Estimation of Economic Rates of Return (ERR) using HDM-4 for Millennium Challenge Corporation (MCC) Compact Road Improvements in Honduras

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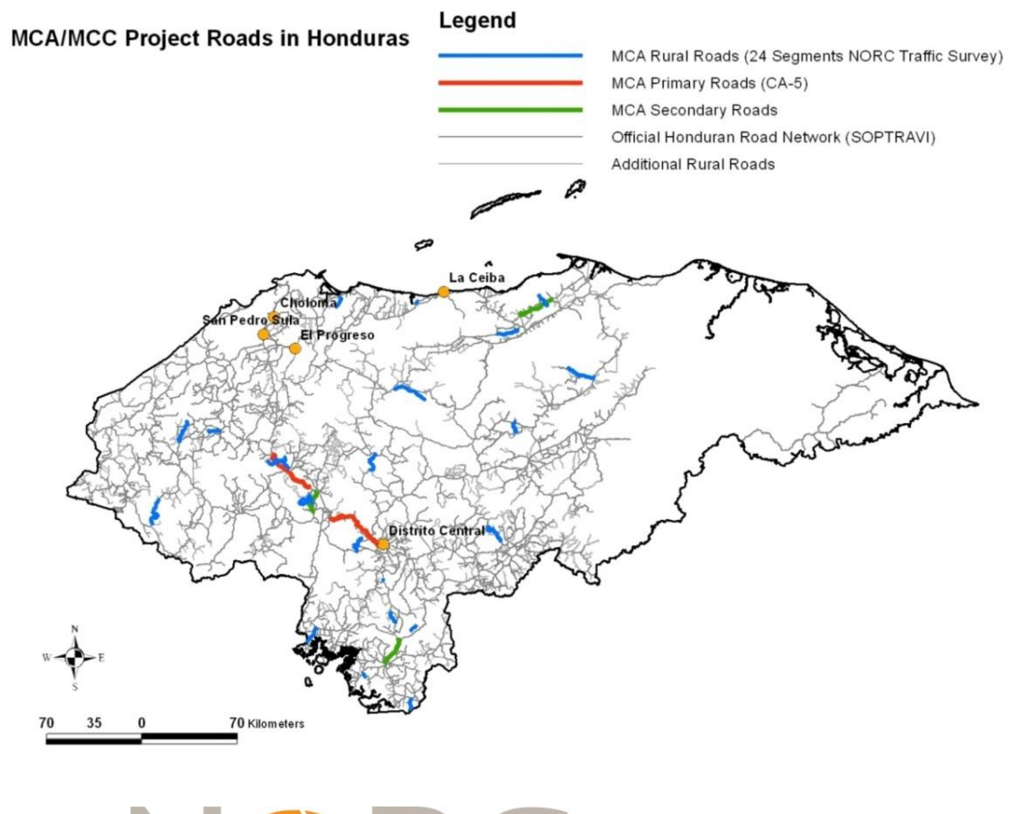

NORC at the UNIVERSITY of CHICAGO

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I. Executive Summary

On June 13, 2005, MCC signed a $205 million Compact with Honduras that included the upgrading of a series of key road segments, specifically:

- the upgrading of 4 primary roads segments on the CA-5 north-south trunk road, running north from the capitol of Tegucigalpa to the San Pedro Sula and the port of Puerto Cortes, which at various points 2-lane, 3-lane and 4-lane improvements[1];
- the upgrading of 3 secondary road sections;
- the improvement of 33 rural road segments, including improvements in grading, re-graveling, bridges, culverts, retaining walls, and improvement drainage[2].

Project road improvements began in 2009 and have been completed as of 2012 except for Sections 1 and 2 of the CA-5 which are still undergoing improvements (due to be completed in 2012-2013). A detailed schedule of the road improvement completion dates supplied by MCA Honduras in October 2011 is provided in Annex V.

The ERR estimations completed for this study on MCC project primary, secondary and rural roads in Honduras represent a significant improvement in terms of robustness and accuracy over previous 2008 and 2011 ERR estimates, and took advantage of significant new data that was made available for this analysis in late 2011, including:

- Actual vehicle traffic counts and road speed measurements for multiple vehicle types using data measured in three rounds of NORC traffic surveys in 2009, 2010 and 2011 on MCC project roads;
- Revised road maintenance unit costs using official Honduran unit costs provided by Fundo Vial, Tegucigalpa, in October 2011, and which were significantly different than the maintenance unit costs used in the previous ERR estimates;
- Final MCC improvement project costs provided by MCA Honduras in October 2011, which were significantly higher than the 2008 HDM estimated project costs;
- On site direct observation by NORC specialists of the MCC project primary, secondary and rural roads – including both improved and unimproved sections – in October 2011 to directly

[1] In October 2011 MCA Honduras informed NORC that the completion of the planned improvements to CA-5 Section 1 had not been completed prior to the end of the MCC Honduras Compact, and that MCA subsequently received funding from CABEI in 2011 to complete this Section. We did not seek detailed information from MCA Honduras on the extent and scope of CABEI funding of MCA project roads beyond the MCC Compact, and we suggest that MCA Honduras can provide such information if needed. We did provide ERR estimates for both Sections 1 and 2 of CA-5 for this report even though the improvements for these Sections were still on-going at the time of the analysis.

[2] Please see Annex III for a discussion of the selection of MCC rural road improvements segments modeled in this ERR analysis.

observe road conditions, project improvement designs, materials and standards, and road deterioration rates.

Utilization of these new data greatly improved the accuracy of the ERR estimates relative to the previous ERR studies, which did not have access to these updated 2011 measured data inputs. Further, we improved upon and in some cases corrected errors in the HDM configuration and inputs that we believe will result in more accurate ERR estimates. Finally, we used the most recent version of the HDM software, HDM-4 Version 2, which includes improved and more robust ERR estimation models relative to those in the HDM-III software which was used for the 2008 ERR estimates (notably the HDM-4 Version 2 ERR model corrects for a known tendency in the HDM-III ERR model to provide inflated estimates).

No major problems in terms of data acquisition needed for robust HDM-4 estimates, nor any data “gaps”, were encountered in order to provide complete calculations. As a result, the HDM-4 ERR calculations reported here represent a relatively straightforward, “classic” HDM-4 analysis. Consequently, we feel confident about the 2011 ERR re-calculated estimates provided in this report for the MCC CA-5 primary and secondary roads.

CA-5 Primary Roads ERR Results. Despite lower than predicted vehicle traffic counts (which directly impact the calculation of Net Present Value benefits through Vehicle Operating Costs (VOC) as well as ERR estimates, higher than expected road maintenance costs, as well as final project improvement costs which were considerably higher than the previous 2008 estimates used in the 2008 HDM-III ERR estimates, we estimate profitable ERRs (using a 10% criterion) for all primary road CA-5 sections except for Section 2. Estimated ERRs for CA-5 Sections 1, 3 and 4 were in fact higher than estimates from all previous studies (conducted in 2003-2005, 2008 and 2011). The primary CA-5 ERR estimates are listed in Table 12, which we copy here:

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value (NPV)	Economic Rate of Return (ERR) Estimate
Section 1	50.180	46.804	91.311	44.507	18.1
Section 2	47.618	42.606	33.953	-8.654	7.6
Section 3-1 (2 lanes)	3.870	2.996	5.801	2.805	20.8
Section 3-2 (3 lanes)	12.449	10.100	20.994	10.895	21.3
Section 3 (global)	16.319	13.096	26.795	13.699	21.1
Section 4-1 (2 lanes)	8.741	7.325	9.358	2.032	12.1
Section 4-2 (3 lanes)	12.291	10.629	18.158	7.529	15.9
Section 4-3 (4 lanes)	4.096	3.665	4.608	0.943	12.7
Section 4 (global)	25.128	21.619	32.124	10.504	14.0

Three sensitivity analyses were conducted to evaluate the sensitivity of the estimated CA-5 ERRs to measured traffic volumes (which have a direct impact on the calculation of future benefits in the NPV cost/benefit stream through reduced VOCs) and on initial capital costs, which of course also impact NPV and ERR by constituting the largest project cost component.

Three scenarios were modeled, as follows:

1. What happens to the estimated ERR if we decrease traffic volume (AADT) of 20%?
   What happens to the estimated ERR if we decrease predicted traffic growth by 50%?
   What happens to the estimated ERR if we decrease project capital costs by 20%?

The sensitivity test results for CA-5 are presented here, copied from Table 19 in the report:

CA-5 Section	Estimated ERR Values			
	Base scenario	Traffic volume - 20%	Traffic growth - 50%	Capital costs - 20%
Section 1	18.1	11.8	11.5	21.6
Section 2	7.6	5.7	4.7	10.1
Section 3 (global)	21.1	14.9	17.7	26.5
Section 4 (global)	14.0	11.4	11.7	16.8

The sensitivity test results indicate that while the estimated ERRs do show a significant reduction with either a 20% drop in traffic volume or a 50% reduction in traffic growth, the drop is not by an order of magnitude: the estimated ERRs for Sections 1, 3 and 4 remain at double digits. Reduction in capital costs by 20%, on the other hand, increases estimated ERRs by approximately 15-20% across the four CA-5 Sections. Clearly, while the changes in traffic volumes and growth, and in capital costs, do have a direct impact on the ERR estimates, the ERRs are not extremely sensitive to changes in these inputs.

Secondary Road ERR Results. The ERR estimates for secondary roads in particular were very strong, and reflected a very strong increase in traffic volumes post-project relative to pre-project measures. Further, MCC secondary road project costs were relatively low compared to primary improvement costs, and road improvement designs and work standards were judged by NORC experts to be very high, with very low projected future road deterioration rates due to the high standards of the improvements. Thus, the MCC secondary road improvements appear to have been a very profitable success, and these are reflected in their estimated ERR values which ranged from 29.4% to 188.3% (copied here from Table 14):

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value	Economic Rate of Return
Section Choluteca - Orocuina	6.731	6.377	19.293	12.916	29.4
Section Comayagua – La Paz	6.465	6.124	63.428	57.304	84.4
Section Sonaguera – km 35	7.676	7.200	171.828	164.628	188.3
All sections grouped	20.872	19.700	254.549	234.848	105.8

As with the primary CA-5 sections, a sensitivity analysis was made, to evaluate the impact of:

- Over evaluated traffic (AADT 20 % lower),
- Traffic growth over estimated (50 % lower).

Three scenarios were modeled, as follows:

1. What if we have over-estimated future traffic volumes: what happens to the estimated ERR if we decrease traffic volume (AADT) of 20%?
   What if we have over-estimated future traffic growth: what happens to the estimated ERR if we decrease predicted traffic growth by 50%?
   How sensitive are the results to the initial project capital costs - what happens to the estimated ERR if we decrease project capital costs by 20%?

A summary of the secondary road sensitivity test results is copied here from Table 20 in the report:

Section	Base scenario	Traffic volume – 20%	Traffic growth – 50%	Capital costs – 20%
Section Choluteca - Orocuina	29.4	22.2	25.7	35.7
Section Comayagua – La Paz	84.4	66.4	79.0	102.8
Section Sonaguera – km 35	188.3	150.4	180.2	229.4
All sections grouped	105.8	86.2	99.9	129.1

As with the sensitivity tests for the CA-5 roads, the impact on estimated ERRs of capital cost decreases is more significant than the impacts from traffic volume reductions or traffic growth rate reductions. Also, the relative impact of the traffic growth rate reduction of 50% on ERRs is greater than for primary CA-5 sections. For both secondary and primary CA-5 sections, these sensitivity tests highlight the importance of inputting correct values for capital costs, and the fact that we were able to input those values increases the accuracy of these ERR estimates over all previous versions.

Rural Road ERR Results. After discussion with MCC in September-October 2011, MCC gave the approval to use HDM-4 as a model to estimate ERRs for all MCC project roads, despite the fact that HDM-4 is not typically used for unpaved roads. The ERR analysis for rural roads was able to take advantage of newly available and highly useful data that should improve the rural road ERR estimates. These data included:

- traffic volumes and speeds from NORC traffic surveys (2009-2011) as well as rural road traffic measurements provided in the 2007 MCA report by Alden Rivera;
- rural road section road alignment data provided in the 2007 Alden Rivera study;
- on-site observations of rural road conditions completed by NORC in October 2011.

The estimated rural road ERRs ranged considerably across the 33 rural MCC segments where it was estimated. The ERR results for all rural segments are provided below, copied from Table 18 in the report:

Rural Road Section	HDM-4 Estimated NPV	HDM-4 Estimated ERR
01 - La Esperanza-Monte Sion	0.956	150.4 (2)[3]
02 - La Unión-El Bambú (Ceiba Mocha)	0.651	205.8 (2)
03 - Ilanga- Monte Abajo (S113)	0.113	24.5 (1)
04 - S113 Holanda Linda La Danta	0.308	35.6 (1)
05 - Chacalapa (S113) - Zonas Productivas	0.032	15.6 (1)
06 - S113 Río Arriba - Los Ángeles	0.475	65.3 (1)
07 - Chacalapa (S113) - Chichiguite	0.126	64.9 (1)
08 - Jutiapa - Limera - Balfate - Rio Coco	0.737	30.9 (1)
09 - El Way - Lorelay	0.102	24.9 (1)
10 - Trujillo - Guadalupe	0.182	20.5 (1)
11 - Dos Bocas - Babilonia (La Casona)	0.029	18.7 (1)
12 - San Luis-Quebradas Amarillas	-0.301	No Solution
13 - Quebradas Amarillas (Desvio Planes)-Trojes	0.614	113.1 (1)
14 - Guatillo- Las Lazadas	0.709	70.3 (1)
15 - Siguatepeque-El Carbonal-Carrizal (CA-5)	2.030	272.1 (2)
16 - La Germania No 1 - Santa Rosita	1.871	297.7 (2)
17 - Lo de Reina-El Pacon (Zona de Riego)	1.435	119.6 (1)
18 - Ajuterique-Playoncito-El Misterio-Ajuterique	2.382	194.5 (2)
19 - San Sebastian - Limite Municipalidad de Tomala	-0.064	8.6 (1)
20 - Tomalá - Limite Municipalidad de San Sebastián	0.258	19.9 (1)
21 - Lepaera - Coros	1.769	129.5 (1)
22 - Arada - Las Marias	-0.591	-9.8 (1)
23 - Oculi_ Desvio Cedrales	0.595	41.4 (1)
24 - Soledad- Los Alpes.	0.401	46.9 (1)
25 - Piedra de Diamante El Aceituno	0.100	21.6 (1)
26 - Apacilagua - Piedra de Diamante	0.536	46.4 (1)
27 - San Benito Nuevo - Rio Grande	0.287	30.2 (1)

[3] The number in parentheses here displays the number of solutions for the ERR calculations obtained in HDM-4. HDM-4 systematically makes a search for all solutions of the equation Net Present Value (NPV) = 0 for a discount rate value range of -100 up to 400 and displays the results. When there is more than one solution, by default HDM-4 uses the lowest result. Note that for Rural Road Section 12, San Luis-Quebradas Amarillas, no solution was found.

Rural Road Section	HDM-4 Estimated NPV	HDM-4 Estimated ERR
28 - Santa Ana de Yusguare - El Zapotillo (La Permuta)	0.080	26.1 (1)
29 - La Corteza - La Catarina	0.418	41.9 (1)
30 - Col la Lucha-Col Buena Vista	0.427	32.6 (1)
31 - Los Puentes - Pueblo Nuevo	0.345	87.8 (2)
32 - Las Mesas San Nicolas Abajo	0.108	45.6 (1)
33 - Concepcion de Maria - El Aguacatal	0.079	36.9 (1)
Total NPV	17.200	

We note that there are a number of important caveats regarding using HDM-4 to produce rural road ERR estimates. The HDM-4 rural road ERR estimates are very sensitive to assumptions on future traffic growth and vehicle speeds post improvements: for rural roads, calculated NPVs and ERRs tend to correlate closely with traffic volumetric flows.

Further, rural road project costs are relatively very low. For these reasons, the economic analysis can in some cases provide very high rates of return due in large part to these low project costs. In addition, for these ERR estimates, we have made assumptions regarding the number of days per year each rural road segment is "passable", which can affect the ERR estimates – however these are rough assumptions and actual passability may vary considerably across the segments;

Therefore at best the rural road ERR estimates are likely only capturing a small part of the true economic impact of rural road improvements. The NPV estimates here may be a more appropriate measure of the likely return on investment. Another option that could be considered for future rural road ERR modeling would be to perhaps include measures of the economic or agricultural productivity of areas immediately adjacent to the rural road section in question, or for cities/towns that the rural road segment leads to. An explicit consideration of the agricultural productivity of adjacent areas to rural roads is a component in the 2007 MCA rural road ERR model developed by MCA consultant Alden Rivera: this complete model is presented in its original excel spreadsheet format in Annex VIII (file *"ERRMCARuralRoads_comité_camino_pop_data Alden.xlsm"*).

Sensitivity Tests for Impact of Alternative Maintenance Regimes on Primary and Secondary Roads. At the request of MCC, we have run some sensitivity tests to evaluate the sensitivity of the estimated ERRs to alternative road maintenance regimes.

The sensitivity to maintenance regimes in Base Alternative was tested on CA-5 section 1 and on the Choluteca – Orocuina secondary road sections. The results are displayed below along with a comparison with the original run (copied here from Tables 21 and 22 of the report).

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value	Economic Rate of Return
Routine + cracks + rehab	50.180	46.804	91.311	44.507	18.1
Poor maintenance	50.122	49.475	317.154	267.679	37.9
Fair maintenance	50.122	47.894	244.751	196.857	29.8
Good maintenance	50.122	46.746	93.434	46.688	18.5
Excellent maintenance	50.122	45.485	61.552	16.068	12.8

For the Choluteca – Orocuina secondary road section:

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value	Economic Rate of Return
Routine + cracks + rehab	6.731	6.477	18.487	12.011	28.1
Poor maintenance	6.731	6.654	25.197	18.544	36.0
Fair maintenance	6.753	6.405	19.973	13.568	30.3
Good maintenance	6.753	6.326	18.681	12.356	28.8
Excellent maintenance	6.775	6.048	14.769	8.720	23.4

The results show that, for the CA-5 section tested, there is a considerable variation in ERR depending on the Base Case maintenance regime that is enacted: the estimated ERRs are as low as 12.8% with excellent baseline maintenance, and range up to 37.9% in the case of very poor baseline maintenance. The ERR results for the secondary road section, however, have much less variation depending on the baseline maintenance regime implemented.

Nonetheless, it should be noted that for both the CA-5 section and the secondary section tested, the Project Alternative is still profitable, even if an excellent level of service is provided by an appropriate maintenance standard: the lowest ERR estimated is 12.8% for the CA-5 section under excellent baseline maintenance, but that value is still strong and supportive of profitability as evaluated in most project cases.

Therefore, these sensitivity tests have indicated that, due to the fact that the secondary and primary project improvements in Honduras are of such high quality, future maintenance regimes implemented by the Honduran government on those project roads are likely to have little effect on future road conditions or profitability. Estimated ERRs for project improvements do vary as a function of the actual baseline (non-project) road maintenance regime implemented, but even in the case of very high quality Base Alternative road maintenance, the project investments are still deemed to be profitable.

Final Sensitivity Test For Impact of Base Year. To evaluate the impact on calculated returns that would occur from converting the vehicle unit costs to 2011 values, we conducted a sensitivity analysis to evaluate the impacts by inflating the vehicle unit costs by 5% (the approximate inflation change in Honduras since 2008). This sensitivity analysis was carried out on CA-5 sections grouped into one single project, and on Secondary roads grouped into one single project. All costs are expressed in US$, and that should limit the inflation coefficient. The results are summarized below (copied from Table 23 in the report):

Roads	Base scenario	VOCs + 5 %
CA-5	13.3	13.5
Secondary	105.8	110.5

The ERR does increase slightly after the cost adjustment. However, the relative impact is not significant.

Some Policy Implications. A key story to emerge from this study is that the ERR return and profitability on the MCC Honduran secondary roads is very high, relative to primary and rural road returns. We note that the very high ERRs estimated for the secondary roads are primarily driven by quite significant post-improvement increases in traffic volumes along those segments. This is an optimal outcome, and it implies that MCC may want to select future secondary or other road improvement candidate sections by choosing those that have high traffic volumes, or which are likely to have high traffic volume increases due to improvements. Further, the results appear to call for a consideration of the estimated returns to secondary compared to primary road improvements, given the relatively very high cost per unit of the primary road improvements.

The rural road analysis reveals, notably, that rural roads that are improved using designs that fall short of paving them tend to return to their pre-improvement road surface condition within 5 years. This implies that many of the economic benefits created by the rural road improvements (accessibility, reduction in road user costs, etc.) are confined to the first 5 years after improvement, and this contrasts notably with the secondary and primary road improvements which predict continued benefits to accrue for up to 20 years or more, due to the durability of the paved improvement designs implement there. This brings up the question of whether or not rural road improvements are worthwhile? Further, it likely becomes more important to know what is going on around these rural roads (e.g. types of agricultural production, what population centers are adjacent and of what size, etc.) to provide a more nuanced assessment of likely impacts of these rural improvements.

HDM-4 brings to bear powerful engineering models and equations and provides for a robust set of quantified outputs and estimates that could well serve larger road improvement economic impact evaluation efforts. This implies that HDM-4 should perhaps be merged with more traditional impact evaluation approaches, such as quasi-experimental designs or double differences, to take advantage of the precision of the HDM-4 road estimates and model predictions.

II. Introduction

MCC contracted with the NORC at the University of Chicago in September, 2011, to conduct a re-estimation of Economic Rates of Return (ERR[4]) using the Highway Development Model (HDM4) for MCC project road improvements completed in Honduras. The study sought to provide updated estimates of previously calculated ERR values completed in 2008 (by consultant Louis Berger), by taking advantage of key updated data, including:

- evolution in traffic volumes and speeds obtained from NORC traffic surveys conducted 2009-2011;
- final updated project costs for each road segment provided by MCA Honduras on October 2011;
- updated key assumptions and parameter values for improved HDM-4 estimation and calibration based on a site visit to Honduras conducted by NORC in October 2011

During September-December 2011, NORC collected data and completed an HDM4 estimation of MCC project road ERRs, including calibration and sensitivity testing. As part of this process, NORC conducted a site visit to Honduras in October 2011 which included on-site assessments of improved primary, secondary and rural roads, as well as collection of updated data on key HDM-4 model inputs. Specifically, the new revised ERR estimates took advantage of significant new data that was made available for this analysis in late 2011:

- Actual vehicle traffic counts and road speed measurements for multiple vehicle types using data measured in three rounds of NORC traffic surveys in 2009, 2010 and 2011 on MCC project roads;
- Revised road maintenance unit costs using official Honduran unit costs provided by Fundo Vial, Tegucigalpa, in October 2011, and which were significantly different than the maintenance unit costs used in the previous ERR estimates;
- Final MCC improvement project costs provided by MCA Honduras in October 2011, which were significantly higher than the 2008 HDM estimated project costs;
- On site direct observation by NORC specialists of the MCC project primary, secondary and rural roads – including both improved and unimproved sections – in October 2011 to directly observe road conditions, project improvement designs, materials and standards, and road deterioration rates.

[4] The HDM-4 software and its documentation uses the term “Internal Rate of Return (IRR)”. However, this report uses the term “Economic Rate or Return”, or ERR, as this is the terminology used by MCC in its projects and evaluations. However, both terms refer to the same process, as described in Section V of this report.

Further, NORC calculated the ERRs using the most recent version of the HDM software, HDM-4 Version 2, which includes improved and more robust ERR estimation models relative to those in the HDM-III software which was used for the 2008 ERR estimates (notably the HDM-4 Version 2 ERR model corrects for a known tendency in the HDM-III ERR model to provide inflated estimates).

NORC also carefully reviewed in detail inputs and assumptions made for three previous HDM ERR estimate studies conducted on Honduras roads in 2003-2005, 2008 and 2011. Finally, NORC conducted detailed discussions with Honduran road engineers and experts. As a result, NORC believes that the revised estimates for the Honduras MCC road improvements are as accurate as possible, and derive from improved assumptions and more accurate inputs than the previous studies.

As a result of discussions held with MCC in September and October 2011, it was decided to use the HDM-4 ERR model to estimate ERRs for MCC rural road improvements, despite the fact that HDM-4 is typically not used for studies or analyses on unpaved roads. While alternative rural road ERR methods were considered, it was decided that HDM-4 should provide a feasible methodology for providing ERR estimates for the unpaved rural roads, albeit with some notable caveats, and thus MCC approved its usage for the rural roads.

This report presents a detailed description of the data that was collected, the inputs and assumptions made for the HDM-4 ERR simulations, and ERR results (including results from sensitivity tests that were conducted under various scenarios). In addition, extensive Annexes are provided including all key reports and data collected and used for input into the HDM-4 estimations. We specifically provide the complete HDM-4 workspace file, along with all input data that is used by that workspace to generate the results reported here. This allows for complete re-running and duplication of all our results by any future parties. Further, we provide in Annexes all files and reports we obtained from MCC or MCA for the previous 2003-2005, 2008 and 2011 ERR estimates conducted in Honduras, as well any additional relevant or useful background reports or data collected.

III. MCC Honduras Road Improvements Project Scope and Improvement Timeline

On June 13, 2005, MCC signed a $205 million Compact with Honduras that included the upgrading of a series of key road segments, specifically:

- the upgrading of 4 primary roads segments on the CA-5 north-south trunk road, running north from the capitol of Tegucigalpa to the San Pedro Sula and the port of Puerto Cortes;
- the primary CA-5 road segments include at various points 2-lane, 3-lane and 4-lane improvements;
- the upgrading of 3 secondary road sections;
- the improvement of 33 rural road segments, including improvements in grading, re-graveling, bridges, culverts, retaining walls, and improvement drainage [5].

Figure 1 shows the official Honduran road network, while Figure 2 shows the location of the MCC project road improvements. All project road improvements have been completed as of 2012 except for Sections 1 and 2 of the CA-5 which are still undergoing improvements (due to be completed in 2012-2013). A detailed schedule of the road improvement completion dates supplied by MCA Honduras in October 2011 is provided in Annex V.

[5] Please see Annex III for a discussion of the selection of MCC rural road improvements segments modeled in this ERR analysis.

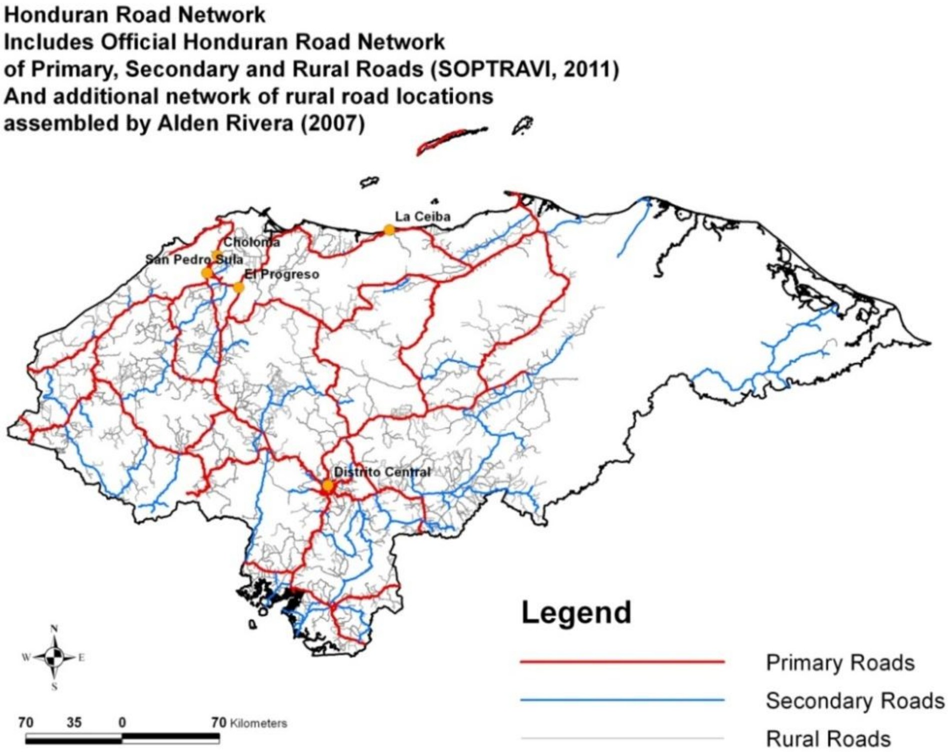


FIGURE 1: OFFICIAL HONDURAN ROAD NETWORK (SOPTRAVI)[6]

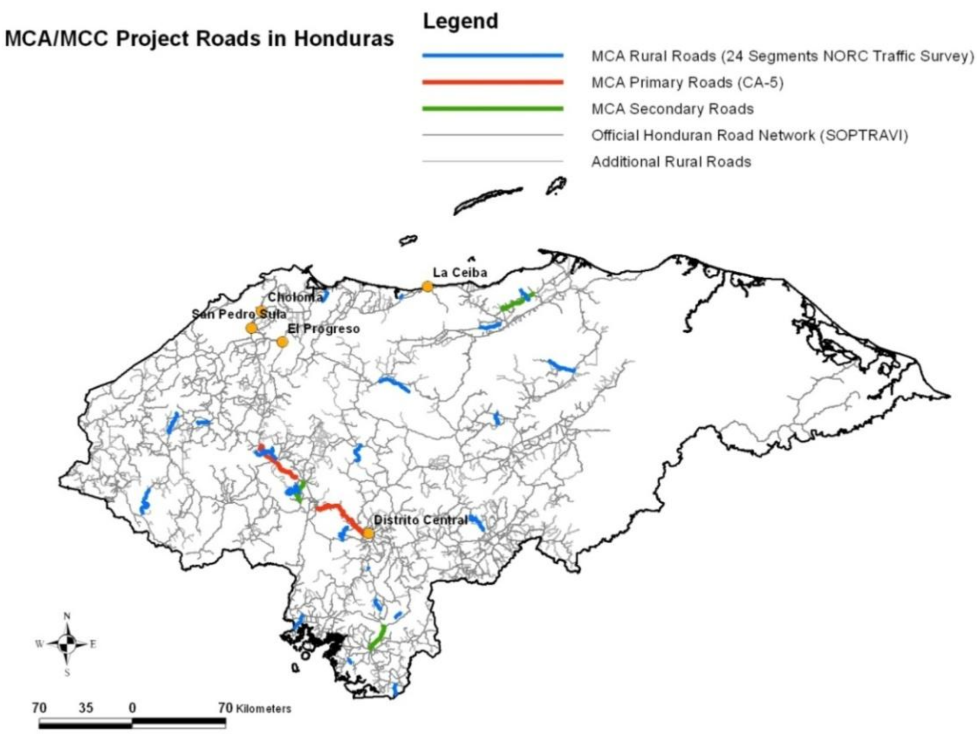


FIGURE 2: LOCATION OF MCC ROAD IMPROVEMENTS[7]

[6] GIS road network data provided by Soptravi, http://www.soptravi.gob.hn/dr/

[7] GIS data for locations of MCC road improvements provided by MCA Honduras.

IV NORC Site Visit to Honduras, October 2011

During the week of October 3, 2011, John Felkner and Pierre Joubert of NORC traveled to Honduras to conduct a site visit with the goal of collection of all essential data for the HDM-4 analysis, including collecting data on project road surface conditions. The following activities were completed during the site visit:

- project road surface conditions were directly observed on all CA-5 primary road improvement segments, on one of the secondary road improvement segments, and on a sample of project rural road segments (see road surface photographs provided in Annex I);
- a visit to an asphalt mixing plant used to produce asphalt used in the MCC road improvements was completed to observe materials used in the asphalt production, and their relative ratios, in order to update the HDM4 modeling of road degradation parameters[8];
- several meetings with Soptravi (http://www.soptravi.gob.hn/dr/), the Honduran government entity responsible for planning, managing, regulating and implementing road construction and improvement projects in Honduras, were held. During one of these meetings NORC made contact with the HDM-4 specialist who completed HDM-4 ERR estimates for Section 1 of the CA-5 in early 2011;
- NORC met with Esther Aleman of MCA-Honduras, and obtained from MCA key information useful for the HDM-4 ERR estimates: final road segment improvement capital costs; finalized road improvement timelines for all primary, secondary and rural segments; finalized lists of rural improvement segments[9]; description and key files from previous 2008 HDM-III and 2011 HDM-IV road ERR estimations;
- NORC also met with the Honduran road fund, Fondo Vial (http://www.fondovial.gob.hn/) and obtained updated official road improvement unit costs, which are fed directly into the HDM-4 model ;
- NORC met with local private sector shipping company executives, to discuss road conditions and road condition changes, as well as vehicle purchase and gasoline prices, routes used for shipping, etc.

As a result of direct observation of the project roads, NORC was able to directly observe CA-5 road conditions before MCC/MCA project improvements, specifically on portion of CA-5 Sections 1 and 2 that were still to be rehabilitated. However, for most of CA-5 Sections 1 and 2, and all portions of

[8] Materials used in asphalt production, and their ratio in the asphalt mixture, vary by location and by country depending on availability of input materials and road improvement budget constraints. Variation in the production materials and mixtures can produce road surfaces that degrade at differing rates, so determining the composition of asphalt input materials and mixing processes was important for accurate modeling in HDM-4.

[9] See Annex III.

Sections 3 and 4, we observed road conditions post-improvement. Consequently, we were able to obtain direct observation of both the pre- and post-improvement CA-5 road conditions which allowed for direct input into HDM-4 accurate parameter values for their conditions (allowing for improved modeling of future road degradation rates). We also observed the final post-improvement condition of the Comayagua-La Paz secondary road segment.

Overall, NORC was impressed with the quality of the road improvements on CA-5: Consultant Pierre Joubert said the improvement quality of the road improvements based both on direct observation of the improved road surfaces and also on the quality of the asphalt going into the road improvements, was quite high and met the highest international standards.

Figure 3 shows the final meeting agenda and contact names for NORC meetings held during the site visit. The site visit was very successful in that NORC was able to meet all pre-visit goals and obtain all needed information for HDM-4 ERR estimations.

<table>
<tr><th>No.</th><th colspan="4">Fecha/Hora</th></tr>
<tr><td>1</td><td colspan="4">Lunes 03 VISITAS A CAMPO
Pueden ver que tramo desean visitar!
- Carretera primaria MCA: CA-5 Tegucigalpa – Siguatepeque
- Carretera primaria SOPTRAVI: Desvío a La Paz – Marcala (en mal estado) o Carretera a Valle de Ángeles o Danlí (Buen estado)
- Carretera secundaria MCA: Comayagua - Ajuterique - La Paz
- Carretera secundaria SOPTRAVI: Comayagua – La Libertad (comienza a partir de la posta en la salida hacia La Libertad)
- Carretera Rural MCA: Ajuterique – Quelepa – El Playón
- Carretera Rural SOPTRAVI: Los Palillos – San José – Flores (entrando por las atoleras a salir a puente San José y luego a Flores</td></tr>
<tr><td>2</td><td>Martes 04
9:00 am</td><td colspan="3">Visita a la Planta Mezcladora de Asfalto
Recomendado por Sofía Maradiaga de la Dirección General de Caminos - SOPTRAVI
Tramo Valle de Comayagua a Ciudad Comayagua, este es el que inicia delante de la Posta de Las Mercedes y termina delante de Palmerola. PRODECON.</td></tr>
<tr><th></th><th>Fecha/Hora</th><th>Contacto</th><th>Institución</th><th>Observación</th></tr>
<tr><td>3</td><td>Miércoles 05
2:00 pm</td><td>Ing. Luis Roberto Benítez, favor solicitarle si puede estar el Ing. Efrain Bustillo.</td><td>UPEG –SOPTRAVI
Tel. 2225-0489</td><td>Diseño y construcción de carreteras.

Mantenimiento de carreteras.</td></tr>
<tr><td>4</td><td>Jueves 06
9:00 am

10:30 am

2:00 pm</td><td>Ing. Esther Alemán

Sra. Magdalena García –
Ing. José Luis Varela</td><td>MCA
Blvard. Morazán, Edif. Los Castaños, 5to. piso, Teg. Tel. 2232-3539

MCA

Fondo Vial, Gerencia Técnica
Col. Lomas del Mayab ½ cuadra el Mall Multiplaza.
Cel. 9978-1971</td><td>Experto Carreteras MCA-H

Planificación Vial</td></tr>
<tr><td>5</td><td>Viernes 07
9:30 am

3:00 pm.</td><td>Preguntar por Pablito o la Licda. Lourdes Callejas

Sr. Vladimir Marroquín
Gerente General</td><td>Depto. de Estudios Económicos
Dirección General de Transporte
3er. Piso, SOPTRAVI

Empresa de Transporte de Pasajero
King Quality - Tegucigalpa
Tel. 2225-5415 – Cel. 3339-4250</td><td>Sector Privado</td></tr>
</table>

FIGURE 3: NORC HONDURAS SITE VISIT MEETING AGENDA

V. HDM-4 Model and HDM-4 NPV and ERR Estimation Process

HDM-4. The Highway Design and Management (HDM-4), originally developed by the World Bank, has become widely used internationally as a planning and programming tool for road and highway expenditures and maintenance standards. HDM is a computer model that simulates physical and economic conditions over the period of analysis, usually a life cycle, for a series of alternatives and scenarios specified. Three interacting sets of costs (related to construction, maintenance and road use) are added together over time in discounted present values, where the costs are determined by first predicting physical quantities of resource consumption and then multiplying these by unit costs or prices. HDM can predict road network performance as a function of traffic volumes and loadings, road pavement type and strength, maintenance standards and environment/climate. It can quantify benefits to road users from savings in Vehicle Operating Costs (VOC), reduced road user travel times, decreases in numbers of accidents and environmental effects. Further, the model is designed to make comparative cost estimates and economic evaluations alternative construction and maintenance options, either for a given road project or for groups of links on an entire road network. It estimates the total costs for alternative project designs and maintenance standards year-by-year, discounting the future costs if desired at different postulated discount rates so that the user can search for alternatives with the lowest discounted total cost. The benefits derived from implementation of other options are calculated over a specified analysis period by comparing the predicted economic cost streams in each year against that for the respective year of the base case option.

Since HDM simulates future changes to the road system from current, the reliability of the results is dependent upon how well the data provided to the model reflects the reality of current conditions in terms of the inputs of the model, and how well the predictions of the model fit real behavior and the interactions between various factors for the conditions to which it is applied. Application of the model thus involves two important steps:

- Achieving a quality of input data that is appropriate for the desired reliability of the results, and a correct interpretation of that data; and
- Calibration of the outputs – adjusting the model parameters to enhance how well the forecast and outputs represent the changes and influences over time and under various interventions.

HDM-4 is first typically calibrated using detailed specific input data from on-site sources pertaining to the specifics of the road segments to be evaluated and the types of upgrades performed. Calibration inputs for HDM-4 may include the following: road characteristics; vehicle fleet characteristics and costs; traffic volume and growth rates; road works standards; economic and financial costs for the proposed improvements or maintenance; and discount rate applied and analysis period (typically 20 years for HDM-4 ERR).

Sensitivity analysis may be conducted under different scenarios that would anticipate different levels of future increases in specific costs, e.g. a 20 percent increase in Road Capital and Maintenance Costs. The economic analysis may be used to produce key indicators, including Net Present Value (NPV) at a given discount rate, Economic Internal Rate of Return (EIRR) and NPV/Cost ratio.

HDM-4 may then be used to estimate potential economic benefits that can be derived from a transport infrastructure program that may include any, or all, of the following:

- Reduced operating expenses for current and futures users of the improved facilities (including savings in VOCs);
- Savings in road maintenance expenditures;
- Stimulation of economic development;
- Savings in time for both passengers and freight shipments;
- Few accidents and reduced property damage;
- Increase comfort and convenience; and
- Improved access to social facilities or amenities.

ERR is calculated in HDM-4, under HDM-4 "life cycle analysis" of road projects, by comparing future forecasted cost streams of two or more alternative road maintenance or improvement options, with one option designated as the "do minimum" or "base case" (with minimal maintenance or improvements) over a specified analysis period, typically 20 years. For each alternative road works option, including the base case, future road user cost (RUC) cost streams are calculated for each year including Vehicle operating costs (VOC[10]) and travel-time costs (TTC)[11]. The benefits from each project alternative are calculated by comparing the predicted economic cost streams in each year against those for the respective years of the base case option, over the analysis. The discounted total economic cost difference between an alternative and the base case is the net present value (NPV). The ERR is the discount rate at which NPV equals zero, and is a guide to the profitability of the investment – the higher the better. If the ERR is larger than the planning discount rate (and that ERR is stable under subsequent sensitivity testing) then this can be considered as an indicator that the

[10] Vehicle Operating Costs (VOC) are the costs of vehicle operation comprised of fuel, tires, labor, depreciation, interest, lubricants, crew, cargo and travel time (HDM Documentation Volume 5, Section 1).

[11] As an option, HDM-4 Life Cycle Analysis can model and consider the costs of future accident rates, vehicle omissions and energy use in addition to VOC and TTC, although doing so requires a number of economic assumptions to express these factors in monetary terms and modeling them may not be appropriate depending on the project (they are not modeled by default in HDM-4). Further, additional "exogenous benefits" can be defined, such as for example indices of accessibility to markets or services created by the road project, and included in the cost streams.

project is economically justified (although depending on the criteria considered for the larger evaluation of project justification there of course may be other indicators or considerations).

Steps typically performed in HDM-4 ERR analysis of one or more proposed road projects include the following:

- ***Assessment of current road conditions and available input data, and creation of HDM-4 software "workspace".*** Key inputs needed for HDM-4 ERR analysis can include road roughness indices, such as international roughness index (IRI), data on traffic volumes and congestion (to simulate future road usage and deterioration rates), road pavement types and strengths, road maintenance standards and their costs, and environment and climate. Many country transport departments maintain road management computer databases (which may or may not reside in a geographic information system (GIS)) and if so, these databases may be used to help provide input data for HDM-4. Prospective data inputs, their quality and their sources must be evaluated and decisions and assumptions made regarding the optimal way to input them into HDM-4. In addition, estimated costs of alternative road improvement options must be obtained. In sum, the HDM-4 user must use the available data to represent the reality of current conditions and influencing factors, in the terms understood by the model.
- ***Model calibration.*** HDM-4 calibration is the process of adjusting the model parameters, describing the road conditions, to enhance how well the forecast and outputs represent the changes and influences over time and under various interventions. HDM-4 calibration focuses on two primary components that determine the physical quantities, costs and benefits predicted for the analysis, namely: Road user effects (RUE), comprised of VOC, travel time, safety and emissions, and; road deterioration and works effects (RUE), comprised of the deterioration of the pavement and the impact of maintenance activities on pavement condition and future pavement deterioration.
- ***Estimation of future cost streams.*** Once data is inputted correctly and the model calibrated, calculation of future cost streams under the analysis period and calculation of NPV and ERR for each road project alternative and the base case.
- ***Sensitivity testing.*** A final very important step is the process of sensitivity testing the stability of the estimated ERR in the case that estimated rates of traffic growth, road deterioration or capital costs, for example, change from initial estimations. In those cases, is the ERR estimate stable, or is it highly sensitive to small changes in capital costs or traffic growth? HDM-4 sensitivity testing of the model allows one to see how much ERR may vary as a function of, say, a lower than expected growth in traffic. An estimated ERR that is relatively stable in the face of these types of changes increases confidence in the estimated economic validity or profitability of the project.

Re-Calculation of ERR Post-Project for Comparison to Baseline Estimates. Updating or re-calculating ERR after a road project has been completed from an estimate done pre-project or at baseline allows for an improved estimate of the actual project ERR using *observed* data on key model inputs – such as actual road deterioration rates, road usage levels, traffic congestion levels, and capital costs – for any measurements of these factors since the project was undertaken. These observed data can be used to improve the accuracy of the HDM-4 model assumptions, and produce a more accurate estimation of ERR. For example, post-baseline measures of traffic counts or congestion levels can be used to improve the model assumptions about future traffic growth on improved roads, while post-baseline measures of road roughness indices can be used to correct assumptions and parameters for road deterioration projected rates. Further, project costs may have been higher than initially estimated (due perhaps to exogenous factors such as fuel prices fluctuations) or changes may have been made during the improvement or construction process in materials used or design standards, further affecting costs and/or deterioration rates. By duplicating as accurately as possible data inputs and data input assumptions of the baseline HDM-4 model, the baseline assumptions for factors such as traffic growth or road deterioration rates can be assessed for their accuracy.

If an HDM-4 analysis (and the creation of an HDM-4 "workspace") was completed at baseline, then the re-calculation of ERR post-project using HDM-4 is relatively straightforward.[12] In that case, the HDM-4 modeler can begin with the existing (baseline) HDM-4 model and its assumptions and data inputs. In this case, the modeler will update the HDM-4 model using any new data obtained post-baseline, and conduct data collection surveys designed to directly measure and provide updates on key inputs (such as traffic congestion levels and road deterioration conditions). If an HDM-4 analysis was not done at baseline, then calculation of ERR using HDM-4 can still be done, but it requires additional work as new assumptions must be made about data inputs.

[12] Due to differences in data formats, additional work is required if the initial study was conducted in HDM-3 rather than HDM-4.

VI. Previous Analyses and Data Obtained

A. Previous ERR Estimates

A primary goal of this study was to provide revised and updated ERR estimates to the existing 2008 ERR calculations and results. Consequently, in August 2011 NORC requested from MCC all files, results and documentation related to those 2008 ERR estimates, their estimation process/methodology, and a description of their inputs and assumptions made. NORC specified that, if possible, sharing the original HDM workspace would be highly preferred, as the HDM workspace preserves all details on inputs, units and assumptions made for all inputs, and would allow direct replication of all results (we provide all inputs and our complete HDM-4 workspace file with this report to allow replication of our ERR results). In addition, we made the same request to MCA Honduras during our October 2011 site visit.

MCC and MCA did share with NORC files and results from three previous studies – conducted in 2003-2005, 2008 and 2011 - that sought to estimate ERRs for Honduran road improvements, although unfortunately they were not able to locate or provide the original HDM workspaces used. We provide here a description of those studies based on our review of the files and their estimated results, supplemented by discussions held with MCC in September and November, 2011, and with MCA in October 2011. Table 1 below provides a summary of the previous 2003-2005, 2008 and 2011 ERR estimates for all four CA-5 sections, while Table 2 provides a summary of the previous 2003-2005 ERR estimates for 7 secondary road candidate segments.

TABLE 1: SUMMARY OF PREVIOUS ERR ESTIMATES FOR CA-5 IMPROVEMENTS SECTIONS 1-4

<table>
<tr><th></th><th colspan="2">July 2004
(Source: "Logistical Corridor ERR101006.xlsx)</th><th colspan="2">April 2008
(Source: "Resumen_TIRE_costos_y_supuestos_actualizados.xlsx)</th><th colspan="2">February 2011
(Source: "Indicadores económicos Sección 1 e Interconector MCA 2011 Burgos.xlsx")</th><th colspan="2">March 2011
(Source: "Benefit Estimates - 3.17.11.xlsx")</th></tr>
<tr><th></th><th>Reported Project Financial Cost, Million $[13]</th><th>ERR</th><th>Reported Project Financial Cost, Million $</th><th>ERR</th><th>Reported Project Financial Cost, Million $</th><th>ERR</th><th>Reported Project Financial Cost, Million $[14]</th><th>ERR</th></tr>
<tr><td>Section 1</td><td>$35,344</td><td>15.4%</td><td>$73,639</td><td>6.8%</td><td>$47,840</td><td>14.9%</td><td>$49,145</td><td>10.7%</td></tr>
<tr><td>Section 2</td><td>$23,698</td><td>19.3%</td><td>$77,795</td><td>12.2%</td><td></td><td></td><td>$52,062</td><td>17.0%</td></tr>
<tr><td>Section 3</td><td rowspan="2">$29,372</td><td rowspan="2">29.1%</td><td>$23,250</td><td>9.2%</td><td></td><td></td><td>$16,887</td><td>12.5%</td></tr>
<tr><td>Section 4</td><td>$31,558</td><td>5.5%</td><td></td><td></td><td>$22,403</td><td>11.2%</td></tr>
</table>

[13] Note that the 2004 project cost estimates are not comparable with those for other years as they were made for improvement of 2 lanes only.

[14] Note project financial cost values summarized by NORC from source data.

TABLE 2: 2003-2005 SECONDARY ROAD ERR ESTIMATES

Secondary Road Segment:	Date of Analysis:	Estimated ERR:
Comayagua - La Paz	01/14/2004	53.90%
Lomas - Santa Maria	03/06/2003	49.40%
Baracoa-Finca Paleto	10/14/2004	39.40%
Telica - San Francisco de la Paz	01/10/2003	38.70%
CA3 - El Triunfo	10/14/2004	37.60%
Planes - Sonaguera	02/23/2005	36.70%
San Bernardo	01/14/2004	28.40%

Source:"Data_Secondary_Roads.xls"

2003-2005 HDM-Manager ERR Estimates. In August and September, 2011, MCC provided to NORC two excel files which displayed results from previous ERR estimates for CA-5 Sections 1-4 and for several sections of secondary roads that were produced between 2003-2005. Based on our assessment of the files, we confirmed that these 2003-2005 estimates were made using a previous version of HDM-4 called HDM-Manager, which ran on the previous version of the HDM software, HDM-III[15]. The two files provided were:

- *"Logistical Corridor ERR101006.xlsx"* (full file provided in Annex VIII) – this file provided HDM-III ERR estimation results for the four CA-5 sections. The estimates are dated 14 July 2004, and MCC informed NORC that these estimates were completed by Soptravi and were likely considered by MCC in its initial investment decision regarding Honduran CA-5 improvements. Sections 1 and 2 of the CA-5 were evaluated separately, while Sections 3 and 4 are grouped together for a single analysis and ERR estimate. The estimated ERR estimates are provided in Table 1, with final estimates of 15.4% and 19.3%, respectively, for Sections 1 and 2, and a relatively high estimate of 29.1% for the combined Sections 3 and 4.
- *"Data_Secondary Roads.xls"* (full file provided in Annex VIII) – this file provided HDM-III ERR calculation results for seven sections of Honduran secondary roads. The runs of the HDM-Manager to obtain the estimates are dated on diverse dates between 2003 and 2005. Though input data for these calculations was not obtainable by MCC, the analyses were also likely completed by Soptravi as part of MCC's initial consideration of funding road

[15] HDM-III was developed by the World Bank and used for over two decades between 1980 and 2000 to combine technical and economic appraisals of road projects, to prepare road investment programs and to analyze road network strategies. The $3.5 million International Study of Highway Development and Management (ISOHDM), led by the University of Birmingham, England, led to the release of a new version of HDM, HDM-4, in 2000 that included significant improvements in the HDM technical models, including improvements to the modeling of traffic congestion and vehicle operating costs, a wider range of pavement types, maintenance effects, safety implications and the adaptability of models to a wide range of environments. Following extensive feedback from the application of HDM-4 in many countries for a diverse range of projects, further extensive improvements to the HDM-4 technical models and applications were implemented, resulting in the release of HDM-4 Version 2.0. Improvements included in the Version 2.0 release included: improved analysis models (sensitivity analysis, budget scenario analysis); improve connectivity; improved data handling and organization (traffic redesign); improved technical models (bituminous road deterioration, bituminous work effects, unsealed road deterioration, unsealed work effects, road user effects); and improved configuration (post-improvement maintenance standards; calibration sets; improved speed flow types and traffic patterns, improved standard effects). Due in part to the considerable improvements and estimation accuracy of HDM-4 Version 2.0 used for this analysis, the resulting ERR estimates are likely to be more accurate than those estimated with previous versions of HDM.

improvements in Honduras. Table 2 displays the estimated ERRs for these segments. The "Data_Secondary Roads.xls" file also provided interesting contextual and introductory information on likely road maintenance strategies both before and after the project improvements, specifying specifically re-gravelling very 4 years before improvements, and re-sealing every five years after improvements. Our opinion is that these maintenance regimes are extremely optimistic and thus unlikely to be sustainable.

2008 HDM-III Estimates. A key task that NORC was hired to complete was to update the most recent complete set of HDM ERR estimates of the CA-5 sections that were completed in 2008 by consultant Louis Berger[16] using the HDM-III Manager to calculate the ERRs and justify the project investments. Reports and results from these 2008 ERR estimates were shared with NORC by both MCC and MCA Honduras, and are included in Annex VIII.

A review of the files by NORC reveals that they include HDM-III model run output files for the four CA-5 sections, with each section being analyzed independently (with a separate HDM model estimation). A first set of runs is dated 1st February 2008, and the second set is dated 21st April 2008. No HDM-III evaluation of Secondary roads or Rural roads was completed in 2008.

The reports do not include the HDM Series A-K data input files in their original form. However, the HDM-III ERR model runs are documented in detail for each CA-5 Section by a text file that was generated by the HDM "Echo print" command that produces a detailed record of each HDM model run, including specifications of inputs and assumptions made. There are four "Echo print" simulation logs, one for each section, entitled "Detalle_corrida_HDM_seccion1.doc", etc. In addition, there are several HDM-Manager economic evaluation reports, alternative comparison summary reports, and vehicle operating cost files for each CA-5 section. Concerning Vehicle Fleet unit costs, the only difference between the two sets of runs is the cost of gas and oil (all prices in US dollars) as follows:

- February 2008 runs: Gas/Petrol Price (C/lt) 0.50, Diesel Price (C/lt) 0.45, Lubricants Price (C/lt) 1.94
- April 2008 runs: Gas/Petrol Price (C/lt) 0.71, Diesel Price (C/lt) 0.68, Lubricants Price (C/lt) 2.00

Table 1 displays the final estimated ERRs for each CA-5 Section from the April 2008 HDM-Manager runs. The estimated ERRs are considerably lower than the 2004 estimates, and in fact ERR values for each Section are single digits except for Section 2 at 12.2%. NORC examined these 2008 HDM

[16] According to MCA Honduras, Louis Berger completed the 2008 HDM-III ERR estimates for CA-5 (as related to NORC in Tegucigalpa in October 2011).

estimates closely, including their input values and assumptions, and these were used to inform our 2011 updated HDM-4 ERR model estimates.

2011 HDM-4 ERR Estimates, CA-5 Section 1. During meetings held with MCA Honduras in October 2011, NORC was informed that MCA had hired an HDM ERR specialist to conduct an HDM-4 ERR estimate for CA-5 Section 1. This was done in order to satisfy a requirement from CABEI as part of an application by MCA Honduras for funding to complete road improvement works on CA-5 Section 1. Consequently, NORC requested from MCA Honduras files related to these 2011 estimates, including if possible the full HDM-4 workspace and files. While MCA Honduras was not, unfortunately, able to share with us the HDM workspace files used to estimate these results, they did share the following files, and we report results from these files in Table 1:

- *"Indicadores económicos Sección 1 e Interconector MCA 2011 Burgos.xlsx" (full file is provided in Annex VIII).* NORC examined the file and determined that it includes only the final table that calculates the ERR, but does not include HDM input data or values. An ERR value of 14.9% was estimated for CA-5 Section 1 (reported in Table 1);
- *"Benefit Estimates - 3.17.11.xlsx" (full file is provided in Annex VIII)*: this file provides a 2011 post-evaluation of October 2005 and February 2008 HDM Manager model runs and estimations. It summarizes ERR estimates for the four CA-5 sections. It was described in the source file as being derived from a HDM-4 evaluation, however MCA was unable to provide any more details or files related to the purported source HDM-4 model simulations and ERR estimations. We report the ERR estimates for the CA-5 sections reported in this file in Table 1, under the "March 2011" column.

2007 Rural Roads ERR Model. During discussions with MCA in October 2011 in Tegucigalpa, MCA related to NORC that in 2007 it had hired Honduran consultant Alden Rivera to select a sample of candidate rural road segments for improvement, and to develop and estimate ERRs for those segments. MCA shared with us the final ERR model developed by Mr. Rivera in excel spreadsheet format *("ERRMCARuralRoads_comité_camino_pop_data Alden.xlsm"*, in Annex VIII). NORC reviewed this file and it contains detailed descriptions of 262 rural Honduran road segments. Further, the ERR model that is implemented for those segments includes assumptions regarding Vehicle Operating Cost (VOC) savings that appear to be derived from those that are implemented in the Road Economic Decision Model (RED), a freely available software featuring a consumer surplus model for performing economic evaluation of road investments and maintenance alternatives that is customized to the characteristics of unpaved roads, and thus would be an appropriate model on which to design an ERR estimation approach for Honduran unpaved rural roads. RED was developed by the Sub-

Saharan Africa Transport Policy Program (SSATP) and is distributed by the World Bank[17]. The Honduran ERR rural model appears to have been created in 2007, as unit costs are expressed in 2007 values and future cost/benefit stream simulations begin in year 2008.

The detailed descriptive data provided in this file for the final rural roads selected by MCC for improvement proved to be highly useful in NORC's calculation of MCC Honduran rural road ERR estimates, particularly the measured road curvature and alignment (rise/fall) data, as well as traffic count and speed data. Although not used by NORC, the file also contains data on agricultural production conditions surrounding each of the rural road segments that could potentially be utilized in the development of a broader rural road ERR model that would consider impacts on surrounding agricultural production.

B. NORC Traffic Surveys

This analysis made direct use of data obtained from traffic surveys implemented by NORC in Honduras 2009-2011. NORC measured both traffic volumes and vehicle speeds for a range of vehicles on all MCC primary and secondary road improvements, and on 24 rural road improvement sections. Three rounds were conducted: in early 2009, in July 2010 and in early 2011. The surveys included vehicle counts for 8 distinct vehicle types, vehicle speed measurements for CA-5, and road speed measurements for secondary and rural roads.

The updated traffic volume and vehicle speed data allow for a revised ERR estimate relative to the previous 2011 and 2008 ERR estimates.

C. Additional Reports Collected

A range of important background reports and datasets were collected directly from MCC or MCA, or during the October 2011 site visit. These reports included the following:

MCC/MCA Road Improvement Capital Costs and Improvement Schedules, and Fundo Vial Road Maintenance Costs. A key result of the site visit to Honduras in October 2011 is that NORC was able to obtain updated final road improvement project capital costs from MCA Honduras, for all primary, secondary and rural improved roads, and updated road maintenance unit costs.

Final updated project costs are a crucial input to updating the ERR estimates, and provide a significant improvement over the 2008 ERR estimates as those did not have the actual final project cost values which directly impact the NPV and ERR estimates. Further, contain detailed road improvement works schedules for all segments. These files are provided in Annex V and are:

[17] See: http://www4.worldbank.org/afr/ssatp/Resources/HTML/Models/RED_3.2/red32_en.htm

- Datos generales CA5 Agosto 2011 MCA-H.xls
- Datos Generales Contratos Secundarias Sep 2010.xls
- Estado de Implementacion Caminos Rurales al sep 2010 MCA.xlsx

NORC also held a meeting with Fundo Vial in Tegucigalpa, and was able to obtain from them a copy of the report "PLAN ESTRATÉGICO DE MANTENIMIENTO VIAL A NIVEL DE RED 2012 – 2016", with appendices (file "INFORME PMV 2012-2016.pdf" provided in Annex IX), which provided official Honduran road maintenance unit costs evaluated both in 2011 Lempiras and US dollars. Road maintenance unit costs are direct inputs to the HDM-4 future road maintenance estimates, which of course directly impact NPV estimates (because they offset future road user benefits) and estimated ERRs, so these improved maintenance unit costs also represent a significant improvement over the 2008 ERR estimates.

Additional Background Reports Collected

Several reports were collected during the different meetings we had in Tegucigalpa, and used in estimating input data for the HDM-4 modeling, particularly in deriving specific road network characteristics for the HDM-models.

For CA-5, we obtained the final CA-5 improvement works Design Reports by consultant Louis Berger, and Final Construction Supervision Reports for Sections 3 and 4 by Consultant DMJM-Harris and Saybe Y Asociados. These two sets of reports were particularly useful because, while they do not include any ERR calculations, they provide useful background details on CA-5 Section road alignment, pavement structures and traffic counts. They also provide International Roughness Index (IRI) measurements for CA-5 Section 3 post-improvements, which helped to calibrate the post-improvement HDM-4 modeling of road condition evolution. The reports are:

- Final CA-5 Louis Berger Design Reports:
  - "Informe de revision del diseno de la Carretera CA-5 Norte, Segmento I: Secciones I y II, Tegucigalpa-Inicio Valle de Comayagua y Seccion Inincio Valle de Comayagua Desvio a Villa San Antonio" (digital file name "Informe Final CA-5 Segmento I LBG.pdf" provided in Annex X);
  - "Revision del diseno de la Carretera CA-5 Norte, Segmento II: Secciones III y IV, Fin Valle de Comayagua-Siguatepeque-Taulabe" (digital file name "Informe Final CA-5 Segmento II LBG.pdf" provided in Annex X).

- Final Construction Supervision Reports:
  - "Construction supervision, services for the construction of CA-5 north, segment II, Section 3" (digital file "FINAL REPORT S-3.pdf" provided in Annex X);

- "Construction supervision, services for the construction of CA-5 north, segment II, Section 4" (digital file "FINAL REPORT S-4.pdf" provided in Annex X).

For secondary roads, key road descriptive characteristics used to inform HDM-4 parameters were obtained from final project design and road improvement supervision reports, specifically:

- Final Report _Comayagua SECCION 1 Vol I.pdf;
- Final Report Comayagua SECCION 2 Vol I Rev1.pdf;
- Final Report Comayagua SECCION 2 Vol 2 Rev1.pdf;
- Final Report Sonaguera.pdf;
- Informe Final Cho.pdf.

VII. Inputs and Assumptions for Estimation of Economic Rates of Return Using HDM-4

This section describes the inputs and assumptions for the estimation of ERRs using HDM-4. All the assumptions made to input data into HDM-4 are documented in detail in the file "HDM-4-input-data.xlsx", found in Annex VI.A.

A. Initial Reproduction of HDM-III ERR Estimates.

As a test to see if we could reproduce the previous HDM-III ERR estimates, we obtained HDM-III and input road characteristics information for al road segments, vehicle data (costs, speeds, types, etc.), primary configuration data and road maintenance regime strategies, and the HDM-III was re-run in an attempt to re-produce previous report estimates.

While this approach proved to be feasible, it also highlighted a number of inconsistencies and ambiguities in the previous HDM-III input data. For example, some data items appeared to be irrelevant (such as the alignment for CA-5 sections 3 and 4), there were inconsistencies between different data items, maintenance strategies were not very clear, and certain vehicle unit costs appeared to be under-estimated.

Because of these problems, and also because the HDM-4 format is very different from the HDM-III format, all input data was redefined for HDM-4 runs. Only a few specific input values were were kept for HDM-4 analysis:

- most of the vehicle fleet unit costs were kept (the exception was new vehicle prices values, which were too low);
- we kept the same list of vehicle types (corresponded to the NORC survey traffic counts).

B. HDM-4 MODEL CONFIGURATION

We provide here a detailed description of the process of constructing the HDM-4 ERR analyses.

Road Project Capital Costs. Final MCC road project capital cost values, provided by MCA Honduras in October 2011, were specified. These values were significantly higher than the estimated capital cost values used in the 2008 HDM-III model configurations, and thus were likely to affect estimated ERRs. A comparison of the CA-5 Section project work capital costs with the 2008 specified costs are displayed in Table 3, showing that the actual costs were as much as 67% higher than those estimated in 2008.

TABLE 3: FINAL CA-5 PROJECT COST DATA AND COMPARISON WITH HDM-III PROJECTIONS

Project capital costs			
	Works financial Costs (Thousands US $ / km)		
CA5 section	**HDM-III**	**HDM-4**	**HDM-4 vs HDM-III**
Section 1	1,872	2,667	**42.5%**
Section 2	1,532	1,934	**26.2%**
Section 3	706	872	**23.5%**
Section 4	757	1,262	**66.7%**

Traffic Counts and Road Speed Measurements. We used data from the NORC traffic surveys to obtain updated measures of traffic counts and speeds for all project roads. Interestingly, total traffic volume was somewhat lower than projected for 2011 in the 2008 HDM-III models. Table 4 displays the Average Annual Daily Traffic (AADT) estimates derived from the NORC traffic surveys, and compares those to ex-ante measures made by MCA, and to 2008 and projected 2011 values from the 2008 HDM-III runs. The table reveals that the actual 2011 traffic volumes ranged from 3.1% to 18.6% lower than those projected for 2011 by the HDM-III runs. Since the primary benefit from road improvements considered by the HDM-4 NPV and ERR models is from reductions in VOC, then reductions in future traffic volume flows should negatively impact estimated NPV and ERR values.

TABLE 4: CA-5 SECTION TRAFFIC COUNTS, 2011 AND 2008 PROJECTED

Average Annual Daily Traffic (AADT) Estimate, CA-5					
	MCA	**HDM-III**		**HDM-4**	
AADT year	2008	2008 (in.)	2011 (calc.)	2011 (counts)	HDM-4 vs HDM-III
Section 1	9834	10012	11590	11119	**-4.1%**
Section 2	6656	7642	8847	7202	**-18.6%**
Section 3	7699	6737	7799	6913	**-11.4%**
Section 4	7941	6737	7799	7560	**-3.1%**

Traffic Flow Patterns. HDM-4 Traffic Flow Patterns by default describe the distribution of hourly traffic flows across an entire year. Unfortunately, traffic volumetric and speed data obtained from NORC traffic surveys and other traffic data provided by consultant Design Reports, for example, were not collected across an entire year. Therefore, a number of specific HDM-4 default assumptions were maintained regarding the specific types of traffic flow on the different classes of improved segments.

Consequently, three traffic flow Patterns were defined in HDM-4:

- HDM-4 option for "Commuter" traffic was assigned to CA-5 Section 1 (the closest CA-5 improvement Section to Tegucigalpa) and all Secondary road segments;

- Because, however, the NORC observed traffic counts on CA-5 Sections 3 and 4 did not show classic “commuter” patterns (namely a strong decrease between a morning peak and an evening peak), these Sections were defined using the HDM-4 option of “Interurban”;
- Finally, all rural improved sections were defined in HDM-4 as having “seasonal” traffic flow patterns.

HDM-4 default values were kept for all three Traffic Flow Patterns. For Secondary and Rural roads, traffic volumes are too low to induce any congestion effects, so these were not modeled.

HDM-4 Speed Flow Types. Speed Flow Types in HDM-4 describe how vehicle operating speed is affected by traffic congestion. Five Speed Flow Types were specified and assigned to different sections, taking into account road class and pavement width, as follows:

- Rural roads were assigned Intermediate HDM-4 default values for Rural Speed Flow Types;
- 2-lane segments were modified from HDM-4 default values, and assigned to all secondary and CA-5 sections for pre-improvement conditions, and to post-improvement conditions in the case that they were not upgrade to 3 or 4 lanes:
- considering the importance of road curvature for these road segments, the HDM-4 free-flow capacity default value was set to 0, assuming that there are always interactions between vehicles regardless of traffic volumes;
- 3-lane and 4-lane sections were assigned HDM-4 defaults for relevant sections of CA-5 that were upgraded from 2 to 3 or 4 lanes, respectively.
- All sections were considered as two way carriageways, even if on some portions the two carriageways are physically separated.

Accident Costs. Accident cost evaluation must be specified in HDM-4, but no data on Honduran road accident rates was available. Thus, the runs were defined with the “No Accident” HDM-4 class, with all accident rates set to zero. While in reality accident costs can be considered to have an impact on road ERRs, calculating the impact of road safety on ERR requires an evaluation of accident rates (fatal, injury, damage only) before road improvement works, an evaluation of the same accident rates (fatal, injury, damage only) after road improvement works, and determining estimates of the relative economic costs for fatal accident, injury, and damage only accidents, in terms of actual local cost values. None of these parameters were available, and further none of them were used or modeled in the previous 2004, 2008 and 2011 ERR estimations in Honduras, and thus do not impact comparability.

Climate Zone. HDM-4 requires specification of a climate zone. A specific Climate zone was defined, with 60 mm/month precipitation, and subtropical-hot temperature classification. This Climate Zone was assigned to all sections.

Calibration Sets. In our analysis of the results and data provided for the previous Honduras ERR estimates, we could find no evidence that a calibration process was used to define the Road Deterioration values used in those HDM estimations. Further, in meetings with MCA, Soptravi and Fundo Vial in Tegucigalpa, we were unable to obtain measured data on Honduran road deterioration rates. Given the lack of data on road deterioration over time, it is impossible to carry out a true calibration study on road deterioration. Consequently, we conducted a sensitivity analysis of the impact of different calibration items on road deterioration as modeled in HDM-4. This analysis was performed on CA-5 section 3, using a specific Calibration set, named "Honduras-calibration". In this set, there are three calibration items for bituminous pavements:

- "Default" calibration item, with all parameters set to HDM-4 default values;
- "HDM-III" calibration item, with all parameters set to previous 2008 HDM-III run values, with extensions to HDM-4 parameters that do not exist in HDM-III;
- "HDM-III mod" calibration item, with parameters set to previous HDM-III run values, but modified in setting the progression factors to 0.7, a value which is more consistent with the 1.45 value for initiation factors.

All three of these alternative calibration sets were used in HDM-4, and the resulting predicted rates of road deterioration were compared and assessed against our best assumption regarding actual road deterioration rates on project roads observed during the site visit. The best results were obtained from the "HDM-III mod" specification, which was subsequently used for all paved roads.

For unpaved road, HDM-4 default values of Quartzitic gravel were specified, although the default value for maximum gravel size was increased to conform with site visit observations.

Vehicle Fleet Characteristics and Unit Costs. The HDM-III ERR models included 6 vehicle types, as all input traffic counts used for those analyses had 6 vehicle categories.

To specify vehicle unit costs in the HDM-4 models, we evaluated the vehicle unit costs specified in the previous HDM-III model runs, and those values were discussed with Soptravi, with a bus company manager in Tegucigalpa, and with other Honduran associates in Tegucigalpa. As a result, a decision was made to keep all vehicle fleet unit costs from the HDM-III models. The only exception to this was for the purchase costs of new vehicles, which seemed erroneous and excessively lower in the HDM-III data. This was also discussed with Honduran experts, and the purchase price value in the HDM-III models was actually much closer to the price of a used vehicle rather than a new one.

To address this confusion, all vehicles-types were specified both as new vehicles and as used vehicles in the HDM-4 estimations. Additionally, some assumptions were made on purchase costs for a new vehicle, the number of km already driven before purchase for used vehicles, and on the ratio of used / new vehicles for each vehicle-type. Table 5 summarizes the values that were input for the vehicle fleet.

TABLE 5: FINAL VEHICLE FLEET INPUT VALUES USED FOR HDM-4 MODELS

Vehicle-type	Unit cost (used)	Unit cost (new)	Km driven (used)	% of used	% of new
1-Car	5,145	15,435	100,000	70	30
2-Pick-up	5,505	19,267	100,000	30	70
3-Bus	13,489	67,445	200,000	20	80
4-Truck 2A	9,081	36,324	200,000	50	50
5-Truck 3A	10,569	42,276	200,000	50	50
6-Truck Art	24,115	120,575	200,000	50	50

The HDM-4 parts consumption parameters were modified for used vehicles, to reflect the higher consumption due to the age of the vehicle. The consumption parameters specified are presented below in Table 6.

TABLE 6: VEHICLE PARTS CONSUMPTION PARAMETERS SPECIFIED

Parts consumption coef.	1-Car	2-Pick-up	3-Bus	4-Truck2A	5-Truck3A	6-TruckArt
A0 New (HDM-4 default)	36.94	36.94	0.57	11.58	11.58	13.58
A1 New (HDM-4 default)	6.2	6.2	0.49	2.96	2.96	2.96
A0 Used (HDM-4 default)	45.91	46.5	0.88	16.09	17.87	19.36
A1 Used (HDM-4 default)	7.71	7.8	0.75	4.11	4.57	4.22

HDM Road User Effects (RUE) Model Parameters Specified. As the RUE models in HDM-III and HDM-4 are different, the original parameters of HDM-III could not be input directly into HDM-4. However, most vehicle parameters were taken from HDM-III runs, but some others were modified. Special attention was paid to specified vehicle power in kW. These values were modified slightly so that they were calibrated to observed traffic speeds from the traffic survey, in order to reproduce the observed vehicle speeds. Table 7 displays the final values that were input in HDM-4.

TABLE 7: FINAL HDM-4 VALUES FOR DRIVING POWER IN KW

Driving power in kW	1-Car	2-Pick-up	3-Bus	4-Truck2A	5-Truck3A	6-TruckArt
New	25	28	80	70	100	130
Used	22	25	70	65	90	115

Equivalent Axle Load (ESAL) is a very important HDM parameter related to road deterioration. While values for ESAL were specified in the 2008 HDM-III models, we also found very different values specified in the Louis Berger Design Reports. Unfortunately there is no information provided on the source of these figures. Table 8 below displays the ESAL values from HDM-III runs, the values from Louis Berger report, and HDM-4 ESAL default values.

TABLE 8: COMPARISON OF EQUIVALENT AXLE LOAD (ESAL) VALUES SPECIFIED IN HDM-III RUNS, LOUIS BERGER DESIGN REPORTS, AND HDM-4 DEFAULT VALUES

	1-Car	2-Pick-up	3-Bus	4-Truck2A	5-Truck3A	6-TruckArt
HDM-III runs	0.00	0.01	0.73	0.95	1.74	2.62
LB report, Segment I	0.00	0.00	1.68	2.19	2.56	2.88
LB report, Segment II	0.00	0.00	1.41	0.97	2.33	4.97
HDM-4 default	0.00	0.01	0.7	1.25	2.28	4.63

It is interesting to note that for a two axle truck, the HDM-4 default value reflects a situation where the overloads are more or less controlled (10% only of vehicles overloaded), and that the value included in the Louis Berger report on segment I reflects a situation where overload is extremely high (30% of vehicles overloaded). For this study, we kept the HDM-III values, assuming that load control will be effective in a near future.[18]

Overhead was set to zero for all vehicles (no data available). This has a low impact on Road User Costs, and no impact on economic comparison, as it is the same amount in base alternative and project alternative.

Traffic Growth Parameters. These parameters, specified in HDM, describe how traffic volume will grow in the future, and thus are key to informing the future estimated road segment expected benefits and costs that go into the NPV and ERR estimates.

A number of Honduran traffic growth rates were specified in the previous 2008 HDM-III and 2011 HDM-4 ERR models, and in the Louis Berger CA-5 Design Reports. These are summarized below in Table 9. In the HDM-III runs, annual traffic growth was set at 5% from the start of the analysis period (2008), then reducing to 3% through the 20-year future cost/benefit stream window of 2018. In Louis Berger Design Report, two sets of traffic growth rates were provided; the first was derived from an analysis of traffic counts in 2001 and 2007 on CA-5 sections 3 and 4; the 2nd set was used for the traffic volume projection up to 2027. The study conducted in 2011 by Roberto Burgos used what we felt were traffic growth rates, 6%, that are too high and not reflective of reality.

[18] A sensitivity analysis was done on this parameter, it showed a very small effect.

TABLE 9: FUTURE HONDURAN TRAFFIC GROWTH RATES SPECIFIED IN PREVIOUS HDM AND DESIGN ANALYSES

	1-Car	2-Pick-up	3-Bus	4-Truck 2A	5-Truck 3A	6-Truck Art
HDM-III 2008 - 2017	5.0	5.0	5.0	5.0	5.0	5.0
HDM-III 2018 - 2027	3.0	3.0	3.0	3.0	3.0	3.0
LB report, 2001 - 2007	13.0	5.5	2.4	4.5	9.2	3.9
LB report, 2008 - 2027	6.0	2.7	4.7	3.0	7.3	4.7
RB study, 2011 - 2030	6.0	6.0	6.0	6.0	6.0	6.0

To determine which future traffic growth rates to adopt for our revised ERR study, we conducted a sensitivity analysis on the traffic growth rate parameter and based on that we adopted the HDM-III 2008-2017 traffic growth rates.

HDM also requires the specification of past traffic growth rates (for calibration of the HDM-4 road deterioration model) since the last CA-5 road overlay, which occurred in 1992. For that we specified an annual 5% rate.

Specification of HDM-4 Road Section Characteristics. CA5 and secondary road sections characteristics were derived from several sources, including the previous HDM-III model specifications, although we considered the Final Road Construction Supervision Reports (DMJM-Harris and Saybe Y Asociados) as the most reliable source. We also used the Louis Berger reports, produced for the final designs for segments I and II (Sections 1, 2, 3 and 4). However, those reports were more focused on the projects, and do not extensively describe the pre-project situation (road alignment, pavement structure and bearing capacity, pavement condition, traffic volume), which is the starting point for a HDM-4 analysis. A site visit on all four CA-5 sections, the Comayagua – La Paz secondary road section and two rural roads close to CA-5 helped in selecting the most appropriate values to input into HDM-4 for missing data. Rural road characteristics were extracted from data provided by Alden Rivera in his 2007 rural road ERR database (see Annex VIII), provided by MCA.

Traffic volume for all sections was based upon counts measured by NORC in two rounds of traffic surveys conducted in 2010 and early 2011. A few of the MCA project rural roads were not included in the NORC traffic surveys (see Annex III for discussion of the rural roads studied in this analysis). For those, sections, traffic data was extracted from Alden Rivera file.

Four separate Road Networks were described in the HDM-4 model, namely for CA-5, Secondary roads, Rural roads, plus one additional as a control for calibration study:

a) The **"CA-5"** Road Network describes the four CA-5 project Sections 1-4. After the improvement completion, Sections 1 and 2 are upgraded to four lane roads, Section 3 is partially a two lane road and partially a 3 lane road, and Section 4 is partially two lane road, partially a three lane road, and partially a four lane road. To adequately evaluate the project ERR, it is necessary to break down Sections 3 and 4 in sub-sections matching with the different lane options. This resulted in a total of 7 HDM-4 road sections.

b) The **"Secondary roads"** Road Network includes three sections, one for each MCC secondary project road. Sections characteristics were derived from the relevant reports, as described above. Road conditions prior to MCC improvements were characterized in HDM-4 based on an evaluation of the pre-improvement measured vehicle speeds recorded in the first round of the NORC traffic survey, from early 2009.

c) The **"Rural roads"** Road Network includes 33 sections (see Annex III), one for each MCC project rural road improvement. Individual rural road section characteristics were obtained from the data compiled by MCA consultant Alden Rivera in 2007 to assess rural road project profitability (provided in Annex VIII), particularly road alignment and curvature data. Traffic counts and vehicle speeds for each rural road section were obtained from the NORC traffic surveys for the 24 rural road improvement sections that were covered by that survey, while traffic count and speed data for the remaining sections was obtained from the Alden Rivera database.

d) The **"Calibration CA-5 S3"** Road network was created as a control for calibration purposes. This network has only one section, CA-5 section 3, under the assumption that the road condition before project improvement is as described in the 2008 HDM-III run. The final construction supervision report ("FINAL REPORT S-3.pdf", Annex X) indicates that the original construction of this section took place in the late 1960s, and that the road was then overlaid in 1992. Based upon these figures, we described and modeled section 3's road condition as it was just after the 1992 overlay. Specifically, pavement structure is specified as 85 mm of asphalt (assumed to be two layers, an original of 35 mm, with an overlay of 50 mm) as surface course, 175 mm of granular base course, and 200 mm of granular sub-base. Soil CBR is extracted from HDM-III runs, 24. We also assume that road roughness was approximately 2.5 IRI, with surface distress and rutting set to zero. Traffic volume in 1992 was evaluated from traffic Average Annual Daily Traffic (AADT) in 2007, assuming that past

AADT annual growth was 5% between year 1992 and 2007. From this we derived a 1992 AADT value of 3240 vehicles per day.

Two additional road networks were subsequently derived from the existing four above, to evaluate the impact of ex-ante project maintenance strategies (see section IX, below). For each of these road networks, one section was duplicated so that the different maintenance strategies ex-ante could be simulated into a single HDM-4 run.

C. Road Work Maintenance Standards

Three types of HDM-4 road maintenance works standards are required to carry out the NPV and ERR analysis:

1. "Base case" maintenance strategy (described within HDM-4 terminology as "maintenance standards"), which reflect the current Honduran road maintenance plans and regimes assuming that no road work improvements have been carried out;

"Project works" maintenance strategy (described within HDM-4 terminology as "improvement standards"), which describe and reflect the road improvement works carried out on the road sections;

"Maintenance strategy after works" (described within HDM-4 terminology as "improvement standards"), describing future road maintenance regimes that are assumed to have been implemented following the road improvements with a high standard of service.

Road Maintenance Unit Costs. Along with initial project cost and increases in VOC over time with road degradation, costs of future road maintenance work constitutes a major component for future road project costs in the Net Present Value future costs/benefits stream. Consequently, once a future road maintenance strategy is defined, it is important to adequately model the future cost of that regime, and to do so requires accurate road maintenance unit costs. Road maintenance unit costs for this study were derived from two sources: documents provided by Fundo Vial listing updated official Honduran road maintenance units costs (provided in Annex IX), and road maintenance unit costs specified in the 2008 HDM-III runs. As is specified in the HDM-4-input-data.xlsx file, these unit costs are very different between the two sources. For the final unit costs specified in this study, we used the 2011 Fundo Vial unit costs[19]. Table 10 provides a summary and comparison of the 2008 HDM-III road maintenance costs specified and those specified for this study, derived from the 2011 Fundo Vial official unit costs.

[19] Note that we made some slight adjustments to the Fundo Vial unit costs: in some cases the Fundo Vial costs included an additional charge for "profit", which we removed; also a few of the reported unit costs seemed extremely high, and thus we reduced them to what we felt were more reasonable values. These specific modifications are detailed in the "HDM-4-input-data.xlsx", found in Annex VI.A.

TABLE 10: 2008 HDM-III ROAD MAINTENANCE UNIT COSTS AND FINAL UNIT COSTS FOR THIS STUDY (DERIVED FROM 2011 FUNDO VIAL ESTIMATES)

Maintenance works unit costs				
		Works financial Unit Costs (US $)		
HDM-4 Works operation	Unit	HDM-III	HDM-4	HDM-4 vs HDM-III
Patching	m²	17.64	60.37	242.3%
Reseal single	m²	1.40	6.71	379.2%
Overlay (5 cm)	m²	10.45	22.49	115.2%
Reconstruction (SD)	m²	18.74	50.31	168.5%
Routine maintenance	km	1,348.00	1,472.59	9.2%

Road Maintenance Standards. A total of fifteen maintenance standards were specified, as follows:

- **Concrete**: this maintenance standard is specified for cement concrete sections (CA-5 S4, project option). This standard includes routine maintenance on roadsides, joint sealing and slab replacement.
- **Routine + cracks + rehabilitation**: this standard includes routine maintenance of shoulders and drainage, and patching of potholes (a maximum of 50 m²/km/year is specified for patching potholes). Patching activities are also carried out on areas with wide cracks. When roughness exceeds 7 IRI, a 50 mm road overlay is triggered. This standard is used to describe the base case for the CA-5 sections. It predicts a roughness evolution which seems sensible and appropriate, given road materials and conditions, and is in good agreement with the 2011 HDM-4 runs.
- **Routine + overlay**: this standard is assigned to CA-5 sections after the construction in the Project alternative scenario. It implements a road maintenance policy with a very high standard and level of service. During meetings in Tegucigalpa with Fundo Vial, NORC was told that this standard is the planned future maintenance policy on the CA-5 rehabilitated sections. This standard includes routine maintenance of shoulders, crack sealing, patching, and 5 cm overlay of Asphalt Concrete when roughness exceeds 5 IRI (which means at a level when road roughness really starts to impact vehicle operating speed).
- **Routine + regravelling (7y)**: this standard includes routine maintenance of shoulders and drainage, and regravelling 15 cm every 7 years. This maintenance standard is assigned to secondary roads in the base case, without project improvements.
- **Routine + reseal**: this standard is assigned on secondary roads after the project improvements. It includes routine maintenance of shoulders, patching, and resealing when cracking exceeds 30%.
- **Routine only (bit)**: this standard includes routine maintenance of shoulders and drainage, and patching of potholes. A maximum of 50 m²/km/year is specified for patching. This

maintenance standard is used for the calibration study, to describe the policy that was actually carried out on section 3.

- **Routine only (UP)**: this standard includes only routine maintenance of shoulders and drainage. This maintenance standard is assigned to rural roads in the base option from the start of the analysis period, and in the project optional scenario after road improvement works.

A set of additional road maintenance standards were also developed to explore the impact and sensitivity of estimated ERRs of alternative road maintenance strategies, as follows:

- **Bit-Poor maintenance:** similar to **Routine only** (bit);
- **Bit-Fair maintenance**: similar to **Bit-Poor maintenance**, plus patching of wide cracks;
- **Bit-Good maintenance**: similar to **Bit-Fair maintenance**, plus overlay of 5 cm AC at 7 IRI;
- Bit-Excellent maintenance: similar to Bit-Good maintenance, with overlay of 5 cm AC at 5 IRI;
- Unp-Poor maintenance: similar to Routine only (UP);
- **Unp-Fair maintenance**: similar to **Unp-Poor maintenance**, plus grading twice a year and 15 cm regravelling at 15 year intervals**;**
- **Unp-Good maintenance**: similar to **Unp-Fair maintenance**, with 15 cm regravelling at 10 year intervals;
- **Unp-Excellent maintenance**: similar to **Unp-Good maintenance**, with grading four times a year and 15 cm regravelling at 7 year intervals.
- **Improvement Standards.** Improvement standards describe the way road sections can be modified by the project road work improvements (rather than road maintenance). One improvement standard was specified for each section or sub-section.

For CA-5 sections 3 and 4, the total improvement project cost was distributed across the different sub-sections, assuming a 1.2 ratio between the cost of 3-lane sub-sections and the cost of 2-lane sections, and a 1.5 ratio between the cost of 4-lane sections and the cost of 2-lane sections (see HDM-4-input-data.xlsx file in Annex VI.A).

- For Secondary roads, the total cost was assigned to the whole section, even in the case of Comayagua – La Paz.

VIII. Description of HDM-4 Model Runs

A. CA-5 Runs

HDM-4 Calibration Run. A preliminary calibration run was made starting in 1992, up to the present time, in order to compare the HDM-4 predicted results from this run with actual conditions observed in 2011. The calibration run was run on CA-5 Section 3, described as it was after the last overlay in year 1992. The HDM-4 run predicted road condition evolution over the 1993 – 2012 period, assuming that patching was regularly carried out. Road condition predicted by the model for 2011 was compared to observed road conditions in 2011 on sections of CA-5 that have not been improved by MCC, to assess the accuracy of the calibration prediction.

Three runs were made, one with the HDM-4 default values for calibration parameters, one with the calibration parameter values taken from the 2008 HDM-III run, and a third one with calibration parameter values taken from the 2008 HDM-III run with the exception that cracking progression factors which were set to 0.7. Graphs in Annex VI.C display show cracking and roughness evolution predicted by HDM-4. As a result of these tests, the HDM-III modified set showed the greatest consistency with observed road condition evolution, and thus these values were used in the final runs.

CA-5 ERR Model Runs. The runs on CA-5 sections compare the MCC project alternative to a base case for which the assigned standard is the **Routine + cracks + rehab.** In the case of the Project alternative, the HDM-4 run includes generated traffic, assumed to be 5 % of the normal traffic for section 1, and 10 % of the normal traffic for sections 2, 3 and 4. Ex-post project improvements, the **Routine + overlay** maintenance standard is assigned. This standard provides a high level of service. The figure below displays a graphic screen shot of the options specification for Section 1.

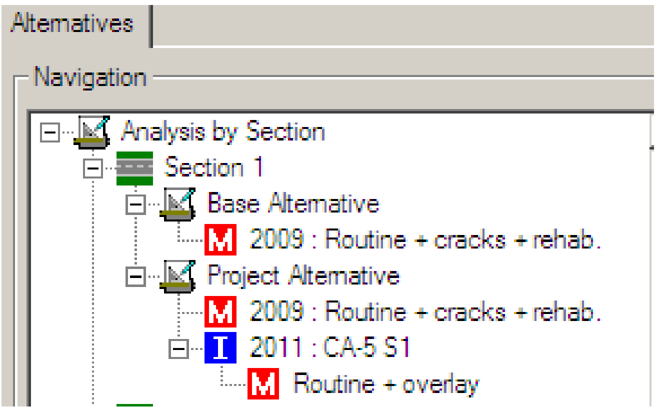


FIGURE 4: CA-5 HDM-4 SECTION 1 SPECFICIATION

Sections 2 and 3 have quite similar specification. However, Section 4 is different because the project option is Concrete:

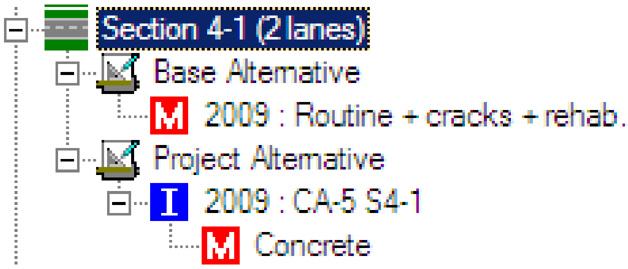


FIGURE 5: HDM-4 CA-5 SECTION 4 SPECFICIATION

The following graphs illustrate HDM-4 simulations for Section 1. Similar analyses can be made for other sections. The graph shows the impact of the rehabilitation works in 2016 for the base option.

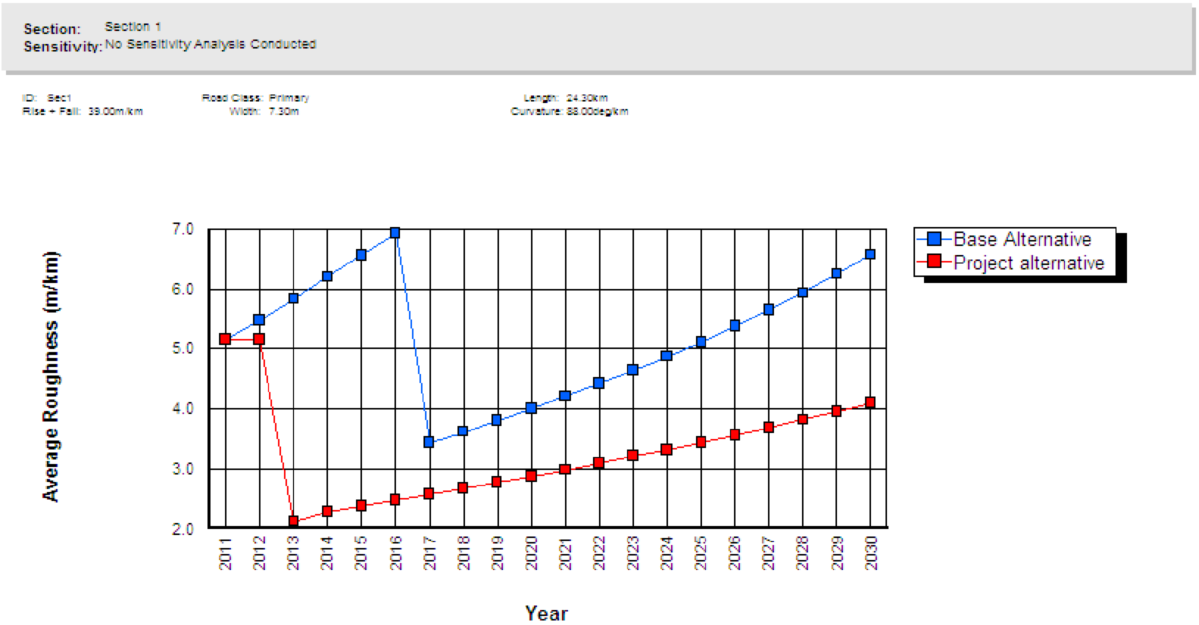


FIGURE 6: CA-5 SECTION 1 ROAD ROUGHNESS EVOLUTION

The following graph shows details of simulated Vehicle Operating Speed evolution over time:

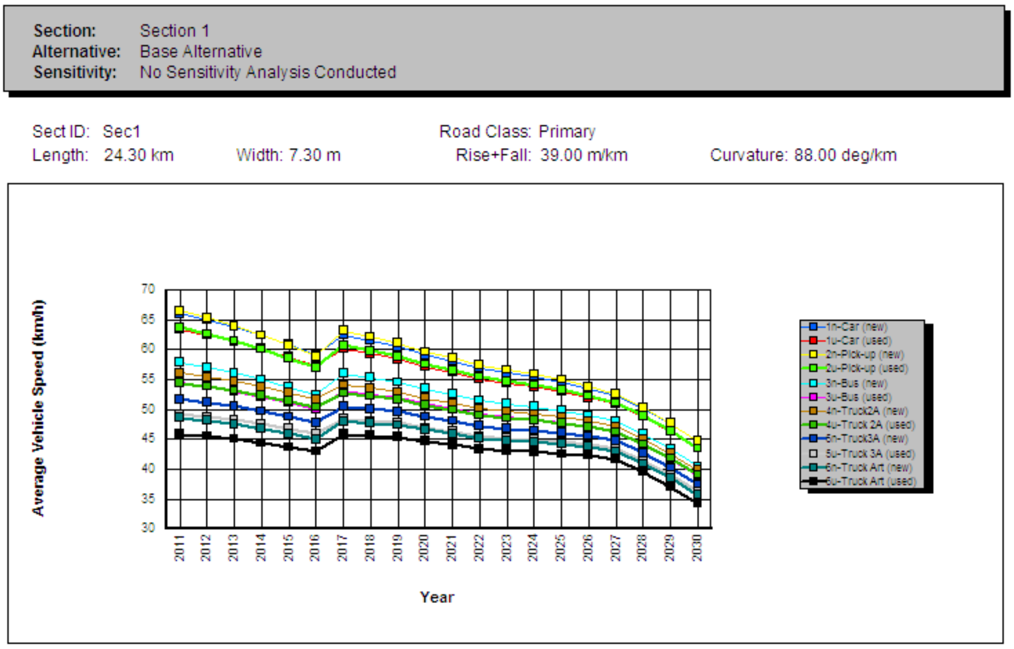


FIGURE 7: CA-5 SECTION 1 VEHICLE SPEED EVOLUTION, BASE CASE

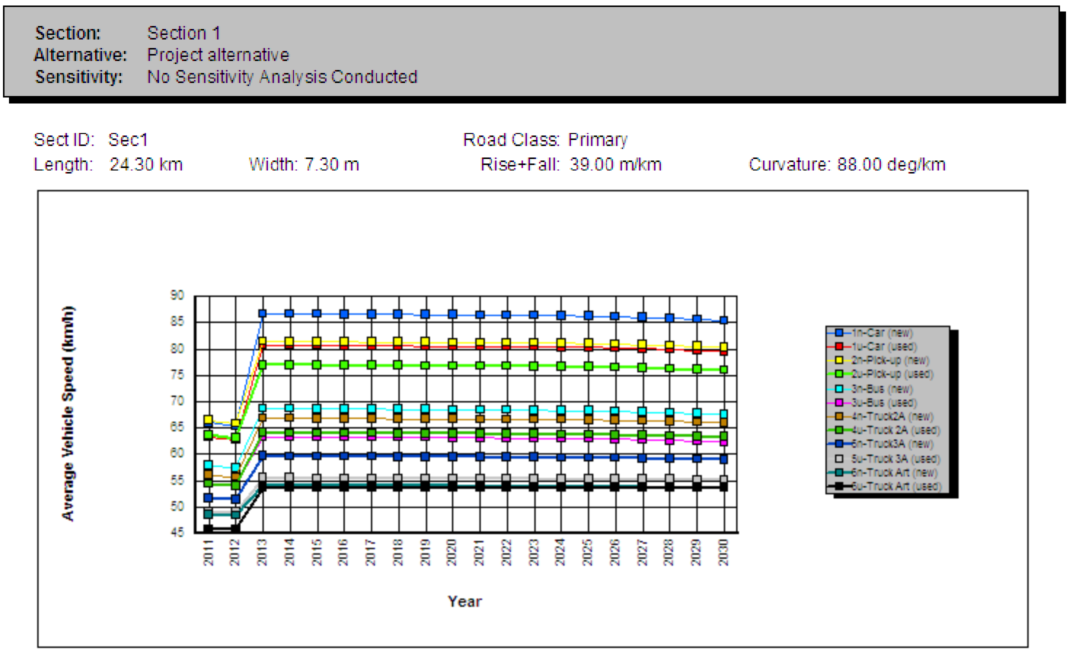


FIGURE 8: CA-5 SECTION 1 VEHICLE SPEED EVOLUTION, PROJECT SCENARIO, MULTIPLE VEHICLE TYPES

In the case of the Base Alternative scenario, vehicle speed decreases considerably, due both to roughness increase and congestion. In the case of the Project Alternative scenario, both roughness and congestion parameters are moderated, and the speeds are approximately constant through the entire 20 year time horizon. A direct comparison between the Base and Project Alternative projected speed evolution for a car on CA-5 Section 1 is shown dramatically in Figure 9:

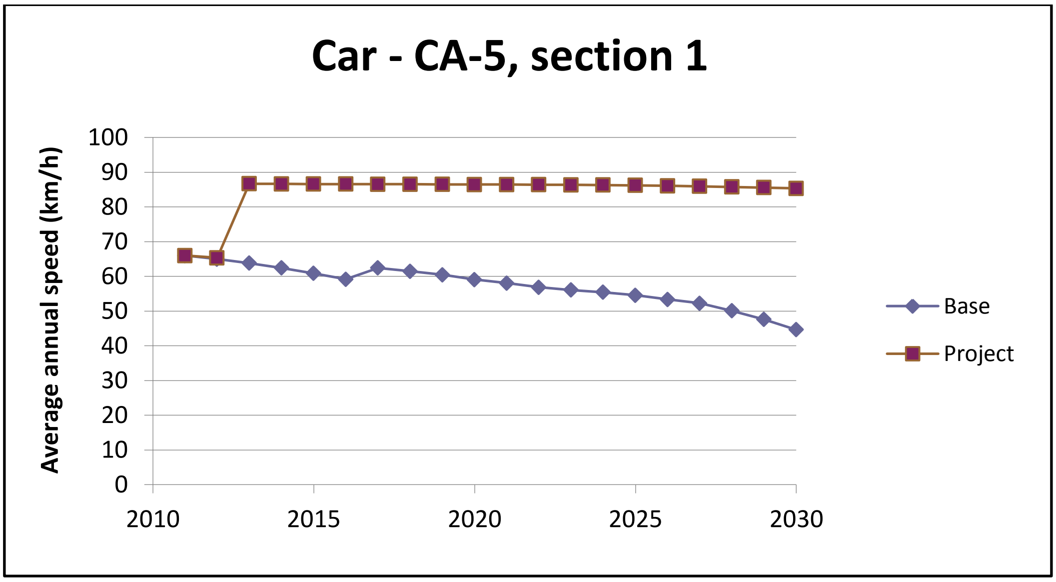


FIGURE 9: BASE VS. PROJECT SCENARIO SIMULATED CAR SPEED

Increases in congestion are shown in Figure 10 below.

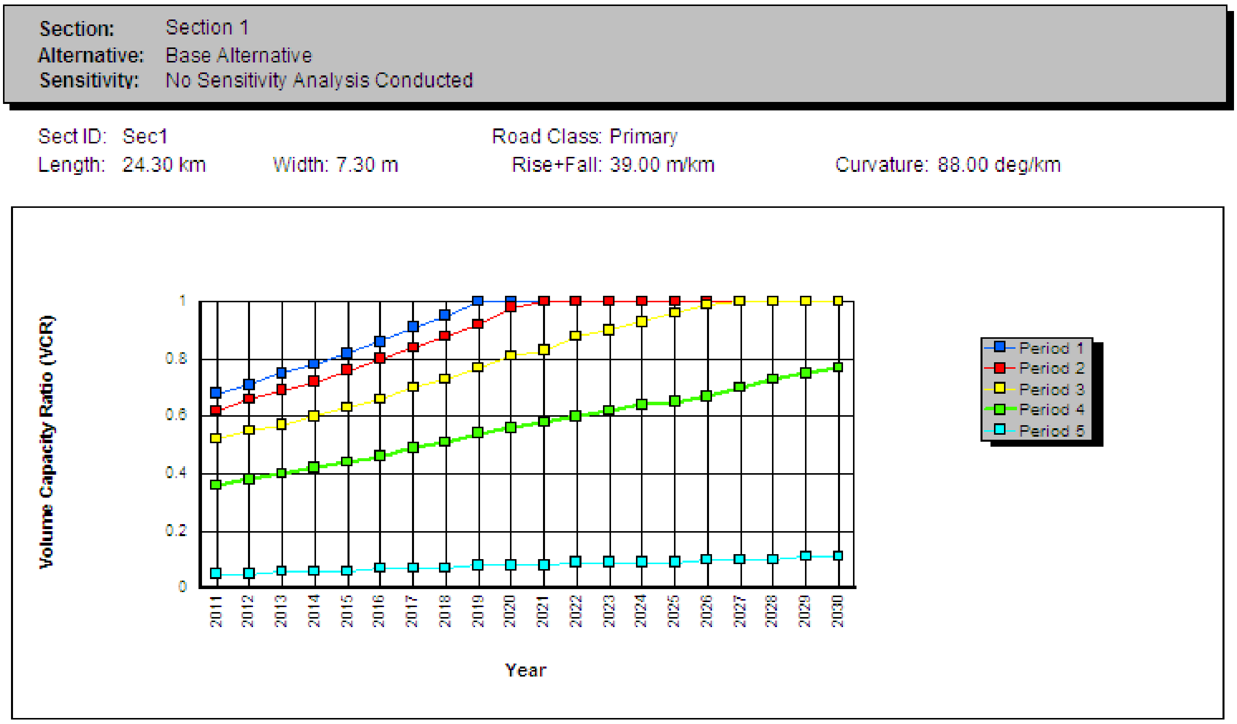
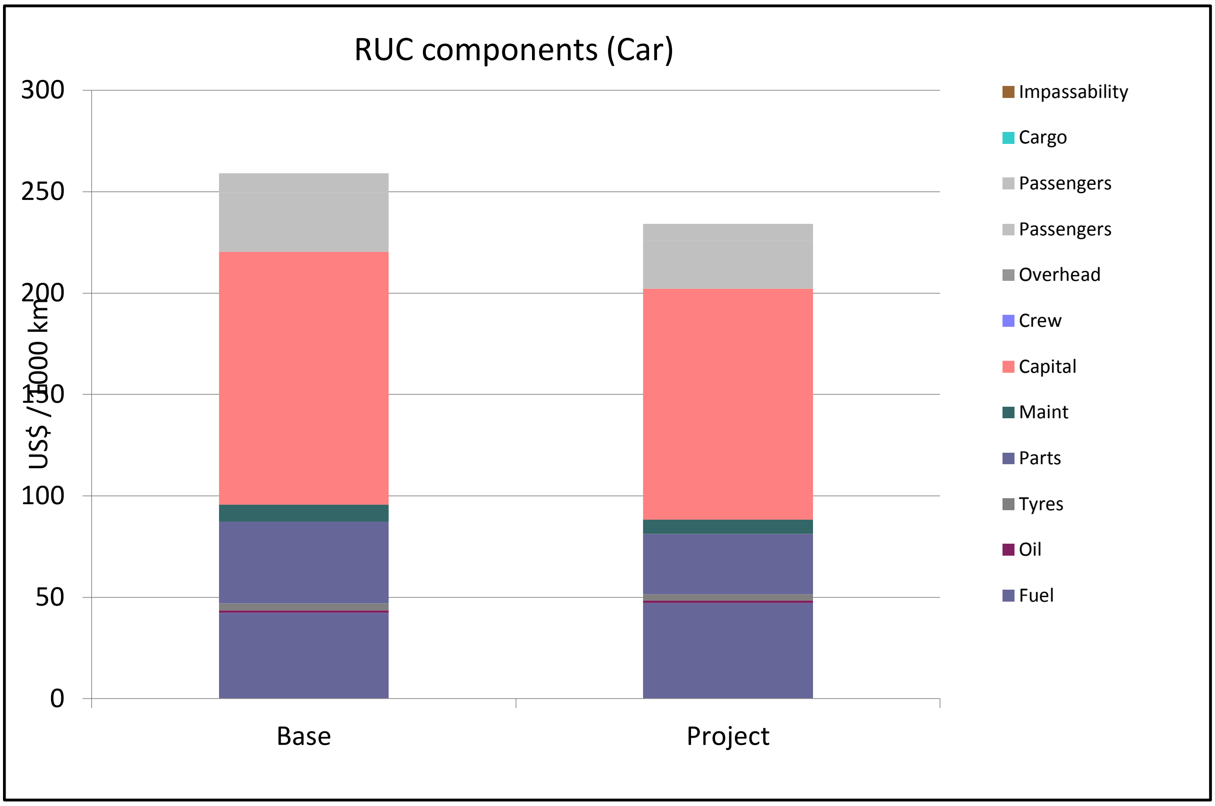


FIGURE 10: HDM-4 CA-5 BASE CASE VOLUME CAPACITY RATIO EVOLUTION

In 2020, traffic flow reaches the ultimate capacity for periods 1 and 2; those two periods total duration is 438 h (5% of the time).

Figure 11 displays the variation in the breakdown of Road User Costs (RUC) estimated by HDM-4 between the Base and Project scenarios for CA-5 Section 2, and also shows the decrease in the total RUC after project:

TABLE 11: BASE VS. PROJECT SIMULATED ROAD USER COSTS (RUC), CA-5 SECTION 1



The Economic indicators, including estimated ERR, can be summarized as follows[20]:

TABLE 12: HDM-4 CA-5 ECONOMIC INDICATORS SUMMARY

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value (NPV)	Economic Rate of Return (ERR) Estimate
Section 1	50.180	46.804	91.311	44.507	18.1
Section 2	47.618	42.606	33.953	-8.654	7.6
Section 3-1 (2 lanes)	3.870	2.996	5.801	2.805	20.8
Section 3-2 (3 lanes)	12.449	10.100	20.994	10.895	21.3
Section 3 (global)	16.319	13.096	26.795	13.699	21.1
Section 4-1 (2 lanes)	8.741	7.325	9.358	2.032	12.1
Section 4-2 (3 lanes)	12.291	10.629	18.158	7.529	15.9
Section 4-3 (4 lanes)	4.096	3.665	4.608	0.943	12.7
Section 4 (global)	25.128	21.619	32.124	10.504	14.0

[20] Note that these final ERR values are slightly different than those presented to MCC in a NORC presentation on December 1, 2011. For the previous estimates presented on December 1, we had used reported fuel costs taken from the February 2011 MCA CA-5 Section 1 ERR estimations. For the final results reported here in Tables 12 and 13, and for final secondary and rural ERR results reported in Tables 14, 15 and 17, we instead used 2008 HDM-III reported fuel costs to maintain consistency with our use of the 2008 values for other vehicle operation costs. This changed the final ERR estimates slightly.

It should be noted that for sections 3 and 4, the "global" indicators are more relevant than the indicators by sub-section, as the cost breakdowns per sub-section were not based upon actual costs surveys, but on assumptions regarding approximate cost ratios per sub-section.

We can now compare the estimated ERR values to the previous ERR estimates, as displayed in Table 13. Notably, our revised ERR estimates are higher for all sections than the 2008 and March 2011 estimates for all sections except Section 2, where we estimate a value of 7.6%. Note also that we estimate highest overall rates of return for Section 3, and lowest overall for Section 2, whereas by contrast the 2011 ERR estimates estimated the highest return of 17.0% for Section 2, as did the 2008 HDM-III estimates.

TABLE 13: SUMMARY OF ALL ERR ESTIMATES, CA-5 SECTIONS

Project Alternative compared to Base Alternative	Net Present Value (NPV)		Economic Rate of Return (ERR), Percent			
	March 2011	December 2011	July 2004 (ex-ante estimates)	Louis Berger April 2008 (HDM-III) Estimates	MCA Feb./March 2011 Estimates	NORC December 2011 Estimates
Section 1	2.03	44.507	15.4	6.8	14.9/10.7[21]	18.1
Section 2	23.02	-8.654	19.3	12.2	17.0	7.6
Section 3 (global)	2.11	13.699	29.1	9.2	12.5	21.1
Section 4 (global)	1.46	10.504		5.5	11.2	14.0

B. Secondary Road Estimations

The HDM-4 runs on secondary roads sections compare the project alternative to a base case for which the assigned standard is the **Routine + regravelling (7y)**. In the case of the Project alternative, there is generated traffic, assumed to be 10 % of the normal traffic. Ex-post project improvements, the **Routine + reseal** maintenance standard is assigned. The figure below displays the options specification for Section Sonaguera – km 35.

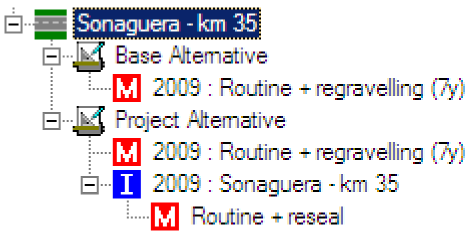


FIGURE 11: HDM-4 SECONDARY ROADS SOFTWARE SCREENSHOT

[21] Both CA-5 Section 1 estimates were produced and shared by MCA: 14.9% ERR estimate from CA-5 Section 1 from the "Indicadores económicos Sección 1 e Interconector MCA 2011 Burgos.xlsx" file, and the 10.7% estimate from the "Benefit Estimates - 3.17.11.xlsx" file (both original files provided in Annex VIII).

The following figures illustrate HDM-4 simulations for the secondary Section from Sonaguera to km 35. The Annexes contain similar analyses for other sections.

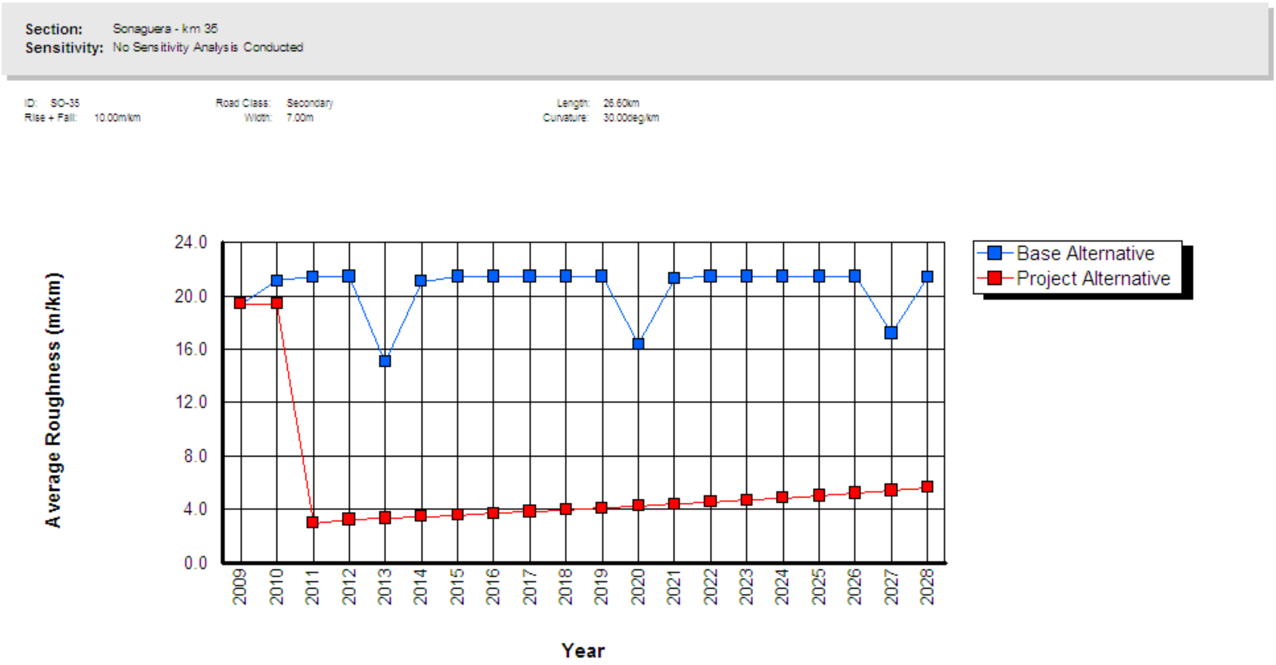


FIGURE 12: BASE VS. PROJECT SIMULATED ROAD ROUGHNESS

The graph shows the periodic decreases in road roughness that follow from a planned secondary road maintenance intervention, with a quite quick return to the former road roughness levels (within one year). By contrast, the project alternative brings road roughness down very dramatically and keeps it down throughout the entire 20-year time horizon.

The graphs below display HDM-4 simulated vehicle speed for years 2015 and 2020 for Sonaguera secondary section.

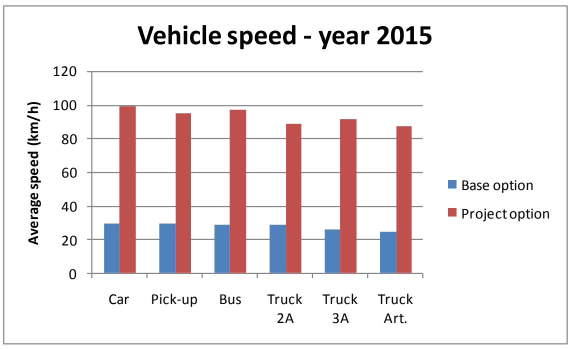


FIGURE 13: SIMULATED VEHICLE SPEEDS FOR SONAGUERA, 2015

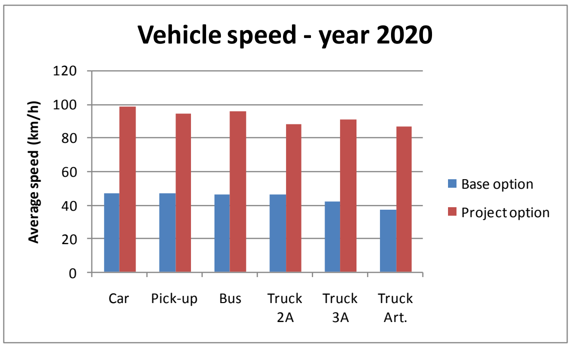


FIGURE 14: SIMULATED VEHICLE SPEEDS FOR SONAGUERA, 2020

In 2020, vehicle speed in the base case is much higher than it was in 2015. The reason is that a regravelling maintenance option was triggered by the model in 2020, giving a much better road roughness for that year. However, this improvement does not last long (see Figure 12).

The Economic indicators for the secondary road HDM-4 estimates can be summarized as in Table 14.

TABLE 14: HDM-4 ECONOMIC INDICATOR ESTIMATES FOR SECONDARY ROADS

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value	Economic Rate of Return
Section Choluteca - Orocuina	6.731	6.377	19.293	12.916	29.4
Section Comayagua – La Paz	6.465	6.124	63.428	57.304	84.4
Section Sonaguera – km 35	7.676	7.200	171.828	164.628	188.3
All sections grouped	20.872	19.700	254.549	234.848	105.8

For these sections, HDM-4 provides very high Net Present Value estimates. A key factor in these high NPV values is the very high measured traffic volumes on those segments. 2009 AADT on these three sections is respectively 632 veh/d, 1598 veh/d, and 1351 veh/d. Given that a consensus in road profit evaluations that 250-300 veh/day is the critical threshold above which paving an unpaved road is profitable, these high NPV results are not surprising.

This can be compared to last HDM 2011 evaluation results, as shown in Table 15. Clearly our revised estimates, incorporating updated traffic data, obtain significantly higher ERR values.

TABLE 15: MARCH AND DECEMBER HDM ERR RESULTS, SECONDARY ROADS

Project Alternative compared to Base Alternative	Economic Rate of Return	
	March 2011	December 2011
Section Comayagua – La Paz	53.9	84.4
Section Sonaguera – CA-13	36.7	188.3

In particular, the estimated ERR for Sonaguera is extremely high at 188%. HDM-4 simulates road condition evolution against different options, and calculates for each option the streams of annual costs for road works on the one hand, and road user costs on the other. Those cost streams are discounted, and a comparison is made between each option and a base option (no road improvement), resulting in the Net Present Value (NPV) of each option compared to the base case. Internal Rate of Return (IRR) (or Economic Rate of Return, ERR) is then computed as the value of the discount rate that sets NPV to zero.

Table 16 below displays a summary of the HDM-4 computed cost streams for Sonaguera – km 35 secondary road section (note: this cost stream and additional background details are provided in the attached excel file "Cost streams.xlsx". Note that the IRR displayed in the NPV summary tab in that excel file is calculated from the cost streams using the Excel IRR function, and is equal to the one calculated by HDM-4).

TABLE 16: SUMMARY OF HDM-4 COMPUTED COST STREAMS FOR SONAGUERA-KM35

	Comparison between Project Alternative and Base Alternative (undiscounted, Millions US$)			
Year	Increase in Agency cost	Normal traffic benefits	Generated traffic benefits	Total Net Benefits
2009	3.846	0.000	0.000	-3.846
2010	3.869	5.196	0.000	1.328
2011	0.022	17.819	0.891	18.688
2012	-0.257	18.683	0.934	19.874
2013	0.022	9.154	0.458	9.590
2014	0.022	20.470	1.024	21.472
2015	0.022	21.534	1.077	22.589
2016	0.022	22.574	1.129	23.680
2017	0.022	23.661	1.183	24.822
2018	0.022	24.798	1.240	26.015
2019	-0.257	25.483	1.274	27.014
2020	0.022	13.255	0.663	13.896
2021	0.022	26.876	1.344	28.198
2022	0.022	27.621	1.381	28.980
2023	0.022	28.348	1.417	29.743
2024	0.022	29.065	1.453	30.496
2025	0.022	29.773	1.489	31.239
2026	1.870	30.461	1.523	30.114
2027	0.022	16.199	0.810	16.987
2028	-2.286	32.101	1.605	35.991

Because of the very high traffic volumes measured in the traffic surveys (2046 vehicles per day) and the very bad condition of road pavement in the base case (very high roughness measures, with very low vehicle operating speeds), the Road User benefits reach a very high value. For year 2011, which is the first year after works completion, Road User benefits total some 18.7 million US$, approximately 2.5 times the improvement cost. This results in a very high IRR/ERR estimate.

This high ERR estimate is not surprising when one considers that in most cases using HDM to estimate road improvement IRR/ERR, the traffic volume that justifies paving an unpaved road by producing a sufficiently high IRR/ERR is around 250 vehicles per day (at a 12% discount rate). Further, in the case that traffic volumes reach 600-700 vehicles per day, HDM-4 Road User costs Road Agency costs by more than a factor of 10.

Thus, the very high IRR/ERR calculation here is a direct result of the very high traffic volumes recorded, and the very poor baseline road surface condition, as confirmed by pre-improvement measured vehicle travel speeds.

More generally, it is possible to plot IRR/ERR versus Average Annual Daily Traffic (AADT). Figure 15 shows this for the Sonaguera – km 35 road section, for different values of 2008 traffic volume, and shows the direct linear relationship between the estimated HDM-4 IRR and traffic volumes. (Note: see the attached excel file " IRRvsAADT.xlsx" for more details of the calculations that produce the figure below).

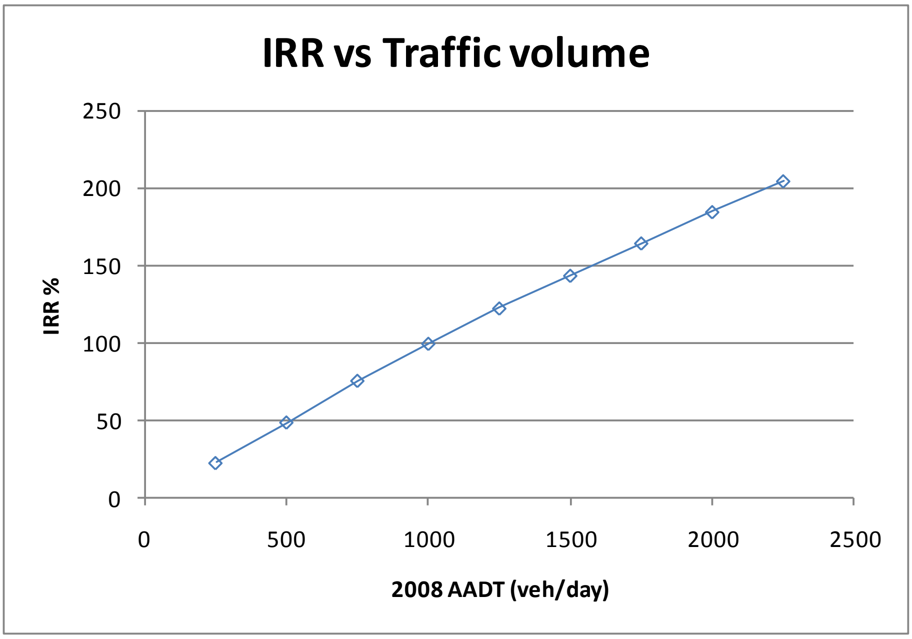


FIGURE 15: IRR/ERR VERSUS AVERAGE AADT FOR SONAGUER-KM35 SECTION

Although unfortunately NORC was not able to obtain from either MCC or MCA any reports providing direct measures of road roughness for project secondary road segment pre-improvement. Consequently, we looked closely at measured pre-improvement vehicle speeds on those segments as a proxy for likely road roughness measures. The observed traffic speeds recorded in the NORC traffic surveys for those segments pre-improvement are quite slow: they are actually consistent with measured vehicle speeds on unpaved rural roads. This implies very high road roughness measures pre-improvement on the paved secondary roads, and this informed our assumption regarding HDM-4 roughness inputs. We note, however, that this initial roughness is important only for the first year of the analysis period, because after that the simulated roughness evolution is dependent more on traffic volume, and not at all on initial roughness.

To try to quantify the possible impact of these input data values, a sensitivity analysis on Road User Benefits provides the following results:

Base scenario	IRR = 188.3%
Road User Benefits – 20%	IRR = 154.5%

The difference is clear, but the order of magnitude of the IRR is still high above the usual values for such projects. Traffic volume is definitely the critical parameter.

C. Rural Road HDM-4 Model Runs

As a result of discussions held with MCC in September and October 2011, it was decided to use the HDM-4 ERR model to estimate ERRs for MCC rural road improvements, despite the fact that HDM-4 is typically not used for studies or analyses on unpaved roads. While alternative rural road ERR methods were considered, it was decided that HDM-4 should provide a feasible methodology for providing ERR estimates for the unpaved rural roads, albeit with some notable caveats, and thus MCC approved its usage for the rural roads. We present here the result of the HDM-4 ERR analysis for rural roads, and we discuss some notable caveats for these results that should be taken into consideration at the end of this section.

The ERR analysis for rural roads was able to take advantage of newly available and highly useful data that should improve the rural road ERR estimates. These data included:

- Traffic volumes and speeds from NORC traffic surveys (2009-2011) as well as rural road traffic measurements provided in the 2007 MCA report by Alden Rivera;
- Rural road section road alignment data provided in the 2007 Alden Rivera study;
- on-site observations of rural road conditions completed by NORC in October 2011.

The HDM-4 rural road analysis was analyzed for only a 10 year time horizon for the cost/benefit stream (for NPV and ERR): the analysis period was from 2010 – 2019. This was done primarily because rural road surface degradation rates are so rapid in comparison to paved roads, and thus rural road improvements are effective for a much shorter time period, so a 20-year time horizon is not meaningful.

The Base Alternative scenario was described by the assignment of Routine only (UP) maintenance standard. The Project Alternative scenario specifies assignment of the regravelling operation, and assignment of regravelling after road improvements with the same Routine only (UP) maintenance standard. Regravelling triggers generated traffic, evaluated at 10% of normal traffic.

Modeling of "Impassability" on Rural Roads Due to Rain Erosion. Given that the MCC rural road improvements specifically included a number of improvements to mitigate impassability and erosion due to rainfall (box bridges, culverts, climbing tracks, retaining walls and improved drainage, etc.), we included in our rural road HDM-4 ERR estimations a simple model designed to capture some of the benefits obtained from these specific improvements in rural road rain erosion and rain impassability resistance. To do this, we used the "Impassability" feature, which increases Vehicle Operating Costs if the gravel thickness falls below a threshold that depends on maximum size of the gravel.

This is modeled in HDM-4 in a relatively simple way, as follows:

- During HDM-4's simulation of the road surface evolution over time (for rural roads in Honduras over a 10 year time frame as modeled by HDM-4) the gradual reduction in the size of gravel thickness on the rural unpaved roads, due to rain erosion and/or scattering by traffic, is modeled. An "impassability" can be optionally activated when the modeled gravel thickness falls below a certain threshold that is dependent on the maximum size of the gravel stones. During NORC's site visit to Honduras in October 2011, we directly measured the variation in gravel stone sizes on MCA rural project and non-project roads, and we also visited a gravel production facility to observe the gravel stone sizes produced for the graveling of Honduran unpaved roads. We found Honduran gravel on these roads and for production to attain a maximum size of 35 mm. Consequently, the "impassability" feature in the Honduran ERR estimates is activated in HDM-4 when the road gravel thickness falls below 70 mm, or twice the gravel maximum size.
- In this case, when the feature is activated, a multiplying factor is applied to Vehicle Operating Costs, to capture the increase in user costs due to road impassability. The specific VOC multiplicative constants used, which vary by vehicle type, for rural roads in our HDM-4 analyses are given in Table 16. While this does not directly measure reductions in accessibility, it does increase road user costs due to increased erosion due to rain. In the estimation of rural road ERR, this increased VOC for the "base" case (no improvement) greatly increases the base case total VOC, and thus improved the ERR estimation of profitability due to the road improvements.

TABLE 17: RURAL ROAD FPLIM VEHICLE PARAMETER VALUES SPECIFIED

FPLIM parameter	1-Car	2-Pick-up	3-Bus	4-Truck2A	5-Truck3A	6-TruckArt
New	1.2	1.2	1.3	1.4	1.4	1.4
Used	1.2	1.2	1.3	1.4	1.4	1.4

As a sensitivity test of the impact that the "impassability" modeling has on the final estimated rural road ERRs (reported below), NORC completed an additional set of ERR estimations for the Honduran rural roads in HDM-4 with the "impassability" feature turned off (i.e. no multiplicative factor for VOC after a specified threshold in gravel thickness reduction). These re-estimated ERRs are reported in Annex XII, entitled "HDM-4 ERR Estimation for the Transport Infrastructure Project: Additional Elements on Rural Roads Impassability." As noted in the Annex, the estimated rural road ERRs are significantly reduced (and in a number of cases become negative) when the impassability feature is turned off. This indicates the highly important impact the rural road erosion/rain resistance improvements have on estimated ERRS, even though we used quite conservative VOC multiplicative impassability factors (ranging from 1.2 to 1.4 out of a possible range of 1-3, as reported in Table 16 of the final Honduras ERR report).

To truly evaluate impassability due to rain would require a measurement of the number of days per year that the road is impassible, before and after treatment. However, these data were not available for Honduras.

Modeling of Road Roughness, Vehicle Speeds and Final Estimated Rural ERR Estimates. Figure 15 illustrates the resulting modeling of road roughness evolution over time in HDM-4 for the unpaved rural roads, in this case the La Esperanza-Monte Sion rural road segment. The project improvement works dramatically reduces road roughness measures (from almost 23 down to around 6) within the first year, but the roughness measures quickly return to pre-improvement levels within 4-5 years.

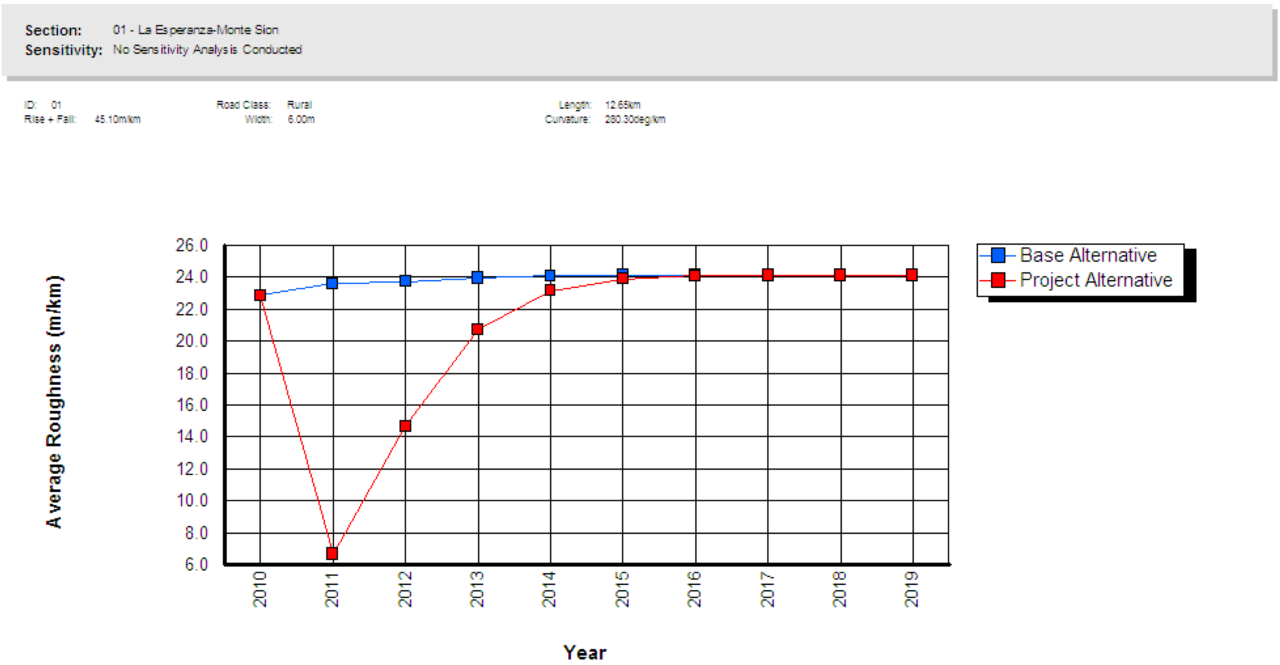


FIGURE 16: BASE VS. PROJECT, SIMULATED ROAD ROUGHNESS, LA ESPERANZA-MONTE SION RURAL ROAD

Figure 16 displays simulated vehicle speed evolution over time on a rural road segment, and it is clear that the speed variation is roughly inversely symmetrical to the roughness measure in Figure 15. That is, vehicle speed is determined almost completely by road roughness, as traffic volume levels do not induce any congestion effects.

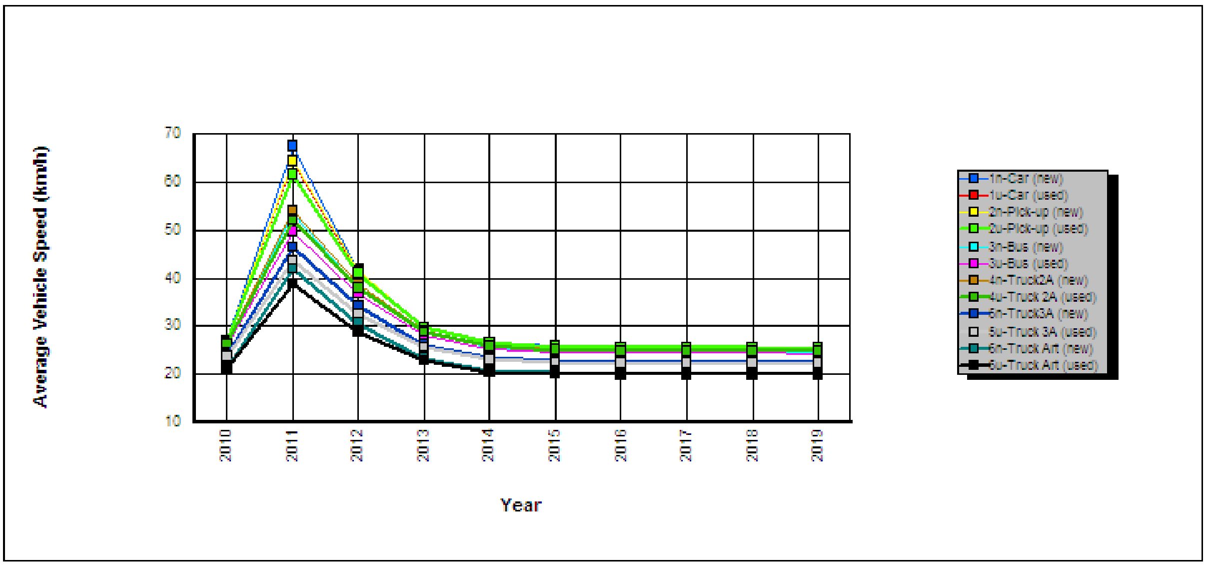


FIGURE 17: EVOLUTION OF VEHICLE SPEEDS ON RURAL ROADS, HDM-4

Figure 17 displays road vehicle speed for a pick-up truck on the La Esperanza-Monte Sion rural road segment, displaying the simulated Base vs. Project scenario speed evolution.

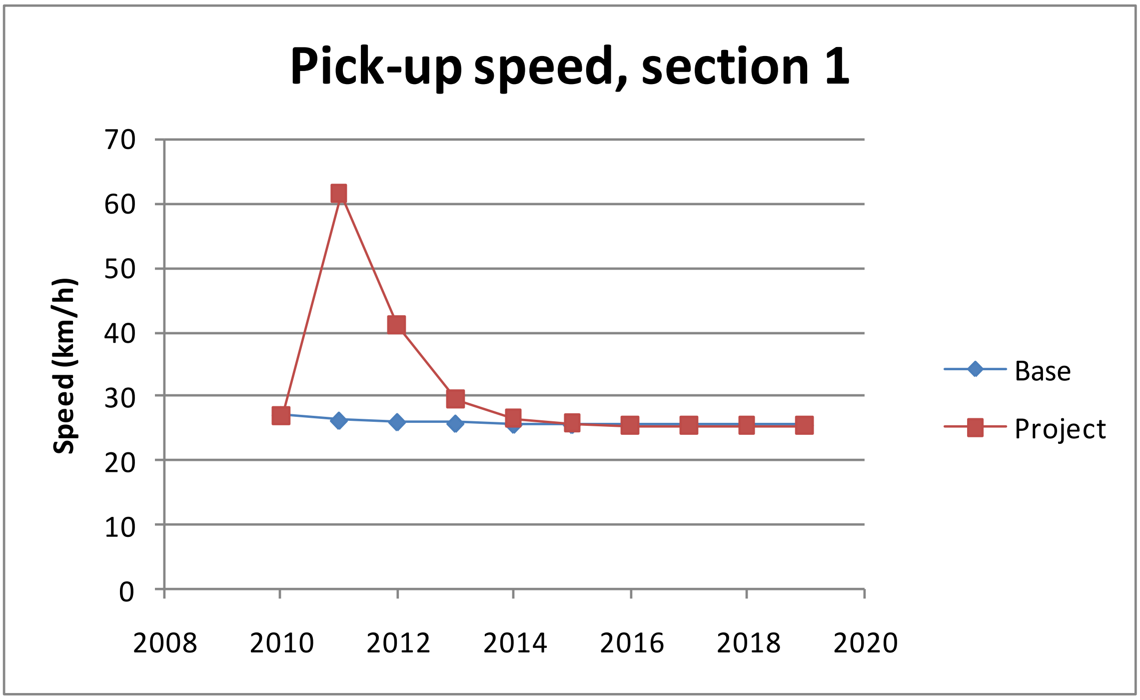


FIGURE 18: PICK-UP TRUCK SPEED EVOLUTION, BASE VS PROJECT, RURAL ROAD

Clearly, for all rural road sections, the benefits from road improvement are limited to a few years after the works. After four to seven years, depending on traffic volume and road alignment, road conditions return to the pre-improvement levels. Table 17 provides the complete list of HDM-4 estimated rural road NPV and ERR values.

TABLE 18: HDM-4 ESTIMATED NPV AND ERR FOR RURAL ROAD SEGMENTS

Rural Road Section	HDM-4 Estimated NPV	HDM-4 Estimated ERR
01 - La Esperanza-Monte Sion	0.956	150.4 (2)[22]
02 - La Unión-El Bambú (Ceiba Mocha)	0.651	205.8 (2)
03 - Ilanga- Monte Abajo (S113)	0.113	24.5 (1)
04 - S113 Holanda Linda La Danta	0.308	35.6 (1)
05 - Chacalapa (S113) - Zonas Productivas	0.032	15.6 (1)
06 - S113 Río Arriba - Los Ángeles	0.475	65.3 (1)
07 - Chacalapa (S113) - Chichiguite	0.126	64.9 (1)
08 - Jutiapa - Limera - Balfate - Rio Coco	0.737	30.9 (1)
09 - El Way - Lorelay	0.102	24.9 (1)
10 - Trujillo - Guadalupe	0.182	20.5 (1)
11 - Dos Bocas - Babilonia (La Casona)	0.029	18.7 (1)
12 - San Luis-Quebradas Amarillas	-0.301	No Solution
13 - Quebradas Amarillas (Desvio Planes)-Trojes	0.614	113.1 (1)
14 - Guatillo- Las Lazadas	0.709	70.3 (1)
15 - Siguatepeque-El Carbonal-Carrizal (CA-5)	2.030	272.1 (2)
16 - La Germania No 1 - Santa Rosita	1.871	297.7 (2)
17 - Lo de Reina-El Pacon (Zona de Riego)	1.435	119.6 (1)
18 - Ajuterique-Playoncito-El Misterio-Ajuterique	2.382	194.5 (2)
19 - San Sebastian - Limite Municipalidad de Tomala	-0.064	8.6 (1)
20 - Tomalá - Limite Municipalidad de San Sebastián	0.258	19.9 (1)
21 - Lepaera - Coros	1.769	129.5 (1)
22 - Arada - Las Marias	-0.591	-9.8 (1)
23 - Oculi_ Desvio Cedrales	0.595	41.4 (1)
24 - Soledad- Los Alpes.	0.401	46.9 (1)
25 - Piedra de Diamante El Aceituno	0.100	21.6 (1)
26 - Apacilagua - Piedra de Diamante	0.536	46.4 (1)
27 - San Benito Nuevo - Rio Grande	0.287	30.2 (1)
28 - Santa Ana de Yusguare - El Zapotillo (La Permuta)	0.080	26.1 (1)
29 - La Corteza - La Catarina	0.418	41.9 (1)
30 - Col la Lucha-Col Buena Vista	0.427	32.6 (1)
31 - Los Puentes - Pueblo Nuevo	0.345	87.8 (2)
32 - Las Mesas San Nicolas Abajo	0.108	45.6 (1)
33 - Concepcion de Maria - El Aguacatal	0.079	36.9 (1)
Total NPV	17.200	

Considerations For HDM-4 Rural Road ERR Estimates. After discussion with MCC, it was decided to use HDM-4 as a model to estimate ERRs for all MCC project roads, despite the fact that HDM-4 is not typically used for unpaved roads. After a thorough discussion with MCC regarding the

[22] The number in parentheses here displays the number of solutions for the ERR calculations obtained in HDM-4. HDM-4 systematically makes a search for all solutions of the equation Net Present Value (NPV) = 0 for a discount rate value range of -100 up to 400 and displays the results. When there is more than one solution, by default HDM-4 uses the lowest result. Note that for Rural Road Section 12, San Luis-Quebradas Amarillas, no solution was found.

specific potential problems in using HDM-4 for unpaved road ERR estimates, as well as a discussion of the feasibility and applicability of using HDM-4 for this purpose, a joint decision was made with MCC to go ahead with the HDM-4 approach.

Our rural road HDM-4 ERR estimates take advantage of very useful data collected for this study, including: traffic volumes and speeds from NORC traffic surveys and MCA Alden Rivera studies; road alignment data from the Alden Rivera study; and on-site observation of rural road conditions conducted by NORC in October 2011. However, as is shown in Table 17, there is considerable variation in estimated ERRs across the rural road segments, ranging up to almost 300% and down to negative values.

We note that there are a number of important caveats regarding using HDM-4 to produce rural road ERR estimates. The HDM-4 rural road ERR estimates are very sensitive to assumptions on future traffic growth and vehicle speeds post improvements: for rural roads, calculated NPVs and ERRs tend to correlate closely with traffic volumetric flows. This is shown in Figures 18 and 19, which plot HDM-4 calculated NPVs and ERRs against Average Annual Daily Traffic (AADT) values for the MCC rural project roads.

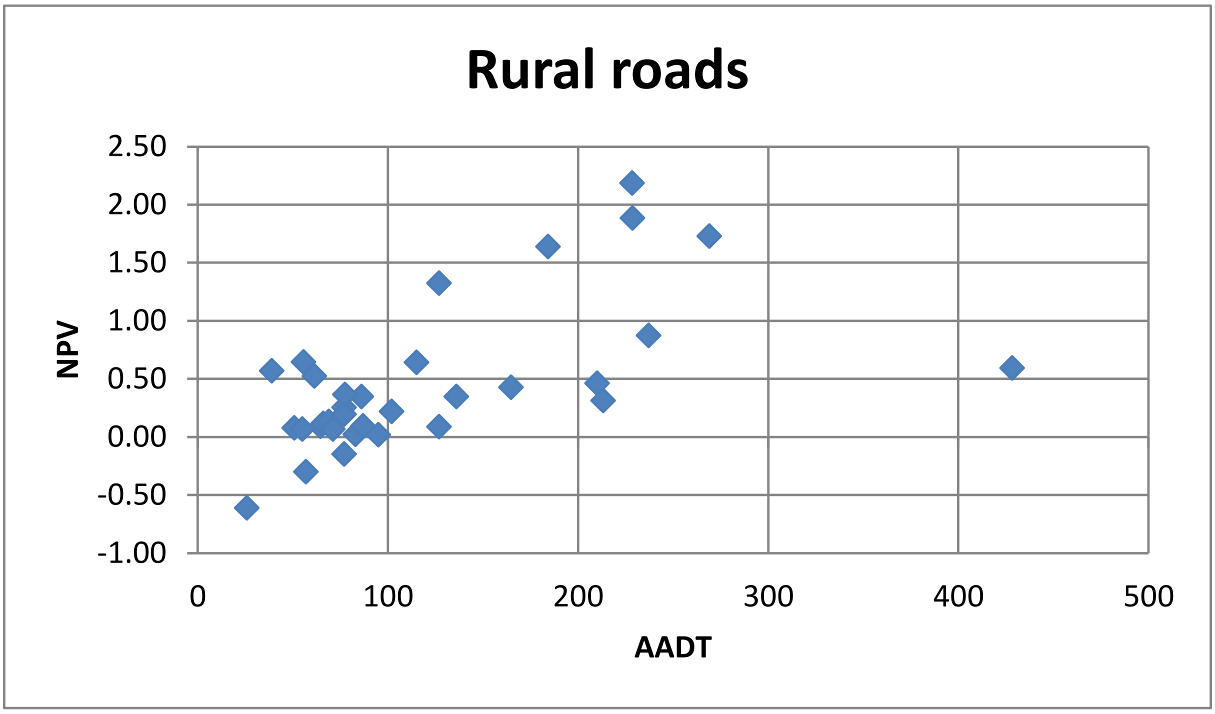


FIGURE 19: CALCULATED NET PRESENT VALUE (NPV) VS. AVERAGE ANNUAL DAILY TRAFFIC (AADT), ALL RURAL ROADS

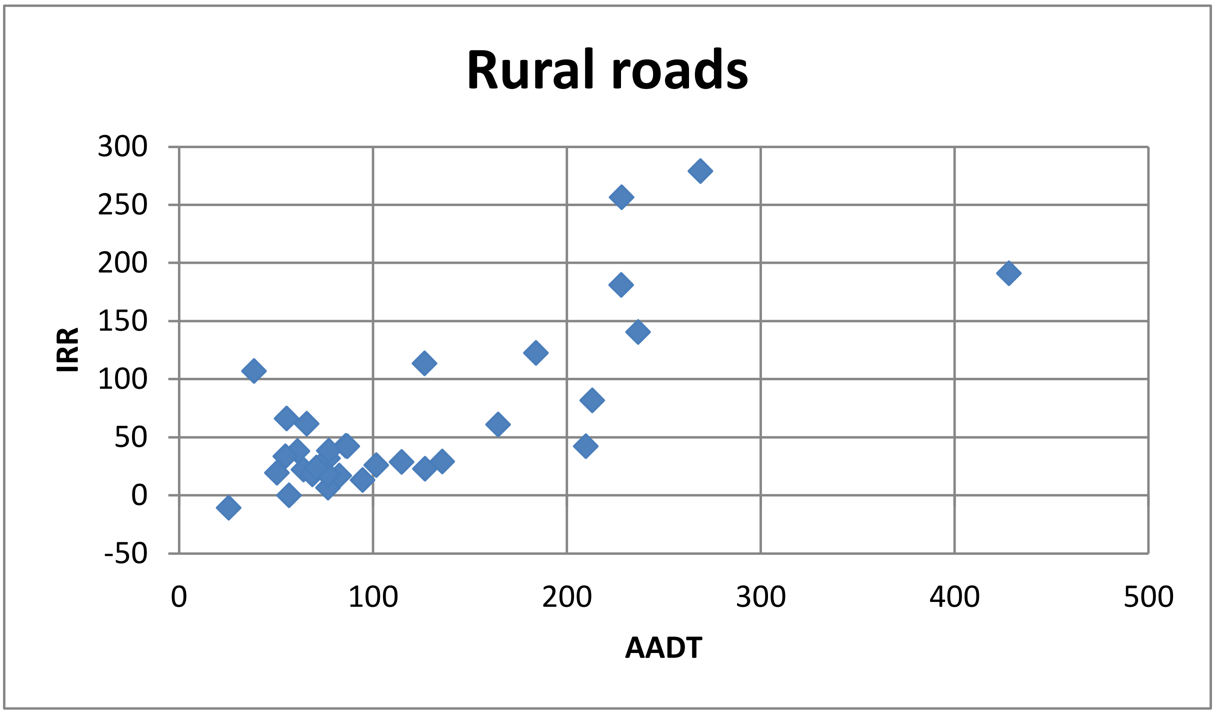


FIGURE 20: CALCULATED INTERNAL RATE OF RETURN (IRR) VS. AVERAGE ANNUAL DAILY TRAFFIC (AADT), ALL RURAL ROADS

Further, rural road project costs are relatively very low. For these reasons, the economic analysis can in some cases provide very high rates of return due in large part to these low project costs. In addition, for these ERR estimates, we have made assumptions regarding the number of days per year each rural road segment is "passable", which can affect the ERR estimates – however these are rough assumptions and actual passability may vary considerably across the segments;

Therefore at best the rural road ERR estimates are likely only capturing a small part of the true economic impact of rural road improvements. The NPV estimates here may be a more appropriate measure of the likely return on investment. Another option that could be considered for future rural road ERR modeling would be to perhaps include measures of the economic or agricultural productivity of areas immediately adjacent to the rural road section in question, or for cities/towns that the rural road segment leads to. An explicit consideration of the agricultural productivity of adjacent areas to rural roads is a component in the 2007 MCA rural road ERR model developed by MCA consultant Alden Rivera: this complete model is presented in its original excel spreadsheet format in Annex VIII (file *"ERRMCARuralRoads_comité_camino_pop_data Alden.xlsm"*).

IX. Sensitivity Testing

A. CA-5 Sensitivity Testing

Three sensitivity analyses were conducted to evaluate the sensitivity of the estimated CA-5 ERRs to measured traffic volumes (which have a direct impact on the calculation of future benefits in the NPV cost/benefit stream through reduced VOCs) and on initial capital costs, which of course also impact NPV and ERR by constituting the largest project cost component.

Three scenarios were modeled, as follows:

1. What happens to the estimated ERR if we decrease traffic volume (AADT) of 20%?
   What happens to the estimated ERR if we decrease predicted traffic growth by 50%?
   What happens to the estimated ERR if we decrease project capital costs by 20%?

The detailed results can be seen in Annex VII. However, Table 18 below summarizes the impact on ERRs.

TABLE 19: SUMMARY OF ERRS UNDER DIFFERENT SENSITIVITY TESTS:

CA-5 Section	Estimated ERR Values			
	Base scenario	Traffic volume - 20%	Traffic growth - 50%	Capital costs - 20%
Section 1	18.1	11.8	11.5	21.6
Section 2	7.6	5.7	4.7	10.1
Section 3 (global)	21.1	14.9	17.7	26.5
Section 4 (global)	14.0	11.4	11.7	16.8

The sensitivity test results indicate that while the estimated ERRs do show a significant reduction with either a 20% drop in traffic volume or a 50% reduction in traffic growth, the drop is not by an order of magnitude: the estimated ERRs for Sections 1, 3 and 4 remain at double digits. Reduction in capital costs by 20%, on the other hand, increases estimated ERRs by approximately 15-20% across the four CA-5 Sections. Clearly, while the changes in traffic volumes and growth, and in capital costs, do have a direct impact on the ERR estimates, the ERRs are not extremely sensitive to changes in these inputs.

B. Secondary Roads Sensitivity Testing

As with the primary CA-5 sections, a sensitivity analysis was made, to evaluate the impact of:

- Over evaluated traffic (AADT 20 % lower),
- Traffic growth over estimated (50 % lower).

Three scenarios were modeled, as follows:

1. What if we have over-estimated future traffic volumes: what happens to the estimated ERR if we decrease traffic volume (AADT) of 20%?

What if we have over-estimated future traffic growth: what happens to the estimated ERR if we decrease predicted traffic growth by 50%?

How sensitive are the results to the initial project capital costs - what happens to the estimated ERR if we decrease project capital costs by 20%?

The detailed results can be seen in Annex VII. A summary of the sensitivity test impacts on ERRs is provided in Table 19.

TABLE 20: SECONDARY ROAD SENSITIVITY TESTS FOR TRAFFIC VOLUMES AND GROWTH, AND CAPITAL COSTS

Section	Base scenario	Traffic volume – 20%	Traffic growth – 50%	Capital costs – 20%
Section Choluteca - Orocuina	29.4	22.2	25.7	35.7
Section Comayagua – La Paz	84.4	66.4	79.0	102.8
Section Sonaguera – km 35	188.3	150.4	180.2	229.4
All sections grouped	105.8	86.2	99.9	129.1

As with the sensitivity tests for the CA-5 roads, the impact on estimated ERRs of capital cost decreases is more significant than the impacts from traffic volume reductions or traffic growth rate reductions. Also, the relative impact of the traffic growth rate reduction of 50% on ERRs is greater than for primary CA-5 sections. For both secondary and primary CA-5 sections, these sensitivity tests highlight the importance of inputting correct values for capital costs, and the fact that we were able to input those values increases the accuracy of these ERR estimates over all previous versions.

C. Sensitivity Testing ERR Impacts of Alternative Road Maintenance Regimes.

At the request of MCC, we have run some sensitivity tests to evaluate the sensitivity of the estimated ERRs to alternative road maintenance regimes. We present the results below, preceded by a discussion.

The economic ERR calculations are based upon a comparison between the Project alternative and the Base alternative without project. Project characteristics are known with a reasonable precision, and the main concerns regarding Project alternatives – and the key variables likely to have large impacts on estimated ERRs - are linked more to traffic volume and traffic growth rates in the next ten years (as shown above in the CA-5 and secondary road sensitivity tests).

Maintenance standards post project improvements were set as indicated by Fundo Vial, ensuring a good level of service. However, this predicted road maintenance regime is actually quite ambitious and optimistic, and its actual implementation in Honduras is questionable, as it represents a considerable improvement over the current actual road maintenance strategy. However, the impact of the post-project maintenance policy is very low on the CA-5 and secondary roads, as the project improvement characteristics are of a very high standard, and this means that the road conditions stay quite high quality for the next ten to twelve years. Thus, future conditions, at least for the next 5-10 years, are relatively independent of whatever maintenance regime is implemented under the Project Alternative scenarios.

Therefore, to evaluate the sensitivity of calculated ERRs to variation in road maintenance regimes, rather than testing alternative maintenance strategies post-improvement in the Project Alternative scenarios, we instead varied the Base Alternative maintenance standards through several sensitivity tests. The impact of the Base Alternative maintenance standard is important, because it drives roughness evolution, and consequently Road User Costs.

We obtained information on current maintenance regimes from Fundo Vial and Soptravi. Currently specified Base Alternative maintenance strategies in the HDM-4 model were described using the following maintenance standards:

- **Routine + cracks + rehabilitation:** this standard includes routine maintenance of shoulders and drainage, and patching potholes (a maximum of 50 m²/km/year is specified for patching potholes). Patching activities are also carried out on areas with wide cracks. When roughness exceeds 7 IRI, a 50 mm overlay is triggered. This standard was used to describe the base case for CA-5 sections. It predicts a roughness evolution which seems sensible, and is in good agreement with observed road condition during the site visit on sections not yet improved.
- **Routine + regravelling (7y)**: this standard includes routine maintenance of shoulders and drainage, and regravelling 15 cm every 7 years. This maintenance standard was assigned to secondary roads in the base case, without project. It may well be optimistic, as the regravelling frequency is questionable. Note that there is no grading.

New Base Alternative maintenance standards were tested to evaluate this impact:

- **Bit-Poor maintenance:** similar to Routine only (bit).
- **Bit-Fair maintenance:** similar to Bit-Poor maintenance, plus patching wide cracks.
- **Bit-Good maintenance**: similar to **Bit-Fair maintenance**, plus overlay 5 cm AC at 7 IRI.
- Bit-Excellent maintenance: similar to Bit-Good maintenance, overlay 5 cm AC at 5 IRI.
- Unp-Poor maintenance: similar to Routine only (UP).

- **Unp-Fair maintenance**: similar to **Unp-Poor maintenance**, plus grading twice a year and 15 cm regravelling at 15 year intervals.
- **Unp-Good maintenance**: similar to **Unp-Fair maintenance**, 15 cm regravelling at 10 year intervals.
- **Unp-Excellent maintenance**: similar to **Unp-Good maintenance**, grading four times a year and 15 cm regravelling at 7 year intervals.

The sensitivity to maintenance regimes in Base Alternative was tested on CA-5 section 1 and on the Choluteca – Orocuina secondary road sections[23]. The results are displayed below in Tables 20 and 21, along with a comparison with the original run.

TABLE 21: SENSITIVITY TESTING ALTERNATIVE BASE MAINTENANCE REGIMES, CA-5

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value	Economic Rate of Return
Routine + cracks + rehab	50.180	46.804	91.311	44.507	18.1
Poor maintenance	50.122	49.475	317.154	267.679	37.9
Fair maintenance	50.122	47.894	244.751	196.857	29.8
Good maintenance	50.122	46.746	93.434	46.688	18.5
Excellent maintenance	50.122	45.485	61.552	16.068	12.8

TABLE 22: SENSITIVITY TESTING ALTERANTIVE BASE MAINTENANCE REGIMES, CHOLUTECA-OROCUINA SECONDARY SEGMENT

Project Alternative compared to Base Alternative	Present Value of Total Agency Costs	Increase in Agency Costs	Decrease in User Costs	Net Present Value	Economic Rate of Return
Routine + cracks + rehab	6.731	6.477	18.487	12.011	28.1
Poor maintenance	6.731	6.654	25.197	18.544	36.0
Fair maintenance	6.753	6.405	19.973	13.568	30.3
Good maintenance	6.753	6.326	18.681	12.356	28.8
Excellent maintenance	6.775	6.048	14.769	8.720	23.4

The results in Tables 20 and 21 show that, for the CA-5 section tested, there is a considerable variation in ERR depending on the Base Case maintenance regime that is enacted: the estimated ERRs are as low as 12.8% with excellent baseline maintenance, and range up to 37.9% in the case of very poor baseline maintenance. The ERR results for the secondary road section, however, have much less variation depending on the baseline maintenance regime implemented.

Nonetheless, it should be noted that for both the CA-5 section and the secondary section tested, the Project Alternative is still profitable, even if an excellent level of service is provided by an

[23] Two specific road networks were created for this run, in order to have all the results within two runs only.

appropriate maintenance standard: the lowest ERR estimated is 12.8% for the CA-5 section under excellent baseline maintenance, but that value is still strong and supportive of profitability as evaluated in most project cases.

Therefore, these sensitivity tests have indicated that, due to the fact that the secondary and primary project improvements in Honduras are of such high quality, future maintenance regimes implemented by the Honduran government on those project roads are likely to have little effect on future road conditions or profitability. Estimated ERRs for project improvements do vary as a function of the actual baseline (non-project) road maintenance regime implemented, but even in the case of very high quality Base Alternative road maintenance, the project investments are still deemed to be profitable.

D. Impact of Reference Year for Cost Estimates

For this study, the economic costs for project road improvements capital and maintenance unit costs were obtained from official 2011 documents from MCA and Fundo Vial, and we are confident on the representativeness of these costs. However, they are all in 2011 values. For the most direct comparison of our revised NPV/ERR estimates to the previous 2008 HDM-III estimates, we considered converting the 2011 cost values to 2008 values. However, we did not do this for two reasons:

a) because ERR estimates depend only on the relative stream of net benefits (net discounted stream of future costs and benefits), whether the cost values are converted to 2011 or 2008 values will have no impact on the estimated ERR, although it will impact the NPV estimates (likewise if you were to do one study with all inputted costs in Honduran Lempiras, and other with the costs converted to US dollars, the estimated NPVs will be different but the estimated ERR will be the same in both studies);

b) we were not sure of the appropriate conversion rate for conversion of the 2011 costs to 2008 values, and since keeping the 2011 values would not affect final ERR estimates we were reluctant to risk using a conversion rate that was uncertain.

The one input cost that was specified in 2008 values were the Vehicle Unit costs, which for the most part were derived from 2008 HDM-III runs. To evaluate the impact on calculated returns that would occur from converting the vehicle unit costs to 2011 values, we conducted a sensitivity analysis to evaluate the impacts by inflating the vehicle unit costs by 5% (the approximate inflation change in Honduras since 2008). This sensitivity analysis was carried out on CA-5 sections grouped into one single project, and on Secondary roads grouped into one single project. All costs are expressed in

US$, and that should limit the inflation coefficient. Table 22 summarizes the impact on ERR estimations.

TABLE 23: ESTIMATED ERR UNDER 5 % INFLATION OF 2008 VEHICLE UNIT COSTS

Roads	Base scenario	VOCs + 5 %
CA-5	13.3	13.5
Secondary	105.8	110.5

The ERR does increase slightly after the cost adjustment. However, the relative impact is not significant.

X. Conclusion

The ERR estimations completed for this study on MCC project primary, secondary and rural roads in Honduras represent a significant improvement in terms of robustness and accuracy over previous 2008 and 2011 ERR estimates, and took advantage of significant new data that was made available for this analysis in late 2011, including:

- Actual vehicle traffic counts and road speed measurements for multiple vehicle types using data measured in three rounds of NORC traffic surveys in 2009, 2010 and 2011 on MCC project roads;
- Revised road maintenance unit costs using official Honduran unit costs provided by Fundo Vial, Tegucigalpa, in October 2011, and which were significantly different than the maintenance unit costs used in the previous ERR estimates;
- Final MCC improvement project costs provided by MCA Honduras in October 2011, which were significantly higher than the 2008 HDM estimated project costs;
- On site direct observation by NORC specialists of the MCC project primary, secondary and rural roads – including both improved and unimproved sections – in October 2011 to directly observe road conditions, project improvement designs, materials and standards, and road deterioration rates.

Utilization of these new data greatly improved the accuracy of the ERR estimates relative to the previous ERR studies, which did not have access to these updated 2011 measured data inputs. Further, we improved upon and in some cases corrected errors in the HDM configuration and inputs that we believe will result in more accurate ERR estimates. Finally, we used the most recent version of the HDM software, HDM-4 Version 2, which includes improved and more robust ERR estimation models relative to those in the HDM-III software which was used for the 2008 ERR estimates (notably the HDM-4 Version 2 ERR model corrects for a known tendency in the HDM-III ERR model to provide inflated estimates).

No major problems in terms of data acquisition needed for robust HDM-4 estimates, nor any data “gaps”, were encountered in order to provide complete calculations. As a result, the HDM-4 ERR calculations reported here represent a relatively straightforward, “classic” HDM-4 analysis. Consequently, we feel confident about the 2011 ERR re-calculated estimates provided in this report for the MCC CA-5 primary and secondary roads.

CA-5 Primary Roads ERR Results. Despite lower than predicted vehicle traffic counts (which directly impact the calculation of Net Present Value benefits through Vehicle Operating Costs (VOC) as well as ERR estimates, higher than expected road maintenance costs, as well as final project improvement costs which were considerably higher than the previous 2008 estimates used in the 2008 HDM-III ERR estimates, we estimate profitable ERRs (using a 10% criterion) for all primary road CA-5 sections except for Section 2. Estimated ERRs for CA-5 Sections 1, 3 and 4 were in fact higher than estimates from all previous studies (conducted in 2003-2005, 2008 and 2011).

Three sensitivity analyses were conducted to evaluate the sensitivity of the estimated CA-5 ERRs to measured traffic volumes (which have a direct impact on the calculation of future benefits in the NPV cost/benefit stream through reduced VOCs) and on initial capital costs, which of course also impact NPV and ERR by constituting the largest project cost component.

The sensitivity test results indicate that while the estimated ERRs do show a significant reduction with either a 20% drop in traffic volume or a 50% reduction in traffic growth, the drop is not by an order of magnitude: the estimated ERRs for Sections 1, 3 and 4 remain at double digits. Reduction in capital costs by 20%, on the other hand, increases estimated ERRs by approximately 15-20% across the four CA-5 Sections. Clearly, while the changes in traffic volumes and growth, and in capital costs, do have a direct impact on the ERR estimates, the ERRs are not extremely sensitive to changes in these inputs.

Secondary Road ERR Results. The ERR estimates for secondary roads in particular were very strong, and reflected a very strong increase in traffic volumes post-project relative to pre-project measures. Further, MCC secondary road project costs were relatively low compared to primary improvement costs, and road improvement designs and work standards were judged by NORC experts to be very high, with very low projected future road deterioration rates due to the high standards of the improvements. Thus, the MCC secondary road improvements appear to have been a very profitable success, and these are reflected in their estimated ERR values which ranged from 29.4% to 188.3%.

As with the primary CA-5 sections, a sensitivity analysis was made, to evaluate the impact of:

- Over evaluated traffic (AADT 20 % lower),
- Traffic growth over estimated (50 % lower).

As with the sensitivity tests for the CA-5 roads, the impact on estimated ERRs of capital cost decreases is more significant than the impacts from traffic volume reductions or traffic growth rate reductions. Also, the relative impact of the traffic growth rate reduction of 50% on ERRs is greater than for primary CA-5 sections. For both secondary and primary CA-5 sections, these sensitivity tests highlight the importance of inputting correct values for capital costs, and the fact that we were able to input those values increases the accuracy of these ERR estimates over all previous versions.

Rural Road ERR Results. After discussion with MCC in September-October 2011, MCC gave the approval to use HDM-4 as a model to estimate ERRs for all MCC project roads, despite the fact that HDM-4 is not typically used for unpaved roads. The ERR analysis for rural roads was able to take advantage of newly available and highly useful data that should improve the rural road ERR estimates. These data included:

- traffic volumes and speeds from NORC traffic surveys (2009-2011) as well as rural road traffic measurements provided in the 2007 MCA report by Alden Rivera;
- rural road section road alignment data provided in the 2007 Alden Rivera study;
- on-site observations of rural road conditions completed by NORC in October 2011.

The estimated rural road ERRs ranged considerably across the 33 rural MCC segments where it was estimated.

We note that there are a number of important caveats regarding using HDM-4 to produce rural road ERR estimates. The HDM-4 rural road ERR estimates are very sensitive to assumptions on future traffic growth and vehicle speeds post improvements: for rural roads, calculated NPVs and ERRs tend to correlate closely with traffic volumetric flows.

Further, rural road project costs are relatively very low. For these reasons, the economic analysis can in some cases provide very high rates of return due in large part to these low project costs. In addition, for these ERR estimates, we have made assumptions regarding the number of days per year each rural road segment is "passable", which can affect the ERR estimates – however these are rough assumptions and actual passability may vary considerably across the segments;

Therefore at best the rural road ERR estimates are likely only capturing a small part of the true economic impact of rural road improvements. The NPV estimates here may be a more appropriate measure of the likely return on investment. Another option that could be considered for future rural road ERR modeling would be to perhaps include measures of the economic or agricultural productivity of areas immediately adjacent to the rural road section in question, or for cities/towns that the rural road segment leads to. An explicit consideration of the agricultural productivity of adjacent areas to rural roads is a component in the 2007 MCA rural road ERR model developed by MCA consultant Alden Rivera: this complete model is presented in its original excel spreadsheet format in Annex VIII (file *"ERRMCARuralRoads_comité_camino_pop_data Alden.xlsm"*).

Sensitivity Tests for Impact of Alternative Maintenance Regimes on Primary and Secondary Roads. At the request of MCC, we have run some sensitivity tests to evaluate the sensitivity of the estimated ERRs to alternative road maintenance regimes.

The sensitivity to maintenance regimes in Base Alternative was tested on CA-5 section 1 and on the Choluteca – Orocuina secondary road sections.

The results show that, for the CA-5 section tested, there is a considerable variation in ERR depending on the Base Case maintenance regime that is enacted: the estimated ERRs are as low as 12.8% with excellent baseline maintenance, and range up to 37.9% in the case of very poor baseline maintenance. The ERR results for the secondary road section, however, have much less variation depending on the baseline maintenance regime implemented.

Nonetheless, it should be noted that for both the CA-5 section and the secondary section tested, the Project Alternative is still profitable, even if an excellent level of service is provided by an appropriate maintenance standard: the lowest ERR estimated is 12.8% for the CA-5 section under excellent baseline maintenance, but that value is still strong and supportive of profitability as evaluated in most project cases.

Therefore, these sensitivity tests have indicated that, due to the fact that the secondary and primary project improvements in Honduras are of such high quality, future maintenance regimes implemented by the Honduran government on those project roads are likely to have little effect on future road conditions or profitability. Estimated ERRs for project improvements do vary as a function of the actual baseline (non-project) road maintenance regime implemented, but even in the case of very high quality Base Alternative road maintenance, the project investments are still deemed to be profitable.

Final Sensitivity Test For Impact of Base Year. To evaluate the impact on calculated returns that would occur from converting the vehicle unit costs to 2011 values, we conducted a sensitivity analysis to evaluate the impacts by inflating the vehicle unit costs by 5% (the approximate inflation change in Honduras since 2008). This sensitivity analysis was carried out on CA-5 sections grouped into one single project, and on Secondary roads grouped into one single project. The ERR was found to increase slightly after the cost adjustment. However, the relative impact is not significant.

Sensitivity Test of HDM-4 "Impassability" Modeling on Final Estimated Rural ERRs. Given that the MCC rural road improvements specifically included a number of improvements (box bridges, culverts, climbing tracks, retaining walls and improved drainage, etc.), we included in our rural road HDM-4 ERR estimations a simple model designed to capture some of the benefits obtained from these specific improvements in rural road rain erosion and rain impassability resistance. As a sensitivity test of the impact that the "impassability" modeling has on the final estimated rural road ERRs (reported below), NORC completed an additional set of ERR estimations for the Honduran rural roads in HDM-4 with the "impassability" feature turned off (i.e. no multiplicative factor for VOC after a specified threshold in gravel thickness reduction). These re-estimated ERRs are reported in Annex XX, entitled "HDM-4 ERR Estimation for the Transport Infrastructure Project: Additional Elements on Rural Roads Impassability." As noted in the Annex, the estimated rural road ERRs are significantly reduced (and in a number of cases become negative) when the impassability feature is turned off. This indicates the highly important impact that impassability due to rain has on the Honduran rural road HDM ERR estimates, even though we used quite conservative VOC multiplicative impassability factors (ranging from 1.2 to 1.4 out of a possible range of 1-3, as reported in Table 16 of the final Honduras ERR report). To truly evaluate impassability due to rain would require a measurement of the number of days per year that the road is impassible, before and after treatment. However, these data were not available for Honduras.

Modeling of Costs in HDM-4 Due to Other Factors. We note that HDM-4 V2 Life Cycle Analysis does have options that allow the modeling and consideration of costs due to other factors besides VOC, project capital costs, future road maintenance costs and vehicle travel times and speeds. These included consideration of the costs of future accident rates, vehicle omissions and energy usage, although doing so requires a number of economic assumptions to express these factors in monetary terms and modeling them may not be appropriate depending on the project (they are not modeled by default in HDM-4). Further, additional "exogenous benefits" can be defined, such as for example indices of accessibility to markets or services created by the road project, and included in the cost streams. However, NORC did not model these exogenous benefits in our Honduras ERR estimates as per agreement with MCC during our presentation of our HDM modeling strategy and assumptions in our initial meeting with MCC in September 2011.

Some Policy Implications. A key story to emerge from this study is that the ERR return and profitability on the MCC Honduran secondary roads is very high, relative to primary and rural road returns. We note that the very high ERRs estimated for the secondary roads are primarily driven by quite significant post-improvement increases in traffic volumes along those segments. This is an optimal outcome, and it implies that MCC may want to select future secondary or other road improvement candidate sections by choosing those that have high traffic volumes, or which are likely to have high traffic volume increases due to improvements. Further, the results appear to call for a consideration of the estimated returns to secondary compared to primary road improvements, given the relatively very high cost per unit of the primary road improvements.

The rural road analysis reveals, notably, that rural roads that are improved using designs that fall short of paving them tend to return to their pre-improvement road surface condition within 5 years. This implies that many of the economic benefits created by the rural road improvements (accessibility, reduction in road user costs, etc.) are confined to the first 5 years after improvement, and this contrasts notably with the secondary and primary road improvements which predict continued benefits to accrue for up to 20 years or more, due to the durability of the paved improvement designs implement there. This brings up the question of whether or not rural road improvements are worthwhile? Further, it likely becomes more important to know what is going on around these rural roads (e.g. types of agricultural production, what population centers are adjacent and of what size, etc.) to provide a more nuanced assessment of likely impacts of these rural improvements.

HDM-4 brings to bear powerful engineering models and equations and provides for a robust set of quantified outputs and estimates that could well serve larger road improvement economic impact evaluation efforts. This implies that HDM-4 should perhaps be merged with more traditional impact evaluation approaches, such as quasi-experimental designs or double differences, to take advantage of the precision of the HDM-4 road estimates and model predictions.

XI. Description of Annexes

Annexes Provided In Main Report:

Annex I: Photographs of Project Roads

This Annex contains a series of photographs of the MCC project road surfaces, with accompanying descriptions, in Honduras collected by NORC during the October 2011 site visit.

Annex II: Detailed Description of HDM-4 Workspace/Configuration

This Annex provides a detailed description of the HDM-4 Workspace/Configuration.

Annex III: Considerations Regarding MCC Rural Roads Studied

This Annex provides a discussion of the sample of MCC rural roads studied for this ERR analysis.

Additional Annexes Provided in a Compressed File Archive:

Annex IV: List of MCC Project Roads Evaluated

Annex IV provides five files listing the MCC project roads that were the subject of this ERR study. The files also provide the road improvement starting and ending dates for each improvement section and the final capital costs for each section (data provided by MCA Honduras), and the starting and ending dates for each of the three rounds of NORC traffic surveys conducted on each segment.

The files in the Annex are:

a) "MCCProjectRoads_NORCTrafficSurveys.xls": provides a complete listing of the MCC project and comparison roads where the NORC traffic surveys were conducted; road improvement start and end dates, final project capital costs, and the dates when of each of the three rounds of the NORC traffic surveys were conducted on those segments are also provided.

b) "NORC_RuralRoadSectionsSummary_v2.xlsx": provides a list of the 33 MCC rural road segments that were provided to NORC by MCC for conducting the ERR study; the file also lists the NORC traffic survey road segments that were not in this list of 33 rural road segments provided by MCC.

c) "MCA_RuralRoadList_NORCTrafficSurveys.xls": provides the list of 24 MCA rural treatment segments that were provided to NORC by MCA Honduras for collection of traffic data in the NORC traffic suveys – the segments are listed with their corresponding "estacioID" identifiers.

d) "Caminos Rurales al spe 2010 MCA_NORCmodified.xlsx": shared with NORC by MCA Honduras in October 2011, and provides project costs and other details for 43 MCA project rural road improvements - in column G ("NORC Round 3 Traffic Estacio #"), we have listed the corresponding NORC traffic survey Round 3 Estacio #s that we were able to match to these segments.

e) "Transport Project Summaries (Rural Roads).xlsx": excel file sent to NORC by MCC on November 17, 2011, identifying 33 Honduran rural road segments for ERR analyses.

Annex V: Schedule of MCC Completed Road Improvements and Capital Costs

This Annex contains excel files provided by MCA Honduras that give the final project costs for all MCC primary, secondary and rural improved segments as well as the starting and ending dates for all road improvements, both contract dates and actual dates. The files are provided in three sub-folders for primary, secondary and rural, respectively.

Annex VI: HDM-4 Workspace and Input Files

This Annex contains three sub-annexes.

Annex VI-A: HDM-4 Input Files

This sub-Annex contains two files providing the full set of inputs for the HDM-4 modeling conducted in this study.

a) "HDM-4-input-data.xlsx": provides a summary of the full set of input values for the HDM-4 modeling for primary and secondary roads, including worksheets providing the following data:

1. Vehicle input values
2. Computed Average Annual Daily Traffic (AADT) values
3. NORC-Round 3 traffic data
4. Louis Berger and NORC recorded traffic data
5. Road alignment inputs
6. Road sections inputs
7. Work unit cost inputs
8. CA-5 project descriptions and costs
9. Secondary road project descriptions and costs
10. Summary of projects as inputted into HDM-4

b) "HDM-import-data-Rural.xlsx": provides a summary of the full set of input values for the HDM-4 rural roads modeling, including worksheets for the following:

Sheet	Comments
Section_data	In this sheet are stored data items prepared from the different sources: Alden file, Summary table from MCA, and last data from MCC.
NORC_Traffic_data	This sheet displays AADTs values derived from traffic counts realised by NORC on rural sections (round 3).
Alden_Traffic_data	This sheet displays AADTs values included in the Alden file. Additional columns were created to calculate percentages.
AADT_Final	This sheet displays AADTs values to be imported into HDM-4. Additional columns were created to breakdown AADRs into the two categories of vehicle-types new- and used-. The name Traffic_data was assigned to zone $N$5:$Z$48.
Config&defaults	This sheet displays all the tables that specify relationships between original values and HDM-4 data, as well as default values for some HDM-4 parameters which are not included in the original files.
SECTIONS_specs	This table specifies how each field of the SECTIONS table of the Road Network import file was valued.
SECTIONS	This sheet displays data that must be copied in the SECTIONS table of the Road Network import file (Access data base).
Vehicle_fleet	This sheet describes HDM vehicle-types codification.
TRAFFIC_specs	This table specifies how each field of the TRAFFIC table of the Road Network import file was valued.
TRAFFIC	This sheet displays data that must be copied in the TRAFFIC table of the Road Network import file (Access data base).

Annex VI-B: HDM-4 Workspace Files

Contains HDM-4 workspace files for primary, secondary and rural road ERR estimations.

Annex VI-C: HDM-4 Output Reports

Contains an extensive set of HDM-4 model output files for primary, secondary and rural road ERR estimations, including reports, graphs and figures showing the modeled evolution over time of AADTs, economic indicators, road roughness and benefit-cost ratios.

Annex VII: HDM-4 Workspace, Input and Output Files for Sensitivity Testing:

This Annex contains HDM-4 workspace files for the sensitivity tests completed for this analysis, as well as HDM-4 output summaries of economic indicators related to the sensitivity tests.

Annex VIII: Digital Files Related to Previous 2003-2005, 2007-2008 and 2011 HDM ERR Estimations

This Annex contains an extensive number of files obtained by NORC from MCC and MCA Honduras that describe previous ERR estimates completed for MCC project roads in Honduras in 2003-2005, 2007-2008 and 2011. The Annex contains four sub-folders for

- 2003-2005 ERR estimates;
- 2007 Rural Road ERR estimates;
- 2008 ERR Estimates Using HDM-III Files
- 2011 ERR Estimates.

Annex IX: Fundo Vial Reports

This Annex contains a number of reports obtained from Fundo Vial in Honduras, including official road maintenance unit costs.

Annex X: Project Roads Design Reports (Louis Berger) and Construction Supervision Reports

This Annex contains CA-5 Project Design Reports completed by Louis Berger and CA-5 Construction Supervisory Reports completed by consultants Consultant DMJM-Harris and Saybe Y Asociados. It also contains five design and supervisory reports for secondary road improvements.

Annex XI: Estimated Exogenous Project Road Speed Estimates from HDM-4 Vehicle Speed Model

This Annex contains estimated vehicle speeds for each MCC project road segment for all vehicle types, estimated using the HDM-4 road speed model. These HDM-4 estimated speeds provide a measure of predicted vehicle speed that is not related to congestion, and thus can be used as an exogenous measure of "uninhibited" road speeds for multiple vehicle types without congestion effects. The inputs to the model are:

1. Vdrive: a measure of engine power for each vehicle type (i.e. potential speed of each vehicle given its vehicle type and engine size)
2. Vcurve: the curvature of the road segment for which the speed is calculated
3. Vrough: the roughness of the road for which the speed is calculated

4. Vdesir: "desired" speed - vehicle speed when there is no constraint (i.e. a straight flat road without any speed limit The final estimated speed is calculated from these inputs using a (non-linear) Weibull function.

Annex XII: Sensitivity Test of Impact of Rain "Impassability" for Rural Road ERR Estimates

This Annex provides a report of an additional sensitivity test completed by NORC HDM-4 expert consultant Pierre Joubert estimating MCC rural road ERRs with the impassability model turned off.

Annex XIII: NORC Responses to MCC Comments on This Report

This Annex provides provides copies of two sets of responses that NORC provided to comments on this report. The comments were submitted in April 2012, and the responses from NORC were provided to MCC in April and May, 2012. The texts of the original emails is included, as well as additional reports created by NORC in response to the comments. This version of the final report integrates changes and additions provided by NORC in response to these comments.

Annex I: Photographs of Project Roads

The following photographs of the MCC project roads were taken in October, 2011, during the site visit by NORC.

CA-5, section 1

This general view shows the wide extent of cracking. Some cracked areas already are developing potholes. The cross profile shows rutting, likely to come from a general fatigue of the pavement.

This is a detailed view of a cracked area on which potholes are developed. Some potholes were patched; another one is not patched yet.

This is a detailed view of the previous pothole. The surface size is considerable, but it is a shallow pothole. Apparently, only the last surface course is disintegrated. The base course is not affected by loss of material.

Other distresses were observed on the section of CA-5 which is to be improved in Comayagua plain (this is not a MCA section).

This lane shows extensive cracking. The cracks are still fine cracks, but they are likely to evolve into wide cracks and potholes. See the other lane, which is much more distressed (detailed on next view).

This view shows a distressed area. On the left, a patch is not distressed yet. Along the axis yellow paint line, a rectangular patch is already extensively cracked. At the top of this area, two new patches on the old patch are still crack free.

This view shows a pothole that was developed from a cracked area. This pothole is smaller than the one observed on section 1, but it seems deeper.

Some areas on this section are even more distressed than those views.

Section 4, after works

Vehicle interactions on Section 3

Secondary Roads

Comayagua – La Paz

Rural Roads

MCC section, good condition

Same, detail

Rural, fair condition (not a MCC section)

Rural, very bad condition, speed < 10 km/h (not a MCC section)

Annex II: Detailed Description of HDM-4 Workspace and Model Run Specifications

HDM-4 workspace is included in HDM-4-runs directory. The workspace is the set of 4 elements: two directories eventlog and recovery, and two files objects.dat and objects.idx.

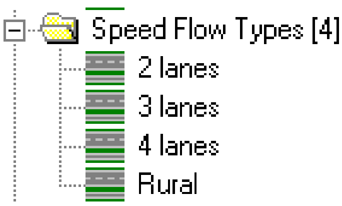
This workspace can be open with a HDM-4 demonstration version. The correct procedure is to copy this workspace anywhere on your computer, to run HDM-4, and to open this workspace, using the function Open workspace…., and browsing to select the appropriate objects.dat file.

Be careful! If you open this workspace with a full version, it can no longer be opened with a demo version. The demo version allows you to display all elements, but its functions are very limited. If you wish to have all functions, you must have a full licence (see www.hdmglobal.com).

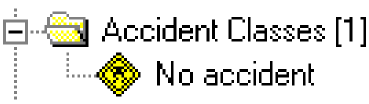
Configuration

The configuration includes three Traffic Flow Patterns, with HDM-4 default values.

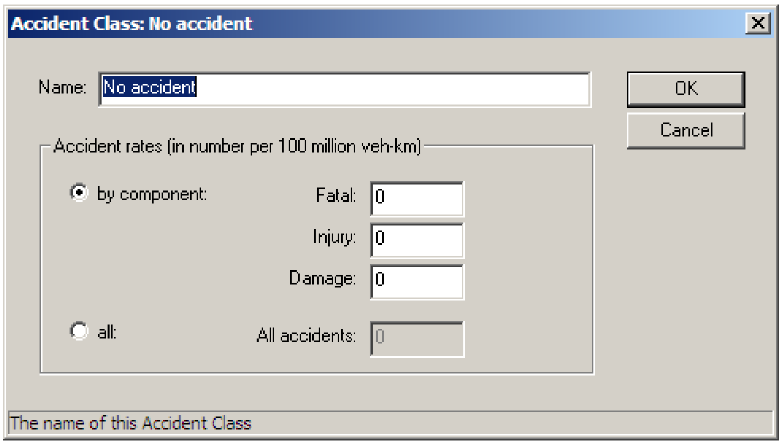
The configuration includes four Speed Flow Types, very similar to HDM-4 default; Rural is similar to Intermediate HDM-4 default.



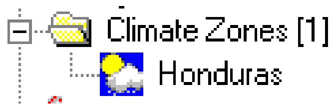
As Accident analysis is not part of the study, only one accident class was specified.



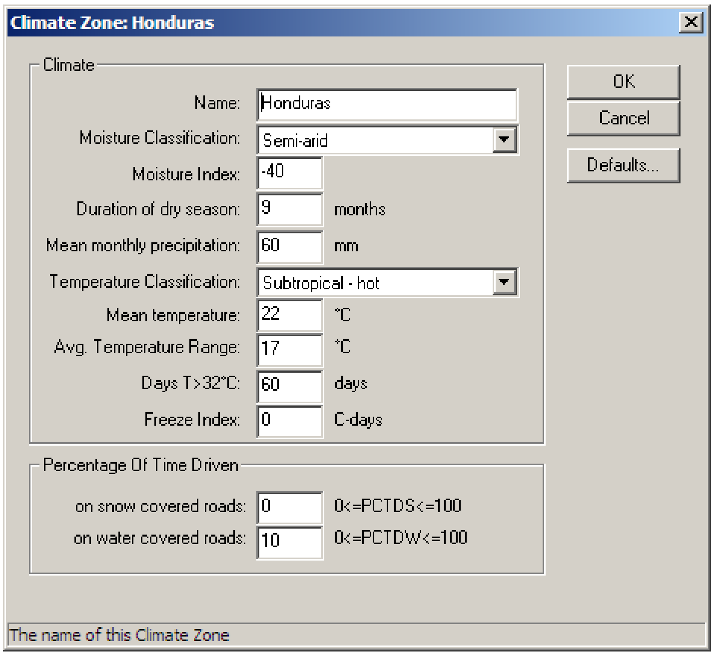
All rates are set to zero



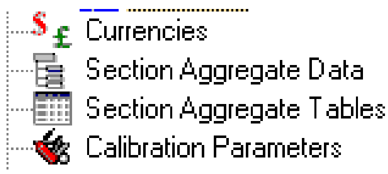
Only one Climate Zone was specified.



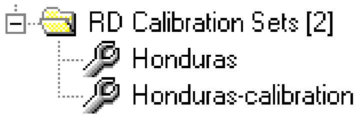
This Climate Zone associates Semi-arid Moisture classification and Subtropical-hot Temperature classification.



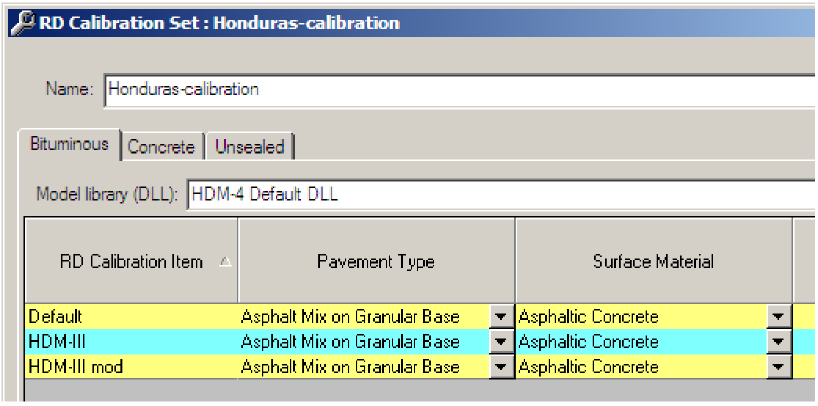
Currencies, Section Aggregate Data, Section Aggregate Tables, Calibration Parameters were not modified.



Two calibration sets were specified.



Honduras-calibration Calibration set was used for calibration. It includes three calibration items for bituminous roads.



These calibration items were used to evaluate road deterioration calibration.

The Default Calibration item uses all default values.

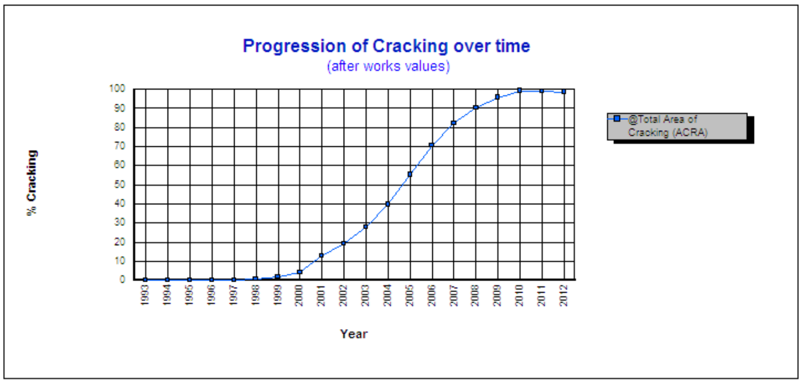
The HDM-III Calibration item extends the calibration coefficients that were used in HDM-III runs to HDM-4 relevant calibration coefficients.

Kcia = Kcpa = Kciw = Kcpw = Kcit = Kcpt = Kvi = Kvp = Kpic = Kpir = Kpp = Krid = Krst = Krpd = Krsw = Kgc = Kgr = Kgp = 1.45, Kgm = 1.74, all other values set to default.

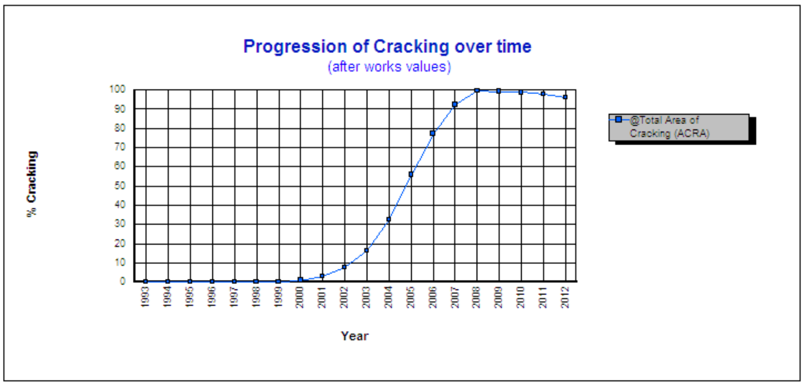
The HDM-III-mod Calibration item uses the same calibration parameters as used in HDM-III runs, slightly adjusted for more consistency.

Kcia = Kciw = Kcit = Kvi = Kpic = Kpir = Kpp = Krid = Krst = Krpd = Krsw = Kgc = Kgr = Kgp = 1.45, Kcpa = Kcpw = Kcpt = Kvp = 0.7, Kgm = 1.74, all other values set to default.

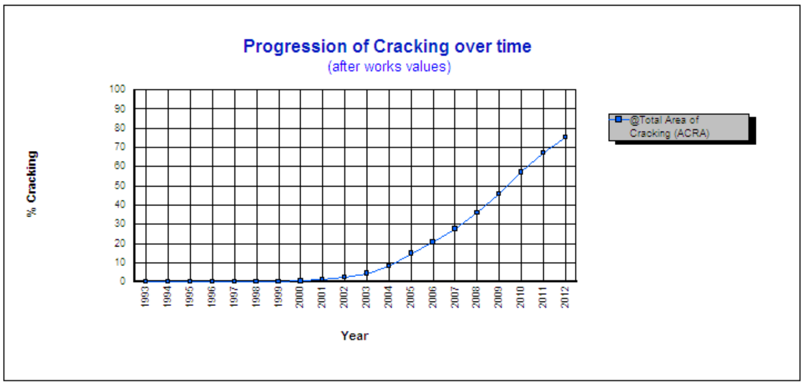
We tested these three calibration items on a section more or less similar to section 3, for which we had some information about year of last surface course, assuming that the condition before works was more or less identical to the non improved segments of CA-5 in Comayagua Valley. The graphs showing cracking and roughness evolution are displayed below.



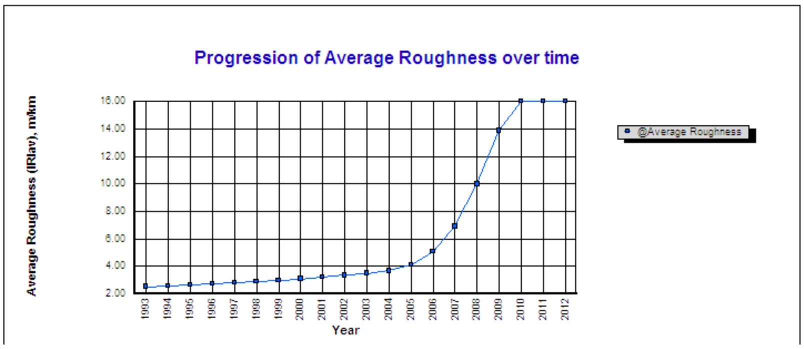
Default



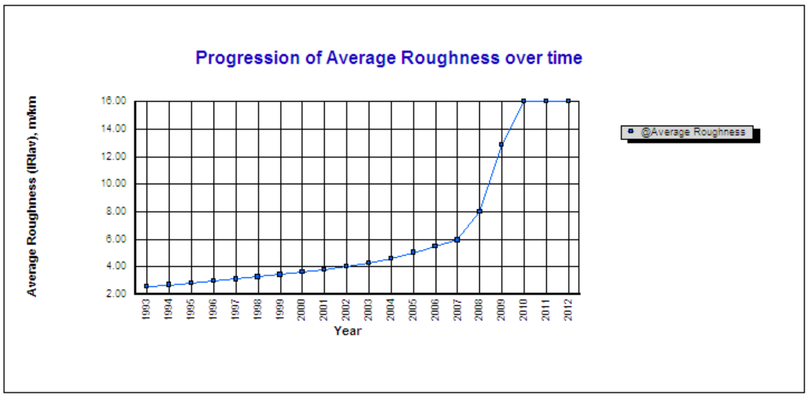
HDM-III



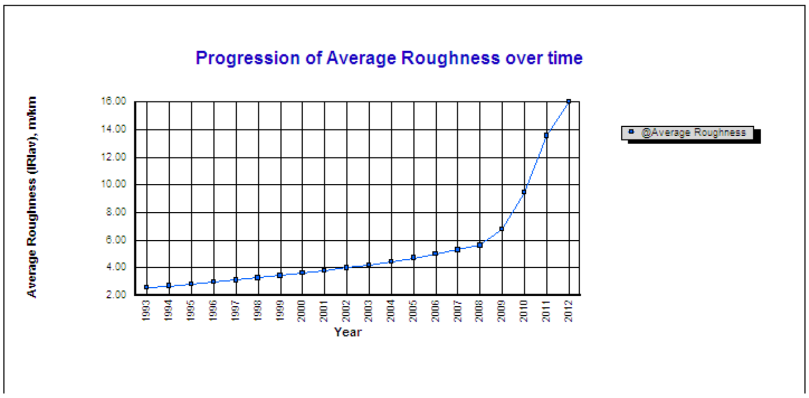
HDM-III mod



Default



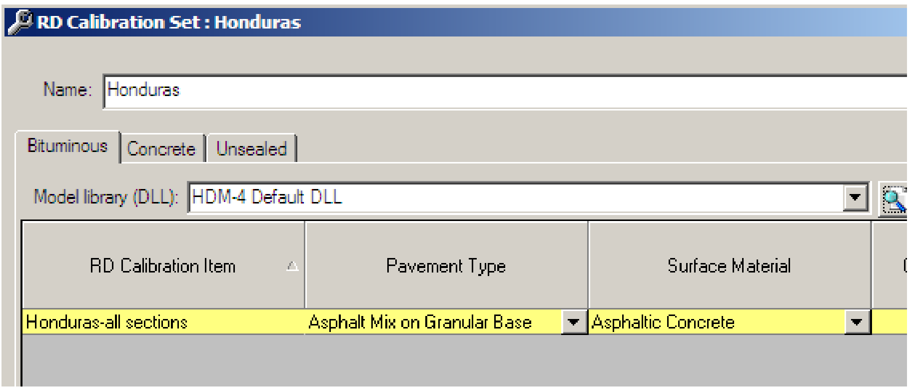
HDM-III



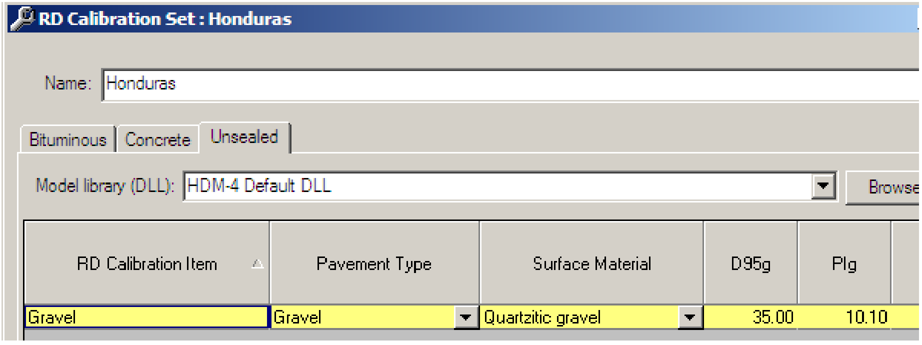
HDM-III mod

Default and HDM-III calibration items predict cracking extent and roughness levels that seem worse than the observed situation. For this reason, we selected the HDM-III-mod calibration item as the most relevant.

The Honduras Calibration set includes two Calibration items, one for bituminous roads, with all parameters values copied from HDM-III-mod,



And one for unpaved roads, with all parameters set to HDM-4 default values for Quartzitic Gravel except D95, set to 35 mm instead of 23.8 mm.



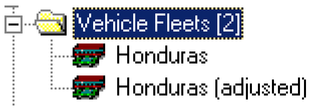
Two remarks:

1-This process is NOT a true calibration. It must NOT be considered that HDM-4 deterioration relationships are calibrated. A true calibration process requires historical reliable data, including history of pavement structure and bearing capacity, past observed traffic volume and loads, frequent reliable visual surveys and roughness measurements.

2-The fact that HDM-4 deterioration relationships are not calibrated is not a major concern for this study, as we always use comparisons between a Project Alternative and a Base Alternative.

Vehicle Fleets

The workspace includes two Vehicle Fleets



The Honduras Vehicle Fleet was specified in the early phases of the study, and used for Calibration runs. It includes six vehicle types, directly copied from HDM-III runs Vehicle Fleet.

The Honduras (adjusted) Vehicle Fleet is the final one, which was used for all other runs. It includes twelve Vehicle-types, each one of the previous six being specified either as a used vehicle, or as a new one.

Vehicle Fleet: Honduras (adjusted) - Definition Data

Name	Class	Data Last Modified	Base Type	Category
1n-Car (new)	Passenger Cars	29/11/2011	Car Medium	Motorised
1u-Car (used)	Passenger Cars	29/11/2011	Car Medium	Motorised
2n-Pick-up (new)	Utilities	29/11/2011	Delivery Vehicle Light	Motorised
2u-Pick-up (used)	Utilities	29/11/2011	Delivery Vehicle Light	Motorised
3n-Bus (new)	Buses	29/11/2011	Bus Medium	Motorised
3u-Bus (used)	Buses	29/11/2011	Bus Medium	Motorised
4n-Truck2A (new)	Trucks	29/11/2011	Truck Medium	Motorised
4u-Truck 2A (used)	Trucks	29/11/2011	Truck Medium	Motorised
5n-Truck3A (new)	Trucks	29/11/2011	Truck Heavy	Motorised
5u-Truck 3A (used)	Trucks	29/11/2011	Truck Heavy	Motorised
6n-Truck Art (new)	Trucks	29/11/2011	Truck Articulated	Motorised
6u-Truck Art (used)	Trucks	29/11/2011	Truck Articulated	Motorised

The basic characteristics and unit costs are displayed in the two tables below.

Vehicle Fleet: Honduras (adjusted) - Basic Characteristics

Name	Class	Data Last Modified	PCSE	Wheels	No.of Axles	Tyre Type	Base Recaps	Retread Cost %	Annual km	Working Hours	Average Life (yrs)	Private Use %	Pass-engers	% Work Journeys	ESAL	Operating Weight	Units
1n-Car (new)	Passenger Cars	29/11/2011	1.00	4	2	Radial-ply	1.30	15.00	15000.00	365.00	13.00	100.00	2.00	75.00	0.00	1.60	tonnes
1u-Car (used)	Passenger Cars	29/11/2011	1.00	4	2	Radial-ply	1.30	15.00	15000.00	365.00	13.00	100.00	2.00	75.00	0.00	1.60	tonnes
2n-Pick-up (new)	Utilities	29/11/2011	1.00	4	2	Radial-ply	1.30	15.00	9000.00	547.00	10.00	0.00	2.00	0.00	0.01	2.20	tonnes
2u-Pick-up (used)	Utilities	29/11/2011	1.00	4	2	Radial-ply	1.30	15.00	9000.00	547.00	10.00	0.00	2.00	0.00	0.01	2.20	tonnes
3n-Bus (new)	Buses	29/11/2011	1.50	6	2	Bias-ply	1.30	15.00	33215.00	2600.00	8.40	0.00	43.00	75.00	0.73	10.10	tonnes
3u-Bus (used)	Buses	29/11/2011	1.50	6	2	Bias-ply	1.30	15.00	33215.00	2600.00	8.40	0.00	43.00	75.00	0.73	10.10	tonnes
4n-Truck2A (new)	Trucks	29/11/2011	1.40	6	2	Bias-ply	1.30	15.00	28000.00	833.00	10.00	0.00	0.00	0.00	0.95	8.40	tonnes
4u-Truck 2A (used)	Trucks	29/11/2011	1.40	6	2	Bias-ply	1.30	15.00	28000.00	833.00	10.00	0.00	0.00	0.00	0.95	8.40	tonnes
5n-Truck3A (new)	Trucks	29/11/2011	1.60	10	3	Bias-ply	1.30	15.00	18000.00	2000.00	10.00	0.00	0.00	0.00	1.74	16.00	tonnes
5u-Truck 3A (used)	Trucks	29/11/2011	1.60	10	3	Bias-ply	1.30	15.00	18000.00	2000.00	10.00	0.00	0.00	0.00	1.74	16.00	tonnes
6n-Truck Art (new)	Trucks	29/11/2011	1.80	18	5	Bias-ply	1.30	15.00	25000.00	950.00	10.00	0.00	0.00	0.00	2.62	23.00	tonnes
6u-Truck Art (used)	Trucks	29/11/2011	1.80	18	5	Bias-ply	1.30	15.00	25000.00	950.00	10.00	0.00	0.00	0.00	2.62	23.00	tonnes

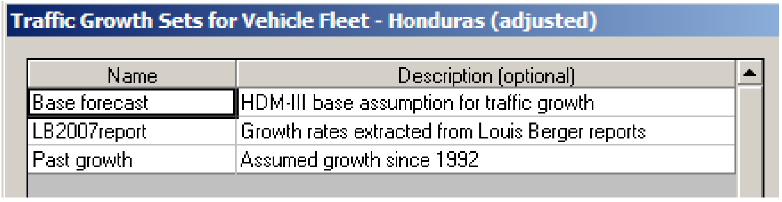
Vehicle Fleet: Honduras (adjusted) - Economic Unit Costs

Name	Class	Data Last Modified	Vehicle	Tyre	Fuel (per litre)	Lubricants (per litre)	Labour (per hr)	Crew (per hr)	Overhead (per year)	Interest Rate %	Passenger Work (per hr)	Non work (per hr)	Cargo Delay (per hr)
1n-Car (new)	Passenger Cars	28/12/2011	15435.00	57.00	0.71	2.00	2.85	0.00	0.00	19.00	1.35	1.35	0.00
1u-Car (used)	Passenger Cars	28/12/2011	5145.00	57.00	0.71	2.00	2.85	0.00	0.00	19.00	1.35	1.35	0.00
2n-Pick-up (new)	Utilities	28/12/2011	19267.00	70.00	0.71	2.00	2.85	0.68	0.00	19.00	1.35	1.35	0.01
2u-Pick-up (used)	Utilities	28/12/2011	5505.00	70.00	0.71	2.00	2.85	0.68	0.00	19.00	1.35	1.35	0.01
3n-Bus (new)	Buses	28/12/2011	67445.00	243.00	0.68	2.00	2.06	1.52	0.00	19.00	0.14	0.14	0.02
3u-Bus (used)	Buses	28/12/2011	13489.00	243.00	0.68	2.00	2.06	1.52	0.00	19.00	0.14	0.14	0.02
4n-Truck2A (new)	Trucks	28/12/2011	36324.00	211.00	0.68	2.00	2.85	1.52	0.00	19.00	0.00	0.00	0.02
4u-Truck 2A (used)	Trucks	28/12/2011	9081.00	211.00	0.68	2.00	2.85	1.52	0.00	19.00	0.00	0.00	0.02
5n-Truck3A (new)	Trucks	28/12/2011	42276.00	211.00	0.68	2.00	2.85	1.52	0.00	19.00	0.00	0.00	0.04
5u-Truck 3A (used)	Trucks	28/12/2011	10569.00	211.00	0.68	2.00	2.85	1.52	0.00	19.00	0.00	0.00	0.04
6n-Truck Art (new)	Trucks	28/12/2011	120575.00	258.00	0.68	2.00	2.85	1.33	0.00	19.00	0.00	0.00	0.08
6u-Truck Art (used)	Trucks	28/12/2011	24115.00	258.00	0.68	2.00	2.85	1.33	0.00	19.00	0.00	0.00	0.08

Some adjustments were made on parameters that are displayed in Calibration tabs.

They are documented in detail in the HDM-4-input-data.xlsx Excel file. Changes were made on Desired speed and Driving power, to reproduce observed vehicle speeds, on ZETAB parameter (Fuel to Power efficiency factor) to introduce a difference in fuel consumption between used and new vehicles, and on a0 and a1 coefficients for parts consumption, to reflect the higher parts consumption of used vehicles.

Three Traffic Growth Sets were specified in each Vehicle Fleet.

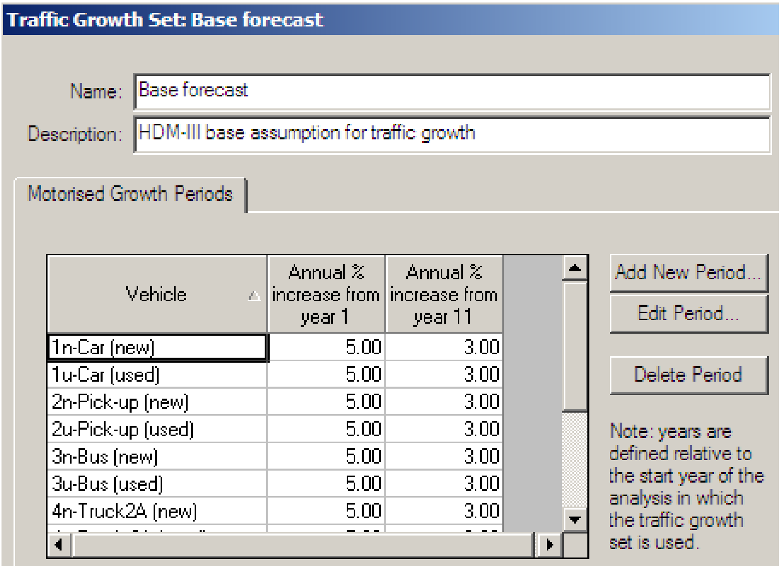


Traffic Growth Sets for Vehicle Fleet - Honduras (adjusted)

Name	Description (optional)
Base forecast	HDM-III base assumption for traffic growth
LB2007report	Growth rates extracted from Louis Berger reports
Past growth	Assumed growth since 1992

Past growth Traffic Growth Set was used for calibration run, along with Honduras Vehicle Fleet.

Base forecast Traffic Growth Set was used for all other runs, along with Honduras (adjusted) Vehicle Fleet. This Traffic Growth Set includes two Growth Periods.



Traffic Growth Set: Base forecast

Name: Base forecast

Description: HDM-III base assumption for traffic growth

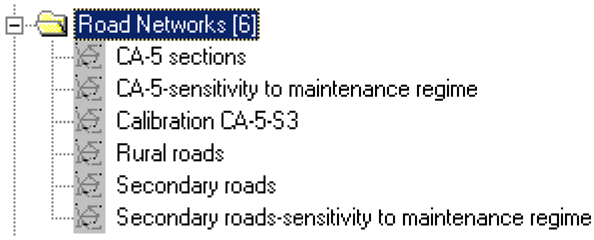
Motorised Growth Periods

Vehicle	Annual % increase from year 1	Annual % increase from year 11
1n-Car (new)	5.00	3.00
1u-Car (used)	5.00	3.00
2n-Pick-up (new)	5.00	3.00
2u-Pick-up (used)	5.00	3.00
3n-Bus (new)	5.00	3.00
3u-Bus (used)	5.00	3.00
4n-Truck2A (new)	5.00	3.00

Traffic growth is 5 % per annum during the first ten years of the Analysis period, then 3 % per annum.

Road Networks

Six Road Networks were specified.



CA-5 sections, Secondary Roads, and Rural roads Road Networks were used for the main runs. Calibration CA-5-S3 Road Network was used for the calibration run, and CA-5-sensitivity to maintenance regime and Secondary roads-sensitivity to maintenance regime were created to facilitate the runs on sensitivity to maintenance regime before improvement.

Input data were evaluated from different sources. The HDM-4-input-data.xlsx Excel file details the sources and assumptions for the main parameters.

The CA-5 sections Road Network was input manually. Similarly, the Secondary roads Road Network was input manually. For Rural roads Road Network, we used the import function, which allows importing into HDM-4 data prepared in an Access database. The data preparation is detailed in the HDM-import-data-Rural.xlsx file. Data from SECTIONS and TRAFFIC sheets of this Excel file are then imported into two tables of the Access database, which includes two additional tables, FILETYPE and ROADNET. The format of these tables is described in HDM-4 documentation.

A special attention was brought to traffic data. The initial traffic counts were distributed into six vehicle-types. It was decided to take into account the mix between used and new vehicle, and this required to specify a proportion. The assumptions that were made are:

Vehicle-type	% of used	% of new
1-Car	70	30
2-Pick-up	30	70
3-Bus	20	80
4-Truck 2A	50	50
5-Truck 3A	50	50
6-Truck Art	50	50

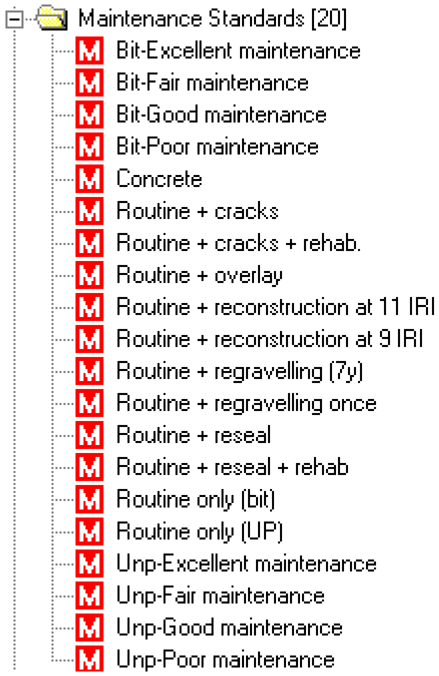
Works standards

Unit costs

The unit costs used in HDM-III runs were much too low to be included in the new runs. Fundo Vial documents gave very much detailed unit costs, for each maintenance activity. These unit costs were adapted to match with HDM-4 maintenance works operations. The detail of the analysis is displayed in the HDM-4-input-data.xlsx Excel file.

Maintenance standards

A total of twenty maintenance standards are included in the HDM-4 workspace. Fifteen of them are used in the runs. The other five were used in some test runs, and not included in the final runs.



Concrete; this maintenance standard was specified for cement concrete sections (CA-5 S4, project option). This maintenance standard includes routine maintenance on roadsides, joint sealing and slab replacement.

Routine + cracks: this standard includes routine maintenance of shoulders and drainage, patching potholes (a maximum of 50 m²/km/year is specified for patching potholes), and patching areas with wide cracks.

Routine + cracks + rehab.: this standard includes routine maintenance of shoulders and drainage, and patching potholes (a maximum of 50 m²/km/year is specified for patching potholes). Patching activities are also carried out on areas with wide cracks. When roughness exceeds 7 IRI, a 50 mm overlay is triggered. This standard is used to describe the base case for CA-5 sections. It predicts a roughness evolution which seems sensible, and is in good agreement with 2011 runs.

Routine + overlay; this standard was assigned to CA-5 sections after the construction in the Project alternative. It implements a road policy aiming at a very good level of service, which is the future maintenance policy on CA-5 rehabilitated sections, as we were told during the meeting with Fundo Vial. This standard includes routine maintenance of shoulders, crack sealing, patching, and overlay 5 cm Asphalt Concrete when roughness exceeds 5 IRI (which means when road roughness really starts to impact operating speed).

Routine + reconstruction at 11 IRI: this standard includes routine maintenance of shoulders and drainage, and patching potholes (a maximum of 50 m^2/km/year is specified for patching potholes). Pavement reconstruction is triggered when roughness exceeds 11 IRI. This standard was used in early runs.

Routine + reconstruction at 9 IRI: this standard includes routine maintenance of shoulders and drainage, and patching potholes (a maximum of 50 m^2/km/year is specified for patching potholes). Pavement reconstruction is triggered when roughness exceeds 9 IRI. This standard was used in early runs.

Routine + regravelling (7y); this standard includes routine maintenance of shoulders and drainage, and regravelling 15 cm every 7 years. This maintenance standard was assigned to secondary roads in the base case, without project.

Routine + regravelling once; this standard includes routine maintenance of shoulders and drainage, and regravelling once, in 2010. This maintenance standard was assigned to rural roads in one alternative of the project. It was not used for the final runs, as it does not allow triggering generated traffic.

Routine + reseal; this standard was assigned on secondary roads after the project. This standard includes routine maintenance of shoulders, patching, and resealing when cracking exceeds 30%.

Routine + reseal + rehab; this standard is similar to the previous one, plus a 5 cm AC overlay when roughness exceeds 7 IRI.

Routine only (bit): this standard includes routine maintenance of shoulders and drainage, and patching potholes. A maximum of 50 m^2/km/year is specified for patching. This maintenance standard was used for calibration study, to describe the policy that was actually carried out on section 3.

Routine only (UP); this standard includes only routine maintenance of shoulders and drainage. This maintenance standard will be assigned to rural roads in the base option from the start of the analysis period, and in the project after the works.

Following questions raised during 1st of December meeting in MCC, additional standards were specified to explore the impact of maintenance regimes.

Bit-Poor maintenance: similar to **Routine only (bit).**

Bit-Fair maintenance: similar to **Bit-Poor maintenance,** plus patching wide cracks.

Bit-Good maintenance: similar to **Bit-Fair maintenance**, plus overlay 5 cm AC at 7 IRI.

Bit-Excellent maintenance: similar to **Bit-Good maintenance**, overlay 5 cm AC at 5 IRI.

Unp-Poor maintenance: similar to **Routine only** (UP).

Unp-Fair maintenance: similar to **Unp-Poor maintenance**, plus grading twice a year and 15 cm regravelling at 15 year intervals.

Unp-Good maintenance: similar to **Unp-Fair maintenance**, 15 cm regravelling at 10 year intervals.

Unp-Excellent maintenance: similar to **Unp-Good maintenance**, grading four times a year and 15 cm regravelling at 7 year intervals.

Some other maintenance standards were specified in earlier phases of the study, but were removed from the final workspace.

Improvement standards

The characteristics of projects for CA-5 sections and for secondary roads were extracted from final reports and tables provided by MCA. The parameters are detailed in the HDM-4-input-data.xlsx Excel file.

For CA-5 section 3, the project was subdivided into two parts: one part of the section is improved but remains a 2 lane road, the other part is improved and widened to 3 lanes. For CA-5 section 4, the project was subdivided into three parts: one part of the section is improved but remains a 2 lane road, a second part is improved and widened to 3 lanes, and a third part is improved and widened to 4 lanes. The reports give the total length for each part, but do not provide the exact location of the different subsections. The breakdown between the different parts was made according to global length indicated in the reports. The physical characteristics of each part were derived from relevant data from sections 1 and 2, and from a personal evaluation from the site visit. The cost breakdown is not available in the reports. In HDM-4, it was made using global estimated coefficients. This is detailed in the HDM-4-input-data.xlsx Excel file.

Roughness after works was set to the HDM-4 default value, 2.0 IRI for AC pavements (CA-5 sections), and 2.8 IRI for surface treatment pavements (Secondary roads). This value is consistent with roughness measurements carried out on CA-5 section 3, but seems a little pessimistic on Secondary roads).

For CA-5 sections and Secondary roads, a 30% salvage value was assumed.

For Rural roads, the improvement works were described as improvements, though the main activity is a regravelling, which could be described in HDM-4 as a maintenance activity. There are two reasons for that:

- The average cost for those works is about 33000 US$ per km, to be compared to the cost of regravelling only, which is less than 10000 US$ per km. Regravelling is not the main activity for these works.
- Specifying the works as Improvement allows triggering a generated traffic, which is not possible if the works are specified as Maintenance works.

As the physical and financial characteristics of the works are different for all sections, it was necessary to specify as many Improvement standards as existing sections.

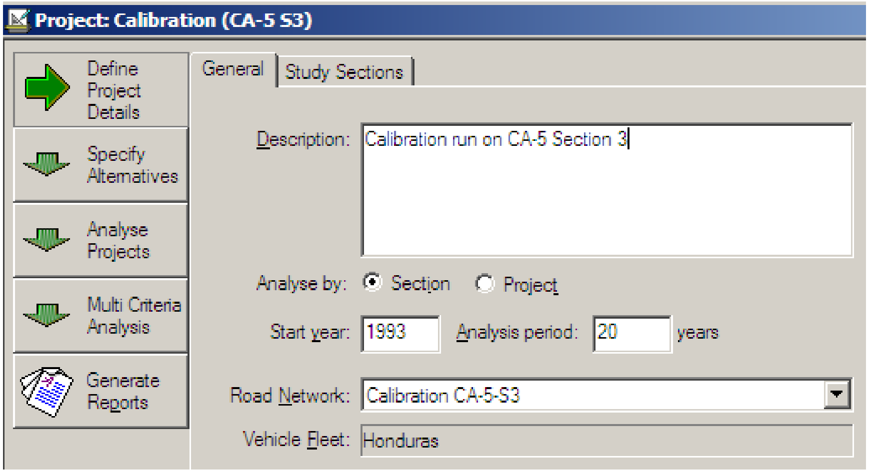
For all these improvements, a 0% salvage value was assumed.

This resulted in a total of 43 Improvement standards (as project improvement unit costs are different for each section, then each section needs its own specific standard).

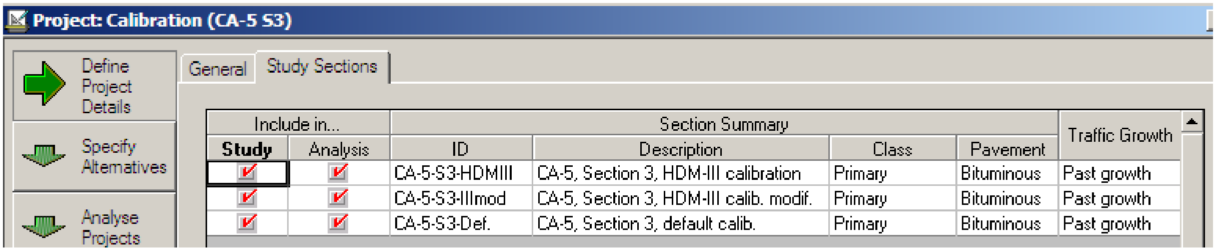
HDM-4 runs

All the runs were made using the Project Analysis function.

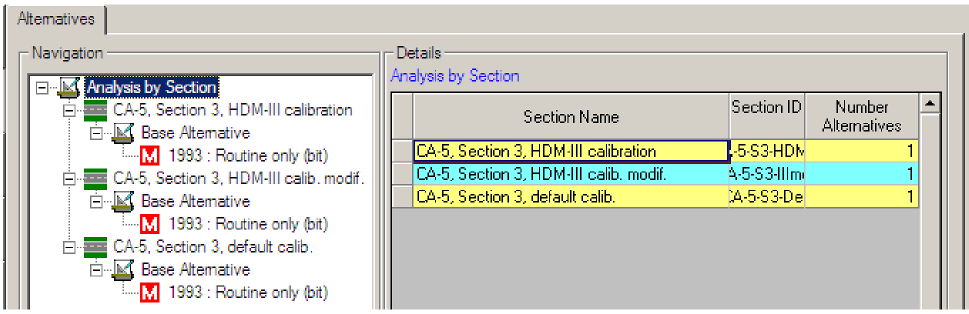
Calibration run



This run was carried out on CA-5 section 3, for which we had the only information on History. The Analysis period starts in 1993, just after the 1992 rehabilitation works.



The Road Network is made of three sections, identical except the Calibration item. All sections are assigned the past traffic growth.



The simulated maintenance policy is the Routine only (bit) maintenance standard, which includes pothole patching activities.

The reports showing cracking and roughness evolution are displayed above. They resulted in confirming that the calibration coefficients used in HDM-III runs were acceptable, but needed a slight adjustment.

CA-5 runs

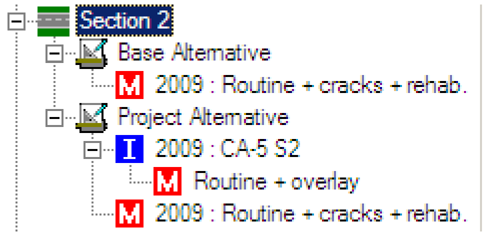
The timing of works on CA-5 and the way this was simulated into HDM-4 is as follows.

	Section 1	Section 2	Section 3	Section 4
Start date	21/06/2010	13/02/2009	16/09/2008	16/09/2008
End date	15/09/2012	20/12/2011	05/05/2010	14/07/2010
HDM-4 start	2011	2009	2009	2009
HDM-4 end	2012	2011	2010	2010
Duration	2	3	2	2

Two Project Analyses were made:

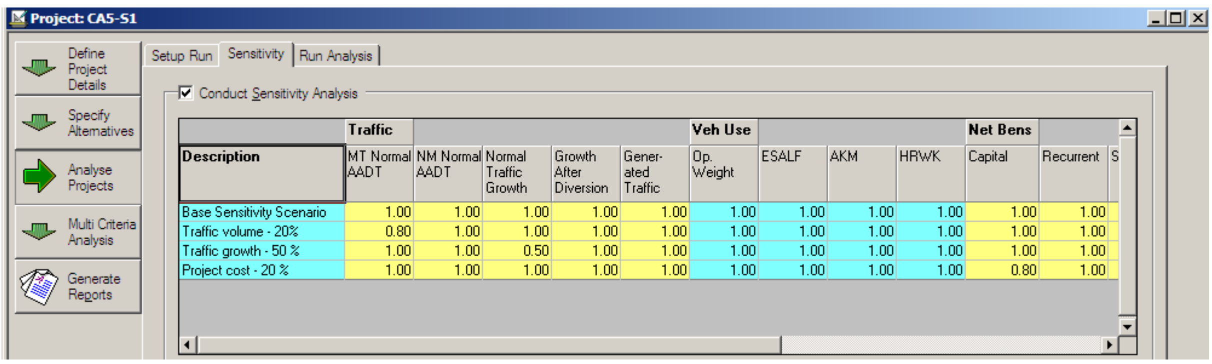
- CA-5-S1 project, including only Section 1, with a 20 year Analysis period starting in 2011, and
- CA-5 sections 2-3-4 project, including Sections 2, 3 and 4, with a 20 year Analysis period starting in 2009.

The two projects were run using the “By section” analysis option. The screen shot below displays the Options definition for section 2.



The options are similarly specified for other sections, assigning the appropriate Improvement standard. The Maintenance standard in the Base Alternative is always Routine + cracks + rehab, the Maintenance standard after improvement is Routine + overlay for sections 2 and 3, and Concrete for Section 4.

The relevant reports are stored in pdf files.

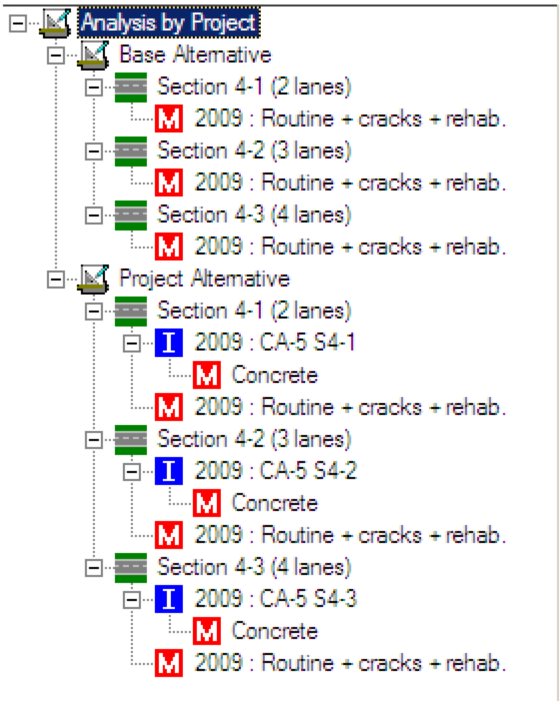


A sensitivity analysis was carried out, with three scenarios:

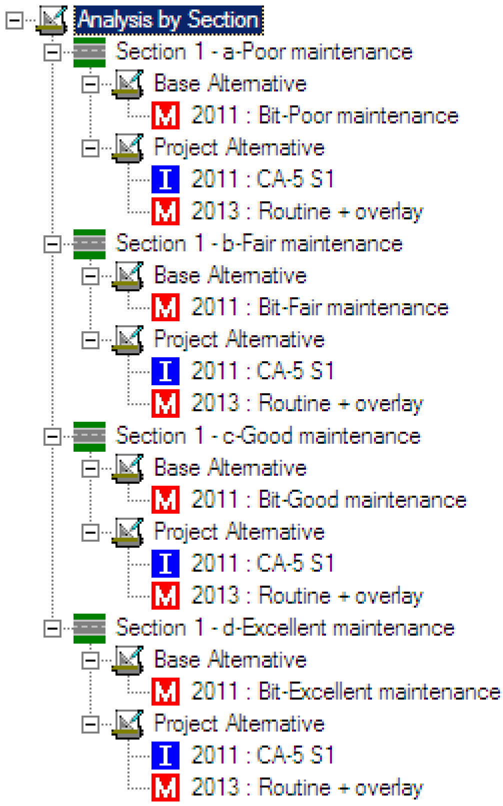
- Traffic volume lower by 20 %
- Traffic growth lower by 50 %
- Project cost lower by 20 %

The Economic Indicators Summary reports are stored in pdf files.

As the project cost breakdown for sections 3 and 4 was more or less questionable, two new Project Analyses runs were made, using the "By project" analysis option, namely CA-5 S3 – by project and CA-5 S4 – by project. The screen shot below displays the Options definition for section 4.



An additional Project Analysis was run to test the sensitivity of the results to the maintenance regime in the base option. Because of HDM-4 mechanic, this required to specify a new Road Network, allowing getting the results on a single report. This Project Analysis was run only on section 1.

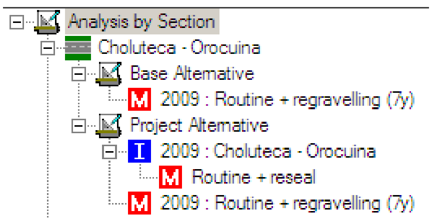


Secondary roads runs

The timing of works on Secondary roads and the way this was simulated into HDM-4 is as follows.

	Comayagua - La Paz	Sonaguera - km 35	Choluteca - Orocuina
Start date	16/09/2008	27/11/2008	23/02/2009
End date	25/08/2010	18/02/2010	15/09/2010
HDM-4 start	2009	2009	2009
HDM-4 end	2010	2010	2010
Duration	2	2	2

As the timing of works was the same for all three sections, one Project Analysis was enough, with a 20 year Analysis period starting in 2009. The project was run using the “By section” analysis option. The screen shot below displays the Options definition for Choluteca – Orocuina section.

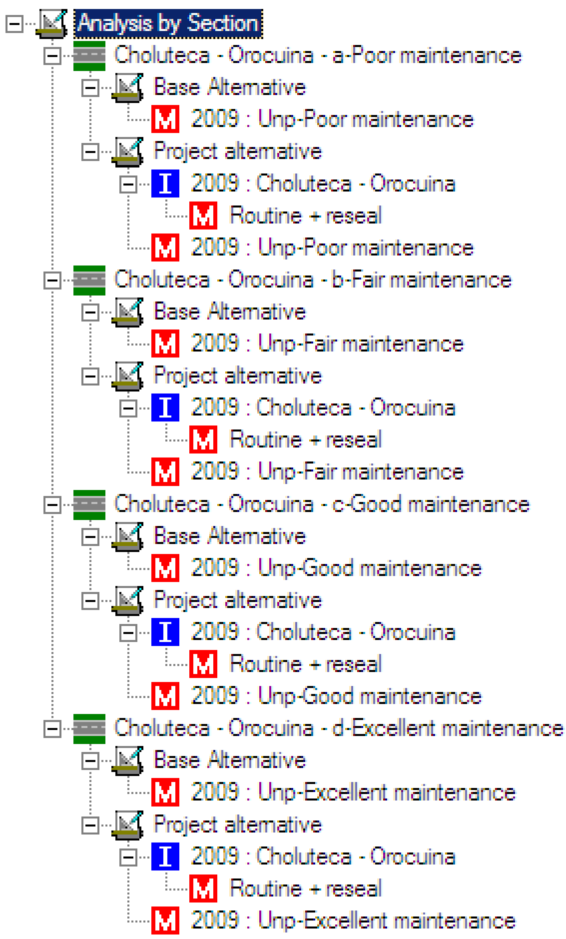


As for CA-5 sections, a sensitivity analysis was conducted, with the same scenarios.

The reports are stored in pdf files.

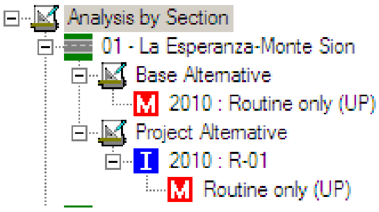
A new project Analysis with all sections was conducted, using the “By project” analysis option. However, as sections are very independent, the economic significance of the results is questionable.

An additional Project Analysis was run to test the sensitivity of the results to the maintenance regime in the base option. Because of HDM-4 mechanic, this required to specify a new Road Network, allowing getting the results on a single report. This Project Analysis was run only on Choluteca - Orocuina section, which is the one with the lowest IRR.



Rural roads runs

As the timing of works was the same for all sections, one Project Analysis was enough, with an Analysis period starting in 2010. The Analysis period was limited to 10 years. The project was run using the “By section” analysis option. The screen shot below displays the Options definition for section 1.



The reports are stored in pdf files.

Additional run for sensitivity to costs evaluation year

Two additional projects were run to evaluate the sensitivity of the results to a reevaluation of costs.

Vehicle Unit Costs are supposed to be evaluated in year 2008, and Works Unit Costs are evaluated in year 2011.

It was decided to convert Vehicle Unit Costs to year 2011. The reverse (converting Works Unit Costs to 2008 reference) was as well possible. This choice of course impacts Net Present Value, which is higher with higher Unit Costs. However it has no impact on ERR, which depends only on the relative annual streams, which are not affected whatever the currency unit is.

As all costs are evaluated in US$, the range of for the sensitivity analysis is from 1.0 to 1.2, as displayed in the screenshot below.

	Traffic					Veh Use				Net Bens					
Description	MT Normal AADT	NM Normal AADT	Normal Traffic Growth	Growth After Diversion	Gener-ated Traffic	Op. Weight	ESALF	AKM	HRWK	Capital	Recurrent	Special	MT VOC	MT Time	NM VC Time
Base Sensitivity Scenario	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
VOCs + 05 %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.05	1.05	
VOCs + 10 %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.10	1.10	
VOCs + 15 %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.15	1.15	
VOCs + 20 %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.20	

It must be noted that the sensitivity is NOT made on Unit Costs, but on VOCs Net Benefits. In other terms, annual costs streams are not changed, the changes are made only in the economic indicators calculations.

CA-5 raised a specific problem, because in the previous runs Section 1 and Section 2 to 4 were evaluated into two separate runs, as the starting year of the Analysis period is not the same. For this global run, all sections were grouped in a single run, starting in 2009. Hence, this introduces a bias in the Section 1 simulation, compared to the original run. This bias tends to minimize the benefits for this section, but is small compared to Unit costs impact.

Annex III: Considerations Regarding List of MCC Rural Road Improvement Sections

This Annex documents decisions made by NORC in consultation with MCC regarding the selection of the sample of Honduran rural road projects where HDM-4 ERR estimates were calculated.

Beginning in 2007, NORC designed and supervised 3 rounds of a traffic survey conducted in Honduras on all MCA project roads, with survey rounds collected in 2009, 2010 and 2011. For these surveys, NORC received a list of the MCC/MCA primary, secondary and rural project roads from MCA Honduras (as well as GIS data for those roads). In particular we were informed by MCA that they were improving 24 rural road segments. The complete list of the 24 MCA rural treatment roads that were sampled for the traffic survey rounds, with their corresponding "estacio ID" identifiers used in the survey are listed in the file "MCA_RuralRoadList_NORCTrafficSurveys.xls" provided in Annex IV.

However, in October of this year NORC met with Esther Aleman at MCA in Honduras and asked her for the final breakdowns for the road improvement project costs (used directly in the HDM ERR models). In response, Esther shared with us the excel sheet "Caminos Rurales al spe 2010 MCA_NORCmodified.xlsx", also provided in Annex IV, that provides project costs and other details for the MCA rural road improvements. Note that this list provided by Esther is considerably longer than 24 rural road segments: Esther's sheet lists 43 separate rural road improvements. In column G ("NORC Round 3 Traffic Estacio #"), we have listed the corresponding NORC traffic survey Round 3 Estacio #s that we were able to match to these segments, but of course 19 of them are not matched (since we only have 24 rural segments for the traffic survey).

Consequently NORC brought this issue to the attention of MCC in early November, 2011, and asked for clarification on exactly which rural project roads ERR estimates should be calculated. On November 17, 2011, Algerlynn Gill of MCC emailed NORC a revised list of 33 rural road segments for estimation of ERRs (the excel file list that Algerlynn sent is "Transport Project Summaries (Rural Roads).xlsx" and is provided in Annex IV). NORC informed MCC subsequently that we would calculate ERRs for that list of 33 rural segments, as per MCC's specifications.

NORC has calculated ERRs for all 33 of these rural segments specified by MCC (see Table 17). However, we would like to note several issues related to this sample:

- Of the list of 33 rural segments specified by MCC on November 17 2011, only 18 of them were included in the NORC traffic surveys;
- further, there are an additional 7 rural segments beyond MCC's list of 33 where NORC did conduct traffic surveys;
- of the 8 rural improvement "Lots", our NORC traffic surveys had none in Lot I-b, although several of MCC's list of 33 rural segments list are from I-b;
- our traffic survey covered 2 rural roads in Lot II-a, but MCC's list of 33 rural segments has none from that Lot;
- in data provided by Esther Aleman of MCA, all of Lot IV-b was listed as "Fracasado", but the NORC traffic survey included 2 segments from Lot IV-b.