ECONOMIC ANALYSIS

1. The Yunnan Sustainable Road Maintenance (Sector) Project will finance the periodic maintenance or rehabilitation of about 1,000 kilometers (km) of highways in Yunnan Province in the People's Republic of China—892.0 km under the project's output 1 and 112.8 km under output 2. The economic analysis could consider only those subprojects that have already been identified for implementation during the first year of the project. The analysis compared the future reductions in vehicle operating costs and travel time costs expected from these subprojects with the initial investment costs.

A. Economic Analysis of First-Year Subprojects

2. The economic evaluation of the subprojects already identified covered 2013–2026. All benefits and costs are in constant 2012 prices. The economic prices were expressed using the world price numeraire.

3. **Investment costs.** The economic costs of the subprojects were derived from the financial costs at the preliminary design stage. They included the costs of initial periodic maintenance and rehabilitation, safety enhancements, routine maintenance, detailed design, construction supervision and management, and physical contingencies. Routine maintenance costs were derived from the 2011 works unit rates and applied to future needs as predicted by the Highway Development and Management Model (HDM-4). The economic costs exclude price contingencies, taxes, and interest during construction. The periodic maintenance and rehabilitation works have a design life of 8–12 years after which their deterioration rate rises. The same 12-year evaluation period was chosen for all subprojects.

4. **Traffic.** Traffic volumes were derived from the annual traffic survey of the Yunnan Highway Administration Bureau (YHAB) and 1-day traffic counts carried out during project preparation. Traffic volumes on the subproject roads range from 1,600 to 15,000 vehicles a day. The traffic counts were classified under eight vehicle categories. Table 1 shows the average vehicle fleet characteristics and economic unit costs, as well as typical composition of daily traffic. The Scientific Research Institute of the YHAB carried out a survey in 2012 to assess the unit values of vehicle fleet economic costs. Conservatively, traffic was assumed to grow at a uniform 3% annual increase rate. No generated traffic was considered.

Table 1: Vehicle Fleet Characteristics by Type

Economic Costs/ Traffic Composition	Car	Bus	Pickup	Light Truck	Medium Truck	Heavy Truck	Articulated Truck
Vehicle cost (CNY)	100,000	400,000	100,000	360,000	360,000	360,000	600,000
Tire cost (CNY)	500	2,000	1,400	1,400	2,000	2,000	2,000
Fuel cost (CNY/l)	6.3	6	6	6	6	6	6
Lubricant cost (CNY/l)	25	25	25	25	25	25	25
Labor cost (CNY/h)	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Crew cost (CNY/h)	9.12	10.68	7.8	11.16	12.96	16	16
Overhead (CNY/year)	5 800	128,900	28,400	27,200	66,800	104,200	106,200
Interest rate (%)	6	6	6	6	6	6	6
Value of time (CNY/h)	13.5	7.5					
Share of average daily traffic, based on 1,000–2,000 vehicles (%)	40.2	4.3	22.0	16.6	12.0	4.3	0.7

CNY = yuan, h = hour, l = liter.
Source: Asian Development Bank estimates.

5. **Project impacts on users.** Periodic maintenance and rehabilitation works make the surfaces of roads more even than they would be without it, which reduces the wear and tear of vehicles. In addition, vehicle speeds fall well below the road's design speed whenever the condition of a road's pavement approaches or falls into the very poor category. By restoring pavement to good condition and thereby allowing design speeds to be met, rehabilitation work generates time savings for users. The operating and time costs for the analysis were derived from the predicted road conditions, using the HDM-4 cost equations. The analysis estimated that the rehabilitation of a highway in very poor condition in Yunnan will reduce transport costs of goods by up to 27% and costs for users of cars and buses by up to 19%.

Table 2: Impact of Pavement Condition on Vehicle Operating Costs by Vehicle Type ($/km)

Pavement Condition	Car	Bus	Pickup	Light Truck	Medium Truck	Heavy Truck	Articulated Truck
Good (IRI = 2.0)	0.20	0.67	0.36	0.50	0.78	0.93	1.18
Fair (IRI = 5.0)	0.21	0.71	0.38	0.54	0.84	0.99	1.26
Poor (IRI = 7.5)	0.22	0.76	0.40	0.59	0.90	1.05	1.36
Very Poor (IRI = 12)	0.24	0.90	0.45	0.70	1.03	1.19	1.61

IRI = international roughness index, km = kilometer.
Source: Asian Development Bank estimates.

Table 3: Impact of Pavement Condition on Passenger Time Costs by Vehicle Type ($/km)

Pavement Condition	Car	Bus
Good (IRI = 2.0)	0.052	0.490
Fair (IRI = 5.0)	0.054	0.495
Poor (IRI = 7.5)	0.054	0.507
Very Poor (IRI = 12)	0.065	0.593

IRI = international roughness index, km = kilometer.
Source: Asian Development Bank estimates.

Table 4: Impact of Pavement Condition on Total Time Costs by Vehicle Type
(% Cost Reduction from Very Poor Condition Baseline)

Pavement Condition	Car	Bus	Pickup	Light Truck	Medium Truck	Heavy Truck	Articulated Truck
Good (IRI = 2.0)	19	22	18	28	24	22	27
Fair (IRI = 5.0)	15	19	15	22	19	17	21
Poor (IRI = 7.5)	12	15	10	15	13	12	15
Very Poor (IRI = 12)	0	0	0	0	0	0	0

IRI = international roughness index, km = kilometer.
Source: Asian Development Bank estimates.

6. **Project impacts on safety and the environment.** The precise impact of pavement rehabilitation on safety is uncertain. While it reduces the number of hazards, it also allows higher vehicle speeds. The subprojects were specifically designed to improve the safety of road users and nonmotorized traffic. About 10% of the costs are for safety features. Overall, the analysis assumed that this strong safety design will more than compensate for the negative safety impacts of higher speeds. Pavement rehabilitation also has a mixed effect on the emissions of greenhouse gases and local pollutants. Vehicle fuel use could rise or drop depending on the actual road speeds before and after the subproject work—motor fuel consumption reaches a minimum at 50–70 kilometers per hour. Still, since pavement roughness is directly linked to fuel use, road rehabilitation projects generally lead to a moderate reduction

in fuel-related pollutants. At less than 1% of the overall economic benefits, this was a very small factor when compared with vehicle operating costs and was not included in the analysis.

7. **Evaluation of benefits.** The subproject benefits have been calculated as the difference between transport costs in the with-project case and a without-project case. In the without-project case, it was assumed that the YHAB would conduct mainly routine maintenance works and patching. Major rehabilitation works were also assumed not to occur before 2018, when the pavement condition on the subproject roads would reach a minimum threshold.[1] Road deterioration was predicted based on pavement type, initial condition, maintenance works, and traffic loading. HDM-4 road degradation equations were calibrated to the YHAB's network, based on the actual degradation rates of a sample of the road network between 2002 and 2012. The predicted road conditions in the without- and with-project cases were then translated into transport costs. The analysis found that reductions in vehicle operating costs accounted for 75% of the benefits of the project and time savings accounted for the rest.

8. **Results of cost–benefit analysis.** The first-year subprojects showed excellent economic viability. The economic internal rate of return (EIRR) of these year subprojects was 20%–198%, producing a total net present value of $289.2 million and an overall EIRR of 109%. The net present value–cost ratio (NPV–C) was 5.6. Table 5 shows a breakdown of the results for each subproject.

9. Such rates of return are high, even for a road rehabilitation project.[2] The economic returns of maintenance projects are much higher than those for road construction, since maintaining a road costs less than building one. The EIRR is particularly high for these subprojects because the roads were selected for their very poor condition and high traffic. On some roads, benefits become higher than the initial costs of the investment after only 1 year. Still, a World Bank paper has stated that EIRRs can "overstate actual rates of returns because the EIRR calculation assumes that all the benefits are reinvested at the internally generated rate of return, yielding further benefits in the next period. If the benefits can only be reinvested at a lower rate, then the EIRR will overstate the true rate of return."[3] The paper said that a modified EIRR that gives an estimate of the "true" value of the returns can be calculated by assuming that benefits will be reinvested at the opportunity cost of capital. Using this approach, the modified EIRR of the subprojects at a 12% reinvestment rate is 34%.

10. **Risk and sensitivity.** The analysis found the economic viability of the subprojects to be very robust. The risk of less future traffic than projected is minimal because most of the traffic assumed already exists and growth assumptions were conservative. Cost risk was limited due to the standard nature of the works. The risk that the YHAB will not maintain the roads properly, while not negligible, would not impact the economic viability because (i) this would affect the with- and without-project cases similarly, and (ii) maintenance needs on the subproject roads will be limited during the 12-year evaluation period. Switching values established the robustness of the evaluation. For the project to yield a net present value of zero, initial investment costs would have to increase by 750% or traffic volume or benefits would have to be reduced by 92%. A combination of a 200% increase in investment cost and a 66% reduction in traffic volume would still yield an EIRR of 13.7%.

[1] The triggers used are an international roughness index rating of 8.5 for a class II highway, IRI 9.5 for a class III highway, and IRI 11 for a class IV highway.

[2] Typical rates of return of a rehabilitation project are more than 35%, but they can reach 200% in situations of high traffic and poor road condition.

[3] World Bank. 2005. When and How to Use the NPV, IRR and Modified IRR. *Transport Notes Series: Economic Evaluation Notes* (TRN-6). Washington, DC.

Table 5: Economic Analysis Results—First-Year Subprojects

Road Section	Length (km)	Baseline Condition (IRI)	Traffic (ADT)	Maintenance Solution	Cost ($ m)	NPV ($ m)	NPV/C	EIRR (%)	MIRR (%)
G108	65	6.1	15,000	Rehab and overlay	10.9	89.7	8.3	162%	37%
G213a	46	5.1	10,500	Rehab and overlay	6.0	51.8	8.6	141%	38%
G213b	15	6.2	11,000	Rehab and overlay	2.7	21.3	7.9	160%	37%
G320a	17	11.8	3,500	Rehab	2.8	16.9	6.0	142%	34%
S211	31	10	3,500	Rehab	4.9	42.2	8.7	198%	38%
X214	17	9	4,500	Rehab	2.7	16.9	6.3	141%	34%
S321	22	15	3,000	Rehab	5.3	14.1	2.6	77%	26%
G320b	28	3.5	8,200	Overlay and seal	2.4	7.6	3.2	49%	28%
G323	57	16.2	1,600	Rehab and overlay	6.4	25.4	4.0	55%	32%
S234	57	3.5	7,500	Overlay and seal	4.9	3.3	0.7	20%	17%
Total					**49.0**	**289.2**	**5.6**	**109%**	**34%**

ADT = Average Daily Traffic, EIRR = economic internal rate of return, IRI = international roughness index, km = kilometer, m = million, MIRR = modified internal rate of return, NPV = net present value, rehab = pavement rehabilitation.
Source: Asian Development Bank estimates.

B. Economic Evaluation of Sub-Projects Appraised after Board Approval

11. Under output 1 of the project, the Executing Agency will identify and appraise new subprojects covering periodic maintenance and rehabilitation of about 700 km of roads during project implementation. The YHAB will chose subprojects according to set technical, safeguards, and economic criteria.[4] The YHAB will evaluate the economic benefits using the same methodology and parameters applied to the first-year subprojects.

12. During project preparation, the Project Preparatory Technical Assistance consultant identified a long list of potential priority works covering about 3,000 km of road. The analysis finds these potential subprojects all to be highly economically viable, with NPV–C ratios of 5–40. The YHAB will update the list annually and propose subprojects with the highest returns to the Asian Development Bank for inclusion in the Yunnan Sustainable Road Maintenance Sector Project.

[4] Operational Manual (Supplementary Linked Document) details the process and criteria to be followed.