

## ECONOMIC ANALYSIS

### A. Project Cost

1. Each project component is evaluated by comparing conditions over a 20-year evaluation period from the assumed year of opening for two cases: a reference case and a project case. The reference case represents future conditions in the absence of the project. Trunk road components are evaluated using the Highway Development and Management Model version 4 (HDM-4) and rural road components are evaluated using the Road Economic Decision Model (RED), while the evaluation of the crash reduction program used ChinaRAP<sup>1</sup> derived values.

2. Project costs and benefits are measured in 2014 economic prices expressed in domestic currency. Traded goods are measured at world prices. An aggregate conversion factor for trunk road works of 0.93 is derived from calculating the economic price of road construction factor inputs. For rural roads, which are expected to have higher labor content, a conversion factor of 0.90 is used. Unskilled labor has a shadow wage factor of 0.80 applied to reflect the low productivity of unskilled labor from poor areas.<sup>2</sup> Vehicle costs in the People’s Republic of China (PRC) are close to international prices, the only adjustment made is to deduct taxes. Fuel is costed at its import parity price.

3. Initial investment costs are spread over the 4 years 2016–2019 in the proportions 20:30:30:20. Resettlement costs were obtained from the resettlement plan prepared by the Shaanxi provincial government. Land acquisition costs represent the opportunity cost of lost agricultural production over the analysis period.<sup>3</sup>

4. Table 1 shows the economic implementation costs,<sup>4</sup> inclusive of standard conversion factors, for the project components by year, exclusive of maintenance costs.

**Table 1: Economic Implementation Costs by Component, 2016–2019**  
(CNY million)

Year	S102	G316	S224	Rural Roads	Total
2016	197.2	57.4	91.1	42.6	<b>388.3</b>
2017	295.8	86.1	136.7	63.9	<b>582.5</b>
2018	295.8	86.1	136.7	63.9	<b>582.5</b>
2019	197.2	57.4	91.1	42.6	<b>388.3</b>
<b>Total</b>	<b>986.0</b>	<b>287.0</b>	<b>455.6</b>	<b>213.0</b>	<b>1,941.6</b>

Source: Asian Development Bank estimates.

5. Maintenance values used for both the project and reference cases were derived from HDM-4 for overlay, reseal, pothole patching and drain clearing. The same values and criteria were used for all trunk road sections.

<sup>1</sup> The ChinaRAP (iRAP) economic analysis methodology uses road attribute risk factors, often called crash modification factors, to relate road attributes and crash rates. These are used to assess the likelihood that a crash will occur, and the severity of those that do occur, for both existing roads and for road designs. The economic analysis considers road safety countermeasure options, with benefits expressed in terms of the value of deaths and serious injuries prevented.

<sup>2</sup> A shadow wage rate factor implies a labor surplus; the factor 0.8 is commonly used on similar projects in the PRC.

<sup>3</sup> An estimate of lost agricultural production due to land acquisition is provided in the resettlement plan. The opportunity cost of lost production is estimated assuming 5% real annual growth in production (reflecting increasing productivity and conversion to crops of higher value). The stream of the projected value of lost production was discounted at 12%, adjusted by the standard conversion factor, and included as a first-year implementation cost.

<sup>4</sup> Excluding all costs associated with Output 4: Institutional Development.

6. The eight rural road upgrades are evaluated using the same general approach as that adopted for the trunk roads, except that RED is used in place of HDM-4, a model that is intended for roads in predominantly rural areas. Tables 2 and 3 show the economic investment and maintenance costs.

**Table 2: Rural Roads Investment Costs**  
(CNY million)

Road	Km <sup>a</sup>	Total Cost <sup>b</sup>	Financial Cost excluding LAR <sup>c</sup>	Economic Cost <sup>d</sup>	Economic Cost/km
1. X304 Shuhe–Xiaohe	38.40	87.60	79.80	75.40	1.96
2. C347 Lijiaba–Baiguo	7.88	6.22	6.06	6.40	0.81
3. Beiguo–Luoja	7.25	5.67	5.55	5.87	0.81
4. C852 Yangpo–Liangheguan	16.60	12.20	11.80	12.60	0.76
5. Y305 Yanba–Dongqiao	10.70	30.00	25.50	24.10	2.25
6. CH69 Zaobao–Yousheng	4.16	3.87	3.76	3.71	0.89
7. CH39 Zaobao–Wujiashin	9.34	8.25	8.01	7.92	0.85
8. Y338 Xianghe–Shuiguo	45.30	83.80	81.40	76.90	1.70
<b>Total</b>	<b>140.00</b>	<b>238.00</b>	<b>222.00</b>	<b>213.00</b>	<b>1.52</b>

km = kilometer, LAR = land acquisition and resettlement.

Notes: (a) project road length; (b) Design Institute figure including all contingencies, LAR etc.; (c) financial base cost; (d) economic cost = (financial cost excl. LAR x 0.9 + net LAR cost) plus 5% physical contingencies.

Source: Project preparatory technical assistance consultants.

**Table 3: Maintenance Costs of Rural Roads**  
(CNY million)

Pavement	Off-Carriageway	Carriageway	Total
Paved	2,000	200	<b>2,200</b>
Unpaved	2,000	28,000	<b>30,000</b>

Source: Asian Development Bank estimates.

7. The crash reduction program involves only safety improvements on 25 sections of additional rural roads (566 km in all). This program has an economic cost of CNY79.6 million.

## B. Project Benefits

8. Traffic growth estimates have been based on an analysis of projections from various sources, including the FSR, historic growth data, and provincial statistics. Giving more weight to historic traffic growth and the FSR estimates, a starting growth rate of 9% has been adopted for all roads. Based on the evidence from recent traffic and FSR calculations, it is assumed that passenger and goods traffic grow at the same rate. Table 4 indicates the adopted growth rates.

**Table 4: Traffic growth: summary of adopted rates**

Road		2014-17	2018-25	2026-36
All	Goods	9.0%	7.0%	4.5%
	Passenger	9.0%	7.0%	4.5%
	Motor-cycles	6.5%	4.5%	2.5%

Source: Consultants' estimates

9. Applying road user cost (RUC) elasticities of -0.3 and -0.2 for passenger and goods traffic implies annual generated traffic increase of 5% and 2%, respectively. The 'rule of half' has been applied to calculate benefits from generated traffic. For detailed information on travel demand forecast, including the projections for the rural roads, refer to the supplementary linked document titled *Travel Demand Analysis*.

10. The benefit streams of the roads upgrading comprise vehicle operating cost savings, travel time savings, and road safety benefits. Car passengers are assumed to value working journey-time savings at a rate of CNY50/hour, dropping to CNY30 for small buses, CNY20 for buses, and CNY10 for passengers in trucks and on motorcycles. Nonworking time is valued at 25% of working time (a conventional approach).<sup>5</sup> It is usually assumed that the value of journey-time savings rises in line with gross domestic product per person. HDM-4 does not accommodate increases in time values, therefore real changes in value of time are ignored.

11. Vehicle operating costs were calculated in HDM-4 by vehicle type on the basis of the economic costs (purchase, consumables, and maintenance) and typical vehicle characteristics. Goods in transit are unproductive—they represent inventory costs. Thus, there is a value in reducing travel times. A value of CNY0.2 per ton-hour is adopted as the value of time saved for a load of 1 ton (value CNY10,000) and allowing for increasing real unit values over time.<sup>6</sup>

12. Table 5 summarizes road user costs and journey time savings for each of the trunk roads applied in the evaluation, comparing the reference case with the project case. Upgrading the roads lead to improved driving conditions as expressed by a lower international roughness index. Similar calculations were made for the rural roads.

**Table 5: Trunk Road User Indicators**

Item	Road	Reference Case <sup>a</sup>			Project Case		
		IRI	Car	MGV	IRI	Car	MGV
VOC <sup>a</sup>	G316	6.00	2.53	4.55	4.50	2.33	3.90
CNY/veh-km	S102	5.40	2.47	4.53	3.60	2.21	3.81
	S224	5.70	2.51	5.75	4.10	2.33	4.33
VOT <sup>a</sup>	G316	6.00	2.50	0.12	4.50	1.95	0.10
CNY/veh-km	S102	5.40	2.45	0.12	3.60	1.94	0.09
	S224	5.70	2.69	0.13	4.10	2.37	0.10

IRI = international roughness index, MGV = medium goods vehicle, VOC = vehicle operating cost, VOT = value of time.

Note: (a) reference case is the situation before any road improvement.

Source: Project preparatory technical assistance consultants' HDM-4 runs.

13. The rural roads annual safety net benefit is estimated at CNY6.6 million. Table 6 shows ChinaRAP estimates of annual crash costs for the trunk roads in the reference and project case.

**Table 6: Fatality, Serious Injury, and Crash Cost Annuities**  
(CNY million)

Road	Reference Case	Project Case
S102	381.1	353.7
G316	230.9	170.8
S224 (A–D only)	76.4	42.9
S224 (E)	49.7	28.5

Note: Annuities are annual crash costs at 2014 prices assumed to persist throughout the evaluation period.

Source: ChinaRAP.

14. Table 7 shows net carbon dioxide emissions as calculated by HDM-4 for the trunk roads. Net impacts are significant for the S102 and S224, where there are substantial improvements in alignment and therefore reduced fuel consumption. However, these gains are offset by the emissions of generated traffic and the carbon embedded in construction, which is not included in the analysis. As the analysis is partial, the results are not included in project evaluation.

<sup>5</sup> Consultant's estimates based on provincial gross domestic product data.

<sup>6</sup> Consultant's estimate.

**Table 7: Trunk Road Carbon Dioxide Operational Emissions**

Road	Net Impact <sup>a</sup>				Reference Case	Project Case	Saving	Saving as % Reference	PV (CNY million)
	2017	2020	2030	2036					
S102	3,990	3,970	5,000	10,440	892,520	782,910	109,610	12	3.7
G316	1,960	1,970	2,240	3,700	457,570	415,200	42,370	9	1.6
S224	11,530	13,650	23,380	31,370	916,500	513,110	403,380	44	14.5

PV = present value.

Note: A positive net impact means a drop in emissions. Impacts do not include those embedded in construction.

Source: Consultants' HDM-4 output.

### C. Results of the Economic Cost–Benefit Analysis

15. Table 8 shows the evaluation results of the three trunk roads. Table 9 shows results by year for all the trunk roads, returning a combined economic internal rate of return of 21.1%.

**Table 8: Evaluation Results by Trunk Road**

(CNY million)

Trunk Road	PV Incremental Cost	PV of Benefits			NPV	EIRR (%)
		VOC Savings	Time Savings	Safety Benefits		
S102 Xunyang–Xiaohe	765	438	546	145	365	16.8
G316 Xunyang–Ankang	222	127	83	320	309	25.5
S224 Shangnan–Hubei	353	520	148	291	607	26.7

EIRR = economic internal rate of return, NPV = net present value, PV = present value, VOC = vehicle operating cost.

Sources: Consultants' HDM-4 runs and ChinaRAP.

**Table 9: Economic Evaluation of All Trunk Roads**

(CNY million)

Year	Incremental Cost	VOC Benefits	VOT Benefits	Safety Benefits	Net Benefits
2016	362.0	0.0	0.0	0	(362)
2017	458.0	0.9	0.0	0	(457)
2018	458.0	7.7	0.5	0	(450)
2019	380.0	16.5	1.4	0	(362)
2020	(41.5)	238.0	96.5	142	518
2021	(4.5)	192.0	102.0	142	441
2022	(25.2)	209.0	111.0	142	488
2023	(7.3)	159.9	116.0	142	424
2024	(0.1)	136.0	122.0	142	401
2025	5.3	147.0	132.0	142	416
2026	25.5	159.0	143.0	142	418
2027	(6.9)	171.0	154.0	142	475
2028	(1.7)	181.0	162.0	142	486
2029	(13.4)	189.0	170.0	142	515
2030	(1.2)	197.0	179.0	142	520
2031	5.4	202.0	188.0	142	527
2032	10.2	188.0	195.0	142	515
2033	(0.1)	219.0	209.0	142	570
2034	54.2	134.0	190.0	142	413
2035	1.5	312.0	234.0	142	687
2036	17.7	328.0	240.0	142	693
2037	(18.7)	417.0	266.0	142	845
2038	(12.1)	408.0	284.0	142	847
2039	(514.0)	405.0	305.0	142	1,367
NPV (at 12%)					1,282
<b>EIRR</b>					<b>21.1%</b>

( ) = negative, EIRR = economic internal rate of return, NPV = net present value, VOC = vehicle operating cost, VOT = value of time.

Source: Project preparatory technical assistance consultants.

16. The eight rural roads have been selected to provide access to communities with a relatively high poverty rate that could be linked to one of the three trunk roads. Selected roads are presently all earth tracks and will be concrete paved to provide all-weather access.

**Table 10: Rural Road Evaluations**

Road	AADT in 2016	Km	Economic Cost/km <sup>a</sup> (CNY million)	EIRR (%)	NPV (CNY million)
X304 Shuhe–Xiaohe	367	38.4	1.96	21.5	65.6
C347 Lijiaba–Baiguo	14	7.9	0.81	12.2	0.1
Beiguo–Luoja	91	7.3	0.81	20.8	4.3
C852 Yangpo–Liangheguan	44	16.6	0.76	18.1	6.2
Y305 Yanba–Dongqiao	129	10.7	2.25	9.7	-4.2
CH69 Zaobao–Yousheng	24	4.2	0.89	10.9	-0.3
CH39 Zaobao–Wujiashin	35	9.3	0.85	13.8	1.1
Y338 Xianghe–Shuiguo <sup>a</sup>	508	45.3	1.70	28.0	121.0
Totals/weighted averages	220	140.0	1.52	22.0	193.0

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

<sup>a</sup> Including safety package cost.

Source: Project preparatory technical assistance consultants' estimates.

17. Unlike the trunk and rural roads upgrades, the crash reduction program involves only site-specific safety improvements on a total of 566 km of rural roads. The evaluation is therefore taken from work by ChinaRAP, adjusted to ensure consistency with the evaluation period assumptions for the trunk and rural roads. Table 11 shows relevant costs, benefits, and economic internal rate of return of the program.

**Table 11: Crash Reduction Program Costs and Benefits**  
(CNY million)

Cost excluding Contingencies	Economic Cost	Annual Fatality, Injury, and Crash Costs		Net Present Value	EIRR (%)
		Reference Case	Project Case		
81.6	79.6	486.0	387.0	455.0	57

Sources: ChinaRAP and project preparatory technical assistance consultants.

## D. Summary and Conclusion

18. All trunk roads, the rural roads package, and the safety measures on additional roads provide positive economic returns. Sensitivity results for the whole project are shown in Table 12. The switching value for a cost overrun is 220%, and for a decrease in consumer benefits is 45%. The degree of uncertainty of the project's economic analysis is moderate. There is little risk to the project's viability. From an economic perspective, the project should be pursued.

**Table 12: Sensitivity Analysis**

Test	EIRR (%)	NPV (CNY million)	Switching Value (%)
Base case	23.3	1,930	
Costs +20%	20.3	1,620	220
Benefits -20%	19.7	1,230	45
Costs +20% and benefits -20%	17.0	916	

EIRR = economic internal rate of return, NPV = net present value.

Source: Project preparatory technical assistance consultants.