ECONOMIC ANALYSIS

A. Introduction

1. An economic analysis has been undertaken for the rehabilitation of the Ulaanbaatar–Darkhan and Darkhan–Altanbulag road sections. The works for the Ulaanbaatar–Darkhan section are estimated to cost $44.0 million (inclusive of physical contingencies), including (i) pavement treatment (asphalt concrete overlay) for 193 kilometers (km); (ii) widening to Mongolian class I-B standard (3.5 meter [m] x two-lane carriageway, 8.5 m pavement) within the current right-of-way for 193 km; (iii) climbing lanes at nine locations totaling 11.8 km; and (iv) safety improvement of road furniture and marking. The works for the Darkhan–Altanbulag section are estimated to cost $4.0 million, including (i) climbing lanes at six locations totaling 10.1 km and (ii) safety improvement of road furniture and marking.

2. This economic analysis considers the economic costs and benefits of the works using a standard evaluation approach, comparing the with- and without-project cases with an appraisal period of 20 years from the first year of operation and an economic opportunity cost of capital of 9% in accordance with Asian Development Bank (ADB) guidelines.[1] The base year for monetary values was updated to 2018.

B. Traffic

3. Traffic forecasts were based on an analysis of existing traffic and general traffic growth trends. Information on existing traffic by vehicle type was provided by the Ministry of Road and Transport Development (MRTD) for 2017 from seasonal counts at several locations along the project road. The data were converted to annual average daily traffic (AADT) and are shown in Table 1.

Table 1: Observed Traffic Volumes
(2017 AADT)

Item	Car	SUV	Minibus	Bus	Light Truck	Medium Truck	Heavy Truck	Total
Ulaanbaatar–Darkhan	3,444	861	206	113	484	184	154	**5,446**
Darkhan–Altanbulag	1,196	299	73	24	252	67	107	**2,018**

AADT = annual average daily traffic, SUV = sport utility vehicle.
Source: Ministry of Road and Transport Development.

4. Traffic was forecast for 20 years beyond the first year of operation of the works by applying factors based on forecast growth in gross domestic product (GDP) per capita and observed elasticities of demand. The forecast of GDP to 2022 was obtained from the International Monetary Fund database (Table 2).[2] Beyond 2022, constant growth of 4% per annum was assumed. Elasticity to GDP of 1.30 was assumed for passenger vehicles and 0.55 for freight vehicles. These are based on observed elasticities over the 10-year period (2006–2015) and are consistent with elasticities used in previous ADB road sector reports.[3]

[1] ADB. 2017. *Guidelines for the Economic Analysis of Projects*. Manila.
[2] International Monetary Fund. 2017. *World Economic Outlook*. Washington D.C.
[3] ADB. 2012. *Mongolia Road Sector Development to 2016*. Manila.

Table 2: Gross Domestic Product Forecast, 2017–2042

(% per annum)

2017	2018	2019	2020	2021	2022	2023	…	2042
(8.27)	1.06	7.45	5.30	5.90	8.46	4.00	…	4.00

( ) = negative, GDP = gross domestic product.
Source: International Monetary Fund. *World Economic Outlook*.

5. Vehicle occupancies and loadings were observed on recent traffic surveys in Mongolia. The average occupancy of cars (including sport utility vehicles [SUVs]) is 3.0, minibuses carry on average 3.0 passengers (plus driver), and buses 9.9 (plus driver). Trucks are 45% fully loaded, 7% partially loaded, and 8% empty.

Table 3: Forecast Traffic Volumes for Ulaanbaatar–Darkhan and Darkhan–Altanbulag

(AADT)

Item	Car	SUV	Minibus	Bus	Light Truck	Medium Truck	Heavy Truck	Total
Ulaanbaatar–Darkhan								
2020	3,864	966	231	127	509	193	162	6,052
2030	6,535	1,634	391	214	638	243	203	9,857
2040	10,313	2,578	617	338	776	295	247	15,164
Darkhan–Altanbulag								
2020	1,342	335	82	27	265	70	112	2,234
2030	2,269	567	139	46	332	88	141	3,582
2040	3,581	895	219	72	404	107	172	5,450

AADT = annual average daily traffic, SUV = sport utility vehicle.
Source: Asian Development Bank estimates.

C. Project Costs

6. The project costs comprise the costs of physical works (widening, rehabilitation, asphalt concrete overlay, surface dressing, and climbing lanes). Other costs include costs of construction supervision and design costs and physical contingencies. The physical works are assumed to be spread across a 6-year implementation period (2020–2025) for each subproject.

7. For the climbing lane sections, a residual value of the works is added as a negative cost in the final appraisal year, based on an estimated economic life of 30 years. Financial costs are converted to economic costs by (i) excluding taxes, price contingencies, and financial charges; (ii) using a 0.800 shadow price factor for low-skilled labor costs; and (iii) applying a shadow exchange rate factor of 1.028, calculated based on Mongolia's trade balance using the domestic price numeraire. The resulting factor of 0.897 is a weighted average composite of these elements.

8. Additional maintenance costs are assumed to be incurred in the with-project case compared with the without-project case in proportion to the increased pavement width, based on an estimated annual cost of $3,438/km for a 7 m pavement cross-section.

D. Project Benefits

9. The sources of economic benefits are savings in vehicle operating costs (VOCs), passenger value of time (VOT), and accident cost savings. It is assumed that the first section of physical works will be completed and operational in 2023.

10. **Vehicle operating cost savings.** The VOC savings were calculated by applying unit VOCs to the total vehicle-km on each section. VOCs vary according to the type of terrain, surface roughness, and type of vehicle. VOCs for different vehicle types and international roughness

index (IRI) were estimated using the VOC module of the industry standard Highway Development and Management Model (HDM-4). The resulting VOCs for a range of IRIs are shown in Table 4.

Table 4: Vehicle Operating Costs
($/kilometer, rolling terrain)

IRI	Medium Car	Four-Wheel Drive	Light Bus	Medium Bus	Light Truck	Medium Truck	Heavy Truck
Paved road							
2.0	0.25	0.66	0.24	0.32	0.24	0.43	0.71
8.0	0.29	0.87	0.28	0.39	0.28	0.52	0.86
12.0	0.33	1.09	0.33	0.46	0.34	0.61	1.00
18.0	0.40	1.34	0.43	0.57	0.44	0.76	1.25

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

11. **Value of time savings.** Unit values of time were derived from the most recent average gross monthly wage rate of the country of MNT960,000,[4] assuming 23% of trips were made for work purposes and an average of 3.0 passengers per car and 9.9 passengers per bus.[5] Following standard practice, trips made for work purposes were valued at the gross monthly wage rate plus employers' overheads (estimated at 50% of the gross wage), while other trips were valued at 30% of the net monthly wage rate. The resulting VOTs were calculated to be $3.71/vehicle-hour for cars and $12.25/vehicle-hour for buses. The unit VOTs were increased in line with forecast growth in GDP on an annual basis.

12. **Accident cost savings.** The value of benefits is based on the road safety assessment carried out by iRAP,[6] which assumes a cost of $222,451 per fatality and $55,613 per serious injury. Additional costs of $2,225 per slight injury and $445 per unit of material damage were derived from relationships to more serious accidents established by Ricardo-AEA[7] and DeJong.[8] Accident rates by category and standard of road were based on rates set out by DeJong, adjusted to the level of motorization in Mongolia. Accident rates for the improved road compared with the existing road were based on the assumption that a road with an IRI of 16 or more will have 40% more accidents than a road with an IRI of 2 or better (iRAP).[9] Roads with an IRI of 2–16 are assumed to have a proportionate change in accident rate.

13. The assumptions made relating to overall travel speed, surface roughness, and accident rates are summarized in Table 5.

[4] National Statistical Office.
[5] As observed in the origin–destination survey carried out for the project preparatory technical assistance.
[6] The iRAP road safety design methodology uses road attribute risk factors to assess the likelihood that a crash will occur, and the severity of those that do occur, for both existing roads and road designs. The methodology involves an economic analysis of road safety countermeasure options, with benefits expressed in terms of the value of deaths and serious injuries prevented.
[7] Ricardo-AEA. 2014. *Update of the Handbook on External Costs of Transport*. https://ec.europa.eu/transport/sites/transport/files/handbook_on_external_costs_of_transport_2014_0.pdf.
[8] DeJong et al. 2012. *Update of the Value of Safety Methodology*.
[9] iRAP. 2017. *Analysis of changes in the rate of severe crashes for typical road infrastructure investments*. https://www.irap.org/2018/01/analysis-of-changes-in-the-rate-of-severe-crashes-for-typical-road-infrastructure-investments/.

Table 5: Project Characteristics and Benefit Assumptions

Item	Scenario	Road Type	Speed (km/h)	Truck Speed (% of light vehicles)	IRI	Terrain Type	Accident Rate (per million vehicle-km)
Ulaanbaatar–Darkhan	Without project	Paved	70	80	6	Rolling	1.05
	With project	Paved	77	80	4	Rolling	1.01
Darkhan–Altanbulag	Without project	Paved	70	80	4	Rolling	1.05
	With project	Paved	77	80	4	Rolling	1.01

IRI = international roughness index, km/h = kilometers per hour.
Source: Asian Development Bank estimates.

E. Results of the Economic Cost–Benefit Analysis

14. The costs and benefits were assessed for the two sections and combined to produce an overall economic internal rate of return (EIRR) and net present value (NPV). The streams of costs and benefits for the two road sections are shown in Table 6. The indicators show that the overall combined project is highly economically viable.

Table 6: Economic Evaluation of Project Sections Combined ($ million)

	Maintenance			Benefits				Net	
Year	Capital	Costs	Total	VOC	Time	Accident	Total	Benefit	NPV
2019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2020	2.6	0.0	2.6	0.0	0.0	0.0	0.0	(2.6)	(2.2)
2021	5.2	0.0	5.2	0.0	0.0	0.0	0.0	(5.2)	(4.0)
2022	7.3	0.0	7.3	0.0	0.0	0.0	0.0	(7.3)	(5.2)
2023	9.5	0.1	9.5	12.7	3.1	3.6	19.4	9.9	6.4
2024	13.8	0.1	13.9	13.3	3.5	4.0	20.8	6.9	4.1
2025	9.0	0.2	9.2	14.0	3.8	4.4	22.2	13.0	7.1
2026	0.0	0.2	0.2	14.6	4.2	4.8	23.6	23.4	11.7
2027	0.0	0.2	0.2	15.3	4.5	5.2	25.0	24.8	11.4
2028	0.0	0.2	0.2	16.0	4.9	5.6	26.4	26.2	11.0
2029	0.0	0.2	0.2	16.6	5.2	6.0	27.8	27.6	10.7
2030	0.0	0.2	0.2	17.3	5.5	6.4	29.2	29.0	10.3
2031	0.0	0.2	0.2	18.2	6.3	7.2	31.7	31.4	10.3
2032	0.0	0.2	0.2	19.1	7.0	8.0	34.1	33.9	10.1
2033	0.0	0.2	0.2	20.0	7.8	8.8	36.6	36.4	10.0
2034	0.0	0.2	0.2	20.9	8.5	9.6	39.1	38.8	9.8
2035	0.0	0.2	0.2	21.9	9.3	10.4	41.6	41.3	9.5
2036	0.0	0.2	0.2	22.8	10.0	11.3	44.0	43.8	9.3
2037	0.0	0.2	0.2	23.7	10.7	12.1	46.5	46.3	9.0
2038	0.0	0.2	0.2	24.6	11.5	12.9	49.0	48.7	8.7
2039	0.0	0.2	0.2	25.5	12.2	13.7	51.4	51.2	8.4
2040	0.0	0.2	0.2	26.4	13.0	14.5	53.9	53.7	8.1
2041	0.0	0.2	0.2	27.4	13.7	14.5	55.6	55.3	7.6
2042	0.0	0.2	0.2	28.3	14.4	14.5	57.2	57.0	7.2
								NPV @9%	**176.37**
								EIRR	**60.7%**

( ) = negative, EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

15. The economic indicators were subjected to sensitivity analysis to test different scenarios of costs and benefits (Table 7). The EIRR remains well above 9% in all cases.

Table 7: Sensitivity Analysis

Scenarios	EIRR (%)	NPV[a] ($ million)
Base Case	**60.5**	**175.52**
Investment cost 20% higher	51.2	170.00
Benefits 20% lower	49.3	134.73
Investment cost 20% higher, benefits 20% lower	41.5	128.36

[a] Discount to 2017 prices at the discount rate of 9%.
EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

16. **Risk analysis**. A Monte Carlo risk analysis was carried out to assess the probability that the NPV of the project is greater than zero. An asymmetric triangular probability distribution was assumed for the investment cost while symmetric distributions are assumed for maintenance costs and total benefits (Table 8). The probability of a positive NPV is 96.5%.

Table 8: Probability Distribution Assumptions

(%)

Item	Investment	O&M	Benefits
Minimum value	90	90	70
Most likely value	100	100	100
Maximum value	130	130	130

Note: Based on 10,000 iterations.
O&M = operation and maintenance.
Source: Asian Development Bank estimates.