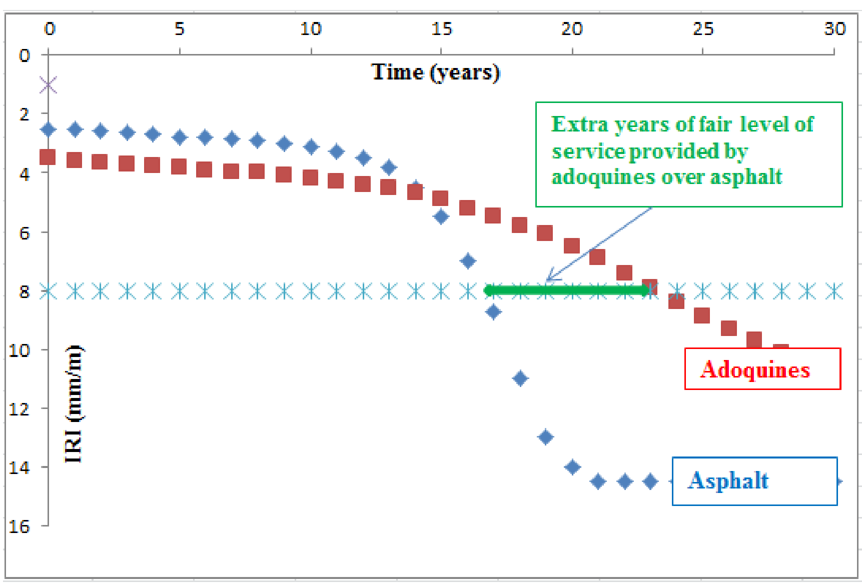
- **Phase 3: Slow Deterioration Phase.** Slow weakening of the road pavement as a result of the traffic and climatic action but still appears to the naked eye to be in good condition with minor surface defects.

- **Phase 4: Critical Structural Deterioration Phase.** Fatigue of the road pavement structure, with real damage beginning to occur with potholes and other physical deformations becoming more frequent and apparent

- **Phase 5: Absolute Failure Phase.** Severe damage and disintegration of the pavement, the road becoming intolerable to drive and unfit for use

With all things remaining equal, the deterioration patterns of different pavement surface materials vary greatly. While performance varies across pavement types, the typical road deterioration curve for an asphalt pavement is an inverted s-curve. The first phase of operation is the slow deterioration phase lasting from 8 to 12 years (depending on traffic and climate); during this phase, the road *appears* in good condition. The critical structural deterioration phase sets in immediately afterward and lasts less than five years, and in this period the road rapidly dissolves into the absolute failure phase. Given the historical observations of pavement performance in Nicaragua, a similar curve for the adoquine pavement has been simulated. It is also shown in Figure 11.

Figure 11: Road Deterioration Curves for Asphalt and Adoquines in Rural Roads



Note: IRI = International Roughness Index.

From the simulated road deterioration curves, a number of observations can be made:

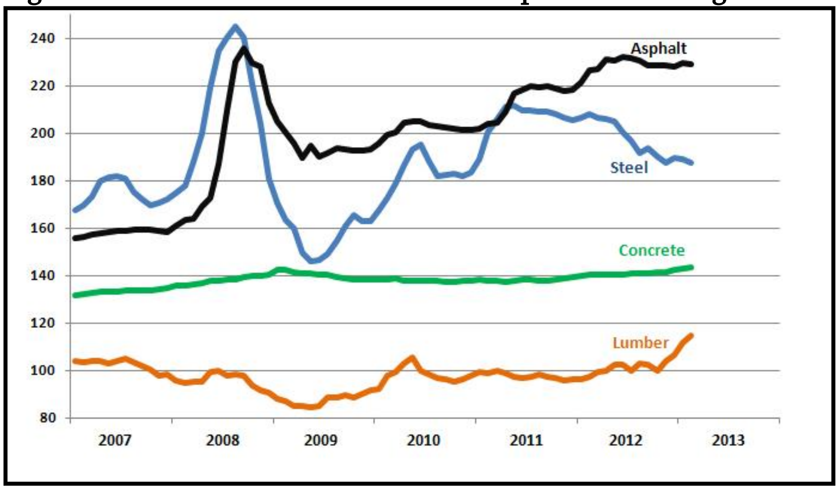
1. With only routine maintenance, asphalt road would hold steady for about 12 years and then begin an accelerated deterioration. Periodic maintenance interventions are needed earlier to ensure target service levels.
2. With only routine maintenance, adoquine roads would hold in steady condition for about 15 years. Removal of the adoquines, restoration of failing road base sections, and reinstating the adoquines would be needed in isolated areas to ensure target service levels.
3. The adoquine pavements exhibit a different deterioration profile from asphalt. The main reason for this is that the asphalt pavement by nature of being a flexible pavement undergoes fatigue failure from continuous load applications and strains within the material itself as well as at the interface with the base/sub-base layers and stresses and strains in the underlying layers themselves. These stresses build until a critical failure phase is reached. With the adoquines, on the other hand, if deformation occurs it is most likely to happen in the initial phases of the pavement. This failure is driven not by the adoquines themselves but by stresses and strains generated in the sand bed, base, and sub-base materials and tensile strains in the joints, which cause adoquines to be displaced vertically or horizontally, respectively. As time goes on the accumulated fatigue in the base and sub-base layers, and the infiltration of water through the displaced joints, create the need for pavement renewal. The adoquines themselves may suffer some marginal deterioration from tensile stresses induced over time and the effects of weather until they need to be replaced or overlaid (typically at the end of their design life of 30 to 40 years). Best practice maintenance of adoquine roads involves the periodic sealing of the joints with sand.
4. The green arrow in Figure 11 indicates the extra years of fair level of service provided by the adoquines over asphalt for a rural roads context (IRI 5–7 range). It is clear that if users demand a lower threshold level of service (for example, on national roads where an IRI of 4 is the maximum tolerable), the adoquine advantage disappears.

4.4 EXTERNAL SHOCK MITIGATION BENEFITS

Adoquines in Nicaragua are prepared from locally sourced materials and thus contribute to reducing the country's trade deficit by eliminating need to import petroleum products like bitumen. For countries rich in the basic raw materials for adoquines (cement, fine aggregates, coarse aggregates, and filler), adoquines are a particularly motivating choice.

In a related vein, the use of adoquines mitigates against the risk of significant cost overruns arising out of unpredictable and volatile fluctuations related to the world price of crude oil. The crude oil price is critical for asphalt projects due to bitumen being one of the byproducts of crude oil refinement. Since 2003, liquid asphalt prices have increased by more than 200 percent and concrete by only 37 percent. Also, previously 40 percent of an oil barrel was converted into asphalt products, but now the conversion is only for 10 percent, resulting in supply side constraints. These crude oil demand and supply imbalances led to significant asphalt road construction price increases between the years 2006 and 2012. Price adjustment clauses in asphalt road contracts have resulted in high cost overruns indexed to asphalt price increases over the past decade. This has important implications for the purchasing power of governments and value-for-money discussions in the context of scarce resources. Figure 12 indicates that the price of concrete (which is a good proxy for adoquines) has been relatively much more stable; this is also true not only in the international market but in Nicaragua as well.

Figure 12: Producer Price Indices for Competitive Building Materials



Source: US Bureau of Labor Statistics.

4.5 SAVINGS IN HEAVY EQUIPMENT USE

Adoquine pavements can be constructed without the need for heavy, expensive, or sophisticated machinery and are thus conducive to manual-labor-based construction approaches and involvement of local communities. The required earthworks inevitably call for more equipment intensity, but the tasks can be easily achieved with the use of a grader, a water tanker, and a roller. All the work afterward on the paving with adoquines can be undertaken with the use of semi-skilled labor. Most important, there is no need to establish and run very expensive asphalt-producing plants. The benefits of using local labor and involving communities in the road construction process were enumerated in further detail in section 3.

4.6 UTILITIES INSTALLATION AND REPAIR BENEFITS

Adoquine pavements are more user-friendly and cost-effective when it comes to utilities installations and repairs that require access to the area beneath the pavement. Adoquines are easier and cheaper to remove and replace than concrete or asphalt pavements. This is an increasingly significant problem, not only in urban areas, but also in many rural communities where water supply, sanitation services, and telecom services usually follow the road construction process. For asphalt and concrete pavements, a lot of effort and expense is spent in dismantling the pavement surface, needing costly and time consuming asphalt or concrete cutting machines. Subsequent repairs to damaged sections are not only expensive but are also done in a hurry and by entities/workers not qualified to the work, leading to failing sections afterward.

4.7 INHERENT ROAD SAFETY BENEFITS

Adoquine surfacing by its nature provides a surface that is conducive for lower driving speeds, thus leading to improved road safety conditions. Better road safety conditions means lower costs to the economy in terms of lives lost, the costs related to long-term health care for seriously injured people, or costs for property damage replacement and repair. The road safety benefit arises in part because adoquines are coarser by nature than alternative pavements like concrete or asphalt. The coarseness is derived from the adoquine surfacing itself, as well as with the presence of a high number of joints between adjoining adoquines. For these reasons, adoquines exhibit better skid resistance and shorter braking distances than either asphalt or concrete, which bodes well for road users when faced with treacherous driving conditions and situations. The visual effects of adoquines also ensure that they induce a sense of order on the road. With the existence of the joints, the monotony of other types of pavements is broken, which further aids in maintaining driver concentration.

On a note of caution, it is obvious that the reductions in speed are not so significant as to negate the need for complementary road safety features in areas of high vulnerability, like urbanized linear settlement areas or areas with schools or hospitals. In fact, in many countries where linear settlements have developed around the road length, it has been found important to not only incorporate vertical and horizontal marking; but also, where warranted, to investigate and implement complementary traffic calming measures (visual and/or physical). Road safety is a critical aspect, not only in the road operation phase, but also in the road construction and maintenance activities, and due attention to this important theme is always needed. Other soft measures like road safety campaigns in intervened areas could be a welcome complement to hard infrastructure measures.

5 ADOQUINES AND MCA MODEL CHALLENGES

The use of adoquines instead of other surfacing methods combined with the choice of the MCA modality presents some specific challenges that have to be carefully considered. Table 7 presents the adoquine-related challenges while Table 8 presents the MCA-related challenges. Some challenges are not unique to either the adoquines or MCAs but are reiterated given their undue influence on project outcomes.

Table 7: Adoquine-Related Challenges

Challenge	Description of challenge and suggested mitigation measure
Level of service demands	Due to the nature of their coarser surfacing, and the presence of multiple joints, adoquines are not suitable for higher category roads (roads needing a higher level of service, e.g., roads classified functionally as trunk or main roads). The ride over adoquine surfacing is not as smooth as the ride over asphalt or concrete roads. Also, the ride over adoquines generates sound levels higher than those attained with asphalt or concrete surfaced roads. This is a big drawback on higher category roads. *No mitigation: adoquines only used for lower level service roads as appropriate or alternatively in urbanized environments where speed is not necessarily the critical design consideration.*
Road base and adoquine joints	The use of poor quality base materials or construction, or laying these bases during rainy days, can lead to premature road failures. Care should be taken to ensure that the adoquine joints are properly sealed with sand to prevent the creation of weak spots. Spacing should also be minimized. *Challenges can be mitigated by incorporating a strong and independent quality control party.*
Heavy rainfall	In areas with high levels of rainfall, water penetration through improperly sealed joints, seepages through side slopes, and storm incidences can lead to premature road failures. This challenge is not unique to adoquine roads. *Mitigation measures include reforestation of catchment areas, revegetation of cut slopes, installation of adequate drainage systems (culverts, sub-drains, catch-water drains, side drains, and use of geotextiles or other drainage materials), and proper sealing of adoquine joints. Alternative non-permeable options like concrete may also be more appropriate.*
Axle load control	Overloaded heavy goods vehicles can lead to displacement of adoquines over road bases and to premature pavement failures. This challenge is not unique to adoquine roads. *Mitigation can be achieved only with proper axle load control and by carrying out public awareness and monitoring campaigns. In the absence of this, more realistic periodic maintenance is necessary.*
Sustainability	The maintenance of the adoquine road after the construction phase is critical for long-term performance and benefits. This challenge is not unique to adoquine roads. *Clear maintenance arrangements have to be made for the continued maintenance of the road after construction is complete. In Nicaragua, this responsibility reverts to the road maintenance agency, which is currently exploring legal and contractual ways to use the MCAs in their maintenance model. Other arrangements can be possible for different country contexts.*

Table 8: MCA Modality-Related Challenges

Challenge	Description of challenge and suggested mitigation measure
Procurement aspects	Since earthworks have to be contracted first, timing challenges exist in terms of the formulation of MCAs and matching the timing of the earthworks, procurement of adoquines, and laying processes. Given physical isolation of some roads, transport becomes a critical factor for areas where adoquine manufacture is far from project sites or where interest in the private sector to supply these areas becomes a challenge. Challenges exist for MCAs in contracting for a supply of adoquines since many transport companies are informal and are not legally incorporated. *Challenges can be mitigated under MTI and local authority planning and coordination, as well as extensive advertising. Also, it can be helpful to incorporate suppliers' requests and suggestions in bidding documents and processes and to adjust as practical to the local context.*
Contractual issues	There is a significant liability issue in terms of responsibility for defects that might occur after the road has been completed, since the contractor responsible for earthworks would be long gone by the time some defects manifest themselves. *Defects are mitigated by incorporating a strong and independent quality control party. Also, the defects liability period for a contractor should be set to match responsibility.*
Financial management concerns	There is a fiduciary burden to ensure proper use of resources given wide geographical spread of interventions (a risk that something could go wrong in one isolated locality and affect the entire program). *This can be mitigated by training in financial management aspects, increased supervision, local citizen engagement to hold MCAs and earthworks contractors accountable, as well as the institution of concurrent audits.*
Administrative burdens	The control over many small contracts raises the administrative burden for all involved (MTI, mayors, MCAs, and the World Bank). There could be inadequate legal support for the MCA. *This has been mitigated by allowing MCAs to handle longer lengths of road (now at 1.5 kilometer per MCA) as well as setting clear standards for pre- and post-reviews. Post reviews are undertaken on a sample risk-based approach. Also, supervisors and promoters are limited to managing a maximum of five MCAs to lighten their administrative load. Still there is a need for further legal support to MCAs.*
Quality	While most MCAs have historically performed with great results, there is always a challenge in terms of technical knowledge and know-how of different MCAs, a situation that can lead into isolated cases of poor performance. *This challenge is mitigated by training during the constitution and incorporation of the MCAs, as well as the contracting of a strong and independent quality control party to check and approve construction materials and processes.*
Gender mainstreaming	There is a desire among numerous stakeholders to have more women work in traditional gender roles like construction. This challenge is not unique for MCAs but affects the transport sector in general. *While women have benefited greatly in the MCA processes, the challenge of incorporating more of them in the road construction process remains. Efforts have been made in the project to incorporate them in supervisory and treasurer roles, and further efforts are in place to create more awareness and opportunity with new-gender focused initiatives.*

6 TRANSFERABILITY OF THE MODEL

The search for and use of alternative surfacing methods has taken on extended significance in many countries around the world. In fact, in the rural roads development context, interesting developing country case studies and trials have been undertaken in many countries in Asia, Africa, and Latin American. In Vietnam, for example, extensive road surfacing trials were undertaken to determine the most appropriate road surfacing options among a number of different alternatives. Similarly, the use of local communities in the provision of road infrastructure is not a novel concept, with interesting case studies available in the development literature. There is also widespread use of communities to provide routine maintenance (especially in Asia, Africa, and Latin America). The combination of using a specific alternative surfacing material (adoquines) and local communities (under MCA modalities) on rural collector (secondary) roads over extended distances while achieving satisfactory results in terms of cost, quality, and timing is what is unique and innovative about the present case. This paper suggests that opportunity exists for the MCA approach to be investigated not only with the use of adoquines but also for other pavement types, depending on the country context: materials availability, material performance, and material compatibility with community delivery. The obvious question becomes therefore: How transferable is this MCA-adoquines model? Box 8 attempts to answer this question.

Box 8: Critical Factors for the Transferability of the MCA Adoquines Model

- **Country context:** There must be a country policy and political context that favors a decentralization of responsibility to local governments and people. There must be a good working relationship between the two levels of government. There must also be the capacity and willingness at the local level to take on this responsibility.
- **Materials availability and appropriateness:** There must be locally available materials that are easily sourced or manufactured and with reasonable haul distances. The surfacing choice must also be appropriate for the functional classification of the road and must lend itself to manual-labor-based construction, at least in the paving stage.
- **Labor availability and appropriateness:** There must be the necessary labor (skilled and semi-skilled) at reasonable costs, requisite capacity, and requisite training to ensure the smooth labor-based construction delivery.
- **Good quality control systems:** There must be good quality control systems to ensure the integrity of the road construction materials and also to ensure that the infrastructure delivery is undertaken in line with set standards, norms, and processes.
- **Good fiduciary arrangements:** Given fiduciary risks, there must be well designed fiduciary systems that can ensure fairness, transparency and accountability with open procurement processes, good financial management systems and records, and concurrent audits to ensure that what is promised is built and that there is limited opportunity for rent-seeking behavior. Citizen engagement as a critical oversight layer is critical to ensuring that value for money is achieved.

7 GENERAL CONCLUSIONS

The advantages and challenges in paving roads using the adoquines MCA model have already been documented. This work supports the results reached by Archondo-Callao and James (2009) that found adoquines to be a viable road surfacing alternative. This also supports the tenets recommended by Banjo et al. (2012) regarding the need to decentralize decision making at the local level, as well as the need to use appropriate technology in order to maximize the impact of rural infrastructure delivery on development outcomes. The summary conclusions are as follows:

Conclusion 1: The MCA model is a tested approach to rural road infrastructure delivery in Nicaragua that is worth exploring for adaptation and use in contexts similar to those presented in this paper.

The MCA model has particular transferability or replicability features and should be considered only in the contexts where it demonstrates obvious advantages over alternative options. The key lesson offered by this model is to *always challenge business-as-usual choices and to search for the most effective combination of labor and equipment and to ensure that the central and local government responsibilities mix for optimal road infrastructure delivery*. This paper also offers that opportunity exists for the MCA approach to be investigated not only with the use of adoquines but also for other pavement surfacing options depending on country context (materials availability, materials performance, and compatibility with community delivery approaches). Solutions evolve, and much iteration is needed to work out what is optimal.

In Nicaragua the critical success factors have been identified as follows:

1. **Experience with adoquines existed for a long time in the country.** The industry for manufacturing adoquines has also been well established for some time, and raw materials for the manufacturing of adoquines are locally available.
2. **There is a good model of decentralization, with a good working relationship between the central government and municipal authorities.** There is an enabling legal framework and the right devolution of responsibilities to the local levels. A good working partnership between the central ministry of transport infrastructure and the local authorities and population is a necessary condition for the success of the model.
3. **There is high government interest and support for the model with champions of the MCA model approach at the highest levels** (Ministry of Transport and Infrastructure and Ministry of Finance).
4. **The central Ministry of Transport and Infrastructure is staffed with highly competent people who provide the requisite training to new MCAs and accompany the road construction process.** The right training of MCAs and local mayors in all aspects (legal, social, environmental, financial management, and procurement) as well as accompanying them throughout the process is critical to ensure model success. There is always room for learning from doing (previous projects) and for continually looking for new tweaks and innovations that are then spread to new project sites.

5. **There is an abundant supply of local labor at competitive rates, and there is a willingness to participate in the road construction process.** Many youths have been incorporated into the model, and more important, the model has provided opportunity for the mainstreaming of women into the road construction process.
6. **Payments are made on time with provision for advance payment to jumpstart the road construction.** It is critically important to have solid financing arrangements with a reliable flow of funds to enable the successful execution of the project. MCAs are resource poor with no access to lines of credit. Any gaps in financing or complicated country payment systems would seriously hamper the success of this model.
7. **Quality control aspects are in place, and these are crucial to ensuring the technical integrity of completed road works.** The right supervision provision (quality control firm, laboratories, central ministry supervisor, and social promoter) is in place to ensure adherence to technical standards for materials as well as compliance with the required construction norms and practices.
8. **Customized procurement and financial management arrangements are in place and are continually reviewed to ensure greater transparency, fairness, and efficiency.** All efforts must be made to keep the model simple and repeatable and to reduce administrative burdens of multiple contracts while ensuring that the funds are used for the purposes for which they are intended.

Conclusion 2: The use of adoquines in a rural context at a secondary road functional level can be justified on multiple grounds, with the two most significant being environmental and economic considerations.

As noted, adoquines present some notable environmental advantages to gravel and asphalt alternatives in the rural road context. Adoquines are also an economically viable alternative for paving roads at the secondary and tertiary road levels and ought not to be limited to the traditional use in urbanized streets when deemed a realistic and acceptable choice.

Conclusion 3: The engagement of local citizens in the road construction process (through the MCA modality) has been proven to provide tangible benefits with works completed in time, within budget, and without compromising quality.

Benefits during project implementation include provision of short-term employment, the building of technical and entrepreneurial skills, and the engendering of a sense of ownership and responsibility for the roads. Putting the target beneficiaries in charge also has welcome benefits in terms of a desire to increase productivity, aim for high workmanship, control cost overruns, and minimize materials theft.

Conclusion 4: Challenges exist in the application of the MCA model and more work is needed to improve it.

On the technical front, there is a need to explore how adoquine pavement surfaces can be made less permeable without affecting pavement performance. The adoquine joints are the key differentiating feature from a concrete surface pavement and are also the weakest points in the adoquine surface. Initial conclusions from the Nicaraguan experience indicate that keeping the joints gap minimized (less than 5 millimeters, ideally 2 millimeters) leads to better pavement performance. There is also an opportunity to investigate the use of granular bases in place of cement stabilized bases, with a view to comparing performance and costs.

Efforts should be made to consider the social needs and benefits of the target beneficiaries, especially the mainstreaming of gender, and the provision of equal opportunities to benefit from the road construction activities. This is a challenging proposition that needs consultations, awareness training, and challenging of gender stereotypes, with conscious efforts to address the topic upfront.

It is also worth exploring ways in which the MCA model can be made more sustainable, for example, extending the work of the MCAs into the maintenance stage or providing help in formalizing them into small enterprises or contracting firms (work has already started on this front in Nicaragua).

Conclusion 5: Opportunities for integrating rural road infrastructure delivery with other key developmental challenges in the sector do exist and should be explored.

For example, more developmental work is needed on gender mainstreaming, disaster risk management, axle load control, and road safety. In the Nicaraguan context, there is a need to base MTI planning and design processes on data from the National System for the Prevention of Mitigation and Attention to Disasters. Work on reforestation of catchment areas is also an opportunity worth exploring. On road safety, project designs should always include shoulder provisions for non-motorized traffic, and planners should explore options for traffic calming where vertical and horizontal road signaling is deemed insufficient. The provision of transport infrastructure in a multisectoral or territorial development approach that integrates efforts in other complementary sectors (water, sanitation, information, communications and technology, energy, education, and health) can also help to magnify project impacts. A focus on rural transport services may also be another avenue worth pursuing to ensure maximum impact and benefit from the infrastructure investments.

Conclusion 6: Rural transport infrastructure delivery is an important tool in the development toolbox, with important implications for development outcomes in terms of creating employment opportunity, improving welfare, and reducing poverty.

Roads paving has impacts on development outcomes in the target communities, as well as for the economy as a whole. These include benefits to agricultural producers and transporters, local accessibility and benefits for local populations, cost savings for the public sector, and contributions to improvements in education and health outcomes (with improved access to these facilities for both the service providers and beneficiaries). As different studies have also shown, the improvements also have poverty alleviation implications, because the impact on the income and welfare over the poor is over and above the impact on average income. (See annex 1 for further details and for the project impact evaluation reports).

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ANNEX 1: WHY INVEST IN RURAL ROAD INFRASTRUCTURE?

The provision of transport infrastructure makes important contributions to the World Bank goals of fighting poverty and increasing shared prosperity. According to the Bank's World Development Report on Infrastructure (World Bank 1994), the adequacy of infrastructure helps determine one country's success and another's failure—in terms of diversifying production, expanding trade, coping with population growth, reducing poverty, or improving environmental conditions. The report also noted that while the precise linkages between infrastructure and development are still open to debate, the evidence shows that infrastructure capacity grows step for step with economic output. The evidence suggests that proximity to transportation networks has a large positive effect on per capita gross domestic product (GDP) growth rates. A 1 percent increase in the stock of infrastructure is associated with a 1 percent increase in GDP across all countries.

Well-managed and adequate transportation systems (inter- and intra-urban roads, urban mass transit systems, railroads, inland waterways, and all main corridors within a given place) are all a key part of a country's economic structure, providing efficient and low cost access of goods and people. Transportation investments link factors of production together in a web of relationships between producers and consumers to create a more efficient division of production, reduce economic distance, leverage geographical comparative advantage, promote regional integration, and provide agglomeration benefits that promote economic growth.

For rural road infrastructure in particular, the contribution to reducing poverty and fostering shared prosperity is achieved in the following ways:

- **Transport cost reductions:** cost and time for passenger and freight movements are reduced.
- **Input price reductions:** productivity is increased due to access to a larger and more diverse base of inputs such as raw materials, parts, energy, and labor. Differences in factor prices are reduced and unexploited opportunities are minimized.
- **Market access benefits:** improved access to wider markets adds to economies of scale in production, distribution, and consumption and also enables farmers to command a higher price in the market than what they would receive at the farm-gate.
- **Social mobility benefits:** access to education, health, administrative, employment opportunities, and leisure functions is improved.
- **Network effects:** linking more locations exponentially increases the value and effectiveness of transport while also working to undermine the negative effects that result from isolation and neglect.

- **Reliability benefits:** improved time performance and reduction of loss and damage minimizes economic drag (benefits of people and products being able to arrive on time and as planned).
- **Product quality benefits**: there are extra benefits for agriculturally sensitive produce like peas, perishable products like tomatoes, and quality sensitive products like beef from cattle. The produce commands a higher price if it arrives intact—less produce is rejected by buyers, because it travels better on a smoother road.
- **Complementary economic opportunity:** other businesses may benefit from improved farm incomes or businesses attracted to the area because of the presence of a good road connection.

A rich literature exists of different research efforts that have employed a variety of econometric and statistical techniques, with different time frames and data, to unlock the effects of rural road infrastructure investments on economic development outcomes.

The poverty reduction impacts stem primarily from enhancements of the income of the poor. These income improvements can in turn be approached from two different fronts: improvements in incomes resulting from (i) farm employment and (ii) nonfarm employment. Cook et al. (2005) carried out an extensive research effort on work done at the Asian Development Bank to investigate the impact of transport and energy on poverty reduction. One major finding was that transport and energy investments have positive impacts on both the income and non-income dimensions of poverty. Rural transport improvements in particular were noted to decrease costs to the poor for personal travel and goods transport. This is important for the poor because transport costs represent a disproportionately larger share of the expenditure basket than for the non-poor. The poor were also noted to value and benefit from not only the cost savings but also from the time savings that allows them to pursue other productive opportunities, while partaking of the normally unquantified benefits such as comfort, and convenience.

A World Bank (2010b) extensive review of the literature found that while the results are far from unanimous, a majority of studies report a significant positive effect of infrastructure on output, productivity, or growth rate. A particularly useful study by Calderon and Serven (2004) entails estimations of infrastructure-augmented growth and income inequality regressions for 121 countries over four years (1996–2000). The authors made five key conclusions from the results of this empirical work. First, they found that the volume of infrastructure stock has a significant positive effect on long-term economic growth. Second, they posited that infrastructure quantity and quality have a robust impact on reducing income inequality. Third, they noted that the results are attained in a framework that controls for reverse causation and survive statistical tests for misspecification. Fourth, they confirmed that the findings reported are significant on both statistical and economical terms. Finally, and perhaps most significantly for policy, they concluded that given that infrastructure both raises growth and lowers income inequality, it may be a key win-win ingredient for poverty reduction.

Jacoby and Minten (2009) use a canonical agricultural model with novel cross-sectional data set for remote rural villages in Madagascar. They found that a hypothetical rural road project that reduces the transport costs of the most remote households by about US$75 per ton would raise their incomes by about 50 percent. They further found that the gain due to the reduction in the cost of goods transport (both exports and imports) is small compared to that from improved access to nonfarm opportunities in the town areas. They conclude in part that, to the extent that remote households are poor to begin with, a policy of building rural roads can have desirable distributional properties, a point elaborated to even greater length in Jacoby (2000). Similar work by Khandker et al. (2006) analyzed the evidence related to the construction of two road projects in Bangladesh and also found significant impact on poverty reduction in targeted rural areas. Other interesting work on this topic from Estache and Fay (1995) finds that enhancement of road infrastructure has a positive impact on income convergence in Argentina and Brazil.

Edmonds (n.d.), in research work done for the International Labor Organization, provides a graphic and succinct description of the link between the lack of access and poverty. He contends that "isolation and access are the two sides of the same coin, with poor access as the defining characteristic of poverty. Lack of access has its impact at the most basic level of living: if there is poor access to health services, people will remain unhealthy; children will die; and any epidemic will be likely to have catastrophic results; if there is poor access to clean water, again health will suffer; if there is poor access to basic information, the household will be unaware of ideas and technology that might help them to lift their level of living; and if there is poor access to education, children will probably share in the future the limitations confronting their parents today." He further elaborates that access is also related to poverty at a different level: "Even if financial and physical access to the basic services is assured, this is actually only a starting point in the development process. If access to markets is difficult, farmers are hardly likely to diversify their production to include cash crops, or even to grow net surpluses of subsistence staples. And without such new ideas and opportunities poverty remains an endemic feature of rural life."

Olivia and Gibson (2008) confirm that the effects of rural infrastructure provision extend to nonfarm employment and income. They used data from 4,000 households in rural Indonesia to show that the quality of two key types of infrastructure—roads and electricity—affects both employment in and income from nonfarm enterprises. They conclude that the evidence suggests that there would be gains from development strategies that improve both the access to and the quality of rural infrastructure. De Janvry and Sadoulet (2000) also note that off-farm employment in nonagricultural activities is enhanced by infrastructure investment, decentralization of economic activity, development of secondary towns, neighborhood effects, and coordination in the location of economic activity. Other summary empirical evidence from the literature is provided in Humphreys et al. (2008).

In summary, the studies have supported the argument that the provision of rural transport infrastructure and services raises living standards in poor rural areas, and helps to reduce poverty and income inequality. The theory of change is that by reducing transport costs and by improving the reliability of the transport system, roads are deemed to influence market activity, affect input and output prices, foster economic linkages that enhance agricultural production, and stimulate off-farm diversification and other income-generating opportunities. It has also been contended that by facilitating access to social service facilities, better roads enhance social outcomes (health and education sectors in particular). Gannon and Liu (1997) contend that transport is an intermediate service—it is a means to an end. They note that transport alone cannot reduce poverty, but it serves a pervasive and crucial complementary role.

A more extensive (but in no way exhaustive) list of positive effects and impacts of rural roads is presented in Box A1.1).

Box A1.1: Positive Effects and Impacts of Rural Roads

1. Improved access to markets for agricultural produce with improved farm based incomes
2. Lower vehicle operating costs
3. Savings in travel times
4. Attraction of service providers to rural or isolated settlements (professionals want to reside/work where access is not an issue)
5. Improved access to health care facilities and treatment (hospitals, health centers, doctors)
6. Improved access to education (schools)
7. Improved access to employment opportunities (work commutes, search for opportunities)
8. Short-term employment opportunities during construction and later during maintenance
9. Improved mobility (access to long-distance transport services)
10. Increased access to agricultural extension services (e.g., better seeds, fertilizer, and knowledge)
11. Increased opportunity for tourism
12. Improved technical capacities and fostering of entrepreneurship in target local communities
13. Improved land values
14. Improved business climate and nonfarm-based income opportunities
15. Improved health effects due to dust reductions
16. Lowered costs for input and output prices (not automatic)
17. Improved ride comfort conditions
18. Lower losses for perishable and motion-damage-sensitive agricultural produce
19. Lower losses on livestock during transfer to markets
20. Catalyst for other investments (e.g., electrification, water supply, and sanitation)
21. Improved country stability with connection of isolated regions or communities
22. Contributions to alleviating rural-urban migration (could work the other way)
23. Facilitate the delivery of emergency relief and secure escape routes for emergency disasters
24. Encourage citizen participation in public programs delivery
25. Improved gender equity, empowerment, and agency by reducing the burden on women of heavy tasks (e.g. fetching water) and maternal tasks; improved voice and participation of women

ANNEX 2: GREEN AND INCLUSIVE GROWTH CONCEPTS

Despite the interest in growth, all care and effort need to be taken to ensure that development takes place in a sustainable manner given the challenges with resource depletion, environmental pollution, and the threat of climate change. To that effect, the concept of green and inclusive growth has taken on greater relevance and resonance in development circles over recent years. For example, the World Bank Sustainable Development Network Strategy (World Bank 2012a) is now anchored in the concept of green and inclusive growth (GIG). The theme carries greatest relevance in the mitigation aspects due to transport's contribution to greenhouse gas emissions. The study and analysis of those impacts is outside the scope of this paper. Nevertheless, the GIG theme is also relevant in the road transport infrastructure sector because there is opportunity to make positive changes on both adaptation and inclusion fronts. Also, there is a window of opportunity to minimize the carbon footprint in road-materials manufacturing and laying processes through a careful selection of less energy intensive sources, processes, and materials.

Green growth means different things to different people. It has been framed as "making growth processes resource-efficient, cleaner and more resilient without necessarily slowing them" (World Bank 2011b). The Organization for Economic Co-operation and Development defines green growth as the fostering of economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. Whatever the definition adopted, the common theme is that green growth ought to be an environmentally informed path to a sustainable future. The term *inclusive* is central to the green growth agenda in that it captures the human elements of growth that encompass all segments of the society irrespective of socioeconomic status.

First, there is a need to incorporate resilience in the construction of infrastructure in order to adapt for the effects of climate change, especially given that the investments inherently have high lock-in effects. Nicaragua, given its location in the Central American isthmus, has had its fair share of natural disaster phenomena over the past years, with significant damage to transport infrastructure. Events have been more frequent and more impactful events over recent years. Given the high initial sunk costs of the transport infrastructure, all measures that can be adapted to ensure its long-term sustainability are critical.

Second, there is an ever increasing need to preserve the environment through the careful selection and use of environmentally friendly materials and the utilization of energy efficient materials and manufacturing, construction, and maintenance methods.

Third, it is becoming increasingly more important to include local communities in investment decisions and to improve their access to transport infrastructure and services so that they can partake in economic development opportunities. Social inclusion aspects in the roads sector have important implications for providing voice, opportunity, capability, integration, empowerment, and accountability.

The goal of inclusive green growth, therefore, is to design the public policies and induce the investments needed to remove the barriers (physical, institutional, social, and so forth) that prevent diverse communities and individuals from taking this path.

ANNEX 3: ROAD SECTIONS CONSTRUCTED BY MCAS: FOURTH ROADS REHABILITATION AND MAINTENANCE PROJECT AND ITS ADDITIONAL FINANCING

Table A3.1: Fourth Roads Project Road Sections Paved with Adoquines (MCA Modality Only)—Original Project Only, Not Additional Financing

Nº	Road section	Municipality	No. MCAs	Total length (km)
1	Junction Aposentillo–Aposentillo	Chinandega	7	8.10
2	San Antonio–San Gregorio	Diriamba	5	5.80
3	PROINCASA–Cofradía (Tipitapa y Nindiri)	Tipitapa/Nindiri	4	4.00
4	Tola–Nancimí	Tola	5	4.30
5	Nacascolo–Talanguera	San Juan del Sur	1	1.86
6	Junction Casares–Huehuete	Jinotepe	3	3.00
7	San Jorge - Buenos Aires–Popoyuapa	San Jorge, Buenos Aires, Rivas	4	5.17
8	Tisma–Empalme Zambrano	Tisma	9	12.00
9	Tisma–Zambrano, section Junction Zambrano–Zambrano	Tipitapa	4	5.46
10	Las Lajitas–Cuapa, Section Cuapa–El Carmen	San Francisco de Cuapa	7	5.00
11	Las Lajitas–Cuapa, Section El Carmen–Llano Grande	San Francisco de Cuapa	6	5.00
12	Teustepe–San José de los Remates, section Teustepe–San Diego	Teustepe	9	11.50
13	San Juan de Río Coco–Telpaneca, section San Juan de Río Coco–Entrance to the Community of Quibuto	San Juan de Río Coco	5	5.07
14	Qda. Honda–San Fco. Libre, section San Fco. Libre–Las Delicias	San Francisco Libre	6	5.00
15	La Subasta–Camoapa, section La Subasta–El Cambio	Boaco	9	9.40
16	Juigalpa–La Libertad, section Comunidad Vigía–San Marcos	Juigalpa	4	5.80
17	Juigalpa–La Libertad, section Cosmatillo–La Curva	Juigalpa	9	8.20
18	El Quino–Santa Cruz-Mérida, section El Quino–Santa Cruz	Altagracia	7	6.50
19	Rubén Darío–PROLACSA	Matagalpa	3	1.60
20	Matagalpa Penitentiary System	Matagalpa	2	1.17
21	Junction Chaguitillo–Hortitech	Sebaco	1	1.16

22	Estelí Penitentiary System	Estelí	2	1.30
23	Las Delicias–El Conteiner (Barrio El Carrizal)	San Juan del Sur	8	5.00
	TOTAL		**120**	**121.40**

Note: km = kilometers.

Table A3.2: Fourth Roads Project Road Sections Paved with Adoquines (MCA Modality Only)—Additional Financing

Nº	Road section	Municipality	No. MCAs	Total length (km)
1	Teustepe–San José de los Remates Road, section 2	Teustepe	16	13.42
2	Las Lajitas–Cuapa, section Las Lajitas–Llano Grande (Etapa III)	Juigalpa/Cuapa	11	8.50
3	Empalme Cuyalí–Las Cruces	Jinotega	15	15.73
4	Rancho Rojo–La Calamidad Tramo 1	Camoapa	12	10.00
5	Empalme Las Cruces–Pantasma	Jinotega	10	11.50
6	Quebrada. Honda–San Francisco Libre, section San Fco. Libre–Las Delicias (stage 2)	San Francisco Libre	9	6.72
7	Empalme Cuyalí–Abisinia–Puente la Pavona	Jinotega	28	26.58
8	La Subasta–Camoapa Road, section 2	Camoapa	9	9.00
9	Palacagüina–Telpaneca–San Juan de Río Coco, section Telpaneca–Quibuto	Telpaneca	12	10.59
10	Santa Lucía–Boaco	Boaco	8	4.91
11	Moyogalpa–La Flor	Moyogalpa	6	4.50
12	Altagracia–Santa Cruz–Balgüe	Altagracia	6	4.50
13	La Subasta–Camoapa, section San Benito–Urban Area Camoapa	Camoapa	5	3.89
14	Las Pampas–Las Delicias	San Juan del Sur	3	2.20
15	Queen Hill–Corn Island	Corn Island	2	0.92
	TOTAL for Additional Financing		**152**	**132.96**

Note: km = kilometers.

ANNEX 4: TECHNICAL ASPECTS OF ADOQUINES USED IN THE NICARAGUA ROADS PROGRAM

The guiding technical standard for road construction in Nicaragua is the General Specification Standard for the Construction of Roads, Streets and Bridges, NIC-2000. It outlines the procedures and norms that should be incorporated into road construction contracts. It also contains basic technical provisions specifically related to environmental and the natural resources protection that must be fully complied with by any contractor. The specifications are part of all road contract bidding documents and contracts. Section 502 regulates aspects related to adoquines in particular.

The manufacture of adoquines is governed by the Technical Standard NTON 12 009-12, approved by the National Assembly on July 13, 2010. The purpose of this standard is "to establish the physical and mechanical requirements of the concrete paving stones used as a running surface in roads, secondary roads, streets, parking lots according to the NIC-2000, as well as for paving stones that are used in walking platforms."[8] The regulations included in this standard are the following:

- Physical and mechanical properties of the materials used
- Physical and mechanical requirements for concrete paving stones
- Quality control
- Criteria for acceptance or rejection
- Transport and storage
- Positioning of the paving stones
- Observance of the standard

The standard NTON 12 009-12 classifies the paving stones in three types:

1. Paving Stone Type 1 (Adoquine Type 1): This is the paving stone used as a running surface in trails, roads, streets, and parking lots for all types of vehicles, with a minimum thickness of 8 centimeters.
2. Paving Stone Type 2 (Adoquine Type 2): This is the paving stone used as a surface in walking platforms and for bicycles paths with a minimum thickness of 6 centimeters.
3. Special paving stone: This is the paving stone used in special cases according to the requirements of design and approved by MTI with a minimum thickness of 5 centimeters.

For the construction of roads under the current project, the standard states that the paving stones should be of Type 1, with beveled edges and in a Holy Cross shape. For the project, paving stone type 1 is used with a thickness of 10 centimeters (see Figure A4.1). The 10-centimeter thick adoquines provide extra pavement structural support. Depending on

[8] www.asamblea.gob.ni

traffic levels, it is conceivable that 8-centimeter thick adoquines laid over a well stabilized base could suffice. The required resistances (strengths) that they should comply with are indicated in Table A4.1.

Figure A4.1: Typical Adoquine Used in Nicaragua Roads Program

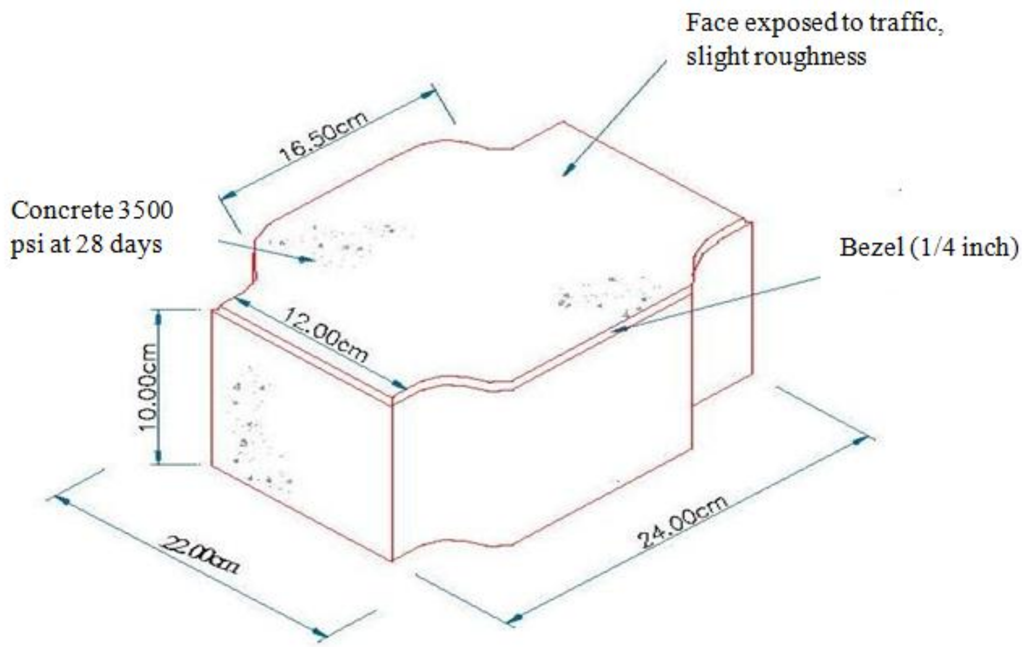


Table A4.1: Adoquine Resistance Requirements

Type of resistance	Average minimum resistance MPa (kg/cm2)	Minimal resistance for MPa (kg/cm2) sample
Flexo-traction	5.00 (50.98)	4.20 (42.83)
Compression	24.22 (247)	21.80 (222)

Source: N-TON 12-009-10.

Notes: 1 MPa = 1 N/mm2 = 10.1972 kg/cm2; Mpa = , kg = kilogram, cm = centimeter. The average minimum resistance for compression of 24 MPa is equivalent to 3500psi.

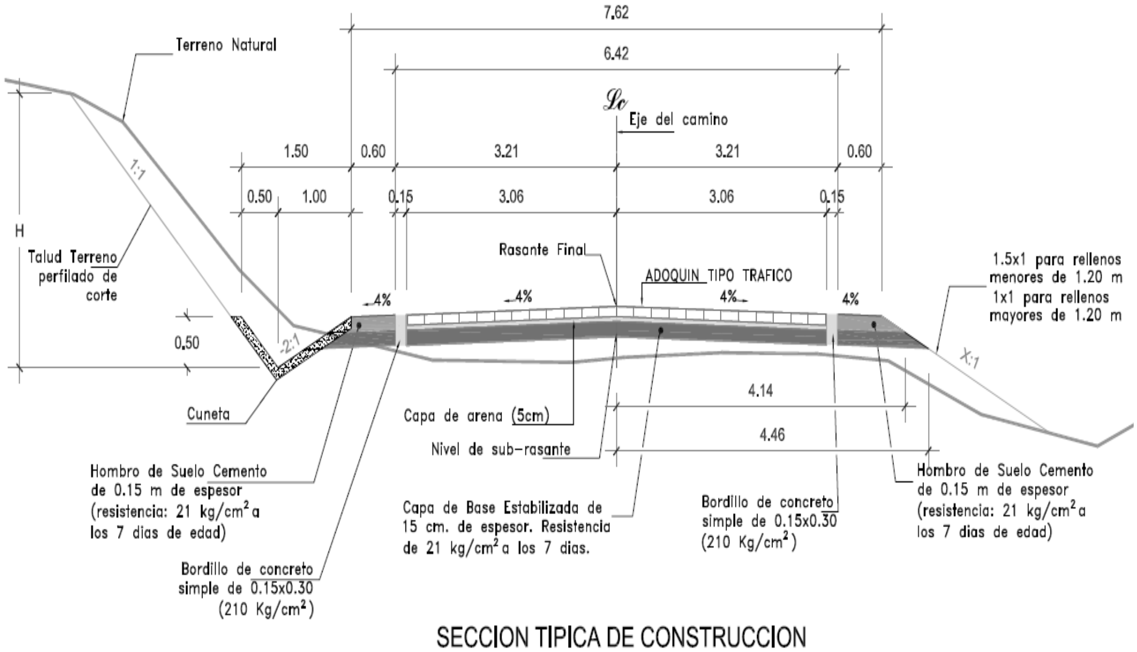
For other international design approaches for adoquine roads, the following references are recommended:

- British Standard BS 7533: 1992 Guide for structural Design of Pavements Constructed with Clay or Concrete Block Pavers
- *The Upgraded Dutch Design Method for Concrete Block Road Pavements,* (Huurman et al.)
- *Design and Construction of Interlocking Concrete Block Pavements* (Shackel 1991)
- The Chilean Institute of Cement and Concrete Adoquine pavements Design and Construction Manual, 1991
- Manual de Euroadoquin
- *Design Guide for Concrete Adoquine Pavements for Vehicular Traffic* (Madrid and German (2001)

- EUPAVE Design Standard for Concrete Paving Blocks NBN B21 311
- Mexican Construction Guide for Adoquine NOM-C-314-1981
- South African Concrete Manufacturers Association Concrete Block Paving Books 1, 2, 3 and 4 of 1997–98

Figure A4.2 shows a typical rural road cross-section in the Nicaragua roads program.

Figure A4.2: Typical Adoquine Rural Road Cross-Section



Source: Nicaragua Ministry of Transport and Infrastructure.

ANNEX 5: ADOQUINES BEST PRACTICE DESIGN AND CONSTRUCTION CONSIDERATIONS

Structural Design

For best practice and simplified structural design considerations of adoquine roads, the following steps are recommended as the bare minimum from a reading of BS 7533:1992, *Guide for Structural Design of Pavements Constructed with Clay or Concrete Block Pavers*:

Step 1: Determine subgrade California Bearing Ratio (CBR) and capping layer requirements. If CBR is variable, the pavement should be designed to cope with the lowest measured CBR. IF a site has soft spots (weak CBR areas), it may be possible to excavate and replace them with suitable fill material to bring the CBR up to an acceptable level. Normally, any subgrade with CBR of 5 percent or less will require a capping layer (subgrade improvement layer). This is constructed from approved granular or cement-bound material, laid and compacted in layers not greater than 200 millimeters thick (see Table A5.1).

Note that plasticity requirements are also very important. It is not advisable to have highly plastic subgrade materials like clay. Plasticity indices of less than 20 percent common with sandy clay and sandy gravel materials are preferred.

Table A5.1: Capping Layer Requirements

	Determine subgrade CBR and capping layer requirements		
	Less than 2%	**2%-5%**	**Greater than 5%**
Capping layer	600mm	350mm	None

Note: mm = millimeters.

Step 2: Determine sub-base requirements depending on traffic volumes and types. An equivalent standard axle load (ESAL) is determined as a single commercial vehicle with a loaded axle weight of 8,200 kilograms making one pass over the pavement. The sub-base requirements depending on the expected daily ESAL are as indicated in Table A5.2.

Table A5.2: Sub-Base Requirements

	Determine sub-base thickness based on ESAL				
	Minimu	**50 ESAL**	**200**	**500 ESAL**	**5000**
Sub-base thickness with	150mm	160mm	200mm	225mm	225mm
Sub-base thickness without	225mm	225mm	225mm	225mm	225mm

Note: ESAL = equivalent standard axle load, mm = millimeters.

Step 3: Determine road base requirements. The decision as to whether a road base is required is dependent upon the cumulative number of axles anticipated over the design life of the pavement and certain special conditions/considerations: presence of channelized traffic for which estimated traffic has to be multiplied by a factor of 3; speeds greater than 50 kilometers per hour for which the traffic volume should be multiplied by a factor of 2 to allow for the dynamic loads imposed on the road; frost heave considerations for which a minimum thickness of capping layer, sub-base, and road base of 450 millimeters is needed; and due control of moisture content. Also, in cases where heavy goods vehicles make frequent turning maneuvers, a road base should be considered. If none of the special conditions apply and the design life ESAL is below 0.5 million standard axles (msa), the road base may be omitted. Table A5.3 indicates recommended design thicknesses of the road base for an 80-millimeter-thick concrete paving block. Thicknesses can be reduced by some 20 millimeters if 100-millimeter-thick concrete paving blocks are used instead.

Table A5.3: Road Base Requirements

	Cumulative number of ESAL (msa)				
	Up to 0.5	**0.5–1.5**	**1.5–4.0**	**4.0–8.0**	**8.0–12.0**
Cement Bound	None	130mm	130mm	180mm	230mm
Sand Bedding	50mm	30mm	30mm	30mm	30mm

Note: msa = million standard axles, mm = millimeters.

Box A5.1 presents elements that should receive special attention during the adoquine construction process.

Box A5.1: 10 Key Adoquine Construction Considerations

1. A concrete kerb or cordon is needed on both sides to lock the adoquines in and also to ensure that the sand bed materials do not wash away. In cases where adoquines are built in areas with high longitudinal gradients, the use of transverse cordons/beams in the adoquine pavement every few meters is recommended.
2. Good drainage of the subgrade is very important. Drainage of rainwater and groundwater benefits the behavior of the pavement as a whole. Before applying capping, sub-base, or base materials, it should be ensured that the underlying layer(s) is free of water, the materials meet the technical specifications, and they are well compacted.
3. A cement bound sub-base or granular base is recommended to avoid pavement deformation or rutting. Where granular materials are bused in place of the cement bound sub-base, special attention should be paid to grading and segregation issues.
4. The proper camber or transverse slope of the sub-base must be achieved as well as for the adoquines themselves (2.5 to 4 percent). In curves, the proper super-elevations should be maintained.
5. The chosen laying course or sand bed layer must be stable, uniform in thickness, and after compaction about 30 to 50 millimeters thick. It should not be deformed by traffic or by fluctuations in moisture content. It should also be relatively porous so that no water can stagnate between it and the adoquines and so that it can serve a draining function (for this reason sand is commonly used with fine elements at less than 3 percent). The sand layer must not be compacted.
6. Adoquines can be placed tightly against each other on a profiled laying course with a target distance between them of about 2 millimeters. In no case should the joints be greater than 5 millimeters as this will encourage adoquine block displacement and water infiltration. Where a greater than 5 millimeters joints exist, the recommendation is to fix these with cement mortars.

7. A concrete kerb or cordon is needed on both sides to lock the adoquines in and also to ensure that the sand bed materials do not wash away. In cases where adoquines are built in areas with high longitudinal gradients, the use of transverse cordons/beams in the adoquine pavement every few meters is recommended.
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12. Adoquines can be placed tightly against each other on a profiled laying course with a target distance between them of about 2 millimeters. In no case should the joints be greater than 5 millimeters as this will encourage adoquine block displacement and water infiltration. Where a greater than 5 millimeters joints exist, the recommendation is to fix these with cement mortars.
13. Gaps that cannot be filled with a full adoquine are closed with filling blocks cut to size (ideally no filling block should be smaller than half a block).
14. Joints should not be filled until the adoquines have been put into place. After the joints have been properly filled in with sand, simple compacting of the finished layer can be undertaken. The adoquines will be ready for opening to traffic immediately, though slow speeds are encouraged.
15. It is recommended to construct adoquine roads starting from the towns to be connected and heading outward toward the main road connection to build a sense of "it's our road" for the communities. This is also an excellent strategy in cases where resources are constrained and the whole road section cannot be built at once.
16. For road sections with an inclined longitudinal gradient, it is recommended to construct the adoquine roads going downhill to avoid water stagnation and road base saturation problems.

ANNEX 6: ADOQUINE MANUFACTURING IN NICARAGUA

There are eight officially known manufacturers of adoquines in Nicaragua with significant production volumes. There are an even greater number of artisan factories. For the purpose of this study, five officials of some of the major manufacturing companies were interviewed.

The main results of these interviews found that the average production is 700,000 adoquines monthly, with a capacity to produce 1 million monthly. The average price of the paving stone is US$0.38. The majority of factories have their own laboratory for quality control. A double control approach is in place: the internal control that adheres to the Technical Standard N-TON 12-009-10 and the external control, requested by the clients (depending on end use of the adoquines and client needs). TMTI carries out physical inspections for all its requests and occasionally carries out random quality control. MCAs undertake a similar function for their orders.

The raw materials for the manufacture of the adoquines are all sourced locally. In the majority of cases, the factories have an integrated structure with their own mines and exploitation permits. The cement is bought from the only two cement factories in the county (CEMEX and HOLCIM). The only imported materials are the additives, but these are seldom used. The main ingredients in the making of adoquines are cement, fine aggregates, filler, coarse aggregates, and water.

The adoquine manufacturers identified as opportunities the existing installed capacity to produce up to 1 million adoquines monthly, but one that has not yet been exploited. Additionally, they see a greater opportunity in the manufacturing of the 8-centimeter adoquines (less weight, less transportation costs, and savings in the use of raw materials). They all stated that they already have in possession the necessary moulds to produce this type of adoquine.

Within the identified challenges in the sector, they noted a need for more flexibility in the bidding processes and the need to change to the use of the 8-centimeter adoquines in place of the 10-centimeter adoquines.