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Tacis

TRACECA - Project

Trade and Transport Sectors

Implementation of Pavement Management Systems

Feasibility Study for Rehabilitation of Transit Roads in Azerbaijan

Draft Final Feasibility Report Volume I

October 1997

KOCKS CONSULT GMBH
Consulting Engineers
Koblenz / Germany

in association with

TECNECON, Economic and Transport Consultants
London / U. K.

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UNITED KINGDOM

Ref.: 243/Rsc-ns/802

Koblenz, 30.10.1997

Dear Ms. O'Grady,

TRACECA Project: Implementation of Pavement Management Systems
Project Number: TELREG 9305
Feasibility Study for Rehabilitation of Transit Roads in Azerbaijan

We take pleasure in submitting to you the Draft Final Report (Volume I - III) for the above project for your review and comment.

According to the Terms of Reference the report is submitted in three copies. Complementary copies are forwarded to the European Commission (DG IA) in Brussels and the Tacis Co-ordinating Unit in Baku. By e-mail a copy was forwarded to the Tacis Monitoring & Evaluation Central Asia in Almaty and to the Monitoring Unit in Kiev.

The Russian version is presently under translation and will be submitted as soon as possible.

Yours faithfully

KOCKS CONSULT GMBH
Consulting Engineers

Ulrich Sprick

i.V. R. Schmidt

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Copies to: The EC, DG IA, Brussels (Attn. Mr. D. Stroobants)
Tacis CU in Baku

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COVER PAGE
FEASIBILITY STUDY FOR REHABILITATION OF TRANSIT ROADS IN AZERBAIJAN
(DRAFT FINAL REPORT, 10/97)

REPORT COVER PAGE

Project Title	:	Traceca Project - Implementation of Pavement Management Systems Addendum No. 1, Component 1, Module A: **Feasibility Study for Rehabilitation of Transit Roads in Azerbaijan**
Project Number	:	TELREG 9305
Country	:	Azerbaijan

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Date of report : 30.10.1997

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Author of report: Carsten Griese, Senior Highway Engineer (Kocks Consult GmbH)

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TACIS Bureau (Task Manager)	(name)	(signature)	(date)

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CONTENTS

1. INTRODUCTION

1.1 General

The study has been undertaken for the European Union - Tacis, Technical Assistance to the Southern Republics of the CIS and Georgia (TRACECA) by Kocks Consult GmbH, Germany in association with TecnEcon Limited, United Kingdom, PhØnix Pavement Consultants, Denmark and in co-operation with Azeravtoyol.

This study is part of the TRACECA Project Implementation of Pavement Management Systems, Project No. TELREG 9305. The contract between the European Commission and the Consultant for this component of the project (Addendum 1) was signed at the end of October 1996.

The work on the study commenced with the arrival of Mr. W. P. Weiler, Project Director and Mr. C. Griese, Senior Highway Engineer in Baku on 13 January 1997.

After the beginning of the project the Consultant has been informed by EC Tacis and the European Bank for Reconstruction and Development (EBRD) that the EBRD will take more active interest in the road section between Gazi Mammad and Kyurdamir. At the request of EBRD the study for this road section must conform to the standards for feasibility studies set by the EBRD.

The first 42 km from Alyat to Gazi Mammad have been the subject of detailed engineering work by M/s. Arab Consult funded by the Islamic Development Bank. This section is, however, included in the Terms of Reference for the study, and it was confirmed to be part of the study.

1.2 Project Objectives

The objective of the project was to prepare a feasibility study for the rehabilitation works on the road Alyat - Ganja - Georgian border. The feasibility will be used for negotiations between Azerbaijan and International Financing Institutions.

Principal study activities have been the identification of pavement repair and rehabilitation measures which is technically feasible on the existing alignment.

The scope of works required is defined in the Study Terms of Reference, a copy of which is to be found in Appendix 1.

1.3 Organisation of the Study

The study has been undertaken by Consultants of Kocks Consult GmbH, TecnEcon Ltd. and PhØnix Pavement Consultants who were assisted by Azeravtoyol staff. The Consultant's team comprised the following:

Mr. W. P. Weiler	Project Director	Kocks Consult GmbH
Mr. U. Willems	Project Co-ordinator	Kocks Consult GmbH
Mr. R. A. W. Smith	Transport Economist	TecnEcon
Mr. C. Griese	Senior Highway Engineer	Kocks Consult GmbH
Mr. R. Schmidt	Highway Engineer	Kocks Consult GmbH

Mr. S. Crudge	Traffic Engineer	TecnEcon
Mr. P. Poitzsch	Bridge Engineer	Kocks Consult GmbH
Mr. H. U. Zimmermann	Materials and Pavement Eng.	Kocks Consult GmbH
Mr. W. Pape	Geotechnical Engineer	Kocks Consult GmbH
Mr. O. Kruse	FWD Expert	Phønix

Fieldworks were based on a project office in the Scientific Research Centre (Institute) of the State Concern Azeravtoyol just outside Baku. Road and bridge condition surveys were undertaken by the Consultant's engineers together with the Azeravtoyol staff. The traffic surveys were planned by the traffic engineer and carried out by Azeravtoyol staff. The analysis of survey results was undertaken by the Consultant in close collaboration with Azeravtoyol.

Final analysis and report preparation was carried out in Kocks Consult's head office in Koblenz, Germany, in TecnEcon's head office in London, United Kingdom and in Phønix's head office in Vejen, Denmark.

1.4 Reporting

The requirements of the Terms of Reference were for the submission of inception report and a draft final report and final report upon receipt of comments from Tacis and the Government.

An inception report was submitted to Tacis at the end of March 1995 in which the proposed approach to carrying out the study and the project's plan of operations were defined.

The section from Gazi Mammad to Kyurdamir, in which the EBRD has a special interest, was analysed and described separately.

This draft final report comprises a full feasibility study. The report is produced in English and in Russian.

1.5 Acknowledgements

The assistance of Mr Yusif Novruzov, President of AZERAVTOYOL, Mr Shahin Hasanov, Vice President of AZERAVTOYOL , Mr M. Mirjavadov, Head of technical department of Azeravtoyol and all their staff are gratefully acknowledged.

Particular appreciation is given for the efforts of the executives and personnel of the Tacis.

Also, grateful acknowledgement is extend to Mr. Nizami Qaraisaev , Director of the Science Research Institute of AZERAVTOYOL, their continued co-operation made possible the successful completion of the Feasibility Study.

2. APPROACH AND METHODOLOGY

2.1 General

The economic analysis of the alternative road improvement options described in this chapter is based on the HDM III information collected during the investigation phase of the study.

The field survey included all investigations and field inspection required to undertake the studies and to prepare the data for the economic appraisal.

The approach adapted was to divide the study road into homogenous section and then to define road improvement/rehabilitation measures for each section.

Calculation of vehicle operating costs was carried out with the use of the World Bank's HDM III Vehicle Operating Cost submodel.

2.2 Assessment of the Characteristics, Condition and Utilisation of the Study Road

In a first step the Consultant collected existing data for the Road between Alyat and the Georgian border (M 4/M 1) available by Azeravtoyol. The next step was the updating and supplement by results of site surveys and investigations carried out by the Consultant and Azeravtoyol. Existing and new data were then analysed to arrive a preliminary assessment of road and culvert condition.

The following site investigations were undertaken:

- Detailed visual inspection
- Measuring of cross-sections, on average every 1 km
- Bearing capacity measurements by Falling Weight Deflectometer, on average every 500 m
- Drop penetration tests and drill soundings to determine the type, compactness and consistency of the soil
- Trial pits to determine the structure of pavement and embankment, to take samples for laboratory testing
- Asphalt mixture tests
- Bridge and culvert inspection

The fieldworks comprise the data collection for the computation of vehicle operating costs

- rise and Fall
- curvature
- road and shoulder width
- roughness

For an easy outline of the result from the roughness measurement, the roughness survey results were classified into roughness ranges based on the recommendation of TRL Road Note 5. the classification of the road roughness which was developed by the Consultant with the introduction of the Pavement Management System (PMS) is shown in the table below.

TRACECA - IMPLEMENTATION OF PAVEMENT MANAGEMENT SYSTEMS

ROAD ROUGHNESS (ROAD UNEVENNESS)
VALUES AND GUIDELINES OF PAVED ROADS

Description	IRI [m/km]	Road Condition Category	Road Condition Class
Ride comfortable at 100 km/h or above. Road unevenness barely perceptible at 80 km/h. No depressions, rutting, potholes, cracks or corrugations noticeable. Typical high quality asphalt concrete or high quality bituminous surface treatment.	4.0 <	very good	0
Ride comfortable up to 100 km/h. At 80 km/h moderately perceptible movements or large undulations may be felt. Very few defects of the road surface for class 1A: - occasional depressions or large undulations - moderate corrugations - moderate rutting - shallow potholes (e.g. 5-15mm/3m or 10-20mm/5m or 10-20mm/5m with frequency 1-2 per 50m) - good quality patches (e.g. 1-2 per 50m) and in addition for class 1B: - occasional longitudinal cracks - occasional transverse cracks NOTE: Road sections measured and/or classified in terms of roughness values as 'GOOD', but with severe rutting or pavement deformation should be downgraded to category 'FAIR'.	> 4.0 - 6.0	good	1A 1B
Ride comfortable up to 70 - 90 km/h, but with strongly perceptible movements and swaying. Usually associated with road surface defects for class 2A: - frequent moderate and uneven depressions - pronounced undulations - pronounced corrugations - pronounced rutting - occasional potholes (e.g. 15-20mm/3m or 20-40mm per 5m with frequency 5-3 per 50m) - poor quality patches (e.g. 1-3 per 50m) and in addition for class 2B: - many longitudinal and/or transverse cracks - alligator cracking NOTE: Road sections measured and/or classified in terms of roughness values as 'FAIR', but with severe rutting or pavement deformation should be downgraded to category 'POOR'.	> 6.0 - 8.5	fair	2A 2B

Description	IRI [m/km]	Road Condition Category	Road Condition Class
Ride quite comfortable up to 50 - 60 km/h, except the worst, not possible to avoid driving across the defects of the road resulting in frequent sharp movements or swaying. Severe defects in the road surface: - frequent deep and uneven depressions - severe undulations - severe corrugations - deep rutting - frequent potholes (e.g. >30mm/3m or >60mm/5m with frequency 4-6 per 50m) - very poor quality patches (e.g. 5-3 per 50m) - severe cracking	> 8.5 - 10.5	poor	3
Necessary to reduce speed to 50 km/h or below, higher speeds would cause extreme discomfort. Disintegration of the road surface associated with many deep depressions or potholes, extreme corrugations or rutting, bad quality patches.	> 10.5 - 12.0	bad	4
Severely disintegrated road pavement allowing a speed of 30 km/h or below, higher speeds would possibly cause damage to the vehicle: - destroyed / failed road pavement - destroyed / failed road pavement repaired e.g. by bad quality patching resulting in an extreme uneven road surface causing wheel bounce - unpaved (gravel or earth) road with high roughness progression.	> 12.0	very bad	5

Source: Consultants estimates based on TRL (Transport Research Laboratory, U.K.) Road Note 5 and on estimates of previous studies.

The results of site surveys were entered into straight line diagrams. The straight line diagram contains the following information

- road chainage
- width of carriageway and shoulders
- road roughness (IRI)
- surface condition
- existing and proposed pavement structure
- rise and fall

Appendix 6 shows the completed forms.

The study road was subdivided into homogenous sections in consideration of the following characteristics:

- road network
- traffic volume
- design standard (road geometry)
- surface type
- road condition
- environmental conditions

The selected road sections are further described below.

2.3 Analysis of Road Maintenance, Rehabilitation and Improvement Requirements

The engineering and economic feasibility analysis of alternative road improvement options was carried out using the World Bank's Highway Design and Maintenance Standards Model (HDM III). The economic analysis will take the form of a benefit-cost analysis which involves the comparison of the economic road user and engineering costs resulting from specified improvement alternatives (the "With Project" case) with the equivalent costs arising in a defined without project scenario ("the Without Situation"). The economic analysis involved discounted cash flow analysis based on the sue of economic costs and the results of the analysis expressed as a Net Present Value (NPV), Economic Internal Rate of Return (EIRR), Benefit Cost Ratio (B/C Ratio) and First Year Return (FYR), the latter being used as a guide to optimum timing of investments. The economic costs on which the economic analysis is based excluded taxes and duties and add back in any identified subsidy elements in prices.

For the purpose of the economic analysis the 444,135 km long study road from Alyat to the Georgian border was subdivided into 13 sections, based on the results of the traffic studies and condition surveys.

The sections were as follows:

Section 1:	M 4 Alyat - Gazi Mammad	(km 0+999 - km 43+450)	43.45 km long
Section 2:	M 4 By-pass Gazi Mammad	(km 43+450 - km 58+980)	15.53 km long

Section 3:	M 4 Gazi Mammad - Kyurdamir	(km 58+580 - km 124+300)	65.32 km long
Section 4:	M 4 Kyurdamir - Ujar	(km 124+300 - km 170+500)	46.20 km long
Section 5:	M 4 Ujar - Yevlakh	(km 170+500 - km 216+500)	46.00 km long
Section 6:	M 4 By-pass Yevlakh	(km 216+500 - km 223+468)	6.97 km long
Section 7:	M 1 Yevlakh - Mingechevir	(km 280+683 - km 288+700)	8.02 km long
Section 8:	M 1, Mingechevir - Ganja	(km 288+700 - km 333+500)	44.80 km long
Section 9:	M 1, By-pass Ganja	(km 333+500 - km 369+300)	36.00 km long
Section 10:	M 1, Ganja - Tovuz	(km 369+500 - km 431+000)	61.50 km long
Section 11:	M 1, Tovuz - Gazakh	(km 431+000 - km 456+500)	25.50 km long
Section 12:	M1, By-pass Gazakh	(km 456+500 - km 463+500)	7.00 km long
Section 13:	M 1, Gazakh - Georgian border	(km 463+500 - km 501+350)	37.85 km long

The section from Gazi Mammad to Kyurdamir (km 43+550 - km 124+300), in which the EBRD has a special interest, was analysed separately.

A sensitivity analysis was carried out in order to test the sensitivity of the results of the economic analysis to changes in certain of the most important input variables.

The main tests undertaken are listed below:

- Variation in base year traffic and traffic growth rates
- Variation in engineering costs
- Variation of the value of passenger time savings

2.4 Assessment of Bridge Conditions and Required Rehabilitation and Improvements

Bridge Data

The local partner institute Azeravtoyol made available existing documentation on all structures of the project road. These documents mainly included the description of bridge geometry and construction details. Description of previous rehabilitation and modernisation works was only incompletely documented and information on the condition of the individual structure was not available. During the field investigations of the Consultant's and Azeravtoyol's bridge specialists data were collected to complement the existing documentation.

Bridge Standard/Bridge Class

The Consultant reviewed the actual standards, standard documents and catalogues of bridge types being relevant for the structures in the course of the project road. In particular design loads and resulting classes of bearing capacity, the road cross section on bridges with the resulting traffic load as well as special constructive details of bridges were studied.

The bearing capacity is of special importance for the assessment of a structure and the determination of rehabilitation requirement. Details for the assessment of the bearing capacity were taken from the aforementioned documents on the bridges.

All structures are classified in classes of bridges according to the standards valid during the time of their construction. The standard used for the design of the existing bridges is the (former) Soviet Union Standard. For detail assessment of the bridges classes and their bearing capacity respectively a comparison with a western European standard was made. For this purpose the German standard DIN 1072 was used and the relevant data are summarised in the table below:

	Bending moments							
Span	Br.cl. 60/30 (DIN 1072) only main lane	Br. cl. 60/30 (DIN 1072) width of carriageway 7m	Br. cl. 30/30 (DIN 1072) only main lane	Br. cl. 30/30 (DIN 1072) width of carriageway 7m	CHNП 2.05.03-84 HK-80	CHNП 2.05.03-84 HГ-60	CH 200 - 62 H-30 (1 lane)	CH 200 - 62 H-30 (2 lanes) width of carriageway 7 m
5 m	612.0	846.4	306.0	504.4	520.0	375.0	265.2	530.4
10 m	1,623.0	2,279.1	891.0	1,487.1	1,520.0	1,125.0	636.6	1,273.1
15 m	2,690.0	3,841.0	1,442.4	2,592.9	2,520.0	1,875.0	1,041.9	2,083.8
20 m	3,794.0	5,524.2	2,129.7	3,850.2	3,520.0	2,625.0	1,454.9	2,909.7
25 m	4,952.0	7,318.0	2,882.3	5,247.8	4,520.0	3,375.0	1,878.5	3,757.0
30 m	6,125.0	9,210.0	3,688.8	6,774.3	5,520.0	4,125.0	2,316.5	4,633.0

The bending moments from the loads of the main lane of the bridge classes 60/30 and 30/30 of DIN 1072 as well as the bending moments from the loads of the bridge deck with a width of 7 m of the bridge classes 60/30 and 30/30 of DIN 1072 were analysed. The bending moments for the bridge class H-30 according to the Soviet standard 200 - 60 were also analysed for a lane and a bridge deck with a width of 7 m. Furthermore, the bending moments of the bridge classes HK-80 and HГ-60 corresponding to the standard CHNП 2.05.03-84 were analysed.

As mentioned above, the bridge classes used depend on the year of construction of the bridge, the combinations of the above-mentioned classes. Before 1962 bridges were designed for the bridge class H-13/HГ-60, after 1962 they were designed for the bridge class H-30/HK-80.

The bridges investigated along the project road have spans of up to 33 m. The moments of the design vehicles of the classes HK-80 or HГ-60 are determining factor for these spans.

A comparison of the results shows that the bridge classes H-13/HГ-60 corresponds nearly to the bridge class 30/30 according to DIN 1072. Structures which can be classified into this or a higher class of bearing capacity comply with present bridge requirements as far as the bearing capacity is concerned.

In summary the brief comparison of the two standards, the Soviet Union and the German standard, for bridge design and corresponding bridge classes which were developed by the Consultant with the introduction of the Bridge Management System (BMS) in 1996 showed that they are in most aspects very similar and adequate.

Condition Rating

The evaluation of the condition of the structures was based on of the following guidelines:

Description of Condition	Mark of Condition	Remedial Works
The structure has no or minor, hardly visible damages only. The deficiencies restrict neither separately, nor in summary the stability and/or the traffic safety and/or the durability of the structure. Examples for typical deficiencies: • dirty facing areas not allowing visual inspection • minor unevenness/rutting of wearing surfaces (carriageway, walkways etc.) • dirty deck joints (expansion joints), bearings and areas around the bearings, joints of steel structures and walkable interiors of structures • not planned vegetation at/on structure • minor alluviated material and/or scouring • dirty/unlegible traffic signs	1	Routine maintenance
The structure has clearly visible damages which do not yet affect the stability. Traffic safety is slightly affected. The existing condition of the structure does not fulfil long term requirements on durability. Examples for typical deficiencies: • minor damages on the bridge furniture and/or it's corrosion protection (railing, guard rails, marker posts, road lights etc.) • bridge furniture in operational condition, but not in accordance with actual standard requirements (out of date) • minor damages on the invert and slope stabilisation, slope stairs, bridge drainage, deck joints (expansion joints), joint sealings • minor damages on the corrosion protection of structural steel units • medium unevenness/rutting of wearing surfaces (carriageway, walkways etc.)	2	Routine and period maintenance and/or repair
The structure has significant damages, which in short term **may** result separately or in summary in a reduction of stability and/or of traffic safety requiring restriction of use (load restriction, one lane traffic by sign posts/barriers etc.). The existing damages are reducing the durability of the structure. Examples for typical deficiencies: • significant damages on railings and covering plates • significant damages on the wearing surfaces of carriageway and walkways • significant unevenness/rutting in the wearing surfaces • significant damages on the corrosion protection and the coating of structural steel units • erosion and corrosion on the superstructure and the substructure with starting reduction of the cross section area of load bearing components • damages on sealings, joint sealings, drainage of bridge and sealing, erosion/scour protection, hindered bearing movement, which may cause considerable other damages	3	Major repairs and/or rehabilitation

• corrosion with reduction of the cross section area of the reinforcement and load bearing steel components • damages, which are the result of partial failure under load (deformation, cracking, deformed structural elements) • railing, safety furniture, wearing surfaces and other units of the bridge furniture are damaged • cable housings are visible, cable housings without grouting, corroded tendons • longitudinal cracks parallel to tendons		
The structure has severe damages , which separately and/or in summary reduce the stability and/or restrict the traffic safety. The durability of the structure is considerably reduced. An immediate restriction of use (load restriction, one lane traffic by sign posts/barriers etc.) and/or an immediate removal of the dangers for the restoration of the traffic safety is required. Examples for typical deficiencies: • failure of tendons • significant damages on main load bearing components which are the result of partial failure under load (deformation, cracking in the area of coupling joints, significant cracks parallel to tendons, deformed fastener) • railing, safety furniture, wearing surfaces and other units of the bridge furniture have damages affecting their function considerably • structural units have damages, which cause an acute danger for the traffic (e.g. reduction of the clearance, parts of the structure which may fall on the road)	4	Rehabilitation or reconstruction

2.5 Economic Analysis

The economic analysis of the road rehabilitation and improvement projects has been carried out using the World Bank's HDM III model. The M4 and the relevant parts of the M1 road links, which are the subject of the study, have been divided into a number of sections for purposes of analysis and the alternative rehabilitation options for each section were then compared. For some sections, particularly those located in the delta of the River Kura, only reconstruction was considered to be a realistic option on engineering grounds. On the western half of the road in the hillier region approaching the Georgian border overlay and reconstruction options were evaluated.

The option of widening the existing road to 4 lane standard was also considered. The Gazi-Mammad - Kyurdamir section, which is of particular interest to the European Bank for Reconstruction and Development (EBRD), was used as a test case in the analysis of the widening option. If widening was economically justified on this section, it would be justified on most other sections because traffic levels are reasonably uniform along the whole road. The results of this analysis are discussed in full in Chapter 8.

The economic analysis of the defined road sections involves the comparison of potential economic costs resulting from the rehabilitation or improvement project and the potential costs arising in the absence of the project, usually called the "Do minimum" or "Without" situation. The cost streams associated with the specified project option or options are compared with those arising in the "Do Minimum"situation over the defined appraisal period of 1997-2021 in a discounted cash flow analysis undertaken within the HDM III model.

The costs being compared are road maintenance, rehabilitation and improvement costs and road user costs. The main economic benefits are in the form of vehicle operating cost and passenger time cost savings to normal traffic. Given the present standard and condition of the existing paved road, the potential for traffic generation as a result of the improvements is considered to be negligible and no generated traffic benefits have been included in the economic analyses. The potential for traffic diversion between the M4 and the M1 roads at the eastern end of the corridor was also examined., but the hilly nature of parts of the M1 between Yevlakh and Baku makes it unattractive to heavier vehicles and the small potential distance savings are negated by longer travel times for through traffic using the M1 route. The potential for future traffic diversion from the M1 to the M4 is insignificant because this diversion has already taken place in recent years. No traffic diversion to or from the study road has, therefore, been assumed and there are accordingly no traffic diversion benefits.

Accident cost savings have not been quantified in view of the absence of reliable accident statistics at the required level of detail. The estimation of accident benefits based largely on assumed accident reduction rates reflecting western European experience from widening projects does not appear to be particularly meaningful in the Azerbaijan context and has not, therefore been attempted. The absence of accident costs reflecting income levels in Azerbaijan is unlikely to have a significant impact on the economic feasibility of the mainly rehabilitation types of projects evaluated in this study.

The costs of delays to traffic during the implementation of road works has also not been quantified in this study because the information on which to base reliable estimates was not available. The effect of including these costs, if they could be quantified, would be to marginally reduce the benefits from the rehabilitation and improvement projects because the road works would be implemented at the beginning of the appraisal period when the effects of discounting the costs of traffic delays would at their weakest. Nevertheless, the consultants do not consider that the inclusion of such costs would have a large negative impact on the outcome of the economic analyses.

The results of the economic analyses for each improvement project or option are expressed in the form of a number of measures or indicators of the economic feasibility of the proposed investment. These include the project's Net Present Value (NPV) or total discounted benefits minus total discounted costs, NPV divided by initial costs (NPV/Cost) and the Internal Rate of Return (IRR). A discount rate of 15 percent has been used in the discounted cash flow analyses. This means that projects with a positive NPV at a 15 percent discount rate and an IRR of 15 percent or over are assumed to be economically feasible for immediate implementation. Where project fail to meet this threshold, the indication is that they are premature and should be reconsidered at a later date.

3. PHYSICAL, ECONOMIC AND TRANSPORT BACKGROUND

3.1 Road Influence Areas, Climate and Terrain

3.1.1 Introduction

The route under study consists of the M4 from Alyat to Yevlakh, and the western half of the M1 between Yevlakh and Red Bridge border post, a total distance of 444.1 km. The two roads meet 5 km to the west of Yevlakh to form a continuous east west route from the Black Sea coast to Georgia. The M4 follows the wide flood plain of the Kura river, Azerbaijan's largest single area of lowland, before crossing the river east of Yevlakh. West of Yevlakh the route of the M1 is along the southern side of the Kura valley, slowly climbing to the Georgian border. The entire route is gently graded, level between Alyat and Yevlakh, and then gradually becoming more undulating from Ganja westwards, although only at Aghstafa, within 50 km of the border, does the main Azerbaijan-Georgia railway line part company with the road. This indicates the easy terrain over which the road passes.

The M4/M1 route, in addition to acting as the main link between Azerbaijan and Georgia connects a series of cities, regions and their chief towns. These include Ganja, Mingechevir, which lies within 20 km of the road, and Ali Bairamly, the second, fourth and fifth largest cities of the country respectively. Although with the major exception of Tovuz these urban centres are effectively bypassed the road provides their main access to the national highway network.

3.1.2 M4: Alyat - Gazi Mammad

The M4 diverges from the M3 Baku to Astara road at Alyat, approximately 70 km south of the capital. It swings around the southern end of a ridge running parallel to the Caspian Sea coast, and across the wide valley of the highly braided Pirsaat River. Turning due west the road reaches Gazi Mammad. The Baku - Tbilisi railway runs directly parallel and immediately to the north of the course of the road throughout this section, 43.5 km long. Gazi Mammad is bypassed, the main road describing a semi-circle of 15.5 km to the south of the town. Ali Bairamly, Azerbaijan's fifth city, is connected to the bypass by a link road of less than 5 km. This is in effect the junction of two significant arteries; the study road linking Alyat and the Georgian border, and the main route to Ali Bairamly and south-west to Nagorno Karabag, southern Armenia and Nakhchivan. Most of the latter route west of Ordzonikidze has been closed to through-traffic for nearly ten years.

No climatic data has been obtained directly pertaining to this section of road, but information from the nearest meteorological stations, Apsheron on the Caspian Sea coast to the east, and Kyurdamir to the west is provided in Table 3.1 and it can be assumed that climatic conditions on the Alyat - Gazi Mammad section lie within the range presented by these two stations.

Table 3.1: M4: Alyat - Gazi Mammad: Climatic Summary Statistics of Region Served by Road

Station	Temperature			Rainfall
	Summer Average ^{0}C	Winter Average ^{0}C	Number of Days Below 0^0C	Annual mm
Apsheron	36.2	-4.3	22	290
Kyurdamir	42.2	-6.9	66	212

Source: Azeravtoyol

The figures show a very high temperature range, difficult weather conditions in winter, and low rainfall. The region can be defined as having a sub-tropical semi-arid climate.

3.1.3 M4: Gazi Mammad - Kyurdamir

From the western end of the Gazi Mammad bypass the M4 runs in a straight line north-westwards, the railway on its right and the main channel of the Kura river approximately 10 km to its left. A canalised tributary of the Kura approaches much closer to the M4. The terrain is flat, such that the alignment, horizontal and vertical, could not be easier. After Padar, the approximate half way point of the section, the road continues on its course and the distance to the Kura and its tributaries increases. The alignment of the road remains unaltered between Padar and Kyurdamir, the only noticeable change being an increase in the number of irrigation channels crossed.

Climatically, the section lies within the region whose meteorological statistics have been summarised under Kyurdamir station in Table 3.1.

3.1.4 M4: Kyurdamir - Yevlakh

The course of the road does not change beyond Kyurdamir, continuing in a straight line to the north west. The topography likewise remains unaltered. The major problem facing drivers is tedium. In fact, the terrain is gently rising but this is virtually imperceptible. Near Mususlu the road passes the northern edge of a substantial area of marshland, approximately one kilometre of road being constructed over it. Prior to reaching Urjar the M4 bears westwards, on either side of the town crossing tributaries of the Kura which have, in part, been canalised to assist drainage and irrigation. The road soon regains a north-western course and after crossing further tributaries and irrigation channels spans the Kura river itself to enter Yevlakh.

Climatic data for the five weather stations located close to this section of road are given in Table 3.2. The road passes through Agdas region between Urjar and Yevlakh, and just to the south of Goychay region east of Urjar.

Table 3.2: M 4 Kyurdamir - Yevlakh: Climatic Summary Statistics of Region Served by Road

Station	Temperature Summer Average ^{0}C	Winter Average ^{0}C	Number of Days Below 0^{0}C	Rainfall Annual mm
Agdas	39.7	-8.9	37	272
Goychay	38.9	-7.1	47	321
Yevlakh	40.7	-7.8	69	272
Kyurdamir	42.2	-6.9	66	212
Urjar	38.5	-8.2	43	245

Source: Azeravtoyol

There is little variation between these stations, all of which display a sub tropical semi arid climate. The temperature range, winter conditions and lack of rainfall are all extreme. The slightly higher rainfall in Goychay is a consequence of the escarpment in the north of the region, well away from the line of the M4.

3.1.5 M1: Yevlakh - Mingechevir Station

The M4 meets the M1 approximately 5 km to the west of Yevlakh. The M1 runs through the centre of Yevlakh whilst the M4 forms a southern bypass of the city. A bridge failure on the M4 close to the junction means that at present traffic is diverted to reach the M1 nearer to the city centre. The section to Mingechevir station, the junction for Mingechevir city, is straight, level and runs east west. This section lies on the southern side of the wide Kura river valley. Its climate is shown by Yevlakh station data in Table 3.2.

3.1.6 M1: Mingechevir Station - Ganja East

West of Mingechevir station the M1 continues on a straight alignment, rising slightly as it passes to the north of Geranboy. The road is now running along the southern side of the Kura valley, wide at this point but progressively narrowing westwards. West of Geranboy the road swings northwards to keep clear of the rising ground and crosses the Kyurakahay river and several of its tributaries.

Meteorological data is available for Geranboy region, and is given in Table 3.3.

Table 3.3: M4: Mingechevir station - Ganja: Climatic Summary Statistics of Region Served by Road

Station	Temperature Summer Average ^{0}C	Winter Average ^{0}C	Number of Days Below 0^{0}C	Rainfall Annual mm
Geranboy	39.2	-8.2	57	278

Source: Azeravtoyol

This shows very little difference to those regions to the east, detailed in Table 3.2. Rainfall slowly increases as the road moves up the valley but there is no significant effect on temperature.

3.1.7 M1: Ganja Bypass

The Ganja Bypass consists of a substantial loop southwards, to reach the valley of the Gancachay river which it crosses at its most southerly point, close to the town of Khanlar, before swinging northwards out of the valley to meet the western Ganja access road. The total length of the bypass is 36 km, compared to a distance through the city of less than 25 km. The bypass traverses rolling terrain, with greater undulations than sections to the east, and a pronounced drop into and rise from the Gancachay valley. Horizontal alignment is also poorer than east of Ganja.

Climatic data from the Khanlar station are given in Table 3.4.

Table 3.4: M1 Ganja Bypass: Climatic Summary Statistics of Region Served by Road

Station	Temperature Summer Average ^{0}C	 Winter Average ^{0}C	 Number of Days Below 0^{0}C	Rainfall Annual mm
Khanlar	27.2	-13.4	63	760

Source: Azeravatoyol

This shows a cooler, wetter climate than the meteorological stations to the east, which were quoted in Tables 3.1 to 3.3. The change is primarily a result of an increase in altitude. The bypass runs between the 550m and 650m contours, Khanlar town is at 700m and the most of the region higher still, climbing up to the Murovdag mountains in the south.

3.1.8 M1: Ganja Bypass - Tovuz

The M1 takes a north-westward course between Ganja and Tovuz , keeping on the south side of the Kura valley and crossing a series of tributaries, most notably the Shamkirchay and the Zayamchay, which descend from the mountains to the south. The alignment of the road is generally good, traversing flat to rolling terrain and with only occasional bends. Its route avoids major settlements, for example it passes between Shamkir and Delilar, both served by short access roads from the M1. The exception to this routing is Tovuz which is effectively bisected.

Climatic data from the nearest meteorological stations are given in Table 3.5.

Table 3.5: M1 Ganja - Tovuz: Climatic Summary Statistics of Region Served by Road

Station	Temperature Summer Average ^{0}C	 Winter Average ^{0}C	 Number of Days Below 0^{0}C	Rainfall Annual mm
Shamkir	37.1	-5.8	45	352
Tovuz	37.3	-8.5	74	643

Source: Azeravtoyol

Tovuz, at a higher altitude and further up the Kura valley, shows markedly higher rainfall and harsher winters than Shamkir. However, its climate retains considerable similarities to that of Yevlakh and regions to the east.

3.1.9 M1: Tovuz - Gazakh

From Tovuz the M1 continues north-westwards over gently undulating land on the western side of the Kura valley. The alignment of the road remains generally good. Aghstafa is bypassed to the west, the M1 turning sharply westwards to run parallel to the Agstev river for the short section to Gazakh. This change of direction takes the road away from the railway which heads north to cross the Kura river near the mouth of the Agstev. Gazakh is also bypassed, the road running along the southern and western limits of the town.

Climatic data from the relevant meteorological stations are given in Table 3.6.

Table 3.6: M1 Tovuz - Gazakh: Climatic Summary Statistics of Region Served by Road

Station	Temperature Summer Average ^{0}C	Winter Average ^{0}C	Number of Days Below 0^{0}C	Rainfall Annual mm
Gazakh	37.5	-10.2	81	361
Tovuz	37.3	-8.5	74	643

Source: Azeravtoyol

Gazakh, although effectively upstream of Tovuz, is little higher in altitude. The difference in rainfall can only be explained by the influence of local topography.

3.1.10 M1: Gazakh - Red Bridge border post (Georgia)

At Gazakh the M1 turns northwards, crossing the Agstev river as it leaves the town, and converges with the Kura river. The river valley narrows as the Georgian border is approached and the easiest alignment for the road is above and close to the river's southern bank which is followed as far as border. The border crossing is formed by a sixteenth century bridge over the river. There is a steady but not severe climb from Gazakh to the border while the horizontal alignment is good.

Climatic data for the meteorological station at Gazakh has been given in Table 3.6.

3.2 Road Influence Areas, Population and Economic Activity

3.2.1 M4: Alyat - Gazi Mammad

This section passes through two administrative areas, the Garadag subregion of Baku for its initial 7 km and Hajigabul region. Summary information relating to the demographic characteristics of these two areas is included in Table 3.7.

Table 3.7 M4 Alyat - Gazi Mammad: Demographic Summary of Regions Traversed

Region	Population (1996) Urban	Rural	Total	Density(/km)	Growth (95-6)
Garadag	91,700	0	91,700	50.8	-0.33%
Hajigabul	26,300	30,000	56,300	43.9	1.26%

Notes: Garadag is a sub region of Baku
Source: Azeravtoyol

Most of Garadag's population is located in small townships along the M3 between Baku and Alyat. The only settlement of note on the study road in Garadag is Alyat itself with a population of 11,800. Hajigabul, with the exception of Gazi Mammad, population 22,700, is almost entirely rural and agricultural. Gazi Mammad's industry includes the processing of agricultural products, quarrying and electronics. The city of Ali Bairamly, administratively independent of Hajigabul, lies less than 5 km to the south of Gazi Mammad bypass. It has a current population of 68,600, making it the fifth largest in Azerbaijan, having developed around the electricity generating industry.

3.2.2 M4: Gazi Mammad - Kyurdamir

This section of the M4 runs through two regions, Hajigabul, described in section 3.2.1, to the east, and Kyurdamir to the west. Table 3.8 provides a demographic summary of these two regions.

Table 3.8 M4 Gazi Mammad - Kyurdamir : Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Hajigabul	26,300	30,000	56,300	43.9	1.26%
Kyurdamir	16,100	71,200	87,300	53.5	1.63%

Source: Azeravtoyol

Hajigabul and Kyurdamir are similar regions, demographically and economically, each consisting primarily of agricultural land plus a single small city. Kyurdamir has a population of 16,100 compared to Gazi Mammad's 22,700. Kyurdamir region is the agriculturally more productive of the two because it lies entirely within the flood plain of the Kura river. Similar to Gazi Mammad, industry in Kyurdamir city comprises the processing of agricultural products and a small electronics plant.

3.2.3 M4: Kyurdamir - Yevlakh

This portion of the M4 enters five regions, from east to west, Kyurdamir, Urjar, Agdas, Yevlakh and Yevlakh city, the last named a separate entity administratively. The latest available demographic summary data for each of these regions is provided in Table 3.9.

Table 3.9 M4 Kyurdamir -Yevlakh: Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Agdas	25,800	56,900	82,700	n/a	1.47%
Yevlakh	6,600	46,500	53,100	34.1	1.14%
Yevlakh City	50,300	0	50,300	n/a	0.80%
Kyurdamir	16,100	71,200	87,300	53.5	1.63%
Urjar	15,700	53,200	68,900	80.8	1.03%

Note: n/a = not available
Source: Azeravtoyol

This section of the M4 crosses the upper flood plain of the Kura river, for the most part productive agricultural land reflected in substantial rural populations and a range of processing industries in the urban centres. Of these, Yevlakh city is much the most significant. Unlike Kyurdamir, Urjar and Agdas, the last named lying approximately 10 km to the north of the road, Yevlakh contains a significant element of non-agricultural based industry including heavy industrial plant. The relative decline of this sector of industry is indicated by the comparatively low recent population growth of Yevlakh city shown in Table 3.9. Yevlakh city's other great function is as a transport interchange, being not only at the junction of the M1 and M4, but also providing access to the industrial city of Mingechevir to the north and to Nagorno Karabag to the south. Yevlakh's significance as the great junction of central Azerbaijan applies equally to rail as to road transport. Much of this significance stems from its location at a major crossing point of the Kura river.

3.2.4 M1: Yevlakh - Mingechevir Station

This short section, 15 km, lies within the boundaries of Yevlakh region and city, both of which have been covered in section 3.2.3 and included in Table 3.9. Although the study road does not pass through Mingechevir city its size, 97,700 people, and proximity, within 20 km, make it a significant generator of traffic for both M1 and M4. Details of Mingechevir have, therefore, been included in Table 3.10.

Table 3.10 M1 Yevlakh-Mingechevir station: Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Yevlakh	6,600	46,500	53,100	34.1	1.14%
Yevlakh City	50,300	0	50,300	n/a	0.80%
Mingechevir City	97,700	0	97,700	763.3	0.51%

Note: n/a = not available
Source: Azeravtoyol

Mingechevir is the fourth largest city in Azerbaijan, its development based upon the generation of hydro electric power at the outflow of the Kura river from the Mingechevir reservoir, the country's largest body of inland water. The reservoir was formed by damming the Kura at Mingechevir and flooding a large portion of its upper valley. The city has subsequently developed considerable medium to heavy industry, including the production of glass, concrete, industrial cables and road machinery. It also produces electronics and has a wide range of processing plants, including fish, milk and alcohol. Mingechevir, given its waterside location, is also noted for sports and recreation.

3.2.5 M1: Mingechevir Station - Ganja East

The initial, fleeting, part of this section lies within Yevlakh region but this has already been covered, see section 3.2.3. The remainder lies within Geranboy region, the eastern junction of the bypass being located on the boundary with Khanlar region. The demographic details of Geranboy are summarised in Table 3.11.

Table 3.11 M1 Mingechevir Station - Ganja East: Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Geranboy	26,100	72,500	98,600	55.1	1.34
Naftalan	8,800	0	8,800	n/a	0.0

Source: Azeravtoyol

Geranboy is a predominantly rural region containing a number of small urban settlements lying close to the road/rail corridor. Of these, the largest are Geranboy itself, of 5,900 people, and the independently administered Naftalan, designated a city although only of 8,800 population. Naftalan is a research centre established under the Soviet regime although, as shown by the lack of population growth, now stagnant.

3.2.6 M1: Ganja Bypass

The Ganja Bypass describes a wide loop to the south of the city, such that only the southernmost section actually lies within the boundaries of Ganja city. The remainder, with the exception of the east and west junctions, lies within Khanlar region. Demographic details of Ganja city and Khanlar region are given in Table 3.12.

Table 3.12 M1 Ganja Bypass: Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Ganja City	293,500	0	293,500	2,743.0	0.34
Khanlar	19,300	32,100	51,400	43.4	1.18

source: Azeravtoyol

Ganja is the country's second largest city and the major industrial centre of central and western Azerbaijan. It possesses a wide range of industrial plants, including mechanical engineering, textiles, ceramics, metallurgy, electronics, brewing plus agricultural processing. As such, it has far outstripped both Yevlakh and Mingechevir although population growth has slowed of recent years, mainly through significant out migration. This itself has been a response to the decline of older industries, land pressures and political uncertainty.

Khanlar city, just to the south of the bypass, has developed as a satellite industrial centre to Ganja and currently has a population of 16,300. Annual growth is comparatively high. Its hinterland is almost entirely rural, consisting of rolling and hilly terrain suitable for pasture and viticulture.

3.2.7 M1: Ganja Bypass - Tovuz

This section of the M1 passes through two regions, Shamkir and Tovuz. Table 3.13 provides a demographic summary of these two regions.

Table 3.13 M1 Ganja Bypass - Tovuz: Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Shamkir	55,300	112,900	168,200	101.3	0.90
Tovuz	25,300	113,800	139,100	73.1	0.94

Source: Azeravtoyol

Of the two regions, Shamkir is the more developed, containing a number of urban settlements, all of which are located on the lowlands between the M1 corridor and the Kura river. Shamkir itself has a population of 29,900 and a significant number of industries, many of which relate to the processing of agricultural products. It also has a quarry and building materials processing.

Tovuz region is both larger and more rural, with a smaller main city, 13,600 in population although neighbouring Govlar contains 11,700 people. Industry in Tovuz consists either of light industry or the processing of agricultural produce. The production of wine and spirits is common to both Shamkir and Tovuz regions.

3.2.8 M1: Tovuz - Gazakh

This section of the M1 passes through three regions, Tovuz, Aghstafa and Gazakh. Table 3.14 provides a demographic summary of these regions.

Table 3.14 M1 Tovuz - Gazakh: Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Aghstafa	13,400	56,800	70,200	46.7	1.30
Gazakh	20,100	59,800	79,900	114.3	0.88
Tovuz	25,300	113,800	139,100	73.1	0.94

Source: Azeravtoyol

Tovuz, which contains no more than 10 km of this section, has been described in 3.2.7. Most of this section of road lies within Aghstafa region; Gazakh contains only the westernmost end and is described in detail in section 3.2.9.

Aghstafa region is divided into two distinct parts by the Kura river, the northern part being isolated and almost devoid of settlements. The M1 passes through the southern part which contains the regions' modest urban population, most of which, 10,900 people, live in the principal town. This has limited industrial development, primarily agriculturally based. Aghstafa is also a railway junction, the branch to Gazakh, the Armenian border and eventually Yerevan diverging from the main line to Georgia and Tbilisi. Aghstafa's function as a railway junction has been severely diminished during the 1990s as a result of the closure of the border with Armenia.

3.2.9 M1: Gazakh - Red Bridge border post (Georgia)

This section passes exclusively through the region of Gazakh, demographic details of which are given in Table 3.15.

Table 3.15 M1 Gazakh - Red Bridge: Demographic Summary of Regions Traversed

	Population (1996)				
Region	Urban	Rural	Total	Density(/km)	Growth (95-6)
Gazakh	20,100	59,800	79,900	114.3	0.88

source: Azeravtoyol

Gazakh itself is the only urban centre in the region, combining mining, quarrying and related industry with the processing of agricultural products. In common with most of the other regional capitals it has traditionally acted as a processing and service centre for the hinterland of the region, which in Gazakh included a number of mining settlements in the valleys close to the Armenian border. Rail branches link the mines to Gazakh city.

3.3 Functional Importance of the Study Road

3.3.1 Introduction

The M4 and M1 together form the primary east-west route across Azerbaijan and the country's main connection with Georgia, the Black Sea and countries further west. The continuing political problems between Azerbaijan and Armenia have reinforced the significance of this route. It is also now the preferred access to Azerbaijan for much of its burgeoning trade with Turkey, the region's most dynamic economy and a traditional ally.

In addition to its international role, the M4/M1 route is Azerbaijan's most significant internal road artery. It connects eastern Azerbaijan, and in particular the capital Baku, with the central and western parts of the country, most notably Ganja, Mingechevir and Ali Bairamly, respectively Azerbaijan's second, fourth and fifth largest population centres. The route, 444 km in length, passes through fourteen administrative authorities with a total 1996 population of 1,391,200, 18.6% of the national total. This total is divided equally between urban and rural population. Including other administrative areas served by, but not directly on the line of the route, almost doubles the population served, to 2,604,100, 34.8% of the national total. It can therefore be seen that the route has a substantial catchment area and performs a vital access function for much of Azerbaijan.

3.3.2 M4: Alyat - Yevlakh

The easternmost half of the route links Baku and the Caspian Sea coast with central Azerbaijan, focused on the city of Yevlakh, the hub of the national transport network. This half of the route is the more sparsely populated and its function is primarily one of long distance haulage. The M4 has superseded the eastern half of the M1 as the primary link between Baku and Yevlakh westwards because of its superior alignment and consequently higher travel speeds. It is approximately 10 km longer than the M1 but 5-10 kph faster throughout for light vehicles and probably more for heavy vehicles given the severe gradients on the Agshu - Shamakhy section of the M1. Currently, there is little indication of heavy goods traffic using the M1 between Baku and Yevlakh.

In addition to Baku traffic, the M4 is also accessed by traffic between the west and Iran. These use the junctions at Kyurdamir, Padar and on the Gazi Mammad bypass, to access the M3 to the south of Alyat. Study traffic surveys indicate that the route via Gazi Mammad is probably the most attractive at present. This junction also serves Ali Bairamly, the largest intermediate urban area served by the M4.

The route is flat throughout and, with the exception of Gazi Mammad bypass, virtually straight.

3.3.3 M1: Yevlakh - Red Bridge Border Post (Georgia)

The M4 and M1 meet at Yevlakh and westwards they form a single route to the Georgian border at Red Bridge. There are no directly competing routes. This half of the route serves a greater density of population, notably Azerbaijan's second largest Ganja, a major industrial centre and local traffic generator. It is noticeable that the Ganja bypass carries noticeably lower traffic volumes, as revealed by study surveys, than either of the adjacent sections. Traffic to and from Ganja comprises 25% or more of total traffic. Shamkir and Tovuz, the two regions to the west of Ganja are also well populated although predominantly rural. However, it is reasonable to assume that local and regional traffic remains significant as far west as Gazakh , the last major settlement before reaching the Georgian border. Although most of the regional centres are bypassed by the M1, it is their primary, if not only, link to the rest of Azerbaijan. Each centre acts as a focus for regional roads feeding into the M1. Because of the barrier presented by the Kura river and the Mingechevir and Shamkir reservoirs to the north the major feeder roads are oriented southwards.

Traffic between central and northern Armenia and Azerbaijan, which traditionally joined the road at Gazakh, has obviously disappeared since the outbreak of hostilities in the late 1980s, but it was significant during the Soviet era.

Alignments and gradients are easy but generally inferior to those on the M4.

3.4 Transport Background

The functional importance of the study raod as part of the east west international transport corridor through the Caucasus region has already been mentioned. It provides one of a limited number of routes between Europe and Turkey to the west and Azerbaijan and the countries of central Asia via the Caspian Sea crossing. The political problems in the north caucasus region have limited access from Baku and the south to Russia via the traditional transport route along the west coast of Caspian Sea and this has added to the importance of the study road as an international land transport artery.

The transport corridor served by the study road is also served by a railway runnijng parallel to the road from Alyat in the east to the Georgian border inthe west. The railway continues to run parallel to the main east-west trans-Caucasus road through Georgia to the Black Sea coast ports of Ponti and Batumi. The railway is now carrying much less freight traffic than during the Soviet era. The main rail movements are Azerbaijan oil exports to the west, but this will presumably transfer to pipeline when the present pipeline project crossing trans- caucasiais completed.

The expected rapid growth of the Azerbaijan economy resulting from the exploitation of ist oil resources will result in the rapid growth of east-west freight movements in the transport corridor of which the study roads form a part. The major bulk movements of oil to the west will be by pipeline, but there will also be a rapid growth in non-bulk movements generated by rising incomes in Azerbaijan. The TRACECA Regional Database and Forcasting Model project´s work suggests that rail will continue to lose traffic to road in the corridor as the value of commodities being transported rises and the need for security during transport increases.

4. UTILISATION OF THE STUDY ROADS

4.1 General

The regular collection of traffic data in Azerbaijan was disrupted during the first half of the 1990s and routine classified volume counts did not start again until 1995. The coverage of the 1995 surveys was less extensive than the routine surveys undertaken during the late 1980s, even when allowance is made for the inaccessibility of a significant proportion of the road network in the occupied parts of the country. The less than complete coverage of the main road network by routine traffic counts is primarily a consequence of shortages in funding. The result of all this is that the available classified count data for the Alyat - Georgian border road corridor was not adequate as a basis for engineering and economic feasibility studies. In order to have an accurate basis for establishing 1997 traffic levels by vehicle type on the various road links in the corridor it was necessary to carry out detailed classified volume counts at selected locations. The following sections describe the surveys undertaken, the results obtained and the process by which these results were adjusted to obtain estimates of annual average traffic in 1997. All traffic surveys were undertaken by Azeravtoyol staff following the Consultants' recommendations and detailed plans.

It should be noted that the Consultants also requested separate surveys of road passengers based on roadside interviewing to provide additional information for the estimation of passenger time costs, but resource limitations and adverse weather conditions precluded these roadside interview surveys being undertaken.

4.2 Traffic Surveys Undertaken on the Study Roads

4.2.1 Scope of Surveys

The road corridor between Alyat and the Georgian border forms the main east-west highway in Azerbaijan and in length it makes up just over half of the road route between the Caspian Sea and the Black Sea. Within Azerbaijan the road comprises the following main sections:

- Alyat - Yevlakh - Ganja - Red Bridge border post (Georgia)

This route links the Caspian Sea coast south of Baku with the Georgian border and consists, in almost equal lengths, of the M4, to the east, and the western half of the M1. For the purposes of the economic analysis of improvement options, the route was provisionally divided into links, each having homogeneous traffic characteristics throughout its length. The initial subdivision was carried out on the basis of the available 1995 traffic data which was used in the TRACECA Pavement Management System and Highway Financing Study of 1996. The number of traffic survey locations originally specified by the Consultants was reduced somewhat to keep survey requirements compatible with Azeravtoyol's available manpower resources.

The road links studied are set out in Table 4.1 below:

Table 4.1. Road Links for Analysis

Road No.	Section From	To	Link No.	Link Length (km)
M4	Alyat	Gazi - Mammad	1	43.4
M4	Gazi Mammad	Kyurdamir	2	80.8
M4	Kyurdamir	Yevlakh	3	92.2
M4	Yevlakh	Mingechevir station	4	15.0
M1	Mingechevir station	Ganja bypass (e)	5	44.8
M1	Ganja bypass (e)	Ganja bypass (w)	6	36.0
M1	Ganja bypass (w)	Tovuz	7	61.5
M1	Tovuz	Gazakh	8	32.5
M1	Gazakh	Red Bridge (bp)	9	37.9
			Total	444.1

Source: Consultants
Note: (e) east. (w) west (bp) border post

The location and duration of the classified volume counts were decided upon after initial discussions with Azeravtoyol. The principle behind the choice of traffic survey location is that the resulting traffic volumes should be representative of the link as a whole. This necessitates locations away from major settlements or junctions where there are likely to be localised peaks in traffic flow and preference is for a location within the middle third, in terms of chainage, of the link.

4.2.2 Survey Methodology

The timetable of the study combined with the staffing resources available to Azeravtoyol determined that each classified volume count should be no longer than one day in duration. Most surveys were undertaken between the twelve hour period 0800-2000 hours, but it was necessary to conduct two 24 hour counts to give an indication of levels of nightime traffic and to enable expansion factors for converting 12 hour count results to a 24 hour basis to be estimated. Site selection for the 24 hour counts was determined by the need to have contrasting locations, each having suitable facilities for an overnight survey.

Vehicle were classified in the counts in the following four ways:

- by direction,
- by time, to the nearest hour,
- by vehicle type and
- by vehicle nationality.

The classification by vehicle type used eleven categories following those used in the TRACECA study of 1996. The vehicle categories were as follows:

- Car/Jeep
- Minibus
- Light Goods Vehicle
- Large Bus
- 2-axle Medium Goods Vehicle
- 3-axle Heavy Goods Vehicle
- 4-axle Heavy Goods Vehicle

- 5-axle Heavy Goods Vehicle
- 6+axle Heavy Goods Vehicle
- Motorcycle
- Agricultural Tractor

This classification was subsequently compressed to the following six vehicle categories used in the economic analysis of road improvements:

- Car
- Utility
- Bus
- 2-axle Truck
- 3-axle Truck
- 3+axle Truck

The vehicle nationality classification was based on vehicle registration plates. For the purposes of this study it was sufficient to distinguish between Azerbaijan and foreign vehicles. The breakdown of vehicles into Azerbaijan and foreign is of interest for three reasons. It provides useful information on the utilisation of Azerbaijan main road pavements by foreign vehicles, particularly heavy vehicles, and it also gives an indication of the distribution of the benefits from highway improvement between Azerbaijan and foreign vehicle owners and operators. A further factor to be considered is that Azerbaijan and foreign traffic can be expected to have different seasonality patterns.

An example classified volume count form is included as Appendix Table A.4.1.

The programme of classified volume count surveys is summarised in Table 4.2.

Table 4.2. Programme of Classified Volume Count Surveys

Road No.	Section		Link No.	Survey Location (km)	Survey Date	Survey Duration (hours)
	from	to				
M4	Alyat	Gazi Mammad	1	31	7/3/97	12
M4	Gazi Mammad	Kyurdamir	2	90	6/3/97	12
M4	Gazi Mammad	Kyurdamir	2	118	5/2/97	12
M4	Kyurdamir	Yevlakh	3	128	5/2/97	12
M4	Kyurdamir	Yevlakh	3	174	5/2/97	24
M4	Yevlakh	Mingechevir station	4	280	9/2/97	12
M1	Mingechevir station	Ganja bypass (e)	5	316	5/3/97	12
M1	Ganja bypass (e)	Ganja bypass (w)	6	364	5/3/97	12
M1	Ganja bypass (w)	Tovuz	7	401	22/2/97	12
M1	Tovuz	Gazakh	8	446	24-25/2/97	24
M1	Gazakh	Red Bridge bp	9	472	26/2/97	12

Note: Alyat = km 0 and km numbering on the M4 is from Alyat. Km numbering on the M 1 is from Baku.

Source: Consultants

4.3. Estimates of Base Year Traffic by Vehicle Type

4.3.1 Results of Traffic Surveys

The full results of the classified volume count surveys in Azerbaijan are given as Appendix Table A.4.2. The process of adjusting these results to bring the 12 hour traffic totals to a 24 hour basis and the further adjustment of Azerbaijan traffic to take account of seasonality is discussed below.

4.3.2 Conversion of Surveyed Traffic Flows to Estimates of Annual Average Daily Traffic (AADT)

A factor has been applied to the results of the 12 hour classified volume counts to convert them to a 24 hour traffic volume basis. The two counts at km 174 and km 446 were carried out for a full 24 hours and thus provided the 12 to 24 hour expansion factors required by the other survey stations. These were derived on the basis of vehicle category to reflect the differing nightime vehicle mix. The adjustment factors from the location at km 174 were applied to data from the eastern survey stations, while the factors from km 446 were used to expand data from the western survey stations, from km 280 to the Georgian border. These factors are given in Table 4.3.

Table 4.3: 12 to 24 hour Traffic Volume Conversion Factors

Vehicle Category	12-24 Hour Expansion Factors					
	Eastern survey stations: Alyat - Yevlakh			Western survey stations: Yevlakh - Red Bridge		
	Azerbaijan	International	Total	Azerbaijan	International	Total
Car	1.34	1.22	1.33	1.43	1.44	1.43
Minibus	2.85	1.83	2.53	1.83	1.14	1.67
LGV	1.42	1.32	1.38	1.30	2.57	1.36
Bus	1.44	2.00	1.47	1.49	1.80	1.52
2-axle Truck	1.84	1.61	1.69	1.39	1.40	1.39
3-axle Truck	1.45	1.65	1.57	1.35	1.79	1.64
4-axle Truck	1.72	1.75	1.74	2.05	1.45	1.53
5-axle Truck	2.11	2.00	2.04	1.38	1.18	1.22
6+axle Truck	0.00	0.00	0.00	0.00	0.00	0.00

Source: Consultants

Table 4.4 provides the hourly distribution of total traffic for each of the two survey stations where 24 hour classified volume counts were conducted. The full results of these two surveys is given in Appendix A.4.3.

Table 4.4: Hourly Traffic Distribution at the Two 24-hour Survey Stations

Hour	Survey station km 174			Survey station km 446		
	Azerbaijan %	International %	Total %	Azerbaijan %	International %	Total %
0000-0100	1.4	2.4	1.7	1.6	3.5	2.1
0100-0200	1.3	2.2	1.5	2.1	2.1	2.1
0200-0300	2.3	1.4	2.1	1.7	1.2	1.6
0300-0400	1.3	1.0	1.2	1.4	1.3	1.4
0400-0500	0.9	1.8	1.1	1.4	1.8	1.5
0500-0600	1.4	1.3	1.4	2.0	2.0	2.0
0600-0700	2.6	4.6	3.1	3.4	2.2	3.1
0700-0800	4.9	6.8	5.4	4.9	6.2	5.2
0800-0900	4.5	4.7	4.6	4.5	5.1	4.7
0900-1000	5.5	3.9	5.1	5.8	5.4	5.7
1000-1100	7.2	4.7	6.6	7.2	5.6	6.8
1100-1200	5.7	5.4	5.7	7.4	4.7	6.8
1200-1300	5.4	5.0	5.3	7.3	3.0	6.2
1300-1400	6.4	5.8	6.3	7.8	7.4	7.7
1400-1500	5.8	7.5	6.2	5.5	3.2	4.9
1500-1600	8.1	6.9	7.8	4.5	5.4	4.7
1600-1700	7.4	7.0	7.3	5.3	5.0	5.2
1700-1800	6.4	4.8	6.0	4.7	6.7	5.2
1800-1900	4.9	5.6	5.1	4.9	5.7	5.1
1900-2000	4.4	3.3	4.2	4.5	7.6	5.3
2000-2100	3.8	3.9	3.8	4.0	4.1	4.0
2100-2200	3.7	5.8	4.2	3.4	5.0	3.8
2200-2300	2.7	2.5	2.7	2.6	4.5	3.0
2300-0000	1.9	1.8	1.9	2.2	1.2	1.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Consultants

All of the classified volume count surveys were conducted within a period of just over one month from early February 1997. Winter traffic volumes are markedly lower than the average in Azerbaijan because of the prevailing adverse weather conditions and the results of classified volume counts undertaken in February and March can be expected to underestimate Annual Average Daily Traffic (AADT). Adjustment for seasonality was based on seasonality factors provided by Azeravtoyol. These were derived from studies conducted in the Soviet era and confirmed by regular surveys on the Alyat - Yevlakh - Red Bridge route during the 1980s. These seasonality factors are given in Table 5.5.

Table 4.5: Traffic Seasonality Variation

Season	Index	Adjustment Factor
Winter	74	1.35
Spring	87	1.15
Summer	106	0.94
Autumn	133	0.75
Annual Average	100	1.00

Source: Azeravtoyol

The surveys all being conducted in winter, a seasonal adjustment factor of 1.35 was applied to the Azerbaijan component of traffic at each of the survey stations. International traffic is considered much less susceptible to marked seasonal variations, consisting as it does primarily of regular movements of essential goods and materials. In the absence of any reliable international seasonality indicators international traffic has not been adjusted for seasonality.

4.3.3 Estimated Annual Average Daily Traffic in 1997

The application of the 12 to 24 hour expansion factors and adjustments for seasonality for Azerbaijan vehicles results in the estimates of annual average daily traffic (AADT) by vehicle type set out in Table 4.6. In this table the compressed vehicle classification used in the subsequent economic analysis is presented. The percentage distributions of traffic by vehicle type and by Azerbaijan / foreign vehicles by type are set out in Appendix Tables A.4.4 and A.4.5.

Traffic levels on the road links in the Alyat-Georgian border corridor are consistently within the range 4,000 - 6,000 AADT. The only discernible trend is a slight decline in flows from east to west. Cars and other light vehicles account for 65-70 percent of total traffic and trucks make up on average 20-25 percent of the total. The proportion of foreign light vehicles and buses is negligible, but it is quite significant for the heavier trucks, particularly west of Padar. In the western half of the corridor foreign vehicles account for more than half the heavier trucks of 3 or more axles. The main concentrations of foreign trucks are between Padar and Yevlakh where trucks from Iran join the corridor and between Tovuz and the Georgian border where there is a significant element of cross border traffic with Georgia.

Table 4.6 ALYAT-GEORGIAN BORDER ROAD: ANNUAL AVERAGE DAILY TRAFFIC BY VEHICLE TYPE, 1997

Road No.	Link Name	Vehicle Nationality	Annual Average Daily Traffic (AADT)						
			Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
M4	Alyat-Gazi - Mammad	Azerbaijan	3,947	328	460	338	457	272	5,802
		Foreign	108	7	14	3	59	96	288
		Total	4,055	336	474	341	516	368	6,090
M4	Gazi Mammad - Padar	Azerbaijan	3,253	165	394	261	496	516	5,085
		Foreign	104	26	14	-	86	231	460
		Total	3,357	191	408	261	581	747	5,545
M4	Padar-Kyurdamir	Azerbaijan	3,447	234	602	288	324	134	5,029
		Foreign	193	35	10	137	272	178	823
		Total	3,639	269	612	425	596	311	5,852
M4	Gazi Mammad - Kyurdamir (weighted average)	Azerbaijan	3,319	202	505	273	393	296	4,988
		Foreign	152	31	12	76	188	198	657
		Total	3,471	232	517	349	582	494	5,645
M4	Kyurdamir-Ujar	Azerbaijan	4,411	269	701	286	400	174	6,240
		Foreign	249	56	44	284	326	202	1,161
		Total	4,659	325	745	570	726	376	7,401
M4	Ujar-Yevlakh	Azerbaijan	2,546	123	428	157	232	84	3,569
		Foreign	156	44	28	188	293	119	828
		Total	2,702	167	456	345	525	203	4,397
M4	Kyurdamir - Yevlakh (weighted average)	Azerbaijan	3,468	195	563	221	315	128	4,891
		Foreign	202	50	36	236	309	160	993
		Total	3,670	245	599	456	624	288	5,883
M1	Yevlakh-Mingechevir Station	Azerbaijan	3,211	177	488	258	235	58	4,427
		Foreign	168	21	13	63	262	47	573
		Total	3,378	199	501	321	497	105	5,000
M1	Mingechevir St.-Ganja bypass	Azerbaijan	4,069	114	456	239	273	345	5,497
		Foreign	116	18	14	3	74	115	339
		Total	4,185	132	470	242	347	460	5,836
M1	Ganja bypass	Azerbaijan	2,903	138	339	181	268	469	4,297
		Foreign	113	17	5	1	106	141	384
		Total	3,016	155	344	182	373	610	4,681
M1	Ganja bypass-Dallar-Tovuz	Azerbaijan	3,915	172	458	296	193	213	5,247
		Foreign	185	49	20	7	271	79	611
		Total	4,099	221	478	303	464	292	5,857
M1	Tovuz-Aghstafa-Gazakh	Azerbaijan	2,642	439	389	277	198	88	4,032
		Foreign	195	46	27	14	373	245	900
		Total	2,837	485	416	291	571	333	4,932
M1	Gazakh-Georgian border	Azerbaijan	2,497	585	335	301	135	87	3,939
		Foreign	205	93	59	29	316	251	954
		Total	2,702	678	394	331	450	338	4,893

Source: Estimate based on classified volume counts carried for the Consultants by Azeravtoyol staff.

4.4 Vehicle Pavement Damage Factors

Our assumptions about the pavement damaging potential of different types of vehicles on the corridor road links are based on the results of axle load surveys undertaken by the Consultants in Azerbaijan and Georgia in 1996 as part of the TRACECA Pavement Management System Study. The axle load survey in Azerbaijan was undertaken on the Baku - Alyat section of the Baku - Astara road and there are reasons to believe that the results may not be completely applicable to the traffic on the Alyat - Georgian border corridor. For this reason we have also taken account of the results of the axle load survey undertaken 25 km west of Tbilisi on the Tbilisi - Kutaisi road in Georgia. This road link carries east-west heavy vehicle traffic which is similar in characteristics, particularly for international truck traffic, to that using the Alyat - Georgian border corridor.

The assumed equivalent standard axles per vehicle category used in this study are, therefore, based on weighted averages of the equivalent standard axles for given vehicle types obtained from the two surveys mentioned. The weights used were the number of the respective vehicle types weighed in the two axle load surveys. The results are set out in Table 4.7.

Table 4.7 Equivalent Standard Axles by Vehicle Category

Vehicle category	Azerbaijan		Georgia		Weighted Average ESA per Vehicle
	Sample size (vehicles weighed)	ESA per Vehicle (both directions)	Sample size (vehicles weighed)	ESA per Vehicle (both directions)	
Car (a)	0	0.0007	0	0.0007	0.0007
Utility (a)	0	0.0011	0	0.0011	0.0011
Bus	8	1.5579	9	2.4005	2.0040
Truck 2 axle	121	0.4567	108	0.9062	0.6687
Truck 3 axle	258	0.5256	145	2.5238	1.2246
Truck >3 axle	135	1.3649	62	2.1385	1.6084

Source: Axle Load Surveys undertaken by the Consultants' as part of TRACECA Pavement Management System Study.

Note (a) Not weighed. ESALs based on international experience.

4.5 Forecasts of Traffic Growth on the Study Roads

4.5.1 General

The traffic forecasts prepared for the study roads are forecasts of "normal" traffic. In theory, traffic forecasts can also comprise predictions of diverted and generated traffic. In view of the present condition of the existing paved study road, with present roughness levels at around IRI 6 m/km, the scale of potential reductions in pavement roughness and road user costs is unlikely to be sufficient to bring about significant traffic generation.

The potential for traffic diversion to or from the study road links is also considered to be negligible for the reasons discussed below. There is only one alternative route of significance to the study road. This is the eastern half of the M1 from Yevlakh to Baku which has effectively lost its status as the country's premier east-west route in favour of the M4/M3 road via Alyat. The principal advantage of the latter route, of which the study road forms part, is its superior horizontal and vertical alignment which results in significantly higher travel speeds and lower operating costs for through-traffic, particularly heavy vehicles.

The Consultants carried out a field reconnaissance of the M1 route during the course of the study. The M1 takes a more direct route between Yevlakh and Baku, shorter by between 10 and 15 km, but this involves crossing a range of hills to the north-east of Agshu, with gradients up of to 15 percent. The 37 km section between Agshu and Shamakhy was covered, in a light vehicle, at an average speed of 40 kph as opposed to 70 kph for the route as a whole. No heavy vehicles were observed traversing this most severe section of the route. Winter closures are reputedly common. The easternmost portion of the route, between Shamakhy and Baku, is less severe, but crosses rolling plateaux subject to adverse winter weather conditions with difficulties compounded by occasional steep gradients. The M1 is, therefore, a slower route for light vehicles and unattractive to heavy vehicles. It would appear to carry predominantly local traffic. Traffic diversion from the M1 to the M4 has already taken place in recent years and the potential for further traffic diversion appears to be negligible.

4.5.2 Forecasts of "Normal" Traffic Growth

It was originally intended to base the normal traffic growth forecasts in this study on the multimodal traffic forecasts for the whole TRACECA region being prepared by W.S.Atkins International as part of the TACIS sponsored Regional Traffic Model project. Unfortunately, the transport forecasts for the Caucasus region from that project were not available as at end May 1997, the latest conceivable date when they could have been incorporated into the work of this study. We have, therefore, had to base our traffic forecasts on the assumptions made in the TRACECA Pavement Management System and Highway Financing Study suitably modified by economic forecasts which have subsequently become available.

No attempt has been made to base traffic forecasts on sophisticated models relating the growth of road transport demand to the growth of Gross Domestic Product (GDP) because, in our view, the quality of the available data is inadequate for such an approach. Our basic assumption is that the growth of traffic on the study road will be in line with the future rates of economic growth in Azerbaijan and its main trading partners. The general consensus is that Azerbaijan, possibly alone among the CIS republics, is about to experience extremely rapid economic growth on the basis initially of investments in the oil sector and subsequently on the rising oil output resulting from that investment. Table 5.8 summarises forecasts of economic growth by the EBRD and W.S.Atkins International.

The time periods for these forecasts have been modified slightly to bring them into line with the time periods used for our traffic forecasts. In choosing time periods for our traffic forecasts a constraint is imposed by the version of the World Bank's HDM-III model which has been used for the economic analysis of the road improvement projects. The model will only accept a maximum of two time periods within an overall project appraisal period and in our forecasts we have accordingly prepared forecasts for the following periods:

1997 - 2010
2010 - 2025

The forecasts of real (constant price) GDP growth in Table 5.8 are shown in the original periods and in the two periods specified above. In practice the EBRD forecasts only extend to the year 2005. It should be noted that W.S Atkins appear to have scaled back their preliminary growth assumptions for Gross Domestic Product in Azerbaijan and their latest available forecasts are less optimistic than the earlier preliminary forecasts. The most likely scenario suggested by the macro economic forecasts is for real GDP growth of around 8 per cent a year during the first of our forecasting periods (1997 - 2010). There are at present no long range economic forecasts for the period beyond 2010. It seems likely, however, that the Azerbaijan economy would continue to grow rapidly after 2010, but at not quite the exceptionally high rates of the 1997 - 2010 period.

The somewhat limited historical evidence suggests that traffic on the study road may not have declined as rapidly as the economy in general during the first half of the 1990s. In more recent years this may be attributable to the growing importance of international through-traffic on the route. We have assumed that the Azerbaijan portion of traffic on the study road will increase more or less in line with the rate of Azerbaijan's economic growth, but the internal portion will increase at a slightly slower rate. The more sophisticated forecasts being prepared under the TRACECA Regional Traffic Model project, which is taking formal account of modal; split aspects of regional transport flows, will contradict this assumption, but unfortunately we have not been able to take advantage of the results of this work given the time scale of this study.

Our forecasts of the rate of growth of "normal" traffic on the study road are set out in Table 4.9. A more detailed picture of traffic growth rates by link and vehicle category is given in Appendix Table A.4.6. These forecasts comprise a central or best estimate and high and low estimates reflecting optimistic and pessimistic assumptions. The high and low estimates are for use in the sensitivity analyses which are regarded as an important part of the economic appraisal of road improvement projects. Our central or best estimate traffic forecasts indicate an overall rate of traffic growth of 6.7 percent a year between 1990 and 2010 and 6 percent a year thereafter. For the same periods, the high and low forecasts indicate annual traffic growth rates of 8.8 and 8.0 and 3.8 and 5.0 percent respectively. Although the central estimate traffic growth assumptions may appear to be slightly conservative given the macro economic forecasts discussed earlier, they do represent rapid traffic growth. This is illustrated in Figure 4.1 which shows the growth profile of traffic by vehicle category on the Gazi Mammad - Kyurdamir road link. The optimistic traffic growth forecasts give rise to extremely rapid traffic growth. A feature of the forecasts which is worth noting is that the heavy truck traffic is assumed to grow more rapidly than the traditional light-medium truck traffic.

Central estimate forecast traffic levels by link and vehicle category are set out for the years 1997, 2010 and 2025 in Table 5.10. The equivalent traffic levels by link and vehicle category under the high and low traffic growth assumptions are presented in Appendix Table A.4.7. In 1997 AADT on the study road links were within the range 6,000 to 4,600 with traffic tending to decline slightly from east to west. By the year 2010 AADT levels will have risen to within the range AADT 14,000 - 11,000. By the end of the appraisal period in 2025 they will have risen further to AADT 26,00 - 34,000.

Under the high and low traffic growth forecasts the relevant AADT ranges along the study road would be as follows:

High growth scenario:	2010	AADT range	18,300 - 14,000
	2025	AADT range	58,000 - 45,000
Low growth scenario:	2010	AADT range	10,000 - 7,600
	2025	AADT range	21,000 - 16,000

Clearly with the rapid traffic growth indicated by the central and high growth forecasts capacity problems will appear within the 1997 - 2025 appraisal period. However, the estimated volume-capacity ratios set out in Appendix Table A.4.8 suggest that capacity constraints indicated by volume capacity ratios of 0.7 or higher will not be experienced before 2011 under the central forecast and 2009 under the high growth forecast. Immediate initiatives to widen the road to 4 lane standard would, therefore clearly be premature. This aspect is subjected to more detailed analysis in the economic appraisal.

Table 4.8 AZERBAIJAN - FORECASTS OF ECONOMIC GROWTH

Period	EBRD				W.S.Atkins International	
	Average Annual Growth (%) of Real Gross Domestic Product				Average Annual Growth (%) of Real Gross Domestic Product	
	Central estimate	Upper bound	Lower bound		Preliminary forecast	Latest available forecast
1997	7.5	7.5	6.0		6.6	4.5
1998	9.5	11.0	4.5		6.6	4.5
1999	10.0	15.0	4.5		6.6	4.5
2000	9.5	12.0	4.0		6.6	4.5
2001	9.0	12.0	3.0		6.6	4.5
2002	8.0	10.0	3.0		8.8	9.0
2005 (a)					9.3	9.0
2010 (b)					8.2	9.9
1997-2000	9.7	12.7	4.3		6.6	4.5
2000-2005	8.2	10.4	3.0		8.8	8.1
1997-2005	8.8	11.2	3.5		8.0	6.7
1997-2010	n.a	n.a	n.a		8.0	7.9

Source: EBRD and W.S.Atkins International

Note. (a) Average annual compound growth percent 2002-2005

(b) Average annual compound growth percent 2005-2010

Table 4.9 ALYAT-GEORGIAN BORDER ROAD: BEST ESTIMATE TRAFFIC FORECASTS - 1997 - 2025

Road No.	Link Name	Annual Average Daily Traffic (AADT) - 1997						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
M4	Alyat-Gazi Mammad	4,055	336	474	341	516	368	6,090
M4	Gazi Mammad - Kyurdamir (wt.avg.)	3,471	232	517	349	582	494	5,645
M4	Kyurdamir - Yevlakh (wt.avg.)	3,670	245	599	456	624	288	5,883
M1	Yevlakh-Mingechevir Station	3,378	199	501	321	497	105	5,000
M1	Mingechevir St.-Ganja bypass	4,185	132	470	242	347	460	5,836
M1	Ganja bypass	3,016	155	344	182	373	610	4,681
M1	Ganja bypass-Dallar-Tovuz	4,099	221	478	303	464	292	5,857
M1	Tovuz-Aghstafa-Gazakh	2,837	485	416	291	571	333	4,932
M1	Gazakh-Georgian border	2,702	678	394	331	450	338	4,893
Road No.	Link Name	Annual Average Daily Traffic (AADT) - 2010						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
M4	Alyat-Gazi Mammad	9,641	775	987	674	1,153	929	14,159
M4	Gazi Mammad - Kyurdamir (wt.avg.)	8,267	536	1,078	691	1,303	1,250	13,124
M4	Kyurdamir - Yevlakh (wt.avg.)	8,801	570	1,258	909	1,407	734	13,678
M1	Yevlakh-Mingechevir Station	8,088	462	1,050	639	1,119	267	11,625
M1	Mingechevir St.-Ganja bypass	9,892	303	972	475	771	1,155	13,568
M1	Ganja bypass	7,109	354	710	357	827	1,527	10,883
M1	Ganja bypass-Dallar-Tovuz	9,741	509	994	599	1,037	737	13,617
M1	Tovuz-Aghstafa-Gazakh	6,772	1,123	869	577	1,281	844	11,467
M1	Gazakh-Georgian border	6,455	1,571	824	657	1,011	858	11,376
Road No.	Link Name	Annual Average Daily Traffic (AADT) - 2025						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
M4	Alyat-Gazi Mammad	23,726	1,828	2,024	1,325	2,611	2,418	33,932
M4	Gazi Mammad - Kyurdamir (wt.avg.)	20,392	1,268	2,217	1,362	2,957	3,259	31,453
M4	Kyurdamir - Yevlakh (wt.avg.)	21,869	1,358	2,605	1,805	3,215	1,927	32,779
M1	Yevlakh-Mingechevir Station	20,068	1,099	2,172	1,267	2,553	700	27,859
M1	Mingechevir St.-Ganja bypass	24,180	709	1,982	929	1,734	2,984	32,517
M1	Ganja bypass	17,328	828	1,442	695	1,853	3,935	26,082
M1	Ganja bypass-Dallar-Tovuz	23,957	1,201	2,039	1,176	2,345	1,916	32,634
M1	Tovuz-Aghstafa-Gazakh	16,757	2,664	1,793	1,142	2,916	2,209	27,480
M1	Gazakh-Georgian border	15,984	3,730	1,701	1,301	2,302	2,245	27,263

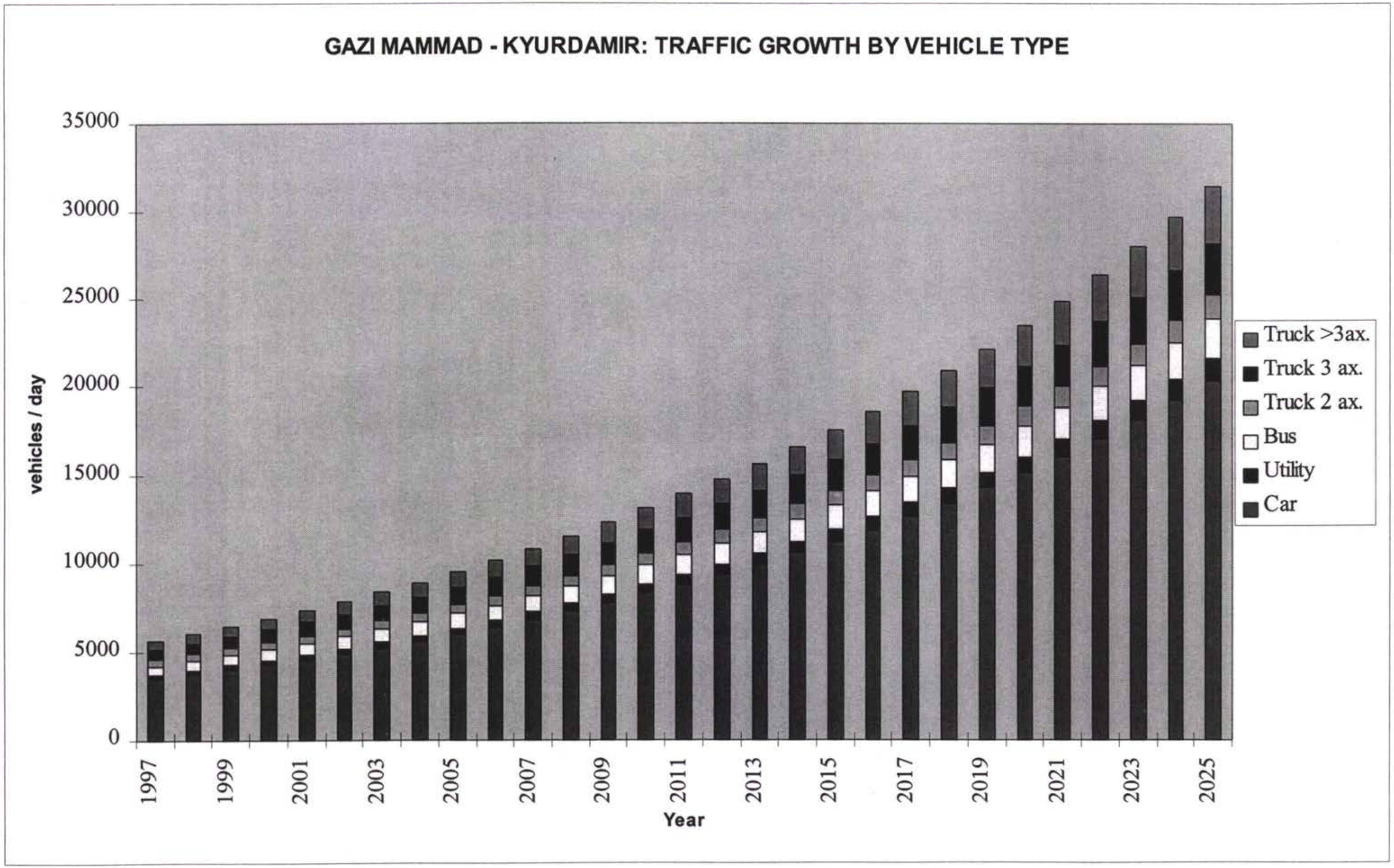
Source: Consultant's estimates
Note: Wt.avg. : weighted average (weighting by road sub-link length)

Table 4.10 ALYAT-GEORGIAN BORDER ROAD: BEST ESTIMATE TRAFFIC FORECASTS - 1997 - 2025

Road No.	Link Name	Annual Average Daily Traffic (AADT) - 1997						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
M4	Alyat-Gazi Mammad	4,055	336	474	341	516	368	6,090
M4	Gazi Mammad - Kyurdamir (wt.avg.)	3,471	232	517	349	582	494	5,645
M4	Kyurdamir - Yevlakh (wt.avg.)	3,670	245	599	456	624	288	5,883
M1	Yevlakh-Mingechevir Station	3,378	199	501	321	497	105	5,000
M1	Mingechevir St.-Ganja bypass	4,185	132	470	242	347	460	5,836
M1	Ganja bypass	3,016	155	344	182	373	610	4,681
M1	Ganja bypass-Dallar-Tovuz	4,099	221	478	303	464	292	5,857
M1	Tovuz-Aghstafa - Gazakh	2,837	485	416	291	571	333	4,932
M1	Gazakh-Georgian border	2,702	678	394	331	450	338	4,893
Road No.	Link Name	Annual Average Daily Traffic (AADT) - 2010						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
M4	Alyat-Gazi Mammad	9,641	775	987	674	1,153	929	14,159
M4	Gazi Mammad - Kyurdamir (wt.avg.)	8,267	536	1,078	691	1,303	1,250	13,124
M4	Kyurdamir - Yevlakh (wt.avg.)	8,801	570	1,258	909	1,407	734	13,678
M1	Yevlakh-Mingechevir Station	8,088	462	1,050	639	1,119	267	11,625
M1	Mingechevir St.-Ganja bypass	9,892	303	972	475	771	1,155	13,568
M1	Ganja bypass	7,109	354	710	357	827	1,527	10,883
M1	Ganja bypass-Dallar-Tovuz	9,741	509	994	599	1,037	737	13,617
M1	Tovuz-Aghstafa-Gazakh	6,772	1,123	869	577	1,281	844	11,467
M1	Gazakh-Georgian border	6,455	1,571	824	657	1,011	858	11,376
Road No.	Link Name	Annual Average Daily Traffic (AADT) - 2025						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
M4	Alyat-Gazi Mammad	23,726	1,828	2,024	1,325	2,611	2,418	33,932
M4	Gazi Mammad - Kyurdamir (wt.avg.)	20,392	1,268	2,217	1,362	2,957	3,259	31,453
M4	Kyurdamir - Yevlakh (wt.avg.)	21,869	1,358	2,605	1,805	3,215	1,927	32,779
M1	Yevlakh-Mingechevir Station	20,068	1,099	2,172	1,267	2,553	700	27,859
M1	Mingechevir St.-Ganja bypass	24,180	709	1,982	929	1,734	2,984	32,517
M1	Ganja bypass	17,328	828	1,442	695	1,853	3,935	26,082
M1	Ganja bypass-Dallar-Tovuz	23,957	1,201	2,039	1,176	2,345	1,916	32,634
M1	Tovuz-Aghstafa-Gazakh	16,757	2,664	1,793	1,142	2,916	2,209	27,480
M1	Gazakh-Georgian border	15,984	3,730	1,701	1,301	2,302	2,245	27,263

Source: Consultant's estimates

Note: Wt.avg. : weighted average (weighting by road sub-link length)


GAZI MAMMAD - KYURDAMIR: TRAFFIC GROWTH BY VEHICLE TYPE
vehicles / day
35000
30000
25000
20000
15000
10000
5000
0
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
2021
2023
2025
Year
Truck >3ax.
Truck 3 ax.
Truck 2 ax.
Bus
Utility
Car

5. ROAD USER COSTS

5.1 General

The road user costs which have been quantified in this study for use in the economic analysis of road improvement projects in Azerbaijan comprise vehicle operating costs and passenger time costs. The costs update and amplify the financial vehicle operating costs which were developed in 1996 as part of the Consultant's TRACECA Pavement Management System Study and Highway Financing Study[1].

The inputs for the vehicle operating cost analyses undertaken for the TRACECA study were based on data collected during fieldwork in 1996 and on information in other consultants' road feasibility study reports. This information, notably on prices, has been updated to reflect changes in prices during the latter half of 1996 and early 1997. Reference has been made to the following study which, although now somewhat out of date, is still relevant in many respects.

- **"Prefeasibility Study of the Baku-Astara Road"** in Azerbaijan which was carried out by Wilbur Smith and Associates for EC TACIS in 1995 and 1996.

The road user costs used in this study differ from the vehicle operating costs developed in the 1996 TRACECA study in the following main ways:

- They are economic rather than financial costs and as such exclude taxes and other transfer payments, and they incorporate a border price approach to the costing of automotive fuels.

- They include an estimate of the economic value of passenger time.

Savings in road user costs are the main economic benefit to be expected from improvements to existing paved roads such as that from Alyat to the Georgian border. These savings arise from reductions in pavement roughness, and, if traffic is sufficiently high, from time savings associated with the relief of traffic congestion.

The basis for the quantification of economic road user costs in Azerbaijan and the way in which these costs change with road roughness and vehicle speeds are discussed in more detail in the following sections.

5.2 Representative Vehicle Types

The vehicle operating costs estimates are based on the use of the vehicle operating sub model from the World Bank's HDM-III model. This vehicle operating cost model predicts the various components of vehicle operating costs based on assumptions about road and vehicle characteristics and unit costs. In order to operate the model it is necessary to select a number representative vehicle models for costing. Each vehicle model is taken to be representative of the category of vehicles to which it belongs. As in the TRACECA study, six categories of vehicles were selected for costing and the operating costs for those vehicles were taken to be representative of the costs of all vehicles in that class.

[1] Study of the Cost and Financing of Road Usage - TecnEcon in association with Kocks Consult GmbH and Phoenix Pavement Consultants.

The following classes of representative vehicle types were selected for vehicle operating cost analysis:

- Passenger cars
- Utility vehicles comprising minibuses and pickups
- Large buses
- 2 axle trucks
- 3 axle trucks
- Trucks with more than 3 axles

This vehicle classification is the same as that used in the traffic analyses undertaken for this study. The choice of representative vehicle models within each vehicle category should in theory be based on an analyses of detailed vehicle registration data. In the absence of such data the selection of representative vehicle models was based on the results of the Consultant's moving observer traffic counts and on visual observations in bus and truck parks. Most of the vehicles in use in the Azerbaijan are of Russian (or former Soviet) manufacture and there is, therefore, a much higher degree of uniformity in the representative models than would be expected in Europe or the Middle East. Details of the representative vehicle types and models used in the analysis are set out below.

• Car:	Lada 124	Truck 2 axle:	Zil 130431410
• Utility vehicle:	GAZ 52	Truck 3 axle:	Kamaz 53212
• Bus:	Ikarus 25058	Truck >3 axle:	Kamaz 54112

5.3 Road User Cost Components

Data inputs required for the operation of the HDM III Vehicle Operating Cost sub model can be divided in to the following seven categories:

- Roadway characteristics
- Vehicle characteristics
- Tyre wear data
- Vehicle utilisation data
- Unit costs
- Additional model coefficients
- Passenger time costs

Where local data is not available for specified non-cost inputs, default values from within the model can be used. Most of the additional model coefficients used in this study are based on default values.

A detailed listing of all inputs for each representative vehicle type is set out in Appendix Table A.5.1. A number of general observations on the input data are in order. Most of the technical coefficients relating to vehicle performance are based on default values within the VOCM. Technical information on the representative truck models, which are all of Russian or Ukrainian manufacture, has been obtained from other studies and technical literature.

5.3.1 Vehicle utilisation levels

In Azerbaijan, as in other CIS countries, these are low by non-CIS international standards and this reflects the depressed economic conditions in most CIS countries during the past 5 years and the problems faced by vehicle operators in a transition economic environment. The age of the vehicle fleet is high by non-CIS international standards and the sale of new vehicles is very low.

5.3.2 Vehicle prices

The scarcity of new vehicles means that it is difficult to obtain realistic information on the prices of new as opposed to second hand vehicles. The prices of second hand vehicles were checked at vehicle auctions and prices of low kilometrage vehicles was noted as a guide to estimating new vehicle prices. Vehicle prices are low by international standards and this reflects their predominantly Russian origin. This is particularly true for heavy trucks where Russian models within a given category tend to be significantly smaller than their international counterparts and also much cheaper.

5.3.3 Economic costs of automotive fuels

The estimated economic costs of automotive fuels have been based on World Bank forecasts of the price of crude oil and an analysis of the relationship between crude oil import costs and the pre-tax retail prices of petrol and diesel in the fourteen member countries of the International Energy Agency (IEA). The difference between the imported costs of crude oil and the pre-tax retail prices in these countries is made up of refining, transport and distribution costs and margins. The average pre-tax retail prices of automotive fuels as a percentage of average imported crude oil costs in the IEA countries were as follows in 1996:

Premium unleaded petrol	239 %
Premium leaded petrol	232 %
Automotive diesel non-commercial	209 %
Automotive diesel - commercial	206 %

The World Bank forecasts average crude oil prices[2] of US$ 20.45 per barrel (US$ 0.129 / litre) in 2000 and US$ 19.84 per barrel (US$ 0.125 / litre) in 2005. These compare with

[2] Deflated by the Group - V countries' Manufacturing Unit Value (MUV) Index.

average IEA crude oil import costs of US$ 19.59 per barrel (US$ 0.114 / litre) in 1996. Details of these and other crude oil price forecasts are set out in Appendix Table A.5.2. Applying the relationship between pre-tax retail automotive fuel prices and crude oil prices shown above gives the following pre-tax retail price forecasts at constant 1996 prices (see Appendix Table A.5.3):

Premium unleaded petrol	2000	US$ 0.308 / litre
Premium unleaded petrol	2005	US$ 0.299 / litre
Premium leaded petrol	2000	US$ 0.299 / litre
Premium leaded petrol	2005	US$ 0.290 / litre
Non-commercial diesel	2000	US$ 0.270 / litre
Non-commercial diesel	2005	US$ 0.262 / litre
Commercial diesel	2000	US$ 0.266 / litre
Commercial diesel	2005	US$ 0.258 / litre

Making a small allowance for converting from constant 1996 to constant 1997 prices we have assumed the following economic costs of petrol and diesel for use in the economic analyses in this study:

Petrol	US$ 0.30 / litre
Diesel	US$ 0.27 / litre

This compares with the following (financial) retail prices prevailing in early 1997 :

Petrol	US$ 0.37 / litre
Diesel	US$ 0.22 / litre

5.3.4 Passenger time costs

The economic value of passengers' travel time savings is defined as the value of the time saved which can be put to productive use. In practice this means that savings in working time are valued in full, but savings in leisure time are not valued. In order to estimate the value of passenger time savings it is necessary to have some idea of passenger occupations and incomes, the purpose of the journey on which time may be saved and, ideally, a clear idea of the proportion of time saved which can be put to productive use. For the purpose of the present study, our inability to undertake the roadside interview surveys which we requested meant that our estimates of passenger time values have had to be based on assumptions rather than data.

In making these assumptions a certain amount of simplification has been necessary because of the absence of information on passenger occupations, trip purpose and vehicle occupancy. The main simplification is in dealing in terms of average income per passenger as a basis for valuing passenger time. The following estimates of average monthly wages, remuneration or per capita income are available for Azerbaijan and, as might be expected they do not give the same answer.

- **Nominal average monthly wage**
  in 1997 this is around US$ 23. Assuming a 165 hour working week this would imply an hourly value of US$ 0.14.

- **Average monthly remuneration**
  The World Bank has estimated that if unrecorded transactions are taken into account, Gross Domestic Product (GDP) in Azerbaijan would be about 25 - 40% higher than GDP based on estimates which take no account of the "black economy". Modified per capita GDP would, therefore be US$ 590 - 660 compared with the US$ 470 based purely on recorded transactions. The World Bank has further estimated average monthly compensation or remuneration at US$ 65 rather than the nominal monthly wage of US$ 23

Assuming a 165 hour working week, the alternative monthly per capita income and monthly remuneration estimates suggest the following hourly income or time values:

Nominal wage basis	US$ 23 / month or US$ 0.13 / hour
Per Capita GDP @ 0% unrecorded transactions	US$ 39 / month or US$ 0.24 / hour
Per capita GDP @ 25% unrecorded transactions	US$ 49 / month or US$ 0.30 / hour
Per capita GDP @ 40% unrecorded transactions	US$ 55 / month or US$ 0.33 / hour
Average monthly compensation @ US$ 65	US$ 0.39 / hour

For the purpose of this study we have adopted a basic passenger time value of US$ 0.30 / hour. In the case of car passengers, who are assumed to belong to the higher income groups, an hourly value of US$ 0.40 has been used. Savings in business time are valued at this rate whereas savings in leisure time are not valued. In the absence of information on passenger trip purpose we have assumed that the following breakdown of business and leisure / social travel applies for the different vehicle types:

Car drivers	50 % business,	50 % leisure / social
Car passengers	50 % business,	50 % leisure / social
Utility Vehicle drivers	100 % business,	
Utility vehicle passengers	50 % business,	50 % leisure / social
Bus and Truck drivers	100 % business	
Bus passengers	50 % business, 50 % leisure / social	

The final set of assumptions required relates to vehicle occupancy. In the absence of direct survey evidence in Azerbaijan, we have taken note of the results of the detailed traffic surveys undertaken in the Kyrgyz Republic as part of the Bishkek - Osh Road

Feasibility Study[3] and modified them in line with our own informal observations in Azerbaijan. The assumed number of passengers per vehicle is as follows:

Car	2 passengers
Utility Vehicle	5 passengers
Bus	32 passengers
Trucks	0 passengers

5.4 Relative Importance of Vehicle Operating Cost Components

The main vehicle operating cost components analysed in the HDM III Vehicle Operating Cost model are the following:

- Automotive fuel consumption
- Lubricants consumption
- Tyre consumption
- Crew time
- Maintenance spare parts consumption
- Maintenance labour time
- Depreciation and interest
- Overheads (in financial costs)

The model also permits passenger time values and the time value of goods in transit to be input if full road user costs are being analysed. The relative importance of the vehicle operating cost components varies according to relative prices and to the vehicle operating environment as dictated by road geometry and surface roughness. Fuel consumption is conventionally regarded as a major component of vehicle operating cost. Fuel consumption also becomes relatively less important in overall operating costs as road conditions deteriorate and vehicle speeds decline. This is counterbalanced by a more than proportionate increase in the importance of maintenance spare parts consumption and vehicle maintenance costs in general.

Basic economic road user costs by component are set out in Table 5.1. These include vehicle operating costs plus passenger time costs, but they do not include an estimate for the time value of goods in transit. The reason for this omission is that the latter are usually insignificant for the traffic levels and potential differences in operating conditions experienced on the study roads. Our main interest is in the reduction in road user costs brought about by improvements in road pavement condition and the changes in the time costs of goods in transit make only a minimal contribution to these net changes.

Fuel is the main component of economic road user costs for all vehicle types accounting for between 20 and 30 percent of the total. The other main components are maintenance

[3] Kyrgyz Republic Road Rehabilitation Project for the Asian Development Bank - Draft Final Report (Carl Bro International a/s and Upham International Corporation)

parts and depreciation and, for heavy vehicles, tyres. The relatively low economic valuation of passenger time reflects low prevailing income levels. Our approach to the valuation of passenger time is described below.

The vehicle operating cost proportions shown in Table 5.1 are not fixed over the whole range of operating conditions. Rising surface roughness levels reflecting deteriorating road condition results in declining vehicle speeds which reduces the relative importance of fuel consumption in total costs. Maintenance costs, however, increase sharply in relative significance with declining road condition. Passenger time costs also become relatively more important as vehicle speeds decline and this obviously forms part of the basis of the theoretical justification of road widening projects designed to relieve traffic congestion.

Table 5.1 AZERBAIJAN - ECONOMIC ROAD USER COSTS

Road User Cost Component	Economic Road User Costs by Vehicle Category (US$/km)					
	Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
Fuel	0.025	0.050	0.124	0.078	0.153	0.235
Lubricants	0.003	0.003	0.005	0.005	0.005	0.008
Tyres	0.005	0.005	0.117	0.048	0.162	0.268
Crew time	0.002	0.005	0.013	0.011	0.012	0.018
Passenger time	0.005	0.012	0.132	-	-	-
Cargo holding	-	-	-	-	-	-
Maintenance labour	0.001	0.001	0.004	0.004	0.005	0.011
Maintenance parts	0.023	0.023	0.033	0.040	0.106	0.148
Depreciation	0.029	0.019	0.092	0.047	0.094	0.097
Interest	0.023	0.012	0.041	0.021	0.052	0.065
Overhead	-	0.010	0.020	0.025	0.025	0.020
TOTAL	0.115	0.139	0.580	0.278	0.613	0.870

Road User Cost Component	Percentage Distribution of Road User Costs by Component					
	Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
Fuel	21.4	35.7	21.3	28.2	25.0	27.0
Lubricants	2.6	2.2	0.9	1.8	0.8	0.9
Tyres	4.0	3.3	20.2	17.1	26.4	30.9
Crew time	2.1	3.6	2.2	4.0	1.9	2.1
Passenger time	4.2	8.9	22.7	-	-	-
Cargo holding	-	-	-	-	-	-
Maintenance labour	1.0	0.8	0.7	1.4	0.8	1.3
Maintenance parts	20.2	16.4	5.6	14.2	17.3	17.0
Depreciation	25.0	13.4	15.8	16.7	15.3	11.2
Interest	19.6	8.5	7.0	7.5	8.5	7.4
Overhead	-	7.2	3.4	9.0	4.1	2.3
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0

Source: Consultant's estimate based on the use of the HDM III Vehicle Operating Cost Model.

5.5 The Effect of Road Conditions on Vehicle Operating Costs

5.5.1 Road Condition and Road User Costs

Deterioration in road conditions results in increases in vehicle operating costs. For the road user changes in road condition are mainly reflected in changes in surface roughness or bumpiness. There are several measures of road surface roughness, but the International Roughness Index (IRI) has emerged as the most commonly used international standard measure. The IRI reflects the cumulative vertical movements in a vehicle's rear axle per kilometre and it is expressed in metres per kilometre. Our discussion of the relationship between road condition and vehicle operating costs must involve frequent references to different levels of IRI and it is important to be quite clear about what they mean in qualitative terms.

The range of surface roughness usually considered in highway studies is from IRI 2 m/km to IRI 20 m/km. A roughness level of less than IRI 3 m/km means that the road is in excellent to good condition. For paved roads an IRI of 10 m/km or more denotes a road in bad to very bad condition and anything over IRI 12 m/km would indicate extensive pavement failure or loss of pavement. On unpaved roads roughness levels are generally higher than on paved roads and slightly more relaxed qualitative standards are usually applied. For example, an unpaved road with an IRI of less than 5 m/km would be considered to be in good to quite good condition and very bad condition might be considered to be IRI 15 and over. When surface roughness levels approach IRI 20 m/km it is doubtful if the road retains any engineered properties and for operating purposes can be considered to be a track.

This study is concerned with inter state main roads and the interpretation of roughness levels on paved roads is the main focus of interest.. The following indications of road condition at different roughness levels will be helpful in understanding the subsequent discussion of the relationship between road surface roughness and vehicle operating costs.

Roughness IRI < 3.0 m/km
Vehicle speeds of over 120 kilometres / hour are comfortable. No depressions, potholes or corrugations are noticeable. This roughness level would be associated with high quality asphalt and, possibly, very good quality surface treatment. International evidence suggests that concrete pavements rarely achieve roughness levels this low.

Roughness IRI 4.0 - 5.5 m/km
In vehicles travelling at 80 kph moderately perceptible movements or large undulations may be felt. Defective surface is evident with occasional depressions, patches or potholes or many shallow potholes. In the absence of visible surface defects there may be moderate corrugations or large undulations. Concrete pavements built during the Soviet era were unlikely to have had initial roughness levels below IRI 4 m/km

Roughness IRI 7.0 - 8.0 m/km
At vehicle speeds of 70 - 90 kph the ride remains reasonably comfortable, but there are strongly perceptible movements and swaying usually associated with defects. These may take the form of frequent, moderate and uneven depressions or patches, and occasionally potholes.

Roughness IRI 9.0 - 10.0. m/km
The ride only remains comfortable at vehicle speeds of 50 - 60 kph and there can be frequent sharp movements and swaying. These are associated with severe defects taking the form of frequent, deep and uneven depressions, patches and potholes.

Roughness IRI 11.0 - 12.0 m/km
Vehicle speeds generally have to be below 50 kph because there are many deep depressions and severe disintegration.

These qualitative descriptions can be further simplified as follows:

- IRI 3 m/km or less - good road surface condition
- IRI 5 - 6 m/km - fair to moderate road surface condition
- IRI 7 - 9 m/km - moderate to poor road surface condition
- IRI 10 m/km or over - bad to very bad road surface condition

The effects of roughness on road user costs are calculated within the HDM-III model and the results for this study are set out in Table 6.2. This shows that road improvements resulting in the reduction of surface roughness from existing levels of around IRI 6 m/km to IRI 3 m/km will result in the following percentage savings in unit road user costs for the different types of vehicles:

- Car 13.5 %
- Utility Vehicle 12.3 %
- Bus 3.7 %
- Trucks 9.3 % - 11.9 %

Table 5.2 AZERBAIJAN - ROAD USER COSTS AND PAVEMENT

Pavement Roughness IRI (m/km)	Economic Road User Costs (US$ / km)					
	Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
2	0.103	0.126	0.562	0.249	0.551	0.797
3	0.107	0.130	0.567	0.258	0.571	0.820
4	0.111	0.134	0.573	0.268	0.591	0.844
5	0.116	0.139	0.580	0.278	0.613	0.870
6	0.121	0.146	0.588	0.289	0.634	0.897
7	0.128	0.153	0.580	0.300	0.657	0.924
8	0.135	0.162	0.608	0.311	0.679	0.952
9	0.144	0.172	0.620	0.323	0.702	0.980
10	0.154	0.184	0.632	0.335	0.726	1.008
11	0.165	0.196	0.645	0.347	0.749	1.037
12	0.175	0.208	0.659	0.360	0.773	1.066
13	0.185	0.220	0.674	0.372	0.797	1.095
14	0.196	0.233	0.689	0.385	0.822	1.125
15	0.207	0.246	0.705	0.398	0.846	1.155

Pavement Roughness IRI (m/km)	Road User Cost Index (IRI 3m/km = 100)					
	Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
2	96.8	97.1	99.1	96.2	96.6	97.2
3	100.0	100.0	100.0	100.0	100.0	100.0
4	103.8	103.4	101.0	103.8	103.6	102.9
5	108.3	107.5	102.3	107.8	107.2	106.1
6	113.5	112.3	103.7	111.9	111.1	109.3
7	119.6	118.0	102.2	116.2	115.0	112.7
8	126.7	124.7	107.2	120.6	119.0	116.1
9	135.2	132.6	109.2	125.1	123.0	119.5
10	144.7	141.6	111.4	129.8	127.1	123.0
11	154.3	150.9	113.8	134.5	131.2	126.5
12	164.1	160.3	116.2	139.3	135.3	130.0
13	173.9	169.9	118.8	144.2	139.6	133.6
14	183.9	179.7	121.4	149.1	143.8	137.2
15	193.9	189.6	124.2	154.1	148.2	140.9

Source: Consultant's estimates based on the use of the HDM III Vehicle Operating Cost Model

5.5.2 The Effect of Reductions in Vehicle Speed on Road User Costs

The effects of vehicle speed on road user costs have been calculated using the HDM-III vehicle operating cost sub model and the results are summarised in Table 5.3. For a given vehicle type desired vehicle speed is a function of road geometry, condition and vehicle interactions. Desired vehicle speeds have to drop to quite low levels before road user costs start to rise sharply. For passenger vehicles this "break" starts at around 30-35 kph and for trucks at around 30 kph. Given the prevailing level of incomes in countries like Azerbaijan, this relatively flat profile of road user costs in relation to reducing speed means that very high traffic levels and vehicle interactions are required for congestion relief benefits to be high enough to justify the costs of major road widening projects.

5.5.3 Road Improvements and Road User Cost Savings

The fact that road user costs are much more sensitive to reductions in pavement surface roughness than to changes in vehicle speed brought about by changes in road geometry or reductions in traffic congestion has important implications for the economic priority of different types of road improvement projects in Azerbaijan. Significant reductions in surface roughness can lead to very large reductions in road user costs for relatively modest expenditures and projects designed to achieve this will have high rates of return. This indicates that at the traffic levels prevailing in Azerbaijan road maintenance and rehabilitation projects designed to reduce roughness have a very high economic priority.

The opposite is probably true of expensive inter urban road widening projects designed for roads carrying less than 10,000 a day. The road user cost savings from the relief of congestion, which has hardly begun at these traffic levels, will inevitably be low in relation to the high construction costs. It is sometimes stated in Azerbaijan that "M" class inter state highways should be dual carriageways by definition since these are the prevailing standards in western Europe and other rich industrial regions. However, this ignores the fact that per capita income levels in Azerbaijan are less than 5 percent of those in the countries referred to and traffic levels on Azerbaijan "M" roads are only 5 - 20 percent of the levels prevailing on the equivalent highways in western Europe.

The nature and scale of potential road user cost savings can give extremely useful guidance on the nature of road improvements required in given circumstances. Ignoring this guidance can result in expensive errors in highway investment strategy.

Table 5.3 ROAD USER COSTS AND DESIRED VEHICLE SPEED

Desired Speed (kph)	Road User Cost (US$ / Vehicle km)					
	Car	Utility Vehicle	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
10	0.245	0.403	1.256	0.486	0.902	1.177
15	0.193	0.300	0.968	0.398	0.778	1.029
20	0.166	0.248	0.828	0.355	0.717	0.964
25	0.151	0.217	0.750	0.331	0.684	0.933
30	0.140	0.196	0.702	0.316	0.664	0.915
35	0.133	0.182	0.672	0.306	0.651	0.904
40	0.127	0.172	0.651	0.299	0.642	0.896
45	0.123	0.164	0.635	0.294	0.635	0.890
50	0.121	0.158	0.623	0.290	0.631	0.885
55	0.120	0.154	0.614	0.288	0.627	0.882
60	0.119	0.150	0.606	0.285	0.624	0.879
65	0.118	0.148	0.600	0.283	0.621	0.876
70	0.117	0.145	0.595	0.282	0.619	0.874
75	0.116	0.144	0.591	0.281	0.617	0.872
80	0.116	0.142	0.587	0.280	0.615	0.871
85	0.116	0.141	0.584	0.279	0.614	0.870
90	0.116	0.140	0.582	0.278	0.612	0.869
95	0.116	0.139	0.580	0.278	0.611	0.868
100	0.116	0.139	0.578	0.277	0.610	0.867
105	0.116	0.139	0.576	0.277	0.609	0.867
110	0.116	0.138	0.575	0.277	0.608	0.866

Source: Consultant's estimate based on HDM-III vehicle operating cost analysis.

6. ENGINEERING STUDIES

6.1 General

From February to May 1997 the engineering survey was carried out, comprising the collection of information and data bases from Azeravtoyol and the field investigation of road and bridge condition. The road inspections were held up by bad weather with periods of frost and snow.

The field survey further included all investigation, field inspection and inventories required to undertake the studies and to prepare the data for the appraisal by HDM III method.

6.2 Road Design Standard Aspects

6.2.1 Pavement Design Standards

The standard for the pavement design used in Azerbaijan is essentially based on the theory of flexible pavement development by the research institutes from the Former Soviet Union under the leadership of Professor Ivanov. The governing factor for pavement design is the so-called stiffness modulus of the pavement structure.

The pavement design general depends on:

- planned design life
- traffic forecast
- properties of subgrade

Pavement design is determined from a set of formulas, tables and graphs. Current design standards specify that pavements should be designed for a 10 ton axle load, but for many years a 6 ton design axle load was the norm.

The above consideration for pavement design have been discussed in detail in the Consultant's study on the REVIEW OF ROAD DESIGN STANDARDS (January 1997) which is attached in Appendix 6.1.

6.2.2 Geometric Design Standards

The Road Design Standards used in Azerbaijan base on those used during in the Former Soviet Union (FSU). The Soviet Union Standard (SNIP) 2.05.02-85 is still in use.

Based on the selected road category and the design speed the geometrical elements are defined. The main design parameters are:

Based on the traffic volume, respectively the traffic forecast, the economic and administrative values of the roads are classified into five categories:

Table 6.1: Road Categories

Road category	Traffic volume (ADT) PCU	vehicles	Economic and administrative value of roads
I-a	14,000	7000	Highways of state value (including for international connection)
I-b II	> 14,000 > 6,000 - 14,000	> 7000 > 3,000 - 7,000	Highways of state (not referred to I-a cat.), republican and oblast value
III	> 2,000 - 2,000	> 100 - 1,000	Roads of state, republican, oblast (region) value (not referred to I-b and II cat.) roads of local importance
IV	> 200 - 2,000	> 100 - 1,000	Roads of republican, oblast (region) and local value
V	> 2,000	> 100	Roads of local value

Source: Soviet Union Road Standard 2.05.02-85, 1986

A selection of the geometric standards is given below:

Table 6.2: Geometrical Design Standard

Category	Traffic volume (ADT)		Design speed (km/h)			No. of Lanes	Lane Width	Carriageway	Width of Shoulder		Width of Median		Total Road Width
	PCU	Vehicle	normal	winding terrain	difficult terrain				total	paved	total	paved	
I-a	> 14000	> 7000	150	120	80	4, 6 or 8	3.75 m	2 x 7.50 m or 2 x 11.25 m or 2 x 15.00 m	3.75 m	0.75 m	6.00 m	1.00 m	28.50 m or 36.00 m or 43.50 m
I-b	> 14000	> 7000	120	100	60	4, 6 or 8	3.75 m	2 x 7.50 m or 2 x 11.25 m or 2 x 15.00 m	3.75 m	0.75 m	5.00 m	1.00 m	27.50 m or 35.00 m or 42.50 m
II	> 6000 - 14000	>3000 - 7000	120	100	60	2	3.75 m	7.50m	3.75 m	0.75 m	-	-	15.00 m
III	> 2000 - 6000	>1000 - 3000	100	80	50	2	3.50 m	7.00m	2.50 m	0.50 m	-	-	12.00 m
IV	> 200 - 2000	>100 - 1000	80	60	40	2	3.00 m	6.00m	2.00 m	0.50 m	-	-	10.00 m
V	< 200	< 100	60	40	30	1	-	4.50m	1.75 m	-	-	-	8.00 m

Source: Road Standard 2.05.02-85, 1986 Soviet Union

However, for most of its length the Alyat to Georgian border road falls within the definition of a category II.

Accordingly the road category II the main design parameters are:

-	design speed	120 km/h
-	min. radius	800 m
-	max. gradient	4 %
-	min. crest curve	15,000 m
-	min. sag curve	5,000 m
-	min. crossfall	1.5 %

The Consultant has reviewed the Former Soviet Union road standards for the road/highway design and compared with European/Western standards. This has also been discussed in the attached REVIEW OF ROAD DESIGN STANDARDS (Appendix 6.1).

6.3 Existing Road Maintenance and Rehabilitation Practices and Standards

After a boom in road construction a grace period of several years - during which roads remained in good condition even without maintenance - followed by a period in which the need for maintenance surges dramatically.

Road maintenance and rehabilitation is based on the 'Technical Standard for Road Maintenance and Rehabilitation' of the Former Soviet Union including:

- Routine Maintenance:
  - cleaning of carriageway and shoulders
  - vegetation control
  - cleaning of ditches, drains and culverts
  - minor repairs for bridges, culverts and road furniture
  - repair of cracks
  - pothole patching
  - patching/grading of shoulders
- Periodic Maintenance: Resurfacing (either resealing or asphaltic overlay)
- Reconstruction of new pavement: Reconstruction of the pavement (subbase, base course, asphaltic road surface)
- Upgrading/Improvements: Improving the technical design standard of the road such as by widening or realignments

For the majority of maintenance activities there are already standards. However, the present activities for road maintenance and reconstruction are carried out on a low level only.

Some stretches of the road have received surface dressing, overlay and pothole repairs. However, the quality of these treatments has generally been poor. Patched potholes are not cut out cleanly or properly filled and compacted.

Road markings and signs have not been maintained.

6.4 Geotechnical Investigation

Sampling and Field Testing

In May 1997 the fieldworks for geotechnical investigation of the existing road was carried out and in general the testing included:

- Excavation of trial pits at the road edge/edge of carriageway down to the subgrade (natural ground or the surface of the embankment fill) including measurement of thickness of the pavement layers at the road edge and extraction of material samples.
- Excavation of trial pits at the carriageway to determine the structure of pavement (layer, thickness) including extracting materials samples to determine the bitumen content and the composition of the existing asphalt.
- Execution of dynamic penetrometer tests and drill-soundings to determine the compactness, the type and the moisture content in different layers of the soil.

Laboratory Testing

The samples taken from the trial pits were tested in the laboratory of Azeravtoyol. The following tests have been carried out:

- Moisture contents
- Sieve analysis according to SIS (Soviet Industrial Standards) and example sieve analysis to DIN (German Standard) for comparison
- Liquid limits according to SIS and example tests to DIN for comparison
- Plastic limits (PL) according to SIS and example tests to DIN for comparison
- sulphate content tests
- California Bearing Ratio Tests, as no CBR-test equipment was available, the tests have been carried out in Ashgabat/Turkmenistan where under the same project title a laboratory according to the western standards was established.

Details of the geotechnical investigations and laboratory testing are given in Appendix 6.3.

Geotechnical Recommendation

Alyat - km 407

According to the test result the bearing capacity of the upper layers of the existing pavement is already insufficient for the present and future traffic load. The existing base course material could be used as sub-base, proved that the CBR value of min. 30 % is reached and the designed thickness has been obtained. Should the material fail to reach 30 % soaked CBR, substitution is necessary. In this case the existing bituminous mixes can be re-used to reinforce the sub-base after milling, sieving and the addition of missing gradations.

km 407 - Georgian Border

The CBR - value of the gravel base layer reaches about 102 %, i. e. that the bearing capacity of the material itself is sufficient, but the thickness of this layer is varying from 10 cm to 55 cm. Therefore a levelling and reinforcing layer has to be partly included in the planning.

The detailed geotechnical report is presented in Appendix 6.3.

6.5 Environmental Investigation between Gazi - Mammad and Kyurdamir

The corridor of the existing road section between Gazi Mammad and Kyurdamir was inspected as well as the proposed construction material quarries in order to identify potential environmental impacts resulting from the proposed rehabilitation works on this road section.

The national and local environmental, health and safety regulating requirements defined in the Azerbaijan laws, norms/standards and regulations were studied.

Details of the environmental investigation, findings, assessments and recommendations are attached as Appendix 6.4, Environmental Assessment.

6.6 Pavement Strength

Pavement Strength Survey

In order to assess the remaining service life of the existing pavement, bearing capacity measurements by means of Falling Weight Deflectometer (FWD) were carried out on the project road from Alyat to the Georgian border in the period between April 12th, 1997 and April 21st, 1997.

The purpose of the measurement was to investigate the bearing capacity of the existing road pavement structure and define the necessary reinforcement for the traffic load of the planned 15 years design horizon.

The FWD used was a Phønix MI,Y 10000 equipped with 6 deflection sensors spaced at radical distances between 0 cm and 180 cm. The loading plate used was a 300 mm diameter plate above which was mounted a load cell to measure the load transferred to the road during the measurement.

As the measurement was supposed to be used for a feasibility study measurements were carried out every 500 m staggered in the right side slow lane and left side slow lane.

The results from each point measured are:

- contact pressure on the loading plate i Deflection (1) in the centre of the loaded area
- deflection (2) outside the loaded area (normally 210 mm from the centre of loading)
- deflection (3) outside the loaded area (normally 330 mm from the centre of loading)

- deflection (4) outside the loaded area (normally 510 mm from the centre of loading)
- deflection (5) outside the loaded area (normally 810 mm from the centre of loading)
- deflection (6) outside the loaded area (normally 1270 mm from the centre of loading)
- temperature of the asphalt in a depth of 4 cm
- description of the position where the measurement was taken

The results from each point are stored in a datafile on the computer attached to the FWD.

All the data from the measurements have then been put onto a computer together with information about the traffic prognosis for the next 15 years, and information about the existing road construction.

From the measured deflections and the thicknesses given, a computer programme calculates the E-moduli of the layers in the measured point. These E-moduli and the traffic prognosis build the basis for calculation of the necessary overlay needed in each measured point for the design period.

Along with the data on expected traffic for the design period and layer thickness, the E-moduli of the road pavement were calculated to determine the service life and required overlay.

Structural Number

In the Highway Design and Maintenance Model (HDM) it is necessary to use measures of pavement strength which summarise the complex interactions between material types, stiffnesses and layer thicknesses. The Structural Number (SN) was found to be the most statistically significant measure of pavement strength affecting the determination of pavement (AASHTO-Test). The SN is defined as a linear combination of the layer strength coefficient and thickness of the individual layers.

The calculation of the structural numbers based on the established E moduli from the FWD measurements. Following principles have been used for the calculation:

- Calculation of the E moduli of each layer
- Calculation of the CBR values for the unbound layers, using the following formula
- CBR = (E(I/17,6)^1,56 (Listers equation)
- Calculation of the layer coefficient for each layer, using the following equations

  For asphalt layers : a(I) = 0,1782*LnE(I) - 0,9917

  For unbound granular layers : a(I) = 0,0844*LnE(I) - 0,3541

- Calculation of the modified structural number contribution of the subgrade, using the following equation

  SNSG = 3,51*log(CBR) - 0,85* (log(CBR))^2 - 1,43

- Calculation of the SNC value using the following equation,

  SNC = 0,394* (a(1)*h(1) + a(2)*h(2) + a(3)*h(3)) + SNSG

The structural numbers for the individual measuring points are presented in Appendix 6.5, Pavement Strength Report.

6.7 Road Condition and Roughness

General Description of the Study Road

The beginning of the study road (M 4) is the junction with the Baku - Astran Road (M 3). The road runs through flat to rolling terrain. At km 223.47 the road joins the M 1. After the junction the study road continues in western direction on the M 1 to the Georgian border.

According to the FSU standard the road is characterised as category II road. The total length of the study road is 444,135 km.

The horizontal alignment, longitudinal gradients and slope stability are generally acceptable.

The road is, however, beset by long straights that may cause problems from headlights at night and that certainly encourage speeding by drivers of cars.

The road was constructed during the Former Soviet Union (FSU) period to a generally adequate design standard for the reduced traffic. However, poor drainage provisions, poor compaction, poor control of vertical finish, incorrect grading aggregate and use of poor quality bitumen have resulted in a road with many problematic areas where strengthening/reconstruction is now required.

Width of the Road

The road from Alyat to the Georgian border is a two lane road with short sections where the road is upgraded to category I (four lanes).

These four lane sections are:

km 5+300 - km 10+800	carriageway width 25.00 m - 28.30 m
km 220+370 - km 223+080	carriageway width 19.00 m - 21.40 m
km 289+990 - km 292+080	carriageway width 16.30 - 20.70 m

Table 6.3: Average Road Width

Section	From km	To km	Average Road Width Carriageway (m)	Shoulder left (m)	Shoulder right (m)
M 4, Alyat - Gazi Mammad	0,00	43,45	8,14	3,07	2,93
M 4, Bypass Gazi Mammad	43,45	58,98	9,47	3,02	3,03
M 4, Gazi Mammad - Kyurdamir	58,98	124,30	8,62	3,05	3,24
M 4, Kyurdamir - Ujar	124,30	170,50	8,94	2,82	2,95
M 4, Ujar - Yevlakh	170,50	216,50	9,39	3,05	2,99
M 4, Bypass Yevlakh	216,50	223,47	10,94	2,85	2,84
M 1, Yevlakh - Mingechevir	280,68	288,70	8,82	3,25	3,12
M 1, Mingechevir - Ganja	288,70	333,50	9,12	3,11	2,96
M 1, Bypass Ganja	333,50	369,50	7,14	2,77	2,61
M 1, Ganja - Tovuz	369,50	431,00	8,56	3,10	3,00
M 1, Tovuz - Gazakh	431,00	456,50	8,51	2,99	3,02
M 1, Bypass Gazakh	456,50	463,50	8,17	2,93	3,05
M 1, Gazakh - Georgian Border	463,50	501,35	7,59	2,50	2,48

Pavement Composition

A total of 30 trial pits were undertaken to determine the pavement structure. Trial pits were dug by hand into the pavement. The composition of the existing pavement differs from road section to road section. In most of the cases the pavement consists of two asphalt layers laid on a granular base. Depending on the overlaying work the present thickness of the combined bituminous layer varies from 40 mm to 160 mm. The top layer of asphalt concrete (A/C) is normally made using aggregate > 15 mm size. The same material was used for overlays. The second layer is very similar to the top layer, but with aggregate size from 20 mm to 40 mm. The granular layer is of varying thickness and usually made of a gravel, sand mixture.

Table 6.4: Existing Pavement Layer

Road chainage	Surface Layer asphalt - concrete (mm)	Second Layer asphalt - concrete (mm)	Basecourse gravel, crushed stone and bitumen (mm)	Subbase gravel sand (mm)	Total pavement thickness (mm)
M 1 km 493.350	40	-	-	230	270
M 1 km 477.350	40	60	-	300	400
M 1 km 460.350	40	120	-	180	340
M 1 km 445.350	40	100	-	120	260
M 1 km 427.350	70	50	30	200	350
M 1 km 411.350	40	45	-	130	215
M 1 km 394.350	30	50	-	100	180
M 1 km 379.350	50	30	-	300	380
M 1 km 366.350	50	30	-	300	380
M 1 km 351.350	30	40	-	>1000	>1070
M 1 km 335.350	50	-	-	>500	>550
M 1 km 320.350	60	-	40	>1000	>1100
M 1 km 304.350	40	60	-	>1000	>1100
M 1 km 289.350	60	60	-	500	620
M 4 km 217.135	40	60	-	100	200
M 4 km 203.135	40	60	-	100	200
M 4 km 187.135	50	70	-	300	420
M 4 km 167.350	30	60 - 80	-	80 - 100	170 - 210
M 4 km 152.135	40	50	-	200	290
M 4 km 137.135	30	60	-	220	310
M 4 km 122.135	50	70	-	300	420
M 4 km 106.135	30	70	-	250	350
M 4 km 91.135	50	-	-	230	280
M 4 km 75.135	50	70	-	180	300
M 4 km 60.135	30	70	-	70	170
M 4 km 46.135	40	60	100	220	420
M 4 km 30.135	40	-	60	100	200
M 4 km 15.135	30	40	-	200	270
M 4 km 0.135	30	60 - 70	-	100	190 - 200

Surface Condition

The road condition data was reduced by visual inspection. The inspection team was trained by the Consultant. The visual inspections were carried out to observe and record the extend and severity of surface defects. Following information was collected:

- cracks in m²
- alligator cracks in m²
- potholes in m²
- settlements in m²
- rutting in m²
- patched area in m²

The measurement of chainage was carried out by using a distance measuring wheel and resulted in an accurate measurement of the road length between the km-part, the location of bridges, culverts, junctions etc.

The road condition survey shows that the present condition of the pavement also subjects large variations. Part of the sections along the road are still in acceptable working condition whilst others already reach a critical phase with typical indications such as cracking and the advanced disintegration of the structural layers.

The surface deficiencies are summarised in the table below.

Table 6.5: Deficiencies of surface

Section	From km	To km	Cracks (%)	Alligator Cracks (%)	Potholes (%)	Settlements (%)	Rutting <=10mm (%)	Rutting >10mm (%)	Patched Area (%)
M 4, Alyat - Gazi Mammad	0,00	43,45	0,3	1,2	0,1	0,6	0,0	0,0	0,1
M 4, Bypass Gazi Mammad	43,45	58,98	0,2	1,2	0,1	1,5	0,0	0,4	0,3
M 4, Gazi Mammad - Kyurdamir	58,98	124,30	0,5	2,7	0,1	1,1	0,0	0,7	0,3
M 4, Kyurdamir - Ujar	124,30	170,50	0,8	2,8	0,1	0,8	0,0	0,2	0,1
M 4, Ujar - Yevlakh	170,50	216,50	0,5	1,8	0,1	0,4	0,0	0,1	0,1
M 4, Bypass Yevlakh	216,50	223,47	0,2	0,7	0,1	1,4	0,0	0,3	0,0
M 1, Yevlakh - Mingechevir	280,68	288,70	0,2	1,3	0,2	1,4	0,0	0,6	0,2
M 1, Mingechevir - Ganja	288,70	333,50	0,3	1,4	0,1	0,5	0,0	0,7	0,0
M 1, Bypass Ganja	333,50	369,50	0,8	4,2	0,1	0,4	0,0	0,0	0,0
M 1, Ganja - Tovuz	369,50	431,00	0,7	3,0	0,1	0,8	0,0	0,4	0,0
M 1, Tovuz - Gazakh	431,00	456,50	0,5	1,5	0,1	0,9	0,0	0,0	0,1
M 1, Bypass Gazakh	456,50	463,50	0,8	1,1	0,1	2,0	0,0	0,0	0,0
M 1, Gazakh - Georgian Border	463,50	501,35	0,6	2,4	0,1	1,4	0,0	0,1	0,0

Details are shown on the straight line diagrams in Appendix 6.

Rise and Fall

Rise and Fall was measured by the use of an optical inclinometer at each point of change. Data were recorded for the chainage of begin and end of a respective slope section and the reading of the slope was done in percent, + for ascending/rising and - for descending/falling road sections.

The results from the rise and fall measurement are presented in Appendix 6.8.

Curvature

The data of the horizontal curvature characteristic of the existing road were extracted from the topographical maps scaled 1 : 50,000. The average value of curvature was expressed in degrees per kilometre of road (degrees/km).

The horizontal curvature characteristic for each section are summarised in the table below:

Table 6.6: Curvature of existing road

Section	From km	To km	Curvature (°/km)
M 4, Alyat - Gazi Mammad	0,00	43,45	5,3
M 4, Bypass Gazi Mammad	43,45	58,98	16,7
M 4, Gazi Mammad - Kyurdamir	58,98	124,30	1,0
M 4, Kyurdamir - Ujar	124,30	170,50	1,1
M 4, Ujar - Yevlakh	170,50	216,50	1,3
M 4, Bypass Yevlakh	216,50	223,47	9,0
M 1, Yevlakh - Mingechevir	280,68	288,70	4,1
M 1, Mingechevir - Ganja	288,70	333,50	2,9
M 1, Bypass Ganja	333,50	369,50	8,6
M 1, Ganja - Tovuz	369,50	431,00	3,5
M 1, Tovuz - Gazakh	431,00	456,50	18,0
M 1, Bypass Gazakh	456,50	463,50	23,4
M 1, Gazakh - Georgian Border	463,50	501,35	12,4

Road Roughness

Road roughness is gaining increasing importance as an indicator of road condition and as a major determinant of road user costs.

The standard roughness scale which has been used is the International Roughness Index (IRI). The IRI is based on simulation of the roughness response of a car travelling, which expresses a ratio of the accumulated suspension motion of a vehicle, divided by the distance travelled during the test.

For the roughness measurement a Bump Integrator (BIU) developed by the United Kingdom Transport Research Laboratory (TRL) was taken to Azerbaijan and installed into a locally available mini-bus (UAZ). The BI unit comprises:

- **B**ump **I**ntegrator **U**nit (BIU)
- **C**ounter/display **U**nit (CU)

The bump integrator system measures the road roughness by recording the cumulative displacement of the vehicle axle relative to its body. The operating speed of 32 km/h (20 mph) and the measured distances were monitored by the longitudinal sensor unit.

The longitudinal sensor unit comprised:

- a longitudinal speed sensor of DATRON M
- DLSV software version
- a portable computer (palm top)

The microwave sensor uses microwave rays to register the relative movement of the sensor to the road surface. The respective signal of the sensor is processed by the software and the computer display shows the actual speed and the distance travelled.

Before starting and after completion of the measurements the bump integrator was calibrated. For calibration a road section with an about homogenous roughness was determined. This section was measured with a TRL MERLIN (**M**achine for **E**valuating **R**oughness using **L**ow-cost **In**strumentation). This device furnished directly the road roughness value. Along the same section of road several runs with the vehicle mounted bump integrator system were carried out and the calibration factor was determined.

Measurements with the bump integrator are expressed in mm/km and converted to International Roughness Index values using the following conversion equation:

$IRI = 0.0032\ (BI)^{0.89}$ (m/km)
where BI are the Bump Integrator units (mm/km).

Results were reported on the basis of an average value for about every kilometre. A summary of the average road roughness from the different sections is shown in the table below.

Table 6.7: Road Roughness

Section	From km	To km	Average IRI (m/km)
M 4, Alyat - Gazi Mammad	0.00	43.45	6.5
M 4, Bypass Gazi Mammad	43.45	58.98	6.6
M 4, Gazi Mammad - Kyurdamir	58.98	124.30	5.9
M 4, Kyurdamir - Ujar	124.30	170.50	5.6
M 4, Ujar - Yevlakh	170.50	216.50	4.8
M 4, Bypass Yevlakh	216.50	223.47	6.9
M 1, Yevlakh - Mingechevir	280.68	288.70	6.2
M 1, Mingechevir - Ganja	288.70	333.50	5.5
M 1, Bypass Ganja	333.50	369.50	5.8
M 1, Ganja - Tovuz	369.50	431.00	5.6
M 1, Tovuz - Gazakh	431.00	456.50	6.2
M 1, Bypass Gazakh	456.50	463.50	6.4
M 1, Gazakh - Georgian Border	463.50	501.35	5.2

The detailed records of the measurements and the resulting mean road roughness for each direction of lane are attached in Appendix 6.10.

Embankment Heights

Embankment heights, measured at the edge of the shoulder range from 1 to 6 m. The table below shows average embankment heights along the road.

Table 6.8: Average Embankment Heights

Section	From km	To km	Average Embankment Height m
M 4, Alyat - Gazi Mammad	0.00	43.45	2.1
M 4, Bypass Gazi Mammad	43.45	58.98	1.6
M 4, Gazi Mammad - Kyurdamir	58.98	124.30	1.5
M 4, Kyurdamir - Ujar	124.30	170.50	1.7
M 4, Ujar - Yevlakh	170.50	216.50	1.9
M 4, Bypass Yevlakh	216.50	223.47	1.7
M 1, Yevlakh - Mingechevir	280.68	288.70	1.1
M 1, Mingechevir - Ganja	288.70	333.50	1.2
M 1, Bypass Ganja	333.50	369.50	1.3
M 1, Ganja - Tovuz	369.50	431.00	1.5
M 1, Tovuz - Gazakh	431.00	456.50	1.0
M 1, Bypass Gazakh	456.50	463.50	2.6
M 1, Gazakh - Georgian Border	463.50	501.35	1.1

6.8 Drainage Condition

In total 729 culverts were inspected and records were taken for:

- geometrical data (length, diameter, etc.)
- material of culverts (concrete, metal, etc.)
- type of culvert (pipe, box, etc.)
- condition of culvert (damaged, broken, silted, etc.)

Further records were made where drainage deficiencies were encountered and the required measure for improvement was determined.

The field investigations of drainage conditions verified that, in general, flooding of the road will not be a problem.

Appendix 6.11 shows the location, types, size, length and deficiencies of existing culverts and lists the necessary maintenance and rehabilitation activities of inspected culverts.

The deficiencies of the culverts are summarised in the table below:

Table 6.9: Deficiencies of inspected Culverts

Section	From km	To km	No. of Culverts	Deficiencies Silted/Blocked % of Total	Sour % of Total	Struct. Damages % of Total
M 4, Alyat - Gazi Mammad	0,00	43,45	48	56,3		18,8
M 4, Bypass Gazi Mammad	43,45	58,98	23	69,6	8,7	21,7
M 4, Gazi Mammad - Kyurdamir	58,98	124,30	69	37,7	1,4	8,7
M 4, Kyurdamir - Ujar	124,30	170,50	59	59,3	1,7	3,4
M 4, Ujar - Yevlakh	170,50	216,50	52	53,8		1,9
M 4, Bypass Yevlakh	216,50	223,47	5			
M 1, Yevlakh - Mingechevir	280,68	288,70	12	58,3		
M 1, Mingechevir - Ganja	288,70	333,50	84	66,7		4,8
M 1, Bypass Ganja	333,50	369,50	63	42,9		3,2
M 1, Ganja - Tovuz	369,50	431,00	159	57,9	0,6	3,8
M 1, Tovuz - Gazakh	431,00	456,50	57	56,1		10,5
M 1, Bypass Gazakh	456,50	463,50	15	33,3		6,7
M 1, Gazakh - Georgian Border	463,50	501,35	83	61,4	1,2	6,0

Most of the inspected culverts were concrete pipes of similar sizes and in good or satisfactory condition. The most common and serious defects observed were cracks and corrosion in the culvert concrete and silted/blocked culverts. These deficiencies can be corrected or repaired with proper maintenance.

Except for blockages of culverts by embankment fill, the culverts reviewed an investigated by the Azeravtoyol engineer appear to be hydrologically adequate.

6.9 Bridge Condition

The data of the existing documents were checked in the course of the field activities and, if necessary, corrected and/or supplemented.

The investigation of the condition of the structures was carried out by visual inspection and testing, using various equipment like profometer, rebound hammer, lens for measuring the cracks, etc.

The condition of non visible structures (e. g. foundations, approach slabs) could only be evaluated with reference to damages at other structural components which indicated the type and nature of the possible damage. All details of the records from the field investigations are listed for each bridge in table Bridge Condition Rating in Appendix 6.15. The last column of this table shows for each bridge the mark of condition which summarises the deficiencies encountered and which are the basis of the cost estimate.

Widening

For bridges with a width of carriageway and/or deckslab less than the width required by the design standard the optional widening has been studied.

The technical solution for the widening comprises two T-shaped prefabricated units of reinforced concrete on each side of the bridge. In order to avoid or to reduce settlements of the new structural unit independent foundation is proposed. The length of the spans of the widening always correspond to those of the existing bridge. The proposed solution for the widening is carried out as a shell, which means up to the upper edge of the beam.

New Structure

In order to evaluate the appropriateness of the rehabilitation and widening of an existing bridge, the cost of a corresponding new bridge were estimated. In the medium or long term under consideration of technical as well as economical aspects for some structures it might be the preferred solution to replace these instead of rehabilitation and widening/improvement.

New structures are planned as prefabricated bridges made of simply supported T-shaped prefabricated units of reinforced or prestressed concrete.

In case of some bridges having short spans it seems to be useful to replace them by a culvert.

6.10 Alternative Road Maintenance, Rehabilitation and Improvement Options

The road maintenance, rehabilitation and improvement measures are to propose to

- arrest ongoing deterioration
- repair existing deficiencies
- provide sufficient strengthening for the design period
- restore acceptable driving comfort
- reduce vehicle operation costs.

Homogenous section of the road were identified for one of the following measures:

Repair and Resealing

In sections where sufficient residual pavement bearing capacity was encountered, spot repairs are proposed, and a sealing shall prevent ingress of water into base course/sub-base layers. Spot repair comprises patching of potholes by bituminous mix, crack repairs, milling and re-filling of deformations/ruttings, followed by a double bituminous surface treatment.

Overlay

It is a precondition to overlaying that the base course and sub-base layers conform to the requirements of the specification or have shown satisfactory performance until now in case where tolerable values to the specification were determined.

The evaluation of the FWD measurements determines an overlay thickness to extend the resident pavement life to the planning horizon under consideration of traffic volume and traffic forecast respectively. Similar as the afore described surface treatment the overlay will seal the surface against ingress of water with resulting damages in the base course and sub-base layers. Prior to overlaying, existing spot damages must be repaired, deformations and ruttings must be milled and refilled by bituminous mixes. Local settlements or undulations must be level-filled prior to overlaying. The existing surfaces are irregular and not to proposed lines and levels. A relative thin overlay may either be laid carpetlike with indulation re-occurring at the surface, or a certain quantity of levelling material needs to be filled to restore line and levels before surfacing.

Overlays of less than 150 mm thickness cannot prevent reflective cracking. Cracking shall receive surface crack sealing under maintenance activities.

New Pavement/Reconstruction of Pavement

A new pavement/reconstruction of pavement is required in sections where

- the pavement has already failed
- sub-standard materials of sub-base and/or base course do not provide the required bearing capacity
- the pavement has reached the end of its service life
- the cost of the required reinforcement, the overlay, exceeds the cost of a new pavement

Reconstruction is also necessary where severe deformation have occurred, which extend down into the base course. The existing bitumen is often very soft, and overlaying of the soft bitumen may lead to damages in an overlay. Reconstruction will re-use the existing bituminous material after milling and sieving. Missing materials gradations must be added before re-use as sub-base/base material.

Summarised three typical repair and rehabilitation options were identified:

Case:	Repair and Resealing
Condition:	Existing pavement is in good condition with occasional depressions, potholes or cracks, the existing pavement bearing capacity is sufficient
Solution:	Repair of damages, followed by a resealing
Case:	Spot Repair and Overlay
Condition:	Existing pavement is in fair condition with minor damages, pavement bearing capacity need a reinforcement
Solution:	Repair of damages and placing of new asphalt layer
Case:	Rehabilitation of Pavement/New Pavement
Condition:	Existing pavement is heavily damaged, road base does not correspond with the technical specifications, the pavement has reached the end of its service life.

Solution: Remove asphalt layer and place new pavement

Preliminary Pavement Design for New Pavement

Considering the traffic forecast with the corresponding number of Equivalent Standard Axles (ESA) and the subgrade CBR new pavements/reconstruction of pavement was design in accordance with TRL Road Note 31:

Design life: 15 years
Traffic classes: T 7 (11.84 * 10^6 ESA in each direction)
Subgrade strength classes (CBR%): S2 (CBR 3)

- 50 mm Flexible bituminous surface
- 175 mm Bituminous roadbase
- 225 mm Granular subbase
- 200 mm Granular capping layer or selected subgrade fill (Chart 7)

According to the Road Note the subbase CBR shall be at least 30 % and the base course CBR shall be at least 80 %.

The detailed calculation of standard axles are attached in Appendix 6.14.

Pavement Rehabilitation Solution

Based on the field investigations, the laboratory test results of subgrade and road base the preliminary pavement rehabilitation design was developed. The rehabilitation needs were therefore determined on the basis of the optimum work to restore and preserve the integrity of previous and followed road investments. Hence, realignment was not considered.

The summarised preliminary rehabilitation solution for each road section is shown in the table below:

Table 6.10: Repair/Rehabilitation Solutions

Chainage		Resealing	Overlay 40 mm	Overlay 60 mm	Overlay 90 mm	Reconstruction/ New Pavement
from (m)	to (m)	length (m)	length (m)	length (m)	length (m)	length (m)
Section 1 - M 4: Alyat - Gazi Mammad; km 0+000 - 43+450						
0	43.450					43.450
Section 2 - M 4: Bypass Gazi Mammad; km 43+450 - 58+980						
43.450	58.980					15.530
Section 3 - M 4: Gazi Mammad - Kyurdamir; km 58+980 - 124+300						
58.980	124.300					65.320
Section 4 - M 4: Kyurdamir - Ujar; km 124+300 - 170+500						
124.300	170.500					46.200
Section 5 - M 4: Ujar - Yevlakh; km 170+500 - 216+500						
170.500	216.500					46.000
Section 6 - M 4: Bypass Yevlakh; km 216+500 - 223+468						
216.500	223.448					6.948
Section 7 - M 1: Yevlakh - Mingechevir; km 280+683 - 288+700						
280.683	288.700					8.017
Section 8 - M 1: Mingechevir - Ganja; km 288+700 - 333+500						
288.700	333.500					44.800
Section 9 - M 1: Bypass Ganja; km 333+500 - 369+500						
333.500	369.500					36.000
Section 10 - M 1: Ganja - Tovuz; km 369+500 - 431+000						
369.500	407.250					37.750
407.250	412.000		4.750			
412.000	414.250				2.250	
414.250	418.000		3.750			
418.000	420.250			2.250		
420.250	425.250		5.000			
425.250	429.750				4.500	
429.750	431.000		1.250			
Section 11 - M 1: Tovuz - Gazakh; km 431+000 - 456+500						
431.000	433.250		2.250			
433.250	437.250				4.000	
437.250	441.250				4.000	
441.250	444.250			3.000		
444.250	448.750				4.500	
448.750	451.000					2.250
451.000	456.500			5.500		
Section 12 - M 1: Bypass Gazakh; km 456+500 - 463+500						
456.500	456.750			250		
456.750	458.750				2.000	
458.750	463.500		4.750			
Section 13 - M 1: End of Bypass Gazakh - Georgian Border; km 463+500 - 501+350						
463.500	467.750		4.250			
467.750	470.750		3.000			
470.750	473.750					3.000
473.750	477.250		3.500			
477.250	480.250		3.000			
480.250	482.250				2.000	
482.250	484.250		2.000			
484.250	489.750		5.500			
489.750	501.350			11.600		
TOTAL			**43000**	**22600**	**23250**	**355.265**

Rehabilitation option 'Overlay' and 'Reconstruction/New Pavement' is illustrated in the typical cross section presented in Appendix 6.16.

7. THE COSTS OF ALTERNATIVE MAINTENANCE, REHABILITATION AND IMPROVEMENT OPTIONS

7.1 General

This chapter sets out the costs of the road maintenance, rehabilitation options which have been defined and subjected to economic and engineering feasibility analysis. The costs used in the economic analysis are economic costs. These exclude taxes and duties and other transfer payments. No attempt has been made to adopt shadow prices for specific cost items such as foreign exchange since there does not appear to be any convincing economic case for doing so. The only cost item to be adjusted is the cost of passenger time and this is discussed in Chapter 5.

7.2 Unit Costs of Road Maintenance, Rehabilitation and Improvement

The unit rates are based on prices from Azeravtoyol and relate to prices from other international projects in the region (e. g. Armenia Highway Project, Airport Tashkent).

Rates and prices estimated in US $ are converted to Manat at the exchange rate of 4050 Manat to the US dollar (May 1997).

Following Unit Prices of Material and Services have been used in the cost estimation:

Description	Unit	Rate US $
Bitumen	ton	121.00
Chippings	m^3	23.20
Sand	m^3	18.50
Gravel	m^3	20.20
Concrete M 300	m^3	64.20
Reinforced concrete M 300	m^3	126.00
Plant-mixed concrete M 200	m^3	74.00
Plant-mixed concrete M 300	m^3	87.60
Plant-mixed concrete M 400	m^3	97.50
Reinforced concrete pipe culvert (1000 mm)	m	237.00
Reinforced concrete pipe culvert (1250 mm)	m	296.30
Reinforced concrete pipe culvert (1500 mm)	m	345.70
Box culvert (2000 x 2000 mm)	m	732.00
Traffic sign	no.	172.90
Crash barrier		23.20
Marker post	no.	34.57
Km post	no.	148.00
Marking	m^2	1.30
Fuel (diesel)	litre	0.22
Fuel (petrol)	litre	0.37
Electric power	kw/h	0.09

Labour (includes social security cost, etc.)	hour	1.40
Transportation	m³/km	0.70

In addition to the Unit Prices of Materials and Services following **Unit Costs for different Maintenance and Rehabilitation Works** have been worked out:

Description	Unit	Rate US $
Sealing	m²	0.81
Tack coat	m²	0.54
Overlay 40 mm	m²	8.22
Overlay 60 mm	m²	9.70
Overlay 90 mm	m²	21.07
Levelling course 30 mm	m²	7.35
Reconstruction	m²	45.93
Patching	m²	22.89
Clean out of culverts	m	4.20
Shoulder regravelling	m²	0.75
Cut to spoil (incl. Transport 2 km)	m³	1.46
Milling of existing bit. Pavement	m²	2.72
Remove of existing bit. Overlay	m²	3.21
Land acquisition	ha	88.90
Removal of top soil, stockpiling and re-use	m³	6.01
Borrow to fill (incl. Transport 5 km)	m³	9.50
New Construction	m²	45.03

The cost of asphalt concrete was estimated by the Consultant from the cost of aggregate, filler, bitumen and asphalt plant operating costs.

Further detailed information is included in Appendix 7.1 and 7.2.

7.3 Unit Costs of Bridge Maintenance, Rehabilitation and Improvement

List of Items and Prices

Description of Work	unit	Unit Price depending on the Size of the Structure Size A (< 100m²)	Size B (100-500m²)	Size C (> 500m²)
(All prices in US$)				
1. Demolition Works:				
Takes down or breaks off of damaged and replacing structural units and surface layers including removal and disposal	m³	126	70	56
Additional costs for scaffoldings	m³	54	30	24
2. Earthwork:				
All work to the construction or reconstruction of dams, embankments and backfillings of abutments or wingwalls. This position contains particularly the transport to the site, the placing and the compaction of suitable soil.	m³	8	8	8
3. Slope protection:				
The slope protection is executed in two layers: min. 150 mm broken stone; 120 mm cast in place concrete with wire fabric 0.2m x 0.2m ∅ 6mm. The item includes the transport to the site and the placing	m²	30	30	30
4. Repair of concrete surfaces:				
Repair of small damages of the concrete surface with concrete replacement system including corrosion protection of visible reinforcement: 1. Investigation of the surface and specification of the areas to repair; 2. Preparation of the underground; 3. Corrosion protection of visible reinforcement; 4. Application of primer; 5. Repair of the surface with polymer modified mortar. This item also includes all necessary scaffold work for the execution of the repairing works.	m²	500	280	225
5. Repair of wearing surface:				
Repair of local damages of the wearing surface: 1. Milling off of the wearing surface in the area of the damages max. 50 mm deep; 2. Construction of a new wearing surface from asphalt concrete 50 mm thick in the area of the local damages	m²	70	40	30

Description of Work	unit	Unit Price depending on the Size of the Structure		
		Size A (< 100m²)	Size B (100-500m²)	Size C (> 500m²)

6. New wearing surface:

Construction of a new wearing surface from one layer asphalt concrete 50 mm thick

	m²	23	13	10

7. New sealing and new wearing surface:

Sealing from bitumen sheets on a levelling layer of reinforced concrete, protective layer mastic asphalt and surface layer asphalt concrete

1. Cleaning of the bridge surface
2. Construction of a concrete levelling layer with a thickness of 80 to 90 mm reinforced with steel bar ∅ 10 mm and spacing 0.10 m each direction
3. Prime coat application; sealing
4. Sealing from one layer weldable bitumen sheets
5. Protective layer mastic asphalt thickness 35 mm
6. Wearing surface asphalt concrete thickness 35 mm

	m²	137	76	61

8. Repairing of sidewalks:

Existing sidewalk of reinforced concrete:

1. Repair of the concrete surface
    - Investigation of the surface and determination of the areas to be repaired
    - Preparation of the underground
    - Corrosion protection of visible reinforcement
    - Application of primer
    - Repair of the surface with polymer modified mortar
2. Rehabilitation (sealing) of the joints between the sidewalk blocks
3. Construction of a mastic asphalt surface with a thickness of 35 mm with sealing joints over every joint between the sidewalk blocks

	m²	85	47	38

Description of Work	unit	Unit Price depending on the Size of the Structure		
		Size A (< 100m²)	Size B (100-500m²)	Size C (> 500m²)

9. New sidewalks:

Construction of new sidewalks from prefabricated reinforced concrete elements

1. Cleaning of the bridge surface
2. Construction of a concrete levelling layer with a thickness from 70 - 80 mm, reinforced with steels ∅ 10 mm, spacing 0.10 m each direction
3. Installation of disc anchors to the anchorage of the prefabricated elements
4. Construction of the sealing
   - Prime coat application; sealing
   - Sealing from one layer weldable bitumen sheets
   - Protective layer from glasfiber-bitumen sheet
5. Assembly of the prefabricated elements including design of the joints
6. Construction of a mastic asphalt surface with a thickness of 35 mm with sealing joints over every joint between the sidewalk blocks

This item also covers the production of the prefabricated elements and the transport to the site.

	unit	Size A	Size B	Size C
	m²	600	335	270

10. Repair of parapets:

Repair of smaller damages of steel railings and new corrosion protection

1. Repair of deformed parts; replacement of missing parts
2. Repair of damaged anchorage's
3. Preparation of the surfaces of the railing
4. Application of a corrosion protection system

	unit	Size A	Size B	Size C
	m	24	13	11

11. New parapets:

Bar railing of galvanised steel with wire-cable in the handrail h=1.00 m.

1. Assembly of the railing
2. Application of a corrosion protection system

This position also includes the production of the railing as well as the transport to the site.

	unit	Size A	Size B	Size C
	m	315	175	140

12. New massive concrete barriers:

Construction of massiv concrete barriers as standard New Jersey profile from prefabricated reinforced concrete elements, h = 0.81 m

This item contains the production of the prefabricated elements, the transport to the building site as well as the erection.

	unit	Size A	Size B	Size C
	m	270	150	120

Description of Work	unit	Unit Price depending on the Size of the Structure Size A (< 100m²)	Size B (100-500m²)	Size C (> 500m²)
13. Expansion joints:				
a.) Construction of the expansion joints as asphalt joints across the total width of the bridge (in the area of sidewalks and carriageway)	m	1910	1060	850
b.) Construction of the expansion joint as waterproof joint constructions with one sealing profile across the total width of the bridge (in the area of sidewalks and carriageway).	m	1980	1100	880
14. New drainage facilities: Installation standard gullies with shutter and dirt trap in existing waste pipes.	no.	750	750	750
15. Maintenance of bearings: Clean, application of a corrosion protection system and greasing of steel slide bearings.	no.	55	55	55
16. New approach slabs: Construction of new approach slabs from prefabricated reinforced concrete elements. 1. Construction of the foundations of the approach slabs 2. Assembly of the prefabricated slabs 1.00 m x 6.00 m, 0.25 m thick 3. Sealing of the approach slabs • Construction of a concrete levelling layer 70 mm thick with reinforcement ∅ 6, span 0.1 m each direction • Prime coat application; sealing • Sealing from one layer weldable bitumen sheets • Protective layer mastic asphalt 35 mm thick The position also includes the production of the prefabricated elements and the delivery to the site.	m	1410	1410	1410
17. New chamber walls: Construction of new chamber walls from reinforced concrete, thickness = 0.40 m, height = 1.50 m. The new chamber walls has to be anchored on the crosshead of the abutment.	m	195	195	195

Description of Work	unit	Unit Price depending on the Size of the Structure Size A (< 100m²)	Size B (100-500m²)	Size C (> 500m²)

18. All kinds of concrete works:

All kinds of concrete work which are not described by the items above.
The item contains the necessary formwork and reinforcement as well as the delivery and the placing of the fresh concrete and the curing of the concrete.

	unit	Size A	Size B	Size C
	m^3	570	320	260

19. Lifting up of the superstructure:

Lifting up of the superstructure at the end of one span for changing or repairing of bearings or the rehabilitation of the crosshead or the production of a new crosshead.
Item includes all necessary work including scaffoldings.

	unit	Size A	Size B	Size C
	no.	2755	2755	2755

20. Widening:

Widening with 2 precast T-beams on each side of the bridge.
(average reference quantities: system width of the beams 1.50 m; span 22.00 m)

1. Production of the foundations (bored piles)
2. Production of piers, abutments and crossheads
3. Assembly of the precast T-beams

The item includes production of the precast T-beams and delivery to the site.
The item also includes the sealing and the road surface for this part of the road which in addition arises from the widening.

	unit	Size A	Size B	Size C
	m^2	4556	2531	2025

21. New bridge:

Construction of a new bridge (without demolition works)

	unit	Size A	Size B	Size C
	m^2	4142	2301	1841

22. Culvert:

Construction of an culvert made of precast reinforced concrete frames, cross section 5.00mx5.00m, width 1.00m
The item includes all necessary work for the construction of the culvert.
(without demolition works)

	unit	Size A	Size B	Size C
	m	1831	1831	1831

7.4 Definition of Road Sections for Feasibility Analysis

The 444 km long Alyat - Georgian border road has been divided up into a number of homogeneous sections for feasibility study based on the results of the traffic, road condition surveys and design standards. These sections are as shown below:

Road no.	Location		Km from	Km to	Road length (km)
	start	finish			
M4	Alyat	Gazi-Mammad East	0.999	43.450	43.45
M4	Gazi-Mammad W	Kyurdamir	43.450	124.300	80.85
M4	Kyurdamir	Ujar	124.300	170.500	46.20
M4	Ujar	Yevlakh East	170.500	216.500	46.00
M4	Yevlakh East	Yevlakh West	216.500	223.468	6.97
M1	Yevlakh West	Mingechevir Station	280.683	288.700	8.02
M1	Mingechevir	Ganja East	288.700	333.500	44.80
M1	Ganja East	Ganja West	333.500	369.500	36.00
M1	Ganja West	Tovuz	369.500	431.000	61.50
M1	Tovuz	Gazakh East	431.000	456.500	25.50
M1	Gazakh East	Gazakh West	456.500	463.500	7.00
M1	Gazakh West	Georgian border post	463.500	501.350	37.85
					444.14

7.5 Definition of Alternative Road Maintenance, Rehabilitation and Improvement Strategies for Analysis

The number of alternative options or strategies analysed for each section depended on the section and its characteristics. For most sections the alternative options or strategies to be compared was limited to the following:

- Do minimum ("without project" situation). This may involve reconstructing the road when future pavement deterioration reaches the point where there is a danger of complete pavement destruction. This may be assumed to be when pavement roughness levels reach around IRI 9 m/km. This is the reference case with which the other options or strategies are compared.

- Spot improvements and overlay plus a subsequent overlay when future road roughness reaches IRI 6 m/km.

- Reconstruction of the existing road.

The spot improvement and overlay option was eliminated on technical grounds as being impracticable in the Kura river delta area east of Ganja.

Additional options were examined for the Gazi-Mammad - Kyurdamir section which was of particular interest to the European Bank for Reconstruction and Development (EBRD). These additional options included the following:

- Reconstruction of the existing pavement plus widening the road to 4 lane standard on the 15.52 km sub-section where there is an existing embankment to reduce the need for earthworks.

- Reconstruction plus widening to 4 lane standard on the 65.33 km sub-section where there is no existing embankment.

Originally, a spot improvement and overlay plus widening to 4 lane standard option was also considered, but this was abandoned when the overlay solution was judged to be technically inappropriate in the delta area.

Routine maintenance and patching is included in all options over the full project appraisal period.

7.6 The Costs of Alternative Options and Projects for Analysis

For each engineering alternative (pavement designs) the respective quantities were computed and the resulting bill of quantities was priced with the above-mentioned rates.

The bill of quantities respectively the cost estimate has been subdivided into six bills:

- Bill No. 1, General Items
  comprises the contractor's mobilisation, demobilisation, guarantees, ensurances, etc.

- Bill No. 2, Earthworks
  the rates shown comprise for example cut to fill, borrow to fill and regravelling of the shoulder

- Bill No. 3, Drainage
  includes all ancillary works for the repair, maintenance and completion of the drainage structure

- Bill No. 4, Bridges
  the rates comprise all materials and rehabilitation works of the respective structure

- Bill No. 5, Pavement Maintenance & Rehabilitation
  the rates include all required works for the repair, maintenance and reconstruction of the pavement

- Bill No. 6, Marking & Safety Works
  the road furniture comprises traffic signs, crash barriers, km posts and road marking

The initial costs of the alternative improvement options for each sections are summarised in Table 7.1.

Table 7.1 SUMMARY OF THE COSTS OF ALTERNATIVE IMPROVEMET OPTIONS

Road no.	Engineering section	Section no.	Location start	Location finish	Road length (km)	Project Description	Project Cost (US$ million)	Project Cost (US$ / km)
M4	M41	1	Alyat	Gazi-Mammad E	43.45	Reconstruction	25.68	591,024
M4	M42	3	Gazi-Mammad W	Kyurdamir	80.85	Reconstruction	41.06	507,792
M4	M431	4	Kyurdamir	Ujar	46.20	Reconstruction	24.68	534,091
M4	M432	5	Ujar	Yevlakh E	46.00	Reconstruction	24.94	542,196
M4	M433	6	Yevlakh E	Yevlakh W	6.97	Reconstruction	5.91	847,920
M1	M11	7	Yevlakh W	Mingechevir Station	8.02	Reconstruction	3.96	494,264
M1	M12	8	Mingechevir	Ganja E	44.80	Reconstruction	25.63	572,121
M1	M13	9	Ganja E	Ganja W	36.00	Reconstruction	15.01	416,833
M1	M141	10.1	Ganja W	Tovuz	44.50	Reconstruction	20.25	455,101
M1	M142	10.2	Ganja W	Tovuz	17.00	Overlay	1.67	98,366
					61.50	Link Improvement	21.92	356,491
M1	M151	11.1	Tovuz	Gazakh E	14.25	Overlay	2.41	169,208
M1	M152	11.2	Tovuz	Gazakh E	11.25	Reconstruction	7.91	703,111
					25.50	Link Improvement	10.32	404,753
M1	M161	12.1	Gazakh E	Gazakh W	3.50	Overlay	0.31	88,205
M1	M162	12.2	Gazakh E	Gazakh W	3.50	Reconstruction	2.60	742,857
					7.00	Link Improvement	2.91	415,531
M1	M171	13.1	Gazakh W	Georgian border post	31.35	Overlay	4.13	131,687
M1	M172	13.2	Gazakh W	Georgian border post	6.50	Reconstruction	8.22	1,264,154
					37.85	Link Improvement	12.35	326,166

The detailed cost breakdown by section and cost item are given in Appendix 7.3.

7.7 Road Costs in the Absence of Specified Improvement Options

In the economic analysis the costs taken into account over the life cycle of the specified road maintenance, rehabilitation and improvement projects include initial capital costs, subsequent recurrent road agency maintenance and rehabilitation costs and road user costs. An estimate is also made of what these various costs would be in the absence os the specified maintenance, rehabilitation or improvement projects.

Even with routine maintenance and patching the existing pavement will continue to deteriorate in the absence of the proposed projects. Taking a pessimistic view of the "Do Minimum" or "Without Project Situation" we have assumed in the economic and engineering feasibility studies using HDM III that routine maintenance and patching will continue to be undertaken and that pavement roughness will continue to rise. When pavement roughness reaches around IRI 9 m/km (very poor for a paved road) there would be a danger that the pavement would be lost unless the road was completely reconstructed. We have, therefore, assumed in the "Do Minimum" situation that reconstruction would be undertaken when roughness reaches IRI 9 m/km. This is why the reference case with which the improvement options are compared in the economic analysis is defined as a "Do Minimum" rather than "Do Nothing" situation. It also emphasises the point that failure to act in time can result in more expensive roadworks at some future date.

The full discounted life cycle costs incurred by the highway agency and by road users in the "With Project" and "Without Project" situations are set out in Table 7.2. The costs are divided into the following catagories for purposes of presentation:

- Capital costs
- Recurrent road agency costs
- Vehicle operating costs
- Passenger time costs

The road user costs comprising vehicle operating costs and passenger time costs are by far the largest category of costs and it is the saving in these costs which is the primary aim of the maintenance, rehabilitation and improvement projects.

Table 7.2 AZERBAIJAN - DISTRIBUTION OF ROAD AGENCY AND ROAD USER COSTS OVER THE APPRAISAL PERIOD

Scenario and Transport Cost Category	Present Value of Costs Over the Appraisal Period (1997 - 2021) @ 15 % Discount Rate - US$ million											
	Alyat - Gazi Mammad	Gazi Mammad - Kyurdamir	Kyurdamir - Ujar	Ujar - Yevlakh	Yevlakh E. -Yvlakh W.	Yevlakh W. - Mingechevir Station	Mingechevir Station - Ganja Bypass E.	Ganja Bypass	Ganja Bypass W. - Tovuz	Tovuz - Gazakh E.	Gazakh E. - Gazakh W.	Gazakh W. - Georgian border
DO MINIMUM - TOTAL	***247,88***	***472,84***	***265,82***	***262,26***	***40,71***	***36,22***	***240,25***	***174,72***	***323,46***	***125,56***	***34,30***	***176,27***
Capital	4,60	10,15	2,67	1,61	1,74	0,60	3,04	2,90	4,21	2,56	0,69	1,97
Recurrent	0,37	0,75	0,47	0,43	0,08	0,08	0,42	0,33	0,63	0,23	0,08	0,42
Total Road Agency Costs	4,97	10,90	3,14	2,04	1,82	0,68	3,46	3,23	4,84	2,79	0,77	2,39
Vehicle Operation	230,71	439,71	248,34	246,00	36,76	33,46	224,81	164,46	301,69	116,77	31,91	165,09
Travel Time	12,20	22,23	14,34	14,22	2,13	2,08	11,98	7,03	16,93	6,00	1,62	8,79
Total Road User Costs	242,91	461,94	262,68	260,22	38,89	35,54	236,79	171,49	318,62	122,77	33,53	173,88
OVERLAY (a) - TOTAL	-	-	-	-	-	-	-	-	***84,09***	***66,40***	***16,02***	***138,79***
Capital									1,63	2,37	0,30	4,04
Recurrent									0,15	0,11	0,02	0,28
Total Road Agency Costs	-	-	-	-	-	-	-	-	1,78	2,48	0,32	4,32
Vehicle Operation									77,90	60,75	14,93	127,56
Travel Time									4,41	3,17	0,77	6,91
Total Road User Costs	-	-	-	-	-	-	-	-	82,31	63,92	15,70	134,47
RECONSTRUCTION TOTAL	***235,72***	***463,83***	***251,88***	***248,98***	***39,04***	***34,61***	***228,12***	***166,88***	***232,95***	***53,87***	***16,55***	***29,22***
Capital	7,18	40,11	7,63	7,60	1,16	1,32	7,40	5,94	1,96	1,87	0,58	1,07
Recurrent	0,36	0,51	0,39	0,35	0,08	0,08	0,36	0,27	0,46	0,09	0,05	0,06
Total Road Agency Costs	7,54	40,62	8,02	7,95	1,24	1,40	7,76	6,21	2,42	1,96	0,63	1,13
Vehicle Operation	216,59	402,50	230,40	227,71	35,71	31,24	209,03	153,99	218,27	49,34	15,14	26,65
Travel Time	11,59	20,71	13,46	13,32	2,09	1,97	11,33	6,68	12,26	2,57	0,78	1,44
Total Road User Costs	228,18	423,21	243,86	241,03	37,80	33,21	220,36	160,67	230,53	51,91	15,92	28,09
RECONSTRUCTION + WIDENING (4 LANES) TOTAL	-	***499,52***	-	-	-	-	-	-	-	-	-	-
Capital		71,65										
Recurrent		1,07										
Total Road Agency Costs	-	72,72	-	-	-		-	-	-	-	-	-
Vehicle Operation		406,95										
Travel Time		19,85										
Total Road User Costs	-	426,80	-	-	-		-	-	-	-	-	-

Source: Consultants' analyses
Note: Total Costs are the discounted total costs to the economy of the specified option or strategy

7.8 Bridge Rehabilitation and Improvement Costs

The costs for the respective rehabilitation works were estimated and are summarised for each bridge in table Cost Estimate for Bridge Rehabilitation Works.

Further costs were estimated for necessary widening of the structures. The sum of the two cost components rehabilitation and widening are the cost for bridge improvement.

To verify the appropriateness of the proposed bridge improvement, costs for replacement of the structure are also included in the mentioned table.

8. ECONOMIC ANALYSIS OF ALTERNATIVE REHABILITATION AND IMPROVEMENT OPTIONS

8.1 General

This chapter sets out the results of the economic analysis of the road maintenance, rehabilitation and improvement projects on the road links comprising the M.4 / M.1 highway linking Alyat with the Georgian border. As mentioned in Chapter 2, the only project option considered in the eastern part of the highway lying within the Kura delta was reconstruction. The reason for this was that an overlay strategy was considered to be inappropriate on engineering grounds. West of Ganja, however, alternative overlay and reconstruction options were analysed on each link.

On the link between Gazi-Mammad and Kyurdamir the economic and engineering feasibility analysis was extended to include the option of widening the existing two-lane road to four lanes. This link was a test case to the extent that, given the relevant uniformity of traffic flows along the road, if widening was economically justified on this link, it would most likely be justified on most of the other road links. The results of this widening analysis are discussed in section 8.3.

The sensitivity of the results of the economic analyses to changes in selected input parameters has also been analysed and the results of this sensitivity analysis are discussed in section 8.4.

8.2 Results of the Economic Analysis

The results of the economic analysis of the road links making up the Alyat - Georgian border highway are summarised in Table 8.1. As mentioned earlier, reconstruction was considered to be the only appropriate option on engineering grounds for the eastern links between Alyat and the western part of the Ganja bypass. On this eastern part of the highway the option of overlaying was subjected to an initial economic analysis, but it was subsequently decided that overlays were not an appropriate engineering solution within the Kura delta region. The widening of the Gazi-Mammad - Kyurdamir link from two to four lane standard was also analysed in considerable detail and the results of this analysis are discussed in the next section.

The economic analysis shows that reconstruction of each of the links making up eastern part of the highway are economically justified for immediate implementation. Base year traffic levels of 4,000 - 7,000 and initial pavement roughness levels of IRI 4.5 - 6.5 m/km provide ample justification for reconstruction as reflected in Economic Internal Rates of Return (EIRR) of between 20 and 70 per cent and high positive Net Present Values (NPVs).

In the western part of the highway, between the western end of the Ganja bypass and the Georgian border, overlay and reconstruction solutions were adopted for different parts of each link depending on road conditions and characteristics. Table 8.1 shows the results of the overlay and reconstruction sub-sections separately and as a combined link rehabilitation project. The overlays generally result in higher economic rates of return, mainly because they are significantly cheaper, but the reconstruction sub-sections are also shown to be economically highly feasible.

The economic cost of the recommended program of overlays and reconstruction on the Alyat - Georgian border highway amounts to US$ 214 million or US$ 482,644 per kilometre. The overall positive NPV at a 15 per cent discount rate is US$ 102.7 million.

Table 8.1 AZERBAIJAN - SUMMARY OF THE ECONOMIC ANALYSIS RESULTS FOR THE M4 / M1 ROAD IMPROVEMENT PROJECTS

Road no.	Engineering section	Section no.	Location start	Location finish	Road length (km)	Pavement width (m)	No.of lanes	Surface type	Structural No. Existing	Structural No. Improved	Pavement Roughness IRI (m/km)	Base Year AADT	Project Description	Project Cost (US$ million)	Project Cost (US$ / km)	Economic Analysis Results NPV (US$ mn.)	NPV / Cost	IRR (%)
M4	M41	1	Alyat	Gazi - Mammad E	43,45	8,14	2	AC	4,81	5,06	6,5	6.090	Reconstruction	25,680	591.024	12,16	0,47	50,5
M4	M42	3	Gazi - Mammad W	Kyurdamir	80,85	8,62	2	AC	4,44	5,07	5,9	5.645	Reconstruction	41,055	507.792	9,008	0,22	20,1
M4	M431	4	Kyurdamir	Ujar	46,20	8,94	2	AC	4,83	5,03	5,6	7.401	Reconstruction	24,675	534.091	13,95	0,57	39,4
M4	M432	5	Ujar	Yevlakh E	46,00	9,39	2	AC	4,74	4,92	4,8	4.397	Reconstruction	24,941	542.196	13,28	0,53	32,5
M4	M433	6	Yevlakh E	Yevlakh W	6,97	10,94	2	AC	2,96	4,92	6,9	4.397	Reconstruction	5,910	847.920	1,68	0,28	72,8
M1	M11	7	Yevlakh W	Mingechevir Station	8,02	8,82	2	AC	4,61	5,18	6,2	5.000	Reconstruction	3,964	494.264	1,62	0,41	34,6
M1	M12	8	Mingechevir	Ganja E	44,80	9,12	2	AC	4,81	5,37	5,5	5.836	Reconstruction	25,631	572.121	12,14	0,47	38,7
M1	M13	9	Ganja E	Ganja W	36,00	7,14	2	AC	4,30	5,76	5,8	4.681	Reconstruction	15,006	416.833	7,83	0,52	41,0
M1	M141	10,1	Ganja W	Tovuz	44,50	7,81	2	AC	4,16	4,53	5,2	5.857	Reconstruction	20,252	455.101	9,34	0,46	33,3
M1	M142	10,2	Ganja W	Tovuz	17,00	8,83	2	AC	3,92	4,51	6,6	5.857	Overlay	1,672	98.366	6,41	3,83	85,8
					61,50								Link Improvement	21,924	356.491	15,75	0,72	47,8
M1	M151	11,1	Tovuz	Gazakh E	14,25	8,79	2	AC	3,80	4,74	5,3	4.932	Overlay	2,411	169.208	3,19	1,32	35,6
M1	M152	11,2	Tovuz	Gazakh E	11,25	7,81	2	AC	3,65	4,69	6,5	4.932	Reconstruction	7,910	703.111	2,10	0,27	45,2
					25,50								Link Improvement	10,321	404.753	5,29	0,51	39,8
M1	M161	12,1	Gazakh E	Gazakh W	3,50	7,67	2	AC	4,45	4,80	6,1	4.893	Overlay	0,309	88.205	1,15	3,73	77,7
M1	M162	12,2	Gazakh E	Gazakh W	3,50	8,49	2	AC	3,90	4,80	6,6	4.893	Reconstruction	2,600	742.857	0,58	0,22	35,9
					7,00								Link Improvement	2,909	415.531	1,73	0,59	56,8
M1	M171	13,1	Gazakh W	Georgian border post	31,35	7,59	2	AC	4,42	4,85	5,3	4.893	Overlay	4,128	131.687	7,52	1,82	38,2
M1	M172	13,2	Gazakh W	Georgian border post	6,50	7,59	2	AC	3,54	4,55	5,1	4.893	Reconstruction	8,217	1.264.154	0,75	0,09	28,3
					37,85								Link Improvement	12,345	326.166	8,27	0,67	36,5
					444,14									214,362	482.644	102,71	0,48	

8.3 The Economic Priority of Road Widening Projects

The stated policy of the Azerbaijan government is that all inter state highways (M roads) should be of 4 lane standard. This policy does not appear to have been established on the basis of rigorous economic and engineering feasibility analysis, but on the basis of physical planning norms inherited from the former Soviet Union. These stated that the traffic threshold for widening a road from two lanes to four lanes is AADT 7,000. This threshold would be considered to be far too low in the OECD countries where widening to four lane standard would generally not be considered at traffic levels of less than AADT 12,000. In fact, in OECD countries such as Germany and the United Kingdom the AADT thresholds would be above 15,000 and 20,000 respectively.

In order to establish whether there is a plausible case for widening the Alyat - Georgian border road to four lane standard it was decided to undertake detailed analyses on one link (Gazi Magomet - Kyurdamir). This was the link in which the EBRD had a special interest. If it could be demonstrated that widening the existing road to four lane standard would be economically justified for this link, then there would be a reasonable basis for assuming other links with similar traffic levels would be candidates for widening to four lane standard.

The analysis of the economic feasibility of widening the Gazi-Mammad - Kyurdamir link to four lane standard falls into two parts. The first part is concerned with the analysis based on best estimate traffic levels and traffic growth rates. The second part extends the analysis to answer the following two questions:

- What level of base year traffic is required for a widening project to achieve an EIRR of at least 15 per cent given best estimate traffic growth rates?
- What increase in assumed traffic growth rates would be required for the widening project to achieve an EIRR of at least 15 per cent given best estimate base year traffic?

The average existing pavement width on the Gazi-Mammad - Kyurdamir road link is just over 8 m which is generous for a two lane road. Existing pavement roughness is IRI 5.9 m/km which is quite high for a road carrying over 5,00 vehicle a day. The following alternative strategies are compared in the widening analysis:

- “Do Minimum” involving routine maintenance and patching until roughness reaches IRI 9 m/km at which point reconstruction is required if the pavement is not to be lost.
- Reconstruction of the existing two lane road.
- Reconstruction of the existing two lane road plus construction of two new lanes to bring the road up to four lane standard.

The 80.85 km link comprises two sections which have to be analysed separately. On 15.52 km of the link there is an embankment which can be used to reduce the earthworks requirements for the widening option. On the remaining 65.33 km of the link the full earthworks costs would be incurred with widening and the total costs of the four lane standard would, therefore, be higher. This latter section has been taken as being more typical of the Alyat - Georgian border highway as a whole and the analysis of traffic levels and / or growth rates required to make the widening option economically feasible have been based on this section. The respective initial economic costs per km of the reconstruction and widening options are as follows:

Reconstruction	US$ 507,792
Reconstruction + Widening	US$ 1,062,754 (15.52 km with existing embankment)
Reconstruction + Widening	US$ 1,255,902 (65.33 km with no embankment)
Reconstruction + Widening	US$ 1,218,825 (whole link)

The main benefits to be expected are reductions in vehicle operating costs, passenger time costs and possibly road maintenance costs. The reconstruction option will reduce pavement roughness and thus help to reduce road user costs. The additional economic benefits to be expected from the reconstruction plus widening options will be a reduction in actual or potential traffic congestion and the associated road user costs. The economic analysis therefore compares the following three sets of alternative options or scenarios:

- Reconstruction option with the "Do Minimum" scenario or without situation.
- Reconstruction plus widening with the "Do Minimum" scenario or without situation.
- Reconstruction plus widening with the Reconstruction only option (incremental analysis).

The reconstruction option will be economically feasible if it has a positive NPV at a 15 per cent discount rate and an EIRR of 15 per cent or over. The reconstruction plus widening option will also be economically feasible if it has a positive NPV at a 15 per cent discount rate and an EIRR of 15 per cent or over, but to be more feasible than the reconstruction only option it must have a higher NPV and EIRR. This aspect is covered in the incremental analysis. Since the object of widening is to reduce traffic congestion costs, these congestion relief benefits must be sufficient to justify the additional costs of widening. ***For the widening plus reconstruction option to be the best economic option it must have a positive incremental NPV at a 15 per cent discount rate or an incremental EIRR of 15 per cent or over.***

The results of the first part of the widening analysis are summarised in Table 8.2. This shows that the reconstruction option has an EIRR of 20.1 per cent and a high, positive NPV at the 15 per cent discount rate. The reconstruction plus widening option has EIRRs of only 9.4 per cent on the section with an existing embankment and 7.1 per cent on the remaining part of the link. The NPV of the reconstruction plus widening option is negative at a 15 per cent discount rate on both sub-sections and this solution is, therefore, premature. This is confirmed by the results of the incremental analysis which isolates the benefits from congestion relief. The incremental analysis shows that, when compared with the reconstruction only option, the reconstruction plus widening option has an incremental EIRR of 2.1 per cent for the section with an existing embankment and 1.2 per cent for the remaining section. The incremental NPV for both sections is highly negative.

The reason why the reconstruction plus widening option is premature is that it costs US$ 711,000 a kilometre more than the cost of reconstruction only. Existing traffic is too low to justify an expensive congestion relief project even with the relatively rapid traffic growth assumed.

Further economic analyses have been undertaken to establish what levels of base year AADT would be required, given best estimate growth rates, for the reconstruction plus widening option to be economically feasible for immediate implementation. Analyses were also undertaken to determine what increases in traffic growth rates would be required, given best estimate base year AADT, for the reconstruction plus widening option to be economically feasible for immediate implementation. The results of the first of these supplementary sensitivity analyses are summarised in Table 8.3 and illustrated in Figure 8.1. These show that base year AADT 3would have to be between 10,000 - 11,000 vehicles for the incremental EIRR to be equal to 15 per cent and the incremental NPV to be positive (at a 15 per cent discount rate). In other words, base year AADT would have to be double present levels, given best estimate traffic growth rates, for reconstruction plus widening to be economically feasible. The results for the 15 km of the link where there is an embankment would me marginally more favourable because of the slight reduction in earthworks costs, but the general conclusion would not be significantly different. The analysis summarised in Table 8.3 was undertaken on the section without the embankment because this is more typical of other links in the corridor for which the results of the widening analysis might be considered to be relevant.

The results of the analysis of the sensitivity of the reconstruction plus widening option's economic feasibility to more rapid traffic growth rates than those assumed are summarised in Table 8.4. Given best estimate base year AADT of 5,645 vehicles, traffic growth rates would need to be between 50 and 60 per cent higher than predicted for the option to be economically justified for immediate implementation. On the section of the link with an embankment traffic growth would have to be just over 55 per cent higher than predicted for the incremental EIRR to reach 15 per cent. On the section without an embankment traffic growth would need to be 80 per cent higher than predicted. This can be translated into required traffic growth rates as shown in Table 8.5.

Table 8.2: Azerbaijan - Evaluation of the Reconstruction and Widening of the Gazi Mammad - Kyurdamir Road Link

Year	Year No.	NET BENEFITS (US$ million) - Link/Section 112 - Gazi Mammad - Kyurdamir						INCREMENTAL ANALYSIS		
		Strategy 2A Reconstruction (no widening) - existing embankment section Length (km) 15.52	Strategy 2B Reconstruction (no widening) - other section Length (km) 65.33	Strategy 2C Reconstruction (no widening) - Whole linl Length (km) 80.85	Strategy 3. Reconstruction + Widening to 4 lanes - existing embankment section Length (km) 15.52	Strategy 4. Reconstruction + Widening to 4 lanes - other section Length (km) 65.33	Strategy 5. Reconstruction + Widening to 4 lanes - whole section Length (km) 80.85	Strategy 3. Reconstruction + Widening to 4 lanes - existing embankment section Length (km) 15.52	Strategy 4. Reconstruction + Widening to 4 lanes - other section Length (km) 65.33	Strategy 5. Reconstruction + Widening to 4 lanes - whole section Length (km) 80.85
1997	1	0.000	0.000	0.000	-0.012	-0.053	-0.065	*-0.012*	*-0.053*	*-0.065*
1998	2	-7.886	-33.193	-41.079	-0.012	-0.053	-0.065	*7.873*	*33.141*	*41.014*
1999	3	0.946	3.981	4.927	-16.349	-81.416	-97.764	*-17.294*	*-85.397*	*-102.691*
2000	4	1.111	4.677	5.788	1.120	4.712	5.832	*0.008*	*0.036*	*0.044*
2001	5	1.341	5.647	6.988	1.354	5.697	7.051	*0.012*	*0.051*	*0.063*
2002	6	1.616	6.801	8.417	1.633	6.876	8.509	*0.018*	*0.074*	*0.092*
2003	7	1.952	8.218	10.170	1.977	8.320	10.297	*0.024*	*0.103*	*0.127*
2004	8	2.356	9.918	12.274	2.388	10.054	12.442	*0.032*	*0.136*	*0.168*
2005	9	2.815	11.849	14.664	2.873	12.094	14.967	*0.058*	*0.245*	*0.303*
2006	10	3.346	14.087	17.433	3.431	14.444	17.875	*0.085*	*0.357*	*0.442*
2007	11	11.811	49.716	61.527	11.913	50.148	62.061	*0.103*	*0.431*	*0.534*
2008	12	-0.164	-0.688	-0.852	-0.038	-0.160	-0.198	*0.126*	*0.528*	*0.654*
2009	13	-0.216	-0.907	-1.123	-0.059	-0.247	-0.306	*0.157*	*0.660*	*0.817*
2010	14	-0.290	-1.222	-1.512	-0.083	-0.350	-0.433	*0.207*	*0.872*	*1.079*
2011	15	-0.399	-1.682	-2.081	-0.113	-0.474	-0.587	*0.287*	*1.207*	*1.494*
2012	16	-0.582	-2.449	-3.031	-0.151	-0.634	-0.785	*0.431*	*1.815*	*2.246*
2013	17	-8.735	-36.771	-45.506	-0.228	-0.961	-1.189	*8.507*	*35.810*	*44.317*
2014	18	0.098	0.415	0.513	-0.278	-1.172	-1.450	*-0.377*	*-1.586*	*-1.963*
2015	19	0.159	0.670	0.829	-0.376	-1.581	-1.957	*-0.535*	*-2.251*	*-2.786*
2016	20	0.241	1.016	1.257	-0.596	-2.508	-3.104	*-0.837*	*-3.524*	*-4.361*
2017	21	0.354	1.491	1.845	-0.750	-3.159	-3.909	*-1.105*	*-4.649*	*-5.754*
2018	22	0.523	2.204	2.727	-0.867	-3.648	-4.515	*-1.390*	*-5.852*	*-7.242*
2019	23	0.816	3.435	4.251	-0.654	-2.751	-3.405	*-1.470*	*-6.186*	*-7.656*
2020	24	1.229	5.172	6.401	0.433	1.822	2.255	*-0.796*	*-3.350*	*-4.146*
2021	25	1.662	6.997	8.659	11.347	55.951	67.298	*9.685*	*48.954*	*58.639*
Net Present Value								***Incremental NPV and IRR***		
@	0%	14.106	59.380	73.486	17.903	70.952	88.855	*3.797*	*11.572*	*15.369*
@	10%	4.226	17.788	22.013	-0.526	-11.792	-12.318	*-4.751*	*-29.580*	*-34.331*
@	15%	1.729	7.278	9.008	-3.349	-23.338	-26.687	*-5.078*	*-30.617*	*-35.695*
IRR (%)		20.1	20.1	20.1	9.4	7.1	7.5	*2.1*	*1.2*	*1.3*
Construction Cost								***Incremental Construction Costs***		
(US$ million)		7.881	33.174	41.055	16.494	82.048	98.542	*8.613*	*48.874*	*57.487*
(US$/km)		507.792	507.792	507.792	1.062.754	1.255.902	1.218.825	*554.961*	*748.110*	*711.033*
NPV/Cost (US$ million)								***Incremental NPV/Cost***		
@	0%	1.790	1.790	1.790	1.085	0.865	0.902	*0.441*	*0.237*	*0.267*
@	10%	0.536	0.536	0.536	-0.032	-0.144	-0.125	*-0.552*	*-0.605*	*-0.597*
@	15%	0.219	0.219	0.219	-0.203	-0.284	-0.271	*-0.590*	*-0.626*	*-0.621*

Table 8.3 Azerbaijan - Results of Economic Analysis of Reconstruction plus Widening

	NET BENEFITS (US$ million) Annual Average Daily Traffic - AADT (Base Year)					
	5,645 (Actual)	8,000	10,000	12,000	14,000	16,000
RECONSTRUCTION (65,33 km)						
Net Present Value						
@ 0%	59,382	116,489	175,320	231,367	311,165	374,931
@ 10%	17,789	41,681	65,758	91,035	121,867	150,651
@ 15%	7,279	24,629	41,926	60,491	82,378	103,554
IRR (%)	20,1	29,9	37,8	45,5	53,3	60,9
Construction Cost						
(US$ million)	33,174	33,174	33,174	33,174	33,174	33,174
(US$ /km)	507,791	507,791	507,791	507,791	507,791	507,791
NPV / Cost (US$ million)						
@ 0%	1,790	3,511	5,285	6,974	9,380	11,302
@ 10%	0,536	1,256	1,982	2,744	3,674	4,541
@ 15%	0,219	0,742	1,264	1,823	2,483	3,122
RECONSTRUCTION PLUS WIDENING TO 4-LANES						
Net Present Value						
@ 0%	70,951	323,703	666,304	916,117	1146,847	1302,974
@ 10%	-11,794	36,021	105,554	176,011	283,238	334,063
@ 15%	-23,339	0,583	38,533	80,519	131,403	183,367
IRR (%)	7,1	15,1	21,6	27,5	33,7	40,2
Construction Cost						
(US$ million)	82,048	82,048	82,048	82,048	82,048	82,048
(US$ /km)	1,255,901	1,255,901	1,255,901	1,255,901	1,255,901	1,255,901
NPV / Cost (US$ million)						
@ 0%	0,865	3,945	8,121	11,166	13,978	15,881
@ 10%	-0,144	0,439	1,286	2,145	3,452	4,072
@ 15%	-0,284	0,007	0,470	0,981	1,602	2,235
	INCREMENTAL NET BENEFITS (US$ million) Annual Average Daily Traffic - AADT (Base Year)					
	5,645 (Actual)	**8,000**	**10,000**	**12,000**	**14,000**	**16,000**
RECONSTRUCTION PLUS WIDENING TO 4-LANES						
Net Present Value						
@ 0%	11,572	207,214	490,984	684,750	802,489	928,043
@ 10%	-29,580	-5,660	39,796	84,976	115,990	183,413
@ 15%	-30,617	-24,046	-3,393	20,028	49,025	79,813
IRR (%)	1,2	9,1	14,4	18,3	22,3	26,6
Construction Cost						
(US$ million)	48,874	82,048	82,048	82,048	82,048	82,048
(US$ /km)	748,110	1,255,901	1,255,901	1,255,901	1,255,901	1,255,901
NPV / Cost (US$ million)						
@ 0%	0,237	2,526	5,984	8,346	9,781	11,311
@ 10%	-0,605	-0,069	0,485	1,036	1,414	2,235
@ 15%	-0,626	-0,293	-0,041	0,244	0,598	0,973

Source: Consultant's estimates
Note. The analysis has been undertaken on the 65.33 km part of the link where there is no existing embankment

FIGURE 8.1 WIDENING & AADT - INCREMENTAL IRR AND NPC / COST

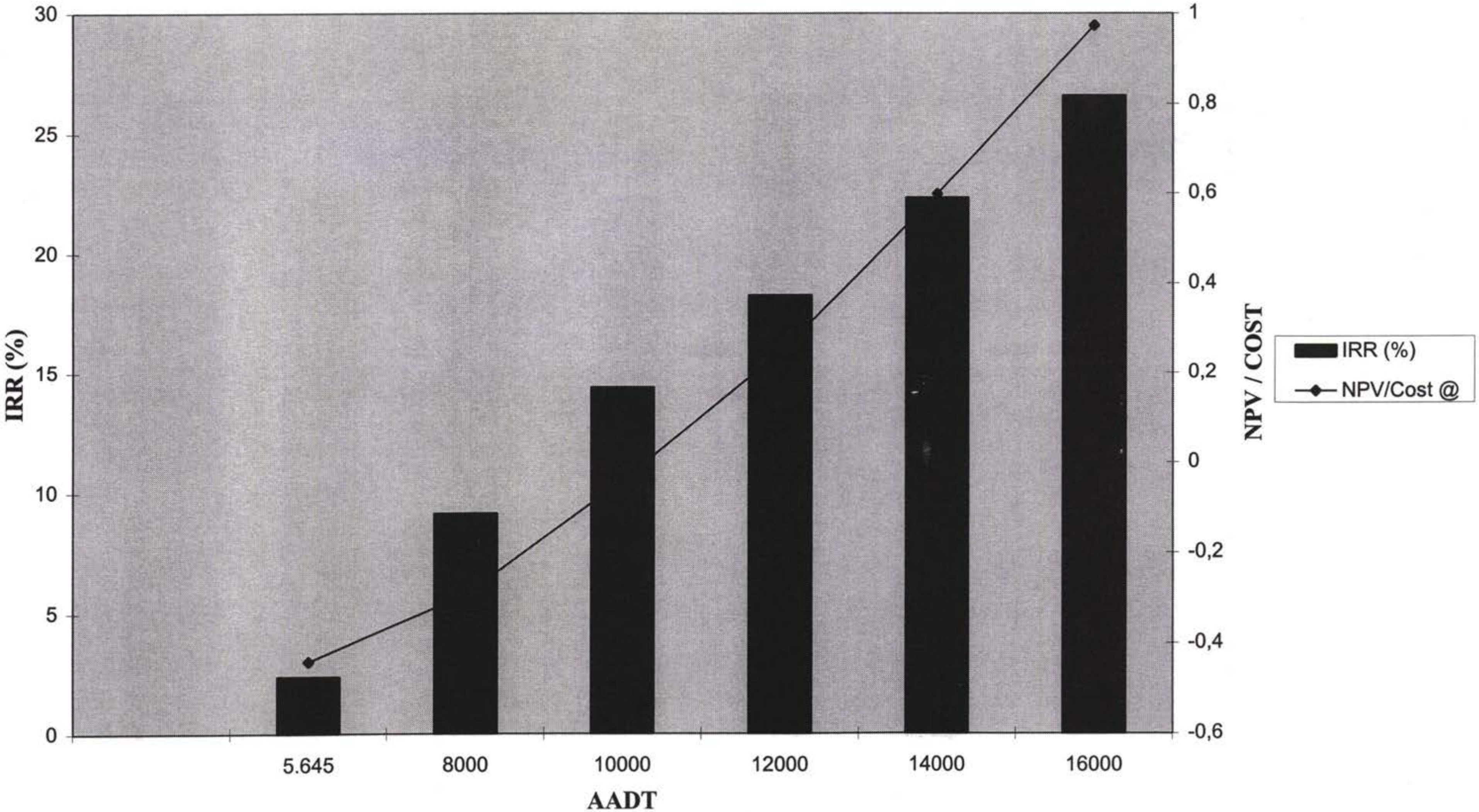


Table 8.4 AZERBAIJAN - SENSITIVITY OF ECONOMIC FEASIBILITY OF RECONSTRUCTION PLUS WIDENING TO INCREASES IN ASSUMED TRAFFIC GROWTH RATES

Year No.	Year	Incremental Net Economic Benefits (US$ million) from Reconstruction + Widening to 4-lane Standard														
		RECONSTRUCTION					RECONSTRUCTION PLUS WIDENING (WITH EXISTING EMBANKMENT)					RECONSTRUCTION PLUS WIDENING (WITHOUT EXISTING EMBANKMENT)				
		Annual Traffic Growth Assumptions					Annual Traffic Growth Assumptions					Annual Traffic Growth Assumptions				
		Best estimate	Best estimate + 30%	Best estimate + 40%	Best estimate + 50%	Best estimate + 100%	Best estimate	Best estimate + 30%	Best estimate + 40%	Best estimate + 50%	Best estimate + 100%	Best estimate	Best estimate + 30%	Best estimate + 40%	Best estimate + 50%	Best estimate + 100%
1	1997						-0.065	-0.065	-0.065	-0.065	-0.065	-0.065	-0.065	-0.065	-0.065	-0.065
2	1998						41.014	41.014	41.014	41.014	41.014	41.014	41.014	41.014	41.014	41.014
3	1999						-90.094	-90.291	-90.361	-90.427	-90.768	-105.684	-105.881	-105.951	-106.017	-106.358
4	2000						0.044	0.064	0.072	0.078	0.121	0.044	0.064	0.072	0.078	0.121
5	2001						0.063	0.095	0.107	0.12	0.195	0.063	0.095	0.107	0.12	0.195
6	2002						0.092	0.141	0.16	0.18	0.305	0.092	0.141	0.16	0.18	0.305
7	2003						0.127	0.198	0.227	0.259	0.465	0.127	0.198	0.227	0.259	0.465
8	2004						0.168	0.27	0.313	0.36	0.69	0.168	0.27	0.313	0.36	0.69
9	2005						0.303	0.464	0.536	0.613	1.169	0.303	0.464	0.536	0.613	1.169
10	2006						0.442	0.676	0.782	0.897	1.766	0.442	0.676	0.782	0.897	1.766
11	2007						0.534	0.856	1.006	1.174	2.469	0.534	0.856	1.006	1.174	2.469
12	2008						0.654	1.092	1.308	1.554	3.478	0.654	1.092	1.308	1.554	3.478
13	2009						0.817	1.416	1.727	2.108	6.144	0.817	1.416	1.727	2.108	6.144
14	2010						1.079	1.925	2.386	3.003	13.529	1.079	1.925	2.386	3.003	13.529
15	2011						1.494	2.699	3.348	4.559	30.859	1.494	2.699	3.348	4.559	30.859
16	2012						2.246	3.849	4.764	7.015	59.139	2.246	3.849	4.764	7.015	59.139
17	2013						44.317	46.86	48.584	56.28	133.494	44.317	46.86	48.584	56.28	133.494
18	2014						-1.963	-1.826	4.135	5.397	104.953	-1.963	-1.826	4.135	5.397	104.953
19	2015						-2.798	1.06	2.793	16.951	106.662	-2.798	1.06	2.793	16.951	106.662
20	2016						-4.407	0.864	14.464	35.73	98.356	-4.407	0.864	14.464	35.73	98.356
21	2017						-5.843	9.214	32.328	59.155	75.655	-5.843	9.214	32.328	59.155	75.655
22	2018						-7.354	14.683	52.802	60.767	7.609	-7.354	14.683	52.802	60.767	7.609
23	2019						-7.829	31.045	57.316	91.155	-50.318	-7.829	31.045	57.316	91.155	-50.318
24	2020						-4.442	54.223	60.774	78.613	-62.979	-4.442	54.223	60.774	78.613	-62.979
25	2021						49.996	109.85	131.458	95.412	14.837	60.129	119.983	141.591	105.545	24.971
Incremental EIRR							***2.0%***	***10.2%***	***13.0%***	***14.8%***	***20.3%***	***1.1%***	***8.5%***	***11.1%***	***12.8%***	***17.4%***
Incremental NPV @ 15% discount rate (US$ million)							***-23.05***	***-14.19***	***-7.26***	***-0.79***	***21.94***	***-32.99***	***-24.13***	***-17.20***	***-10.73***	***11.99***

FIGURE 8.2 - WIDENING: TRAFFIC GROWTH AND INCREMENTAL EIRR

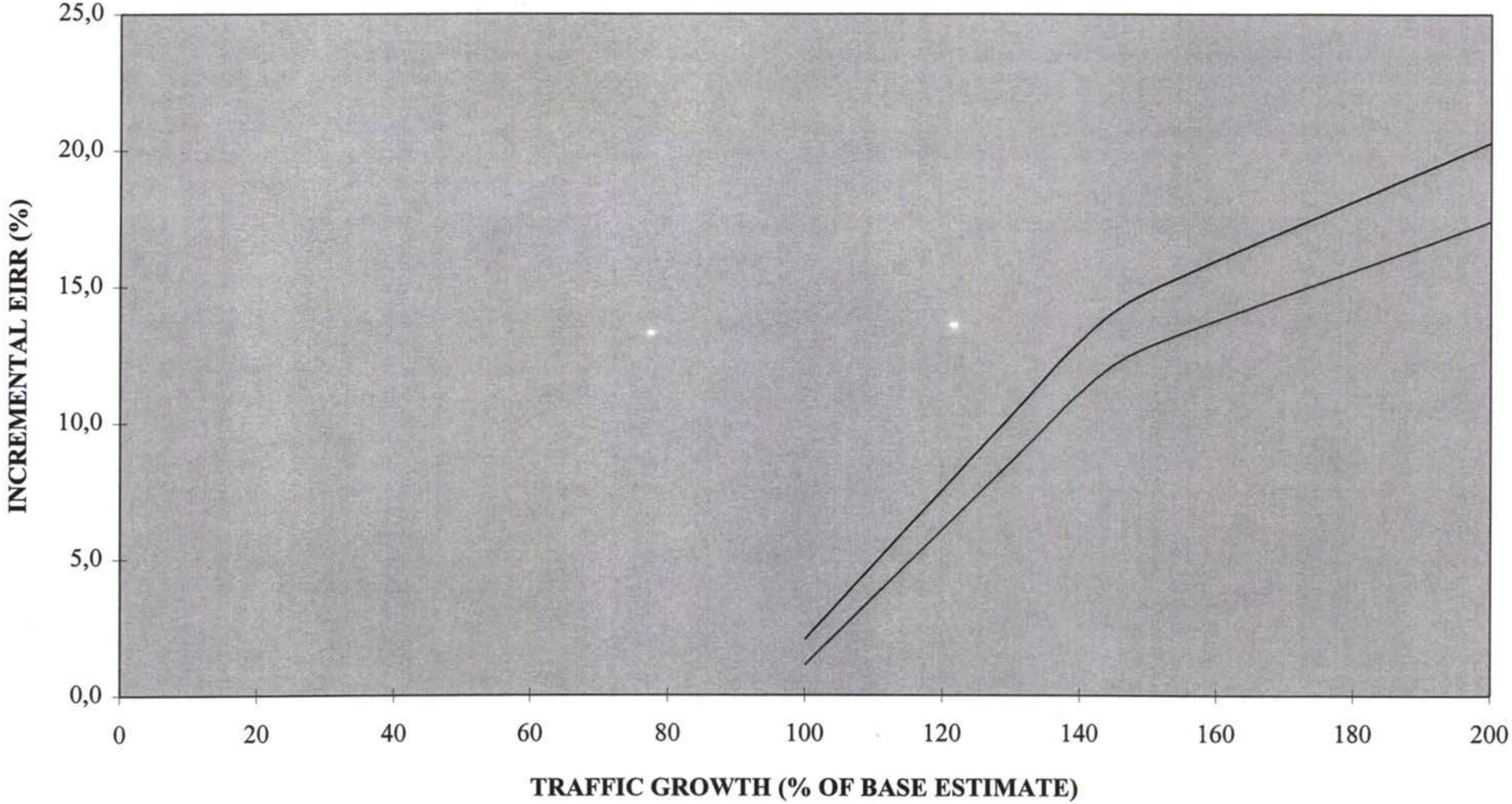


Table 8.5 TRAFFIC GROWTH RATES REQUIRED FOR RECONSTRUCTION PLUS WIDENING TO BE ECONOMICALLY FEASIBLE

Vehicle type	Traffic Growth (% per 1997 - 2010		
	Best estimate	Required to justify With embankment	No embankment
Car	6.9	10.7	12.4
Utility	6.7	10.4	12.1
Bus	5.8	9.0	10.4
Truck 2 axle	5.4	8.4	9.7
Truck 3 axle	6.4	9.9	11.5
Truck > 3 axle	7.4	11.5	13.3
Vehicle type	Traffic Growth (% per 2010 - 2025		
	Best estimate	Required to justify With embankment	No embankment
Car	6.2	9.6	11.2
Utility	5.9	9.1	10.6
Bus	4.9	7.6	8.8
Truck 2 axle	4.6	7.1	8.3
Truck 3 axle	5.6	8.7	10.1
Truck > 3 axle	6.7	10.4	12.1

Source: Consultant's estimate based on HDM lll

The sensitivity analyses of the economic feasibility of the reconstruction plus widening option on the Gazi-Mammad - Kyurdamir link also provide guidance on when the implementation of this option would be justified. The best estimate traffic forecasts indicate that the required AADT threshold of around 11.000 - 12.000 would be reached in the years 2008 or 2009. For the section with an embankment the threshold might be reached one year earlier. With the higher traffic growth assumption adopted for sensitivity analysis purposes in Chapter 4 the threshold year would move forward to 2006 - 2007. The lower traffic growth assumption adopted for sensitivity analysis would result in the threshold period for economic feasibility receding to 2014 - 2016.

A final aspect of the reconstruction plus widening option for this link is the possible benefits of stage construction. in particular the use of the existing embankment to reduce future earthworks costs. There would of course be no benefits to road users from the immediate provision of a widened formation for subsequent completion to 4-lane pavement standard and it is even open to doubt whether there are any significant engineering benefits. Earthworks costs only account for 14 per cent of the total cost of the reconstruction plus widening option. If the earthworks costs were incurred at the beginning of the project appraisal period rather than when the widening option is economically feasible. there would be a significant penalty in terms of discounted earthworks costs. The present value of the cost of earthworks for the widened formation incurred in. say 1999 would be US$ 9.1 million whereas it would be US$ 2.59 million for the same costs incurred in 2008. The discounted cost penalty for stage construction in the form of initial provision of a widened formation would. therefore be US$ 6.5 million.

The analysis of the economic feasibility of reconstruction plus widening of the Gazi-Mammad - Kyurdamir link points to a number of results and conclusions which could. with caution. be considered to be applicable to the whole Alyat - Georgian Border road or indeed to any other "M" road in the country. The present value of the cost to the Azerbaijan economy of premature widening of the Gazi-Mammad - Kyurdamir link would be of the order of US$ 36 million or US$ 440.000 per km. Extrapolation of this result to the whole of the Alyat - Georgian border road suggests that premature widening to 4-lane standard could result in a present value economic cost of the order of US$ 195 million or US$ 25 per head of population. This suggests that the rigid application of highway capacity standards based on out of date physical norms could have expensive consequences for a low income country. even where economic growth is likely to be high as in Azerbaijan.

8.4 Sensitivity Analysis of Non-Widening Options

The results of the economic analyses of the reconstruction and. where relevant. overlay. options summarised in Table 8.1 indicate that the proposed rehabilitation projects are economically robust with internal rates of return generally in excess of 30 per cent. The EIRR for reconstruction of the Gazi-Mammad - Kyurdamir link. while still healthy at 20 per cent. was the lowest of any link on the Alyat - Georgian border road. This link is. therefore. an appropriate candidate for sensitivity analysis of the non-widening options. the sensitivity analysis of the widening option having been discussed in the previous section. The sensitivity analysis of the reconstruction only option on the Gazi-Mammad - Kyurdamir link covers changes in initial capital costs. increases in base year traffic levels and optimistic and pessimistic traffic growth assumptions. The results of these sensitivity tests are summarised in Table 8.6.

Table 8.6 SENSITIVITY OF ECONOMIC FEASIBILITY OF RECONSTRUCTION TO CHANGES IN INITIAL CAPITAL COSTS AND TRAFFIC ASSUMPTIONS
(Kazi Magomet - Kiurdemir link)

		Net Present Value (US$ million)	Change (%)		Economic Internal Rate of Return (%)	Change (%)
Initial Capital Costs						
Base		7.28			20.1	
+10%		3.82	-47.5		17.9	-10.9
+20%		1.31	-82.0		15.9	-20.9
+30%		-1.20	-116.5		14.2	-29.4
+40%		-3.71	-151.0		12.6	-37.3
+50%		-6.22	-185.4		11.2	-44.3
+100%		-18.77	-357.8		5.6	-72.1
Base Year AADT	(Change %)					
5645		7.279			20.1	
8000	41.7	24.629	238.4		29.9	48.8
10000	77.1	41.926	476.0		37.8	88.1
12000	112.6	60.491	731.0		45.5	126.4
14000	148.0	82.378	1,031.7		53.3	165.2
16000	183.4	103.554	1,322.6		60.9	203.0
Traffic Growth						
Best estimate		7.28			20.1	
High growth (1)		13.04	79.1		22.1	10.0
Low growth (2)		0.96 -	86.8		15.6 -	22.4

Source: Consultant's estimate

Note (1) 1997 - 2010 8.8% annual growth overall
2010 - 2025 8.0% annual growth overall
Note: (2) 1997 - 2010 3.8% annual growth overall
2010 - 2025 5.0% annual growth overall

The main results of the sensitivity analysis can be summarised as follows:

- Initial capital costs of the reconstruction option can rise by between 20 and 30 per cent before the economic feasibility of the project is threatened. Increases above about 25 per cent results in EIRRs of below 15 per cent and negative NPVs.

- Every 10 per cent increase in base year AADT results in a 50 - 60 per cent increase in NPV or 11 per cent increase in EIRR. It is extremely unlikely that base year AADT would be lower than the best estimate and this aspect has. therefore. not been tested in the sensitivity analysis.

- The adoption of the high or optimistic traffic growth forecast increases the EIRR from 20.1 per cent to 22.1 per cent. Conversely. overall annual traffic growth can be as low as 3.8 per cent between 1997 and 2010 and 5.0 per cent between 2010 and 2025 before the economic feasibility of reconstruction is threatened.

It should be emphasised that the reconstruction option for all the other links in the Alyat - Georgian border road is economically even more robust than on the link on which on the sensitivity analysis has been carried out. The overall conclusion of the economic feasibility analyses is that in the absence of overlaying possibilities on the eastern half of the road. the reconstruction option has a high economic priority. but widening is premature. On the western half of the road both overlaying and reconstruction of the relevant sub-links have a high economic priority and it must be assumed. on the basis of the results on the Gazi-Mammad - Kyurdamir link. that widening would also be found to be premature.

9. RECOMMENDATIONS AND CONCLUSION

The studies and discussion of the various technical and economic aspects of the project are leading to the following conclusion and recommendation.

The existing traffic level on the road links are constantly between 4,000 and 6,000 AADT (1997). The only discernible trend is a slight decline in flows from east to west. The traffic forecasts indicate an overall rate of traffic growth of 6.7 % a year between 1990 and 2010 and 6 % thereafter. By the year 2010 AADT levels will have risen to within the range AADT 11,000 - 14,000 and by the end of the appraisal period in 2025 they will reach a level between AADT 26,000 - 34,000. The estimated volume capacity suggests that capacity constraints will not be experienced before 2009. Immediate initiatives to widen the road to 4 lane standard would be premature.

According to the present traffic volume the road is characterised as category II road (FSU standard) with 7.50 m carriageway and 3.75 shoulder.

The present road condition is, except short stretches, good to fair. But the test results from the geotechnical investigation show that the road base from Alyat to km 407 (Ganja West) is already insufficient. A new pavement is recommended for these sections.

From Ganja West (km 407) to the Georgian border the road base materials provide the required bearing capacity therefore an overlay is recommended for most parts of the sections. The thickness of the overlay is between 40 mm and 90 mm dependent on the existing bearing capacity.

High traffic volume and the economic analysis justified the reconstruction and overlay solutions of each of the links between Alyat and the Georgian border. Economic Internal Rates of Return of between 20 % and 70 % and high positive Net Present Values reflected the ample justification for immediate implementation.