Tacis

TRACECA - Project

Trade and Transport Sectors

Implementation of Pavement Management Systems

Feasibility Study for Rehabilitation of Transit Roads in Georgia

Volume I

Final Feasibility Report

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KOCKS CONSULT GMBH
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PHØNIX
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REPORT COVER PAGE

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		Local Operator	EC Consultant
Name	:	State Concern of Roads, **SAKAVTOGZA**	KOCKS CONSULT GMBH Consulting Engineers
Address	:	29a Gagarin Street 380060 Tbilisi GEORGIA	Stegemannstraße 32 - 38 56068 Koblenz GERMANY
Tel. Number	:	(99532) 370666	xx49 - 261 - 1302-0 (operat.) xx49 - 261 - 1302-143 (direct)
Fax number	:	(99532) 376458	xx49 - 261 - 1302 - 152
Telex number	:	212189	862807
E-mail	:	--	kocks@t-online.de
Contact person	:	Tamaz A. Shilakadze, Vice chairman of the State Concern SAKAVTOGZA and Director of the Institute SAKGZAMETSNIEREBA	Werner P. Weiler
Signatures	:		

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

EC M & E Team	(name)	(signature)	(date)
EC Delegation	(name)	(signature)	(date)
TACIS Bureau (Task Manager)	(name)	(signature)	(date)

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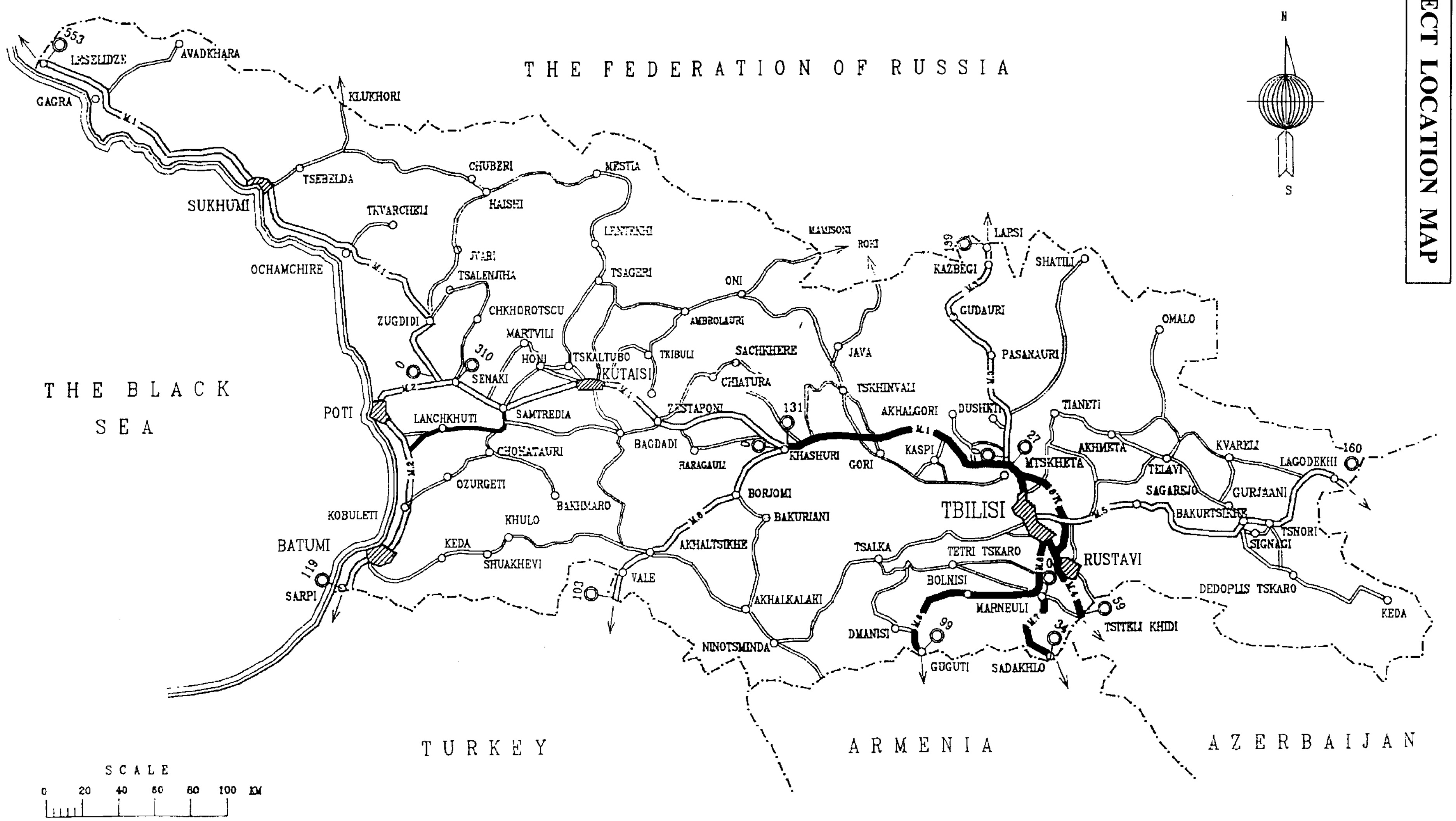

1. INTRODUCTION

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 Sakavtogza.

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 the Consultant's staff in Tbilisi on 30 January 1997.

1.2 Project Objectives

The objective of the project was to prepare a feasibility study for the rehabilitation works on the roads

- Tbilisi - Kashuri (S 1)
- Tbilisi - Red Bridge / Azerbaijan border (S 4)
- Tbilisi - Marneuli - Guguti / Armenian border (S 6)
- Marneuli - Sadakhlo / Armenian border (S 7)
- Tbilisi by-pass(S 9)
- Samtredia - Lanchkhuti - Ureki (S 12)

The feasibility will be used for negotiations between Georgian 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 Sakavtogsa 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. 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. E. Chrissochou	Geotechnical Engineer	Kocks Consult GmbH
Mr. O. Kruse	FWD Expert	PhØnix

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

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 1997 in which the proposed approach to carrying out the study and the project's plan of operations were defined.

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

1.5 Acknowledgements

The Consultant wishes to express his appreciation for the co-operation of Sakavtogza and the Scientific Research Institute Sakyzametsniereba as well as of the assistance received from many institutions and individuals in Georgia.

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 study roads available by Sakavtogza. The next step was the updating and supplement by results of site surveys and investigations carried out by the Consultant and Sakavtogza. 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 study roads was subdivided into 11 sections, based on the results of the traffic studies and condition surveys.

The sections were as follows:

	Length (m)
S 1, Tbilisi - Kashuri	
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)	11,940
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	57,760
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)	41,970
S 4, Tbilisi - Red Bridge / Azerbaijan border (km 11+000 - km 57+170)	46,170
S 6, Tbilisi - Marneuli - Guguti / Armenian border	
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	25,840
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	25,040
Subsection: Bolnisi - Guguti / Armenian border (km53+880 - km 99+127)	45,247
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	34,152
S 9, Tbilisi by-pass	
Subsection: west (km 0+000) - km 34+800)	34,800
Subsection: east (km 34+800 - km 49+008)	14,208
S 12, Samtredia - Ureki (km 0+000 - km 56+528)	56,528

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 Sakavtogza 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 Sakavtogza'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 2.1.

Table 2.1

	[illegible]							
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	СНиП 2.05.03-84 НК-80	СНиП 2.05.03-84 НГ-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	540,4	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
						СНиП 2.05.03-84 НГ-30	CH 200 - 62 H-10 (1 lane)	CH 200 - 62 H-10 (2 lanes) width of carriageway 7 m
5 m						187,5	154,4	308,8
10 m						562,5	341,1	682,2
15 m						937,5	580,1	1.160,2
20 m						1.312,5	897,5	1795,0
25 m						1.687,5	1.205,2	2.410,4
30 m						2.062,5	1.582,6	3.165,2

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 main-tenance 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 • 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	3	Major repairs and/or rehabilitation

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 in Georgia has been carried out using the World Bank's HDM III model. The study roads have been divided into a number of sections for purposes of design and analysis and the rehabilitation options for each section were then compared.

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 or reference case. In the "Do Minimum" scenario annual routine maintenance and patching. is assumed to be undertaken. Depending on initial road condition and traffic levels, this will generally not be sufficient to prevent pavement roughness rising, as the pavement deteriorates. Eventually reconstruction will be required to prevent the complete destruction of the pavement and this is assumed to be required when roughness reaches IRI 9 m/km. The "Do Minimum" case is, therefore, definitely not a "Do Nothing" case. 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 most of the existing paved roads, the potential for traffic generation as a result of the improvements is not considered to be large and no generated traffic benefits have been quantified in the economic analyses. To the extent that present pavement roughness levels on the two roads linking Marneuli with the Armenian border at Guguti and Sadakhlo are significantly higher than on the other road links studied, this could result in slightly conservative rates of return on these roads, but not so conservative as to significantly alter the conclusions of the analyses.

The Tbilisi bypass and the road between Samtredia and Ureki are the only roads studied where there is an alternative route and, hence, the theoretical possibility of traffic diversion. For the reasons discussed in Chapter 5, the potential for traffic diversion with road rehabilitation and any resulting benefits to diverted traffic is considered to be very small and these have not been quantified in the economic analysis. 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 Georgian context and has not, therefore been attempted. The absence of accident costs reflecting income levels in Georgia is unlikely to have a significant impact on the economic feasibility of the mainly rehabilitation types of project 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 Economic Internal Rate of Return (EIRR). 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 EIRR of 15 percent or over are assumed to be economically feasible for immediate implementation. Where projects fail to meet this threshold, the indication is that they are premature.

3. PHYSICAL, ECONOMIC AND TRANSPORT BACKGROUND

3.1 Road Influence Areas, Climate and Terrain

3.1.1 S4: Tbilisi - Red Bridge border post (Azerbaijan)

This road, 47 km in length, connects the capital with Georgia's principal border crossing with Azerbaijan. It forms the easternmost section of the country's great east-west route, known as the Magistrale, which runs from Azerbaijan to the Black Sea and the Turkish border.

The course of the S4 lies on the upper, western slopes of the Mtkvari, or Kura, river valley as far as Rustavi, the third largest city in the country with a population of 159,000 as of the 1989 Census, south of which it moves away from the river and traverses hilly, and later rolling, terrain to reach a tributary valley. This valley is followed to the Azerbaijan border, the crossing being formed by a sixteenth century red brick bridge.

Climatically, the road effectively lies within a single zone, that covering the south-eastern of Georgia. This is characterised by low rainfall, a high annual temperature range and a significant number of days per year below 0^0C. Climatic statistics for the two meteorological stations on the course of the road, those at Tbilisi and Rustavi, are given in Table 3.1.

Table 3.1: S4 and S9:
Climatic Summary Statistics of Region Served by Road

Station	Temperature Summer Average ^{0}C	Temperature Winter Average ^{0}C	Temperature Number of Days Below 0^0C	Rainfall Annual mm
Rustavi	23.9	2.0	24	437
Tbilisi east	22.9	1.6	24	555

source: Sakavtogza

Those sections of the road through hilly terrain to the south of Rustavi can be expected to experience slightly more extreme conditions than indicated in Table 3.1.

3.1.2 S9: Tbilisi Bypass

This forms the next section westwards of the Magistrale route. It was constructed approximately 25 years ago to provide an alternative route for traffic through Tbilisi, particularly heavy goods vehicles, at a time of rapidly increasing delays and congestion in the capital. The bypass is 49 km in length and links the S4 Tbilisi to Red Bridge road with the S1 from Tbilisi to Khashuri and Western Georgia.

The S9 forms a wide loop to the north and east of Tbilisi traversing predominantly rolling terrain. Close to its junction with the S4 it crosses the Mtkvari river, and northwards there are bridges over several lesser rivers. To the north it approaches the foothills of the Kartli mountain range and the alignment becomes more severe. A combination of difficult geological conditions and poor standards of construction has resulted in a major road failure at km 20, from the S1, plus a series of minor failures on the northern section of the road. Having flanked the most northerly suburbs of Tbilisi the bypass rejoins the valley of the Mtkvari river and feeds into the S1 near Mtskheta.

Climatically, the bypass is entirely situated within the Tbilisi region, whose meteorological statistics have been summarised in Table 3.1.

3.1.3 S1: Tbilisi - Khashuri

This comprises the next westward section of the Magistrale, 128 km in length from the Tbilisi city boundary to the regional capital, Khashuri. The S1 is much the most important link between Tbilisi and Western Georgia.

Its course runs to the north of the Mtkvari river, crossing the Inner Kartli Plain in a wide northern arc before taking a line tighter to the river west of Gori. The terrain is generally easy with the exception of drops into five tributary valleys of the Mtkvari. These consist of sections of between two and five kilometres at gradients of 8 to 10%.

Climatic data for the five weather stations located close to the road are given in Table 3.2.

Table 3.2: S1 Tbilisi - Khashuri: Climatic Summary Statistics of Region Served by Road

Station	Temperature: Summer Average ^{0}C	Temperature: Winter Average ^{0}C	Temperature: Number of Days Below 0^0C	Rainfall Annual mm
Tbilisi west	22.9	1.6	24	680
Mukhrani	20.7	0.1	44	591
Kaspi	22.0	0.2	n/a	636
Gori	21.2	-0.1	n/a	585
Khashuri	19.6	-0.8	n/a	644

source: Sakavtogza

There is a slight but perceptible drop in average temperatures moving westwards, and, although the data set is incomplete, an increase in the number of sub zero days. This reflects the steady increase in altitude as the road follows the River Mtkvari upstream. There is a less clear pattern in terms of rainfall with no great variation between stations, all of which show higher figures than stations to the east.

3.1.4 S 6: Tbilisi - Marneuli - Guguti border post (Armenia)

The S6 is one of the two main routes between Tbilisi and the Armenian border, the other being the S7 via Sadakhlo, which is covered in section 3.1.5.

The S6 climbs southwards out of the Mtkvari river valley to leave Tbilisi and traverses rolling and hilly terrain to reach Marneuli, a regional and industrial centre located on the Algeti River, a tributary of the Mtkvari. At Marneuli the S6 diverges from the S7 to Sadakhlo and heads westwards to reach another tributary valley east of Bolnisi. This valley is then followed upstream, taking the road in a southwest direction, as far as the village of Didi Dmanisi where the road for Dmanisi diverges following the river. The terrain is no more severe than rolling from Marneuli to this point, but leaving the river valley the serious climbing to the Armenian border begins. Gradients of 5 to 10% are almost continuous and the horizontal alignment is poor and often tortuous over the 23 km to the border post at Guguti.

Four meteorological stations cover the length of the road, and summaries of their climatic data are provided in Table 3.3.

Table 3.3: S6: Climatic Summary Statistics of Region Served by Road

Station	Temperature Summer Average ^{0}C	Winter Average ^{0}C	Number of Days Below 0^0C	Rainfall Annual mm
Bolnisi	22.4	1.5	32	572
Dmanisi	17.1	-1.6	n/a	799
Marneuli	22.7	1.3	n/a	495
Tbilisi east	22.9	1.6	24	555

source: Sakavtogza

The road can be conveniently divided into two climatic regions, the lowlands and the uplands, the latter represented by the Dmanisi station. It shows distinctly lower temperatures, both winter and summer, and much higher rainfall. It is reasonable to assume that had data been available it would also show more days per year below freezing point. There is little variation between the "lowland" stations.

3.1.5 S7: Marneuli - Sadakhlo border post (Armenia)

The S7 diverges from the S6 at Marneuli and runs southwards over flat to rolling terrain to reach the Armenian border at Sadakhlo. The route is not a difficult one, as indicated by the proximity of the Tbilisi - Armenia railway line. The approach and crossing of the border is by way of a lesser tributary valley of the Mtkvari. Total length of the S7 from Marneuli to Sadakhlo is 34 km.

There are no significant settlements between Marneuli and Sadakhlo, and the only meteorological data available relates to Marneuli, as given in Table 3.3. It is reasonable to assume only a slight increase in weather severity with approach to the Armenian border.

3.1.6 S 12: Samtredia - Lanchkhuti - Ureki

Of those roads in the current study the S12 is the only one in Western Georgia. It comprises a section of the quickest route between Tbilisi and Batumi and the Turkish border at Sarpi. Prior to independence the official primary route was via Senaki, Poti and Ureki. The Samtredia to Ureki road was of republican status. However, its potential significance has been acknowledged by recent upgrading to international status and the designation S12.

The road, 59 km long between the S1 at Samtredia and the S2 at Ureki, runs through flat terrain along the southern fringe of the Kolkheti Lowlands which extend inland from the Black Sea as far as Zestaponi. The lowlands are drained by a large number of rivers, three of which, the Rioni, Pichori and Supsa, are encountered by the S12. The Rioni is crossed almost immediately south of Samtredia, and its south bank then followed as the road swings westwards. Having left the Rioni river the S12 skirts the head of the Pichori river en route to Lanchkhuti. After Lanchkhuti the land opens out to the south as the road approaches the coastal plain. Its second major river crossing, of the Supsa, lies immediately to the west of Supsa village, but the condition of the bridge means that it is currently banned to heavy vehicles. These have to divert northwest at Supsa to cross the river by the S2.

Climatic data from stations close to the route of the S12 are given in Table 3.4.

Table 3.4: S12: 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
Lanchkhuti	22.2	5.2	3	1980
Samtredia	22.6	5.8	6	1526
Supsa	21.7	5.4	3	2379
Ureki	22.0	6.8	2	2078

source: Sakavtogza

These show considerable consistency with the exception of rainfall. There is a general trend of higher rainfall towards the western, coastal end of the road, while comparison with Tables 3.1 to 3.4 shows that all these stations have rainfall of a three to fourfold factor greater than the more continental stations in Eastern Georgia. Summer temperatures are similar to the east but winters are milder under the moderating influence of the Black Sea.

3.2 Road Influence Areas, Population and Economic Activity

3.2.1 S4: Tbilisi - Red Bridge border post (Azerbaijan)

The road passes through three regions, Tbilisi, Marneuli and Gardabani, from northwest to southeast respectively. Summary information relating to the demographic and economic characteristics of these three regions is included in Table 3.5.

Table 3.5
S4 Tbilisi-Red Bridge: Demographic and Economic Summary of Regions Traversed

	Population (1989)				Industry	
Region	Urban	Rural	Total	Density(/km)	Production	No. of sites
Gardabani	22,734	92,028	114,762	71.5	88.6	18
Marneuli	5,695	87,581	93,276	103.4	1,232.0	20
Tbilisi	1,246,814	122	1,246,936	n/a	11,934.0	1169

notes: industrial production in '000 Lari for Jan 1997
source: State Department of Statistics, Georgia

The regional pre eminence of Tbilisi is clearly shown in the above figures. It should be noted that for the purposes of these data Rustavi is included within Tbilisi region. Gardabani and Marneuli, by comparison, have predominantly rural populations and limited industrial development.

3.2.2 S9: Tbilisi Bypass

The Tbilisi Bypass runs through three regions, two of which it has in common with the S4. A demographic and economic summary of these regions is provided by Table 3.6. Gardabani contains the eastern end of the bypass, Tbilisi the central section and Mzkheta the west.

Table 3.6
S9 Tbilisi Bypass: Demographic and Economic Summary of Regions Traversed

Region	Population (1989)				Industry	
	Urban	Rural	Total	Density(/km)	Production	No. of units
Gardabani	22,734	92,028	114,762	71.5	88.6	18
Mzkheta	14,273	48,358	62,631	78.3	76.0	74
Tbilisi*	1,246,814	122	1,246,936	n/a	11,934.0	1169

notes: industrial production in '000 Lari for Jan 1997
* see Table 3.4 for fuller, more recent information: this table for purposes of comparison only
source: State Department of Statistics, Georgia

The bypass runs through predominantly rural terrain beyond the existing extent of Tbilisi, except at its northern end where it passes through some of the outermost suburbs. Although not urban in character the bypass is directly related to the economic and demographic development of Tbilisi in particular, and Georgia in general. The bypass, therefore, has a wide area of influence consisting of considerably more than the two rural regions through which it passes. The status and growth of the economy and population of Tbilisi itself is the key to the road's existence and future usage. Table 3.7 provides a summary of the latest relevant information on Tbilisi.

Table 3.7 Economic and Demographic Summary Statistics for Tbilisi

Tbilisi	
Total Population	1,359,700
Proportion of National Population	24%
Population Growth, 1990-6	1.06% p.a.
Population Growth, 1994-6	-0.06% p.a.
Population Density	3,885/km2
Administrative Districts	10
Employment	460,000
Total Industrial Output	191,700,000 Lari
Proportion of National Output	32%
No. of State Enterprises	1779
Change, 1995-6	+562
No. of Private Enterprises	6,632
Change, 1995-6	+1,122
Capital Investment	64,900,000 Lari
Total Public Transport Passengers	239,700,000
Change, 1995-6	+32%

note: all figures for 1996 unless stated
source: State Department of Statistics, Georgia

These statistics are taken from the first such publication for six years. As yet, information of this detail and currency is not available for other regions and districts in Georgia. For example, the prime source of population data for provincial regions remains the last National Census of 1989.

3.2.3 S 1: Tbilisi - Khashuri

This portion of the S1 enters five regions, from east to west, Tbilisi, Mzkheta, Kaspi, Gori, Kareli and Khashuri. The latest available demographic and economic summary data for each of these regions is provided in Table 3.8.

Table 3.8 S1 Tbilisi - Khashuri: Demographic and Economic Summary of Regions Traversed

Region	Population (1989)				Industry (Jan 1997)	
	Urban	Rural	Total	Density(/km)	Production	No. of units
Gori	67,787	81,685	149,472	n/a	869.1	43
Kareli	12,793	37,937	50,730	73.3	5.4	11
Kaspi	17,138	38,491	55,629	68.9	330.1	33
Khashuri	38,159	27,608	65,767	114.1	143.5	18
Mzkheta	14,273	48,358	62,631	78.3	76.0	74
Tbilisi*	1,246,814	122	1,246,936	n/a	11,934.0	1169

notes: industrial production in '000 Lari
* see Table 3.4 for fuller, more recent information: this table for purposes of comparison only
source: State Department of Statistics, Georgia

The road links Tbilisi with the major industrial city of Gori, which has the fifth largest urban population in Georgia, as assessed by the 1989 National Census. Gori is also a current industrial growth pole, in common with other urban areas with good access to Tbilisi, although modest in comparison with the capital itself. Khashuri region is also primarily urban although of considerably less economic and industrial significance than Gori. Kaspi and Kareli regions are rural, centred on small towns, of which Kaspi is considerably the more industrialised.

3.2.4 S 6: Tbilisi - Marneuli - Guguti border post (Armenia)

The S6 has sections in six regions, Tbilisi, Gardabani, Tetri Tskharo, Marneuli, Bolnisi and Dmanisi. Table 3.9 provides demographic and economic summary statistics for each of these regions.

Table 3.9
S6 Tbilisi-Marneuli-Guguti: Demographic and Economic Summary of Regions Traversed

Region	Population (1989)				Industry	
	Urban	Rural	Total	Density(/km)	Production	No. of sites
Bolnisi	24,849	56,698	81,517	101.8	906.0	13
Dmanisi	8,564	43,280	51,844	43.5	0.0	6
Gardabani	22,734	92,028	114,762	71.5	88.6	18
Marneuli	32,813	87,581	120,394	n/a	1,232.0	20
Tetri Tskharo	12,581	23,909	36,490	31.0	11.0	8
Tbilisi	1,246,814	122	1,246,936	n/a	11,934.0	1169

notes: industrial production in '000 Lari for Jan 1997
source: State Department of Statistics, Georgia

The two major centres on the S6 are Marneuli and Bolnisi, each capitals of industrialised regions and like Gori, reference section 3.2.3, poles of recent growth with a significant number of newly registered industrial developments as of early 1997. The "Tbilisi effect" is evident in Marneuli's superior performance to date. An important element in the industry of Bolnisi region is the town of Kazreti, located within 3 km of the S6 and with direct access from it. Kazreti was developed for copper processing and remains a one industry town. The plant was closed following the civil war but a resumption of production is anticipated within 1997.

Dmanisi region is predominantly rural and the statistics show that its few industrial plants are currently non productive. The most southerly and mountainous sections of the S6 lie within Dmanisi region. Gardabani and Tetri Tskharo regions contain only short sections of the S6 and their influence on the road is limited.

3.2.5 S 7: Marneuli - Sadakhlo border post (Armenia)

The S7 passes through three regions, Marneuli, Gardabani and Tetri Tskharo. Table 3.10 provides demographic and economic summary statistics for each of these regions.

Table 3.10: S7 Marneuli-Sadakhlo: Demographic and Economic Summary of Regions Traversed

	Population (1989)				Industry	
Region	Urban	Rural	Total	Density(/km)	Production	No. of sites
Gardabani	22,734	92,028	114,762	71.5	88.6	18
Marneuli	32,813	87,581	120,394	n/a	1,232.0	20
Tetri Tskharo	12,581	23,909	36,490	31.0	11.0	8

notes: industrial production in '000 Lari for Jan 1997
source: State Department of Statistics, Georgia

Marneuli is the only significant centre directly served by the S7. The road passes through a number of villages the frequency of which decreases with distance from Marneuli. These villages are predominantly agricultural in character and include Sadakhlo itself which lies some 3 km from the border.

The significance of Marneuli is discussed in section 3.2.4. Economically, the other major areas of significance for the S7 are removed from the road. In brief, these are the Tbilisi region and the major development poles of northern Armenia, including Yerevan.

3.2.6 S 12: Samtredia-Lanchkhuti-Ureki

Four regions are directly accessed by the S12. These are, in a westward direction, Samtredia, Tshokhatauri, Lanchkhuti and Makhradze. Table 3.11 provides the latest available demographic and economic summary data for these regions.

Table 3.11: S 12 Samtredia-Lanchkhuti-Ureki:
Demographic and Economic Summary of Regions Traversed

	Population (1989)				Industry	
Region	Urban	Rural	Total	Density(/km)	Production	No. of sites
Lanchkhuti	8,999	32,334	41,333	78.5	15.3	22
Makharadze	33,598	56,127	89,725	133.4	207.7	50
Samtredia	37,331	27,467	64,798	177.2	353.2	28
Tshokhatauri	2,605	24,390	26,995	31.0	12.0	15

notes: industrial production in '000 Lari for Jan 1997
source: State Department of Statistics, Georgia

The S 12 passes through an area of relatively high population density, much of it suburban in character and linear in form, with development following the road/rail corridor. The section between Lanchkhuti and Supsa, for example, is almost continuously developed with residences directly accessed from the road.

Industrial development in the region consists of a significant number of units, many of limited output. In part this is due to the weakness of the national economy but it also reflects the regional significance of small, light industrial units. Samtredia, a major transport junction and access to Western Georgia, is also the largest urban and industrial centre served by the S12. Westwards, development keeps close to the road and is more suburban than urban, giving the S12 an untypical character for a major long distance route.

3.3 Functional Importance of the Roads

3.3.1 S 4: Tbilisi - Red Bridge border post (Azerbaijan)

In terms of function the S4 can be readily divided into three sections; 10 km within the developed area of Tbilisi under the responsibility of the metropolitan highway authority; the subsequent 13 km south-eastwards to the major industrial and commuter town of Rustavi which lies immediately to the east of the road; the remainder of the route to the Azerbaijan border at Red Bridge, which is rural, of poor horizontal and vertical alignment and largely devoid of settlements. The function of this final section of the S4 is predominantly that of a route for international traffic.

Other than the access roads to Rustavi, the only significant junction outside Tbilisi is that with the S9 Tbilisi Bypass at km 18, immediately to the northwest of Rustavi. The S9, also covered by this study, forms the westward continuation of the east west Magistrale route.

3.3.2 S 9: Tbilisi Bypass

The design function of the Tbilisi Bypass is self explanatory; to provide a suitable alternative route for traffic travelling through Tbilisi. However, declining road use since the collapse of the Soviet Union has led to reduced delays and congestion in the capital with the result that the bypass has become comparatively less attractive in time terms. This was compounded by a lengthy closure due to a bridge failure which rendered the road closed to through traffic until late 1996. Consequently, a majority of the traffic currently using the bypass is no longer genuinely through traffic.

There is a marked difference in traffic volumes between the sections of the bypass on either side of the junction with the Tbilisi-Sagarejo road. Local and regional traffic uses this junction to access the southern section of the bypass, primarily to reach Rustavi. To the north of the junction there is little local traffic and the majority of vehicles are undertaking through, including international, trips. The existing balance between through and local traffic is revealed by the results of the classified volume counts conducted for the study; 900 vehicles per day to the north of the junction, 2,900 vehicles per day to the south. This gives an approximate 30:70 split, through to local, showing that the road's actual function has diverged from its design function. However, it is reasonable to assume that future economic growth will lead to a readjustment back towards its use predominantly as a bypass.

The Tbilisi Bypass remains an essential link in the strategic east-west Magistrale route.

3.3.3 S 1: Tbilisi - Khashuri

This road is one of the busiest inter urban roads in the country, comprising as it does that part of the strategic Magistrale route which runs immediately to the west of the capital, Tbilisi. It therefore forms the easternmost section of the route between Tbilisi and Western Georgia, including the Black Sea ports and the Turkish border at Sarpi.

Tbilisi to Khashuri can be conveniently divided into three sections, as reflected by the distribution of traffic surveys, described in section 5.2. On crossing the Tbilisi city boundary at km 21 the road is of dual carriageway standard as far as the junction at Mzkheta where the S3 to Kazbegi and the Russian border, for Vladikavkaz, diverges. The

S3 is now, following civil unrest in Abkhazia, the principal Georgia - Russia route. The short, 6 km, section between Tbilisi and Mzkheta therefore carries traffic on two of Georgia's major strategic routes. In terms of inter urban roads its significance and traffic levels are without equal.

West of the S3 junction the S1 reduces to single carriageway. The section to Gori, 54 km, carries both long distance east west traffic and significant volumes of local and regional traffic. Gori, as described in section 3.2.3, is one of Georgia's most populous and industrialised cities, which together with its comparative proximity to Tbilisi ensure a relatively high level of road usage between the two. In common with all the major centres served by the road, with the exception of Khashuri, Gori is bypassed by the S1 which runs approximately 3 km to its north.

Gori to Khashuri is of comparable standard and traffic usage to Mzkheta-Gori. Traffic levels reflect the significance of Gori as a regional centre, and also the size of Khashuri which has one of the ten largest urban populations in the country. Therefore, inter regional traffic remains significant, including that between Tbilisi and Khashuri. With the exception of the short access roads linking the S1 with the major urban settlements there are few important junctions between Mzkheta and Khashuri where the S8 to Borjomi and Vale diverges. However, at the western Gori access junction the Republican road north to Tskhinvali and Oni meets the S1.

3.3.4 S 6: Tbilisi - Marneuli - Guguti bp (Armenia)

The S 6 has two main functions; linking Tbilisi with the regional and industrial centres of Marneuli and Bolnisi, and providing one of the main connections between Georgia and Armenia. In terms of traffic volumes the former is certainly of more significance than the latter, because there is a progressive fall in traffic with distance from Tbilisi such that the section nearest to the Armenian border carries of the order 350 vehicles per day. This is almost entirely cross border traffic given the section's isolation from centres of population. In comparison, more than 4,000 vehicles per day use the section between Tbilisi and Marneuli.

Likewise, it compares with traffic flows of the order 1,800 vehicles per day on the road to the Sadakhlo border crossing. The Guguti crossing is both further from Tbilisi, 98 km as opposed to 63 km, and its approach is more severely graded. Currently, the poor surface condition of the final section to the Sadakhlo border ensures that the Guguti route remains competitive.

The importance of the S6 as an inter regional road is likely to increase given continued industrial regeneration in Marneuli and Bolnisi, the potential revival of Kazreti for copper processing being one significant factor. The S6 is also the main long distance access to Dmanisi town and region.

3.3.5 S 7: Marneuli - Sadakhlo border post (Armenia)

The S7 is primarily an international link between eastern Georgia, and Tbilisi in particular, and northern Armenia. It is the shortest and most easily graded route between Tbilisi and Armenia, making it attractive to heavy goods haulage, although the final 13 km section to the border is currently in very poor condition. Local traffic is not significant, other than close to Marneuli which acts as a regional centre for the surrounding agricultural area. There are no major intermediate junctions.

3.3.6 S 12: Samtredia - Lanchkhuti - Ureki

Recent reclassification of this road to international status reflects its changing pattern of use. As mentioned in section 3.1.6 it has become part of the principal route between Tbilisi and Batumi and the Turkish border. The S12 currently forms the quickest route between Samtredia and Batumi, and is considerably shorter than the S2 via Poti. In consequence, it carries the great majority of international truck traffic to and from Turkey, the most dynamic economy in the region. Not only are Turkish goods imported into Georgia, but there is also considerable transit traffic to Azerbaijan, routes via Armenia being at present politically unacceptable. These goods are commonly carried in convoys of between three and ten trucks, consisting either of three axle vehicles or articulated sets. The convoys return westwards either lightly loaded or unladen, often with unneeded axles lifted clear of the road.

The loadings carried by the S12 have seriously damaged the road surface on certain sections, exacerbated by heavy annual rainfall. The Supsa river bridge has been banned to heavy vehicles, necessitating diversion on to a poor quality unpaved road to reach the S2. These are consequences of the S12 taking axle loadings it was not designed for.

There is also a significant amount of local traffic using the S12 serving Samtredia, Lanchkhuti and the substantial residential development along the road. This traffic consists predominantly of light vehicles.

The only intermediate junction of note is 8.5 km from Samtredia where the Republican road to Tshokhatauri, Ozurgeti and Kobuleti diverges. This road forms an alternative route between Samtredia and Batumi but traverses hilly terrain and consequently has an inferior vertical and horizontal alignment to the S12. Road closures are also more frequent.

4. UTILISATION OF THE STUDY ROADS

4.1 General

The regular collection of traffic data in Georgia was completely disrupted during the first half of the 1990s and routine classified surveys did not start again until 1995, and then only at a few locations on the main road network. This was primarily a result of shortages in funding and staffing. There was, therefore, no significant traffic database that could be drawn upon for this study. For these reasons, it was necessary to conduct classified volume surveys for the study, to provide a sound basis for the estimation of base year traffic levels on the study roads. The following sections describe the surveys undertaken by Sakavtogza staff for the Consultants, the results obtained and the process by which these results were adjusted to obtain estimates of 1997 annual average daily traffic on each study road link.

4.2 Traffic Surveys Undertaken on the Study Roads

4.2.1 Scope of Surveys

The study comprises six separate roads within Georgia:

- Tbilisi - Red Bridge bp (Azerbaijan)
- Tbilisi Bypass
- Tbilisi - Khashuri
- Tbilisi - Marneuli - Guguti bp (Armenia)
- Marneuli - Sadakhlo bp (Armenia)
- Samtredia - Ureki

These roads were provisionally divided into links, each having homogeneous traffic characteristics throughout its length, for the purposes of the economic analysis of improvement options. The initial subdivision was carried out on the basis of the available traffic data, mainly from the preceding TRACECA study of 1996, and a reconnaissance, incorporating the Consultants' Moving Observer Counts (MOCs), of each of the roads. The study road links are summarised in Table 4.1 below.

Table 4.1 Road Network Studied

Road No.	Section From	Section To	Link No.	Link Length (km)
S4	Red Bridge bp	Tbilisi Bypass (S)	1	38
S9	Tbilisi Bypass (S)	Tbilisi Bypass (C)	2	13
S9	Tbilisi Bypass (C)	Tbilisi Bypass (N)	3	35
S1	Tbilisi (north)	Vladikavkaz jct	4	28
S1	Vladikavkaz jct	Gori junction	5	54
S1	Gori junction	Khashuri	6	46
S7	Marneuli	Sadakhlo bp	7	34
S6	Tbilisi (south)	Marneuli	8	29
S6	Marneuli	Bolnisi	9	24
S6	Bolnisi	Guguti bp	10	44
S12	Samtredia	Ureki	11	59
			Total	856

Source: Consultants

The starting point for the engineering and economic analysis of improvement options on the study road links is a detailed and accurate estimate of base year annual average daily traffic (AADT) by vehicle type for each link. The recent rather scanty evidence on traffic levels on the study roads required supplementing by a number of classified volume counts on the study road links. The location and duration of the classified volume counts were decided upon after initial reconnaissance and discussions with Sagavtogsa. The principle behind survey location is that of representativeness, in traffic terms, of the full length of the link. 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 Sagavtogsa determined that each survey should be no longer than one day in duration. The majority were of 12 hours, 0800-2000 hours, but it was necessary to conduct two 24 hour counts to obtain an indication of the hourly distribution of traffic over a complete day and night 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.

Classification of vehicles was fourfold; direction, time, to the nearest hour, vehicle type and nationality. Vehicle type classification used eleven categories following those adopted by 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

It should be noted that this 11 vehicle type classification is subsequently compressed into the following vehicle classification in the economic analysis of road improvements:

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

In addition, vehicles were classified by nationality. Reference to their registration plates provided a distinction between Georgian and international vehicles. In terms of the derivation of estimates of AADT, classification by nationality is significant because it distinguishes between Georgian and international beneficiaries of road improvements and because Georgian and international traffic can be expected to have different seasonal variations.

An example of the classified traffic count form used is included as Appendix 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 from	Section to	Link No.	Survey Location (km)	Survey Date	Survey Duration (hours)
S1	Tbilisi (n)	Vladikavkaz jct	4	25	20/2/97	12
S1	Vladikavkaz jct	Gori junction	5	55	26/2/97	12
S1	Gori junction	Khashuri	6	85	27/2/97	12
S4	Tbilisi (s)	Red Bridge	1	30	19/2/97 & 5-6/3/97	24
S6	Tbilisi	Marneuli	8	18	19/2/97	12
S6	Marneuli	Bolnisi	9	38	20/2/97	12
S6	Bolnisi	Guguti bp	10	68	27/2/97	12
S6	Bolnisi	Guguti bp	10	98	26/2/97	12
S7	Marneuli	Sadakhlo	7	16	11/3/97	12
S9	Tbilisi bypass (n)	Tbilisi bypass (c)	3	32	19/2/97	12
S9	Tbilisi bypass (c)	Tbilisi bypass (s)	2	41	5/3/97	12
S12	Samtredia	Ureki	11	37	11-12/3/97	24

Source: Consultants
Note: (n) north (c) centre (s) south

4.3. Estimates of Base Year Traffic by Vehicle Type

4.3.1 Choice of Road Sections for Traffic Analyses

The provisional set of road links, shown in Table 4.1 and used in the selection of classified volume count survey locations, has been retained following completion of the survey programme.

4.3.2 Results of Traffic Surveys

The results of the classified volume count surveys in Georgia are set out in 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 Georgian traffic to take account of seasonality is discussed below.

4.3.3 Conversion of Surveyed Traffic Flows to Estimates of Average Daily Traffic

A factor has been applied to those classified volume counts of 12 hours duration to convert them to a 24 hour traffic volume basis. The two counts at S4 km 30 and S12 km 37 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 night-time vehicle mix. Except for the Samtredia-Ureki road link the adjustment factors used were derived from the location on the S4, Tbilisi - Red Bridge, road because of its greater proximity to the 12 hour classified volume count stations, in central and eastern Georgia. These factors are set out in Table 4.3.

Table 4.3. 12 to 24 hour Traffic Volume Conversion Factors

Vehicle Category	12-24 Hour Factor Expansion Factors		
	Georgian	International	Total
Car	1.22	1.44	1.22
Minibus	1.22	1.50	1.24
LGV	1.00	1.33	1.10
Bus	1.63	3.14	1.97
2-axle MGV	1.06	1.00	1.06
3-axle HGV	1.83	1.00	1.54
4-axle HGV	1.50	1.00	1.20
5-axle HGV	2.00	1.22	1.36
6+axle HGV	1.00	1.00	1.00

Source: Consultants

All the classified volume count surveys were conducted within a period of one month from the middle of February 1997. Winter traffic volumes are markedly lower than the average in Georgia because of the prevailing adverse weather conditions and therefore the classified volume count survey results can be considered underestimates of AADT. As previously stated, traffic data collection in Georgia is only slowly returning to normality and as yet cannot provide a satisfactory database from which to adequately quantify seasonal variations. The consultants were unable to obtain a dataset from which reliable seasonality factors could be derived. Consequently, factors were used from neighbouring Azerbaijan where there has been much greater continuity of traffic counting over recent years. These seasonal factors are given in Table 4.4.

Table 4.4 Seasonal Traffic 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 Georgian element 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.

4.3.4 Estimated Annual Average Daily Traffic in 1997

The application of the 12 to 24 hour expansion factors and adjustments for seasonality for Georgian vehicles results in the estimates of annual average daily traffic (AADT) by vehicle type set out in Table 4.5. In this table the compressed vehicle classification used in the subsequent economic analysis is presented.

Table 4.5: Estimates of Annual Average Daily Traffic

Road No.	Section		Vehicle	Annual Average Daily Traffic (AADT)						
	from	to	Nationality	Car	Utility	Bus	2-ax Truck	3-ax Truck	4+ax Truck	Total
S1	Tbilisi	Vladikavkaz jct	National	6,557	372	1,193	205	455	122	8,903
			Internat	4	1	47	1	64	85	203
			Total	6,561	373	1,240	206	519	208	9,106
S1	Vladikavkaz jct	Gori junction	National	4,147	204	711	123	284	103	5,572
			Internat	0	0	38	0	57	46	140
			Total	4,147	204	749	123	341	149	5,712
S1	Gori junction	Khashuri	National	4,244	276	810	135	353	169	5,987
			Internat	0	2	72	6	74	97	251
			Total	4,244	278	882	141	427	267	6,238
S4	Tbilisi	Red Bridge	National	1,058	47	53	72	45	14	1,288
			Internat	13	7	22	1	10	18	71
			Total	1,071	54	75	73	55	32	1,359
S6	Tbilisi	Marneuli	National	3,419	210	367	102	153	28	4,279
			Internat	0	0	6	0	0	0	6
			Total	3,419	210	373	102	153	28	4,285
S6	Marneuli	Bolnisi	National	2,275	108	233	41	42	2	2,701
			Internat	1	0	16	0	2	3	22
			Total	2,276	108	249	41	44	5	2,723
S6	Bolnisi	Guguti	National	554	32	75	32	22	0	715
			Internat	9	0	20	1	15	2	48
			Total	563	32	95	33	37	0	763
S7	Marneuli	Sadakhlo	National	1,354	37	183	36	37	20	1,667
			Internat	104	3	47	7	6	0	167
			Total	1,458	40	230	43	43	20	1,834
S9	Tbilisi bypass (northwest)		National	209	55	200	140	86	77	768
			Internat	0	0	0	0	16	137	153
			Total	209	55	200	140	102	214	921
S9	Tbilisi bypass (southeast)		National	2,111	90	253	123	250	51	2,878
			Internat	1	0	3	0	21	18	43
			Total	2,112	90	256	123	271	69	2,921
S12	Samtredia	Ureki	National	803	53	188	51	35	26	1,156
			Internat	3	0	22	1	43	57	126
			Total	806	53	210	52	78	83	1,282

Table 4.5 shows that the highest flows are to be found on the main east-west trans-Georgian highway west of Tbilisi, notably on the first 25 km west of the capital. Here traffic to and from Vladikavkaz and Russia to the north west joins the to east-west traffic flows. Daily traffic volumes on the S.1 road remain in over 5,000 vehicles as far west as Khashuri. Apart from the Tbilisi-Marneuli road link, average daily traffic levels on the other study road links were below 3,000 vehicles.

Of the two roads leading to the Armenian border, the shorter Marneuli-Sadakhlo route carries the most of the traffic between the Tbilisi region and the Armenian border, the majority of traffic on the Bolnisi road being local as confirmed by the very low flows on the approaches to the Armenian border at Guguti. The Tbilisi Bypass has contrasting traffic volumes on its northwestern and southeastern sections, separated by the junction with the Sagarejo road. Significant volumes of local traffic use this junction to access the southeastern end of the bypass which has an AADT of close to 2,000 vehicles, but traffic on the norther section carries fewer than 1,000 vehicles a day.

4.3.5 The Relative Importance of International Transit Traffic

Foreign vehicles account for less than 5 percent of total traffic flows on most study roads except on the approaches to the Armenian border at Guguti and Sadakhlo. However, this overall figure disguises considerable variations in the relative significance of foreign traffic by different vehicle types. In the light vehicle, bus and 2 axle truck categories Georgian vehicles generally account for over 90 percent of the total except on the approaches to the Armenian border and on the Tbilisi bypass. The relative importance of foreign vehicles increases with truck size. In the case of 3 axle trucks, for example, foreign vehicles account for 10 - 20 percent of total 3 axle truck movements except on the approaches to the Armenian border where the proportion is higher. On most road links foreign trucks account for a very significant proportion of movements by the heaviest category of trucks, those with more than 3 axles. Table 4.6 sets out the respective percentage shares of domestic and foreign vehicles by vehicle category and road link.

To sum up, therefore, international traffic consists predominantly of heavy vehicles of 3 or more axles. It is clear from the results of our surveys that much of the long distance and international haulage in Georgia is conducted by foreign operators.

Table 4.6 RELATIVE IMPORTANCE OF DOMESTIC AND FOREIGN TRAFFIC BY VEHICLE CATEGORY, 1997

Road No.	Section Name	Vehicle Nationality	Percentage Distribution of Traffic by Domestic / Foreign Vehicles, 1997						
			Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
S1	Tbilisi - Vladikavkaz junction	National	99.9	99.6	96.2	99.5	87.7	58.8	97.8
		Foreign	0.1	0.4	3.8	0.5	12.3	41.2	2.2
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S1	Vladikavkaz junction - Gori jct	National	100.0	100.0	95.0	100.0	83.3	69.2	97.5
		Foreign	-	-	5.0	-	16.7	30.8	2.5
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S1	Gori junction - Khashuri	National	100.0	99.5	91.8	95.7	82.7	63.6	96.0
		Foreign	-	0.5	8.2	4.3	17.3	36.4	4.0
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S4	Tbilisi - Red Bridge bp	National	98.8	87.1	70.5	98.6	81.7	42.9	94.8
		Foreign	1.2	12.9	29.5	1.4	18.3	57.1	5.2
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S6	Tbilisi - Marneuli	National	100.0	100.0	98.3	100.0	100.0	100.0	99.9
		Foreign	-	-	1.7	-	-	-	0.1
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S6	Marneuli - Bolnisi	National	99.9	100.0	93.7	100.0	95.5	37.1	99.2
		Foreign	0.1	-	6.3	-	4.5	62.9	0.8
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S6	Bolnisi - Guguti	National	99.4	100.0	86.1	100.0	89.6	-	97.3
		Foreign	0.6	-	13.9	-	10.4	100.0	2.7
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S6	Bolnisi - Guguti	National	94.1	100.0	61.6	86.6	27.5	-	81.3
		Foreign	5.9	-	38.4	13.4	72.5	100.0	18.7
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S6	**Bolnisi - Guguti (weighted average)**	**National**	**98.3**	**100.0**	**78.6**	**96.9**	**59.0**	**-**	**93.7**
		Foreign	**1.7**	**-**	**21.4**	**3.1**	**41.0**	**100.0**	**6.3**
		Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
S7	Marneuli - Sadakhlo	National	92.9	92.9	79.5	83.6	86.1	100.0	90.9
		Foreign	7.1	7.1	20.5	16.4	13.9	-	9.1
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S9	Tbilisi Bypass (northwest)	National	100.0	100.0	100.0	100.0	84.4	36.0	83.4
		Foreign	-	-	-	-	15.6	64.0	16.6
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S9	Tbilisi Bypass (southeast)	National	99.9	100.0	98.8	100.0	92.2	74.3	98.5
		Foreign	0.1	-	1.2	-	7.8	25.7	1.5
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
S12	Samtredia - Ureki	National	99.6	100.0	89.5	98.1	44.9	31.0	90.2
		Foreign	0.4	-	10.5	1.9	55.1	69.0	9.8
		Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Classified estimates based on traffic survey results.

4.4 Vehicle Weights, Axle Loads and Pavement Damage Factors

The assumptions regarding axle loads and vehicle equivalent standard axles (ESA) used in this study are based on the results of the axle load surveys carried out by the Consultants west of Tbilisi in 1996 as part of the TRACECA Pavement Management System and Highway Financing Study. An exception to this is made for cars and other light vehicles which were not weighed in that survey and whose ESA per vehicle are based on international experience.

Table 4.7: GEORGIA - ESAL PER VEHICLE 1997

Sample size	Vehicle type	ESA per vehicle (both direction)
Car	0	0.0007
Utility	0	0.0011
Bus	9	2.4005
Truck 2 axle	108	0.9062
Truck 3 axle	145	2.5238
Truck > 3 axle	62	2.1385

Source: Consultant's estimates based on the 1996 TRACECA study axle load survey
Note: Cars and other light vehicles were not weighed and the assumed ESAs are based on international experience.

4.5 <u>Forecasts of Traffic Growth on the Study Roads</u>

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 most of the existing paved study roads the scale of potential reductions in pavement roughness and road user costs is unlikely to be sufficient to bring about significant traffic generation

4.5.2 Diverted Traffic

Of the roads being studied only one, Samtredia-Ureki, currently has clearly identifiable alternative routes. The Tbilisi Bypass forms an alternative to travelling through the capital for through-traffic. Indeed, it was originally designed specifically to keep through-traffic out of the Tbilisi urban area and thus alleviate delays arising from traffic congestion. Today it attracts traffic from the urban road network of Tbilisi mainly in response to the official prohibition on heavy vehicle movements within the capital. This prohibition has been reinstated since the reopening of the bypass after bridge repairs in late 1996. Given the present condition of the bypass, the scope for further traffic diversion to it in the event of its improvement appear to be rather limited.

The Samtredia - Ureki road link has two competing alternative routes.

- The northerly route via Senaki and Poti using the S1 and S2 roads and
- a more southerly route using a republican road via TshokhataurindOzurgeti. The former route is longer by 29 km but generally has much better surface condition such that it is competitive in terms of time; the latter is approximately 5 km shorter but of poorer surface quality and, in part, traverses hilly to mountainous terrain which is

unsuitable for the heavy vehicles which comprise the bulk of the long distance traffic moving between Samtredia and the Black Sea coast.. It is reasonable to assume, therefore that there is no potential for diversion from this more southerly route.

Reconnaissance revealed that the more northerly route between Samtredia-and Ureki (and ultimately Batumi) via Senaki and Poti was comparable in terms of travel times with the study road via Lanchkhuti, but produced no evidence that it was being used as an alternative route. Informal discussions with the local police confirmed that very little traffic between Samtredia and Ureki moves via Poti and Senaki principally because of the significantly greater distance. Traffic diversion has, therefore, already taken place and there remains no scope for further diversion in response to improvements in the condition of the study road .

4.5.3 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 Georgia and its main trading partners. W.S.Atkins' preliminary forecasts of the growth of Georgian real Gross Domestic Product (GDP) indicated the following annual rates of increase:

1997 - 2001	7.8 % a year
2001 - 2006	7.0 % a year
2006 - 2011	8.5 % a year

These growth rates have been modified in Atkins' latest forecasts as follows:

1997 - 2000	8.0 % a year
2000 - 2006	5.5 % a year
2006 - 2011	5.0 % a year

This reflects a more optimistic view of the short term economic growth prospects and a more cautious view of Georgia's longer term economic growth. The rapid initial growth reflects recovery from the extremely depressed levels of economic activity prevailing in the first half of the 1990s. 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 periods 1997 - 2010 and 2010 - 2025.

The above forecasts of real (constant price) GDP growth have, therefore, modified as follows:

W.S.Atkins preliminary GDP growth forecast	1997 - 2010	7.7 % a year
W.S.Atkins latest available GDP growth forecast	1997 - 2010	6.1 % a year

Using W.S Atkins' assumed elasticity of demand for freight transport (as measured by tonne-kilometres) of 0.92 per 1.0 percent change in real GDP, the above forecasts translate into the following forecasts of total growth in freight transport by whatever mode:

W.S Atkins preliminary freight tonne km forecast	1997 - 2010	7.2 % a year
W.S Atkins latest freight tonne kilometre forecast	1997 - 2010	5.8 % a year

There are at present no long range economic forecasts for the period beyond 2010. It seems likely, however, that the Georgian economy would continue to grow reasonably rapidly after 2010 in view of the amount of recovery required to compensate for the economic disasters of the 1990s.

Our traffic forecasts are based on the assumption that road traffic on the study roads will grow in line with the growth of the Georgian economy and those of its neighbours and main trading partners. 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 presumably present these aspects more explicitly, but unfortunately we have not been able to take advantage of the results of this work given the apparently incompatible time scales of the two TACIS sponsored projects.

Our forecasts of the rate of growth of "normal" traffic on the study road are set out in Table 4.8. A more detailed picture of traffic growth rates by link and vehicle category is given in Appendix Table A.4.4 and future traffic levels by vehicle type and road link under the high and low traffic growth assumptions is set out in Appendix Table A.4.5. These traffic forecasts comprise a central or best estimate and high and low estimates reflecting optimistic and pessimistic assumptions regarding economic growth. 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 4.8 percent a year between 1997 and 2010 and 6.7 percent a year thereafter. For the same periods, the high and low forecasts indicate annual traffic growth rates of 6.3 and 7.3 and 3.4 and 5.7 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, particularly during the second part of the project appraisal period. 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.

Table 4.8 GEORGIA - ASSUMED TRAFFIC GROWTH ON THE STUDY ROADS

Average Annual Traffic Growth Rates Best Estimate							
	Vehicle category						
Period	Cars	Utility vehicle	Buses	Trucks 2 axle	Trucks 3 axle	Trucks >3 axle	Total
1997-2010	5.0	4.5	4.0	3.0	4.5	5.5	4.8
2010-2025	6.5	6.3	5.4	5.0	6.0	7.0	6.3
Average Annual Traffic Growth Rates Optimistic							
Period	Cars	Utility vehicle	Buses	Trucks 2 axle	Trucks 3 axle	Trucks >3 axle	Total
1997-2010	6.5	6.2	5.5	4.2	6.0	6.2	6.3
2010-2025	7.5	7.0	6.0	5.5	7.0	8.0	7.3
Average Annual Traffic Growth Rates (%) Pessimistic							
Period	Cars	Utility vehicle	Buses	Trucks 2 axle	Trucks 3 axle	Trucks >3 axle	Total
1997-2010	3.6	3.5	2.7	2.0	3.0	4.0	3.4
2010-2025	6.0	5.8	4.5	4.0	5.0	6.0	5.7

Source: Consultant's estimates

Table 4.9 GEORGIA STUDY ROADS: CENTRAL ESTIMATE TRAFFIC FORECASTS, 1997 - 2025

Road No.	Section Name	Annual Average Daily Traffic (AADT) - 1997						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
S1	Tbilisi - Km 25	6561	373	1240	206	519	209	9,108
S1	Km 25 - Gori junction	4,147	204	749	123	341	149	5,713
S1	Gori junction - Khashuri	4,244	278	882	141	427	267	6,239
S4	Tbilisi - Red Bridge (Azer.border)	1,071	54	75	73	55	32	1,360
S6	Tbilisi - Marneuli	3,419	210	373	102	153	28	4,285
S6	Marneuli - Bolnisi	2,276	108	249	41	44	5	2,723
S6	Bolnisi - Guguti (Armenian border)	563	32	95	33	37	1	761
S7	Marneuli - Sadakhlo	1,458	40	230	43	43	20	1,834
S9	Tbilisi bypass (west)	209	55	200	140	102	214	920
S9	Tbilisi bypass (east)	2112	90	256	123	271	69	2,921
S12	Samtredia - Ureki	806	53	210	52	78	83	1,282
Road No.	Section Name	Central Estimate - Annual Average Daily Traffic (AADT) - 2010						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
S1	Tbilisi - Km 25	12,372	661	2,065	303	920	419	16,739
S1	Km 25 - Gori junction	7,820	362	1,247	181	604	299	10,512
S1	Gori junction - Khashuri	8,003	493	1,469	207	757	536	11,463
S4	Tbilisi - Red Bridge (Azer.border)	2,020	96	125	107	97	64	2,509
S6	Tbilisi - Marneuli	6,447	372	621	150	271	56	7,917
S6	Marneuli - Bolnisi	4,292	191	415	60	78	10	5,046
S6	Bolnisi - Guguti (Armenian border)	1,062	57	158	48	66	2	1,393
S7	Marneuli - Sadakhlo	2,749	71	383	63	76	40	3,383
S9	Tbilisi bypass (west)	394	97	333	206	181	429	1,640
S9	Tbilisi bypass (east)	3,982	159	426	181	480	138	5,368
S12	Samtredia - Ureki	1,520	94	350	76	138	166	2,344
Road No.	Section Name	Central Estimate - Annual Average Daily Traffic (AADT) - 2025						
		Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle	TOTAL
S1	Tbilisi - Km 25	31,818	1,653	4,544	629	2,204	1,157	42,005
S1	Km 25 - Gori junction	20,111	904	2,745	376	1,448	825	26,408
S1	Gori junction - Khashuri	20,582	1,232	3,232	430	1,814	1,478	28,767
S4	Tbilisi - Red Bridge (Azer.border)	5,194	239	275	223	234	177	6,342
S6	Tbilisi - Marneuli	16,581	931	1,367	311	650	155	19,994
S6	Marneuli - Bolnisi	11,038	479	913	125	187	28	12,768
S6	Bolnisi - Guguti (Armenian border)	2,730	142	348	101	157	6	3,484
S7	Marneuli - Sadakhlo	7,071	177	843	131	183	111	8,515
S9	Tbilisi bypass (west)	1,014	244	733	427	433	1,184	4,035
S9	Tbilisi bypass (east)	10,242	399	938	376	1,151	382	13,488
S12	Samtredia - Ureki	3,909	235	770	159	331	459	5,863

Source: Consultant's estimate.

Clearly with the traffic growth indicated by the central and high growth forecasts capacity problems will appear within the 1997 - 2025 appraisal period on certain study road links. However, the estimated volume-capacity ratios set out in Appendix Table A.4.6 suggest that capacity constraints indicated by volume capacity ratios of 0.7 or higher will not be experienced before 2015 (S.1 Gori Junction-Khashuri) under the central forecast and 2012 under the high growth forecast. Other parts of the S.1 east-west route will begin to experience congestion two or three years later. Immediate initiatives to widen study roads to 4 lane standard would, therefore clearly be premature.

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 Georgia 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.

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. 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 Georgia 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 data and assumptions about road and vehicle characteristics and unit costs. In order to operate the model it is necessary to select a number of 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. The following classes of representative vehicle types were selected for vehicle operating cost analysis:

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

- 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 has been based on an analysis of detailed vehicle registration data supplemented by 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 Georgia 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 130-80
• Utility vehicle:	Raf 2203	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 Georgia, 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 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):

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

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$ 0.35 / litre
Diesel	US$ 0.26 / 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 and remuneration or per capita income can be made for Georgia and, as might be expected the two sources do not give the same answer.

- **Nominal average monthly wage:** In early 1997 this was around US$ 20 in the public sector and US$ 60 in the private sector. Assuming a 165 hour working week this would imply an hourly values within the range US$ 0.12 - 0.36. If allowance is made for unrecorded transactions in the economy, a rate nearer the top end of this range may be more appropriate.

- **Estimates based on Per Capita Gross Domestic Product (GDP).** Estimated GDP per capita of US$ 720 in 1997 would equate with an hourly rate of US$ 0.36 assuming a 165 hour working month. If estimates of unrecorded transactions as a proportion of GDP made by the World Bank for other CIS countries such as Azerbaijan also apply in Georgia, Gross Domestic Product (GDP) in Georgia 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$ 900 - 1,010 compared with the US$ 720 based purely on recorded transactions and would indicate hourly rates in the range US$ 0.45 - 0.50.

In the absence of soundly based research evidence about the significance of unrecorded transactions in the Georgian economy, we have made the conservative assumption that the average time value should be based on the 1997 per capita GDP of US$720 and for the purpose of this study we have adopted a basic passenger time value of US$ 0.35 / 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 Georgia, 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 Georgia. 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

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

- 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 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: GEORGIA - 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	0.024	0.060	0.130	0.078	0.153	0.235
Lubricants	0.003	0.003	0.005	0.005	0.005	0.008
Tyres	0.004	0.007	0.075	0.031	0.083	0.145
Crew time	0.002	0.005	0.013	0.011	0.012	0.018
Passenger time	0.005	0.014	0.132	0.000	0.000	0.000
Cargo holding	0.000	0.000	0.000	0.000	0.000	0.000
Maintenance labour	0.001	0.001	0.004	0.004	0.005	0.011
Maintenance parts	0.021	0.033	0.048	0.056	0.114	0.150
Depreciation	0.023	0.025	0.077	0.028	0.078	0.101
Interest	0.021	0.016	0.048	0.023	0.051	0.064
Overhead	0.000	0.010	0.020	0.025	0.025	0.025
TOTAL	0.105	0.173	0.551	0.262	0.526	0.757

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	23.1	34.3	23.6	29.9	29.0	31.0
Lubricants	3.0	1.8	0.9	2.0	1.0	1.1
Tyres	3.9	3.7	13.6	11.8	15.8	19.2
Crew time	2.3	3.1	2.3	4.3	2.2	2.4
Passenger time	4.6	7.8	23.9	0.0	0.0	0.0
Cargo holding	0.0	0.0	0.0	0.0	0.0	0.0
Maintenance labour	1.1	0.7	0.8	1.6	1.0	1.5
Maintenance parts	20.0	19.1	8.7	21.3	21.7	19.8
Depreciation	22.3	14.5	13.9	10.8	14.8	13.3
Interest	19.7	9.1	8.7	8.8	9.8	8.5
Overhead	0.0	5.8	3.6	9.6	4.8	3.3
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 5.2. 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	18%	Utility 19%	Bus 4%
Trucks	10 - 16%		

Table 5.2: GEORGIA - ROAD USER COSTS AND PAVEMENT ROUGHNESS

Roughness (IRI in m/km)	Road User Costs (US$ per vehicle kilometre)					
	Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
2	0.090	0.149	0.532	0.223	0.465	0.691
3	0.095	0.157	0.538	0.236	0.485	0.713
4	0.101	0.166	0.545	0.249	0.506	0.736
5	0.106	0.176	0.552	0.262	0.526	0.759
6	0.113	0.186	0.561	0.275	0.547	0.782
7	0.119	0.197	0.570	0.289	0.568	0.806
8	0.126	0.209	0.580	0.303	0.590	0.830
9	0.133	0.222	0.590	0.317	0.611	0.855
10	0.141	0.235	0.602	0.331	0.633	0.880
11	0.149	0.249	0.614	0.346	0.656	0.905
12	0.158	0.264	0.627	0.360	0.679	0.931
13	0.167	0.279	0.640	0.375	0.702	0.957
14	0.176	0.295	0.655	0.391	0.725	0.984
15	0.186	0.312	0.670	0.406	0.749	1.011

Roughness (IRI in m/km)	Indices of Road User Costs (RUC @ IRI 3 = 100)					
	Car	Utility	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
3	100.0	100.0	100.0	100.0	100.0	100.0
4	105.6	105.7	101.3	105.5	104.2	103.2
5	111.6	111.9	102.7	111.1	108.4	106.4
6	118.0	118.6	104.3	116.8	112.7	109.7
7	124.9	125.7	106.0	122.6	117.1	113.0
8	132.1	133.2	107.8	128.4	121.5	116.4
9	139.8	141.2	109.8	134.4	126.0	119.9
10	147.9	149.7	111.9	140.5	130.5	123.4
11	156.5	158.6	114.2	146.6	135.1	127.0
12	165.4	168.0	116.6	152.9	139.8	130.6
13	174.8	177.9	119.1	159.3	144.6	134.3
14	184.5	188.2	121.8	165.7	149.4	138.0
15	194.7	198.9	124.6	172.3	154.3	141.8

Source: Consultant's estimates based on the use of the HDM Vehicle Operating Cost Sub Model
Note: Road User Costs comprising economic vehicle operating costs and passenger time costs.

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 Georgia, 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 Georgia. 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 Georgia 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 Georgia and other CIS countries that 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 Georgia are less than 5 percent of those in the countries referred to and traffic levels on Georgian “S” 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	Bus	Truck 2 axle	Truck 3 axle	Truck >3 axle
10	0.229	0.449	1.210	0.464	0.804	1.061
20	0.153	0.285	0.787	0.335	0.623	0.848
30	0.128	0.232	0.665	0.297	0.571	0.800
40	0.116	0.206	0.616	0.280	0.550	0.781
50	0.110	0.192	0.590	0.272	0.540	0.771
60	0.108	0.184	0.575	0.268	0.535	0.765
70	0.106	0.179	0.565	0.265	0.531	0.761
80	0.106	0.176	0.558	0.263	0.528	0.758
90	0.105	0.174	0.553	0.261	0.525	0.756
100	0.105	0.173	0.549	0.261	0.524	0.755

Source: Consultant's estimates based on HDM-III Vehicle Operating Cost Model 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 Sakavtogza 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 Georgia 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 Georgia is in general the standard of the Former Soviet Union (FSU). The Soviet Union Standard (SNIP) 2.05.02-85 is still in use.

Based on the traffic volume, respectively the traffic forecast, the economic and administrative values of the roads are classified into five categories: Details of this standard and the respective categories are shown in table 6.1.

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

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

The study roads are fall within the definition of the following categories:

Section	Road Category
S 1, Tbilisi - Kashuri	
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)	I
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	II
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)	II
S 4, Tbilisi - Red Bridge / Azerbaijan border (km 11+000 - km 57+170)	III
S 6, Tbilisi - Marneuli - Guguti / Armenian border	
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	II
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	II
Subsection: Bolnisi - Guguti /Armenian border (km53+880 - km 99+127)	III
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	III
S 9, Tbilisi by-pass	
Subsection: west (km 0+000) - km 34+800)	III
Subsection: east (km 34+800 - km 49+008)	II
S 12, Samtredia - Ureki (km 0+000 - km 56*528)	III

Accordingly the road categories the main design parameters are:

Parameter	Category Ib + II	Category I
- design speed	120 km/h	100 km/h
- min. radius	800 m	600 m
- max. gradient	4 %	5 %
- min. crest curve	15,000 m	10,000 m
- min. sag curve	5,000 m	3,000 m
- min. crossfall	1.5 %	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).

The field investigation carried out showed that several road sections, in particular on the S 6 and S 7, does not fully comply with the requirements of the respective road category.

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 asphalt overlay)
- Reconstruction of new pavement: Reconstruction of the pavement (subbase, base course, asphalt 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 Investigations

Methodology

(1) At the commencement of the field work a general reconnaissance was made in order to identify and classify the various soil formations occurring along the project roads. This classification was based on visual appearance of the soil, on analysis of former laboratory test results and on the Consultants experience on the project area.

(2) Hand-dug pits were excavated up to one meter in depth along the project roads to an interval of approx. 8,5 km in length. The type of the existing pavement, the thickness of the individual layers and subgrade condition were recorded.

(3) Representative samples from the existing subgrade, gravel base course and from the asphalt pavement were collected from site and brought to the laboratory for testing.

(4) Sites posing particular geotechnical problems were intensively investigated. The overall stability of the road prism has been assessed by reviewing existing subsoil condition data. Additionally, on these locations dynamic penetration tests were executed in order to assess the in-situ density of the material at greater depth

Geological outline

The project roads are located in the depression between the two major mountain massifs of Georgia (Caucasus and Anticaucasus). The depression is divided by the crystalline massif of Dzirula into the Kolkheti valley in the west and the planes of inner/lower Kartli in the east. The plains usually consist of alluvial deposits of the Quarter age. They are crossed by several ridges formed during the Neogene age with conglomerates, sandstones and clays. Only the Khrami and Somkhiti mountain chain in the south belongs to the Chalk age and are of volcanic origin. Limestone and tuffecious sandstone deposits are here often interbeded within the volcanic formation.

Existing data

The main sources of data were:

a) Technical passports. Their contents are:

- overall situation of the road and its history
- geometric of the alignment
- location and size of structures
- composition of the pavement
- description of subgrade soils.

These documents mostly give the supposed parameters of the pavement which differ from the actual ones. Additionally, the description of the subgrade soils is very general.

b) Geological survey of the roads:

- Tbilisi - Red Bridge
- Tbilisi - Marneuli - Guguti
- Marneuli - Sadakhlo

These documents describe the geological situation along the road corridor including maps in scale 1 : 25 000.

c) Detail soil investigation of the two landslide areas along the Tbilisi - Khashuri road (km 27 and km 73).

These documents include the subsoil investigation, results, description of the slide mechanism in each case and proposals for remedial measures.

Field investigations

(1) The field survey was carried out from April, 6 to May, 2 by team from SAKAVTOGZA Institute supported by the Material Engineer from KOCKS Consult GmbH.

Briefly the field studies for the material and site investigations consisted of the following:

- 46 No. Trial pit excavations.

- 24 No. Dynamic penetration tests with a light test equipment (LDP) as described in the German standard DIN 4094 (cone area = 5 cm2, cone angle 2 a = 90°, falling weight 10 Kp, falling height = 0,50 m). Maximum depth 5,9 m below ground level.
- 4 No. Determination of in-situ density.
- 16 No. Determination of natural moisture content.

(2) A summary showing the location and type of the individual test performed is given in Appendix 6.3.

Laboratory testing

(1) Except of CBR all other laboratory tests performed on samples taken from the site were carried out on the SAKAVTOGZA laboratory in Tbilisi. The samples collected for the CBR test were sent to the Turkmendorproyekt laboratory in Turkmenistan for testing, where we under the same TRACECA project (Component 2: Preparation of a Road Improvement Project Ashgabat to Mary) a soils and materials testing laboratory installed.

(2) Summarised the following tests were performed:

- 35 No. determination of grain size distribution by means of sieve analysis.
- 32 No. determination of plasticity limits.
- 10 No. determination of moisture density relationship.
- 7 No. determination of California Bearing Ratio under soaked conditions
- 1 No. determination of bitumen content.

(3) The above testing and soil classification carried out as follows:

- The tests conducted base on SU Standards. On the reason that these standards do not differ significantly from western testing procedures the evaluation of the obtained test results was possible.
- The classification of soils was carried out according to the specifications of the U.S. Highway Research Board (HRB). For reference a copy of the chart is given as Table 2 in Appendix 6.3.
- The moisture density relationship (max. dry density) is made using a cylinder having a volume 1000 cm³. The soil is compacted in three layers by 40 drops of hammer of a mass of 2,5 Kg. The height of the drop is 455 mm. The compaction effort involved by the method is approx. 136 tm/m3. In comparison with the Proctor test this compaction energy is higher than the standard (60 tm/m3) but less than the modified one (275 tm/m3)
- The CBR and swell measured on 4 days soaked specimens moulded at OMC and standard compaction.
- The laboratory and field test results are presented in Table 3.1 in Appendix 6.3.

Results of the Investigations

A. Existing pavement

(1) The composition of the existing pavement significantly differs from road to road. Variations in pavement composition within the individual road were also identified. In most of the cases the pavement consists of two bituminous courses laid on a granular base. The upper bituminous layer, the wearing course, is a dense continuously graded mix with bitumen content ranging from 5,5 % to 7,0 %, whilst the lower one, the binder course, has a less dense aggregate structure and bitumen content laying between 4,0 % to 6,0 %. In many of the project roads the binder course represent the old surfacing which usually is a bitumen penetration macadam made of 25 mm or 40 mm nominal size crusted stone and sealed with a surface dressing. Depending on resealing work the present thickness of the combined bituminous layer varies from 5 cm to 36 cm. The bitumen content was found to lie by approx. 6,6 % by mass of total mix. The granular layer supporting the asphalt is of varying thickness and usually made of natural gravel (river gravel) except the Tbilisi Bypass and the road Tbilisi - Khashuri (up to km 75) where crushed stone has been partly used. Details of the pavement composition along the individual road sections are given in Appendix 6.3.

(2) The road condition survey shows that the present condition of the pavement also subjects large variations. Some sections along the roads are still in acceptable condition whilst others already reach a critical phase with typical indications such as deep permanent deformations and the advanced disintegration of the structural layers.

(3) The reasons for the deficiencies identified are:

- insufficient thickness of the bituminous layers; thin overlay has been used in many places.
- insufficient internal drainage of the pavement. The granular base course is often confined between continuous impermeable shoulders and/or kerbstones.
- poorly designed / constructed pavement; In many places a single base course layer of less than 200 mm thickness is placed straight on subgrades of poor bearing capacity (CBR < 5 %).
- insufficient external drainage. On roads traversing hilly terrain the majority of the side ditches are under designed or filled with sediments.
- saturation of the subgrade. The roads often traverse low laying area and cuttings where pondings respectively seepage water exist.
- settlement of the road body. The majority of the embankments are constructed using clayey soil and without initial compaction.
- Lack of maintenance. Neglected repairs on initial minor deficiencies accelerate the fatigue performance of the pavement.

(4) The common deficiencies identified along the project roads are included in road condition survey (chapter 7.6) whilst defects based on particular geotechnical reasons are presented below and Appendix 6.3.

B. Subgrade

(1) The predominant soils of the project area are clays. They are developed from the chemical disintegration of the sedimentary respectively volcanic bedrock or are of alluvial origin. These clays form extended deposits of varying thickness ranging between 1.5 m and 10 m depending on the stage of weathering of the underlaying rock. Deposits of alluvial origin generally are much thicker reaching in some places 200 m in depth. Layers and lenses of conglomerates often are interbeded within the clays. Their extension and thickness is very irregular. Uniform hard-rock outcrops occur only along the road Tbilisi - Marneuli - Guguti beyond km 40.

(2) The results of the laboratory tests show that in terms of soil properties the subgrade soils could be divided into the following groups.

a) Clays of high plasticity

These types of soil are originated from the decomposition of poorly consolidated marls. In terms of the HRB classification these materials belong to the groups A-7-5 and A-7-6 and are highly plastic. The LL varies from 47 % to 68% whilst the PI ranges from 20 to 34%. The maximum dry density is around 1400 kg/m^3 and the CBR value very low ranging within 2% to 3%. The pronounced plasticity of these soils renders the material prone to seasonal volume changes. However, the extension of such deposits generally is limited.

b) Clays of moderate plasticity

This type is the most common subgrade material found on site. According to the HRB classification this soil falls into the A-6 group. The material is fine grained and has a plasticity index from 12 to 16%. The maximum dry density averages 1580kg/m^3 and the soaked CBR ranges between 3 to 7%.

c) Silty, sandy clays of low plasticity

These are the second common soil types found along the project roads. They mostly occur on the geological terraces located along the main river system. The material belongs to the A-4 group of the HRB classification, and has a lower plasticity index than the type above ranging from 7 to 10%. The maximum dry density is around 1750kg/m^3. The material is more sandy and hence produces a higher CBR ranging between 5 to 12%.

d) Conglomerates

They are composed of a variable blend of rounded to flat gravel and cobbles in a clayey matrix of moderate plasticity. The hardness and the chemistry of the aggregates varies significantly depending on its geological origin and the degrees of transportation. The plasticity index of the material varies from 10 to 24% depending on the plasticity of the matrix of fines in which the aggregates are embedded. According to the HRB classification this material falls into the A-2-4, A-2-6 groups.

Although no more tests were carried out there is no doubt that such a material will produce CBR values in excess of 8%.

(3) The in-situ moisture content measured at depth between 40 cm to 80 cm below road surface level ranges between 7,3 % to 19,0 %. This would indicate that the in-situ moisture conditions of the subgrade materials generally are around the optimum. These results also indicate that the influence of the ground water on the existing subgrade is limited except in swampy areas where the road crosses on shallow to moderate heights of embankment (i.e. < 1,3 m) and in section of cut where drainage problems exist. The in-situ moisture content of the subgrade on these places was found to be between 20,1 % and 29,0 %. This result indicates clearly that in such places the subgrade is liable to saturation.

(4) As a result of the long consolidation period under the compactive effects of public traffic the level of compaction of the soils measured at subgrade level ranges between 94 % and 100 % of the maximum dry density (intermediate compaction effort).

(5) Direct measurements of CBR under the existing pavements were not foreseen in this stage of investigation. However considering the material properties, the moisture content condition and the level of compaction it was possible to estimate an appropriate in-situ subgrade strength for each individual road section. The so determined CBR-values are presented in Table 6 of Annex 6.3.

C. Embankments

(1) Owning to the morphology of the project area a great part of the project roads is formed in embankment.

(2) The embankments were constructed with material taken directly from the road side in a straight cut to fill operation. The exception to this occurs in some low laying areas and in some high embankments where imported material has been used. Consequently the material consists of a mixture of clayey soils, often containing stones, with mechanical characteristics similar to these described in article 6.2 above.

(3) At present most of the embankments expose large deficiencies such as settlement, deformation and slope failure. The possible reasons are:

- Settlement due to consolidation. During initial construction the fill material has been simply dumped and compacted at its natural moisture content only by the site traffic. As a result of the traffic and time the consolidation of the embankments can be assumed to be completed except in cases where lateral movement of the side slopes has occurred. The LDP tests performed on such locations result in low resistance of 3 to 10 blows per 10 cm penetration indicating loose material to a depth up to 5.0 m below shoulders surface.

- Inappropriate treatment of the road bed. The vegetation of the natural ground was not completely cleared and the top soil had not been removed carefully.

- Inadequate shear strength in the embankment foundation. In some locations embankment is placed on compressible subsoil (i.e. swamps, pondings). The

LDP tests performed on these locations reveal that the thickness of such weak soil deposits could reach 1,7 m in depth.

- Lack of internal stability. High embankments are often constructed using clays of high plasticity. In spite of the expansive behaviour of these soils no precautions have been taken to prevent large moisture variations of the fill material.
- Ground instability. High embankments placed on steep side sloping ground are constructed without the required benches, to prevent the possibility of sliding.
- Instable embankment slope. Slopes of high embankments are often steeper inclined than 1 to 1,5. Additionally filling material often becomes saturated due to the insufficient drainage of the shoulders.

The project roads

(1) This article provides a general description of the geotechnical characteristics of the individual project roads and a summary of the identified damages which base on particular geotechnical reasons.

(2) For easy of reference and in order to optimise the elaboration of cost estimates typical repetitive works were combined and coded as follows.

Code	Required Work
1	- remove existing pavement - shape and compaction of subgrade - provision of subsoil drainage - reconstruction of pavement
2	- remove existing pavement - remove embankment up to 0,50 m depth - reconstruction of embankment and pavement - sealing of shoulders
3	- provision of paved ditch
4	- trimming of cut batter (m^3)
5	- retaining wall (1,50 m height)
6	- provision of culvert

Road No S 1, Tbilisi - Khashuri

(1) The road is located in the area of the inner Kartli plain. The alignment following mostly the ridge of Kvernaki crosses the alluvial terraces of the river Kura and its tributaries. From km 73 to km 79 the road is situated along the southern part of the Saguramo ridge.

(2) The ridges and the hills along the road consist of sandstones and marls covered by conglomerates and clays. The greatest part of the road is formed on long-shallow to moderate in height embankments which are rather consolidated and generally stable. The subgrade is of moderate to high bearing capacity except along some short sections where highly plastic clays occur.

(3) Several sections of the road are repeatedly resealed so that the actual thickness of the bituminous pavement varies from 7 cm to 30 cm. On the first part of the road up to km 75 the upper part of the granular base is made of crushed stone. Beyond this chainage only river gravel had been used for this purpose. The thickness of the combined base course varies from 15 cm to 68 cm.

(4) The defects of the road encountered together with their quantification are given in Appendix 6.3.

Additionally damages of large extension where identified in the three locations described below:

a) Landslide at km 27

(1) The road in this location is situated on the foothills of the Kvernaki ridge. The flank of the ridge dipping by approx. 30° runs out on a small terrace located about 20 m downhill the road.

(2) The terrain on the up-hill side of the road is drained by two gullies. One of them had been clogged and used for irrigation purposes. The so created pond, located about 500 m away from the road is artificially feeded by pumping water from the river.

(3) The landslide has occurred soon after the erection of the pond. At that time after detailed subsoil investigations it has been agreed to realign the road by about 5 km away from this location. The realignment has been included in the Tbilisi-Gori highway project which is presently suspended. For the time being, a subsoil drainage has been constructed along the toe of the cut.

(4) The results of the present investigation may be summarised as follows:

- The road forms here one sided cuttings of approx. 8 m in height. The cutting face inclines by approximately 50°.
- The irrigation pond has been abandoned since 1989 and is now dried out.
- The seasonal ground water level is about 5 m below the ground surface. During the main rainy season water appears along the cut face. Since the pond is not functioning the intenseness of springs along the cut face is considerably reduced.
- The existing subsoil drainage is not functioning any more.
- The main zone of the landslide is about 250 m long and limited to the uphill side of the road.
- The soils belongs to the A - 6 (a) group which means clays of moderate plasticity. The LDP tests indicate that dense ground could be found by approx. 3.2 m below the road elevation.

(5) The sliding mechanism may be presented as follows:
The cuttings are made on soils dealing with poor internal stability ($\varphi°$ = 15°-20°, C = 0,3 - 0,5). During rains the clays saturate and slide along the rather inclined cutting face. The high pressure of the seepage water involved from the water of the pond speeds up this process. Since the pond is dried out the slides considerably are diminished.

(6) The main work required for a permanent treatment are:

- construction of catch ditches along the slope of the hill.
- trimming the cut face to a inclination of 1 to 2 (vertical : horizontal)
- construction of paved side ditch along the toe of the cut
- provision of additional subsoil drain
- reconstruction of the road over 1000 m in length
- sealing the entire road platform
- protection of the slopes by vegetation
- sealing of the pond entirely in case of reuse.

b) Embankment failure at km 72

(1) The embankment in this location is 300 m long and approx. 30 m high. The box culvert at the bottom of the embankment is very large and used as an under pass too.

(2) The embankment is constructed with material from the adjacent cut sections. The material comprises clays of moderate plasticity with a large amount of cobbles and stone fragments.

(3) The damages include extended deformations of the road prism and sliding of the slope on both sides of the embankment. The reasons for these deficiencies are the consolidation of the fill material, the inappropriate inclination of the slope (1 to 1) and the erosion of the toe of the embankment.

(4) The required measures for the repairs are:

- reconstruction of the embankment slopes
- extension of the culvert head walls
- reconstruction of the pavement
- sealing of the shoulders

c) Damage at km 72+ 600

(1) The alignment here runs along the southern part of the Atchara ridge. The flanks on the down hill side of the road dipping by approx. 40° form long slopes reaching in some places 100 m in length running out on flat terraces. The natural flank on the up-hill side of the road is lesser inclined (10° to 15°).

(2) The road in the damaged zone crosses a steep inclined gully. The road is constructed half in cut and half in fill. The cut is about 6.0 m high. The cut face is inclined by 35 °.

(3) The drainage conditions of the terrain on the top of the ridge are rather impeded. It means that during rains surface water ponds in many places. One of those ponds is

located about 200 m away from the road. The difference in elevation between the road and the floor of the pond is approx. 7.0 m.

(4) The natural soils consist of conglomerates and clays. The clays belong to A-7-5 (15) group, are fine grained and of high plasticity.

(5) The seasonal ground water table is around 4 m below the ground surface elevation. During rains water appears at the lower part of the slope. Observations made during previous investigations reveal a direct connection between groundwater and the water of the pond.

(6) The damage is caused by the slide of the road body in the vicinity of the gully. The reason for the failure might be:

- inadequate shear strength in the embankment foundation. The natural ground has been neither cleared nor benched prior to the placing of the embankment.
- saturation of the fill material caused by the subsurface water infiltrated from the pond.
- erosion of the embankment slope due to uncontrolled runoff water.

(8) At present the affected road section totals 230 m in length. The damages include the failure of the embankment slope and parts of the pavement up to the centre line.

(9) Because the proceeding of the damage could cause the interruption of the traffic emergency repairs are scheduled by the administration. The emergency repairs include:

- drainage of the pond
- construction of a retaining wall by precast concrete frames to a height of 4.0 to 6.0m along the damage section for approx. 35 m,

(10) For a permanent solution, however, the following additional work will be required:

- piles foundation for the retaining wall
- construction of paved ditch along the toe of the cut
- trimming the cut face to a inclination of 1 to 2
- provision of subsoil drainage
- sealing the entire road platform

Road No S 4, Tbilisi - Red bridge

(1) The road is located in the plain of lower Kartli. The terrain up to km 11 is generally flat. Beyond this chainage it can be characterised as undulating.

(2) The subgrade is mostly formed in shallow embankment with clays of moderate to high plasticity often containing some gravels and cobbles from the conglomerates. The in situ bearing capacity of the subgrade is generally low. Its moisture content is often controlled by water ponding against the road embankment.

(3) Some of the high fills show settlements and lateral movements but an acute danger concerning the overall stability of the embankment is not evident.

(4) The old pavement consists of a bitumen macadam placed on a granular base. Kerbstones lined along the edge of the carriage way have been used as a lateral abutment. The kerbstones are placed on a layer of sand. This drainage layer is not functioning any more so that the internal drainage of the pavement is rather impeded. This results into the saturation of the granular base and subgrade over long period of time. The first part of the road up to km 11 (town Rustavi) has been strengthened by a bituminous overlay whilst the remainder section has been resealed by a bituminous wearing course only. Consequently, the thickness of the combined bituminous pavement varies between 24 cm and 36 cm at the first part of the road respectively from 8 cm to 11 cm for the remainder stretch. The granular base is made of natural river gravel. Its thickness ranges between 20 cm to 50 cm.

(5) The main deficiencies identified are settlement, deformation and surged failure. Their detailed quantification is given in Appendix 6.3.

Road No S 6, Tbilisi - Marneuli - Guguti

(1) The first part of the road up to km 40 is located in the plain of lower Kartli. The residual soils consist of poorly consolidated shales, tuffecious sandstones and their weatherings. Beyond km 40 the alignment following the canyon of the Mashavera river is situated along the northern side of the Khrami / Somkhiti range. The geological complex includes limestones and tuffs. Throughout the section there are numerous andesit and tuff outcrops of various degrees of weathering.

(2) The terrain over the first section of the road up to km 43 is flat to undulating with the road forming short shallow cut and long moderate in height embankment sections. Beyond this chainage the road passes through a mountainous area forming medium to high cuts.

(3) The subgrade is mainly made of silty clays of moderate plasticity often containing a certain percentage (approx. 10%) of gravel and cobbles. In the mountainous area, due to the cut/fill manner of original construction, both the embankment and the existing subgrade consist of a cut rock platform or on an embankment platform constructed from either decomposed or slightly weathered rock. The bearing capacity of the subgrade along the whole road could be considered as fair to good.

(4) Up to km 10 the old surfacing, a bitumen macadam, has been strengthened by two bituminous layers whilst for the remainder part of the road one layer, mostly of binder course quality, has been applied for resealing purpose. The actual thickness of the bituminous pavement ranges between 6 cm and 26 cm. The granular base is usually made of natural gravel (river gravel of conglomerates) except the section beyond km 80 where crushed stone of volcanic origin has been used. The thickness of this layer varies from 10 cm to 33 cm.

(5) The face of the cuttings in the section south of km 67 consist for the most part either of tuff or weathered andesit. These are not considered particularly sensitive to erosion, however, the installation of paved side drains is recommended for cuttings. In general the existing cutting slopes are well consolidated and stable at their present inclination. Some minor landslip debris can be seen beyond km 70 however slips are

superficial and are limited to surface layers only. In order to avoid functional failure of the drainage system through slides of soils into the ditch on those locations the construction of retaining walls to a height of 1,5 m along the side drains is recommended too.

(6) Despite the embankment failure at km 12+500 it can be said that the embankment fills along the road are rather consolidated and generally stable.

Except for the damage at km 12+500 the most frequent defect identified along the road is the failure of the pavement caused by the saturation of the subgrade due to the inadequacy of the internal / external drainage system. Details of the damages identified along the road is given in Appendix 6.3.

Damage at km 12+500

(1) The results of the investigation in this location may be presented as follows.

- The alignment here running along the foothills of the adjacent plateau forms cuttings of medium height. The slope of the natural ground inclines between 25° to 35°. Just before the end of the ascent the road crosses a steep inclined gully.

- The bedrock comprises poorly consolidated shales and seams of sandstone. The bedrock is covered by a clayey layer of a thickness varying between 1.0m and 2.0m.

- The seasonal ground water level is around 5 m below the ground elevation and during rains water appears along the flanks of the gully and in some places on the exposed cutting face.

- The embankment over the gully is 30 m long and approx. 20 m high. It is constructed by end-tipping manner without any initial compaction and having steep side-slopes (1:1). The fill material used comprises shales and clays of moderate plasticity and low shear strength (φ = 15° - 17°, c = 0,3 - 0,4). Soon after its construction the embankment presented several types of defects like gross differential settlements, deep deformations and slope failures.

- The culvert at the bottom of the embankment does not function properly. Due to the inaccurate elevation of the culvert inlet water perches along the toe of the embankment for long period of time.

- The cuttings are 8m to 10m high and formed either in slightly weathered sedimentary bedrock or clayey native soils derived from bedrock. The cutting faces are inclined by 40° to 45°. The landslides occurring here are triggered by the construction of the road and promoted by the oversteep slopes and water influence. However the slips are superficial and are mostly limited to native soils layer only.

- The evaluation of the LDP tests revealed:

- the fill material used in embankment comprises a large amount of stone fragments.

- in area of shoulders and side lopes the in-situ density of the fill material, up to one meter in depth, is very low. The reasons may be high moisture content, arching within the dumped material and previous lateral movements of the slopes.

- at depths greater than 0,7 m the in-situ material in cut area is in a medium dense state. This indicates that those zones of the natural ground have not been dislocated at all.

(2) In 1980 a attempt was made to realign the road avoiding the sections of cut and the gully. A 1,2 m long embankment of approx. 15 m height was erected near to the existing one. This attempt, however, was abandoned because the embankment collapsed in many places. The reason for the failure may be the inappropriate method of construction used i.e. end-tipping manner of construction.

(3) For an appropriate permanent solution the following work will be required:

- excavation of all fallen and/or loose material laying on the slope of the cut and flatterning of the cut batter to an inclination of 1 to 2
- construction of subsoil drainage along the toe of the cut face.
- installation of paved site drain.
- extension of the existing culvert by about 25 m in length
- reconstruction of the embankment slope on the down-hill side of the road. This work will include the construction of a retaining wall of 3 m height over a length of approx. 100 m
- canalisation of the waterflow at the inlet side of the culvert
- reconstruction of the pavement over a stretch of about 200 m in length
- sealing of the shoulders
- protection of the slopes by vegetation

Road No S 7, Marneuli - Sadakhlo

(1) The main part of the road is located along the depression of Marneuli. The alignment crosses flat to undulating terrain forming long shallow embankment. Beyond km 19 the road made in mixed profile manner forms one sided shallow cuts respectively fills over long sections.

(2) Due to the unfavourable position of gradient in regards to the ground elevation the drainage condition of the road is poor. More over in some locations the side ditches conduct water for irrigation purposes.

(3) The subgrade, up to km 19, comprises material derived from the alluvial terraces. Beyond this chainage the residual soils are of volcanic origin. The subgrade soils fall into HRB groups A-6 and A-2-6. This means clays of moderate plasticity often containing a large amount of cobbles and/or stone fragments. The soil mechanical properties of these materials are generally fair and often produce an acceptable CBR-value. However the in-situ strength of the subgrade will be much lower because for reasons mentioned above water controls the moisture content of the subgrade for the most time of the year.

(4) The pavement comprises a bituminous wearing course laid on a granular base. The wearing course is mainly a bitumen macadam. Some sections of the road have been

resealed so that the actual thickness of the bituminous layer varies between 5 cm and 7 cm. The granular base is made of natural river gravel. Its thickness ranges between 10 cm and 23 cm.

(5) The embankments are rather consolidated and generally stable. The deficiencies identified along the road are mainly attributed to the saturation of the subgrade and the insufficiency of the pavement. The location and the extent of the damages are presented in Appendix 6.3.

Road S 9, Tbilisi bypass

(1) The road is located along the Sagumaro ridge. The terrain is rolling or hilly with no observable drainage problems. Due to the morphology of the area the road forms high embankment in many places. In some locations the road was constructed on steep side long ground in a typical cut/fill operation. This has resulted in high cuttings to one side, and steep side - sloping embankment to the other.

(2) The native soils up to km 20 consist of poorly consolidate shales and sandstones overlaid by conglomerates and clays of considerable thickness. The clays in some locations are highly plastic and have an expansive behaviour. Beyond km 20 terrace soils prevail. They comprise sandy clays and silty sands often containing a large amount of gravel and cobbles. Mainly the subgrade soils belong to the HRB groups A-4 and A-2-6 except the highly plastic clays which fall into A-7-6 group. Consequently the bearing capacity of the in-situ subgrade subjects large variations. The A-4 and A-2-6 soils have a reasonable bearing strength whilst the soaked CBR-value of the A-7-6 soils normally is below 3%.

(3) The moisture content measured at depths between 0.4 to 3 m below road surface level ranges between 10.5 to 23,4 %. This would indicate that the in-situ moisture conditions of the subgrade and embankment material generally are drier of than optimum. In areas of cut and in places where the pavement is confined between kerbstones, however, saturation of the subgrade has been observed. The reason is the insufficiency of the external/internal drainage system.

(4) The fill material consists of stony/gravely clays from the adjacent cuttings. The material has not been systematically compacted during the initial construction. At present, shallow and moderate in height embankments are well consolidated, whilst the consolidation of some high embankments is not yet completed. The LDP tests performed in area of shoulders and along the side slopes resulted generally in low resistance of 1 to 10 blows per 10 m penetration, indicating a palpy to soft consistency respectively loose material up to 3,6 m in depth. At various depths higher resistance were determined indicating the presence of gravels and stones as stated above.

(5) The pavement mainly comprises two bituminous layers laid on a granular base. According to the standards used the thickness of the combined bituminous layers should be 12 cm. Depending on wear and/or resealing work, however, its present thickness varies from 7 cm to 24 cm. The granular base is made partly of crushed stone and partly of natural river gravel. In some sections of the road a subbase layer made of natural gravel (river or conglomerate) has been used too. The present thickness of the combined granular material ranges between 12 cm and 80 cm.

6) The most frequent defects identified are deformation and subgrade failure. Their quantification is given in Appendix 6.3.

In addition to the above deficiencies damages of considerable extent were identified in the three locations described below.

a) Landslide km 15

(1) In this location the road runs along the southern slope of a ridge. The slope of the hill inclines by 30° and ends on the bank of the river Khevdzmari, which is located about 60m to 100m downhill the road. Initially the road was constructed in mixed profile method i.e. half in cut, half in embankment.

(2) The landslide has occurred soon after the initial construction of the road on 1983 damaging the described section over a length of approx. 80 m. To overcome this problem a bridge of 110 m in length was erected. This structure was founded on reinforced concrete piles of 800 mm diameter with a length of 18 to 20 m. However this structure has also moved horizontally and settled after few years. Last year, in order to keep traffic going, the road has been shifted approx. by 5 m to the mountain side and is now founded completely in cut. Presently the section of the road affected by landslide is approx. 600 m in length.

(3) The results of the investigations during the present mission may be summarised as follows:

- The main zone of the landslide is approx. 350 m long. The movements include not only the roadside but also the entire slope of the hill down to the river.
- The soils belong to the A-7-$6_{(15)}$ group which means clays of pronounced plasticity. These soils are prone to swelling and shrinking with changing moisture content. Additionally these soils deal with poor internal stability. Recent laboratory test results reveal that the shear strength of these soils at natural density do not exceed 15°. The content of soluble salts ranges between 0,2% to 0,4 %.
- Due to the low in-situ density of the soils, rain water can penetrate into the ground. Additionally the penetration is accelerated by seams of sandstone often embedded within the clays. The seasonal ground water level measured in the control boreholes, ranges between 12 m and 14 m below the ground surface. During the main raining period water appears in some places along the lowest hillside.
- The lateral deplacement of the 20 m long piles indicates that the plane of sliding is located at least 25 m below the road elevation.
- The river is located about 60 m to 100 m downhill the road. The difference in elevation ranges between 18 to 30 m. The river is seasonal but during floods the water engraves continuously the river bed.
- The soil mechanical conditions along the northern slope of the ridge are similar. A realignment of the road to this side will create similar problems.

(4) Briefly the slide mechanism may be presented as follows:

The construction of the road has disturbed the balanced stability of the system. Embankment fills constructed on the slope increased its stress considerably and potential slide area was created along the cuttings. Additionally water ponding along the site drains could easily penetrate into the ground. The slide begun at the bank of the river and reached by creeping the road and the upper parts of the ridge. From experience such types of slides can be managed only by an appropriate regulation of the run off and the catchment water. This was here not the case.

(5) Alternative solutions

(5.1)Construction of a bridge, of similar type as the collapsed one, using longer piles. The bridge would be approx. 600 m long with piles exceeding 30 m in length. A detailed subsoil investigation will be necessary to determinate the required length of the piles. This approach should also include an overall water regulation. Considering the amount of required work it is obvious that this remedial method will involve considerable high costs.

(5.2)Relocation of the road. This method should include the following:

- shifting the road to the mountain side by approx. 7 m over a length of about 1 km.
- trimming the cutting face to an inclination of 1:2 (vertical : horizontal)
- provision of subsoil drain along the toe of the cut.
- construction of paved ditch over the whole length and discharge the collected flow down the face of the embankment in lined shutes
- sealing the entire road platform
- construction of catch ditches along the slope of the hill
- trimming the slope of the lower hillside up to the river to an appropriate inclination
- protection of the slopes by vegetation
- construction of flow velocity control structures along the river bed

b) Embankment failure at km 33+200

(1) The embankment in this location is 100 m long and approx. 30 m height. The side - slopes are inclined by 45°.

(2) The fill material being used are clays of moderate plasticity containing a significant amount (30% - 40%) of cobbles and stone fragments.

(3) The damages include large deformations in the pavement and the one-sided lateral displacement of the embankment in the area of the gully.

(4) The reasons for the failure may be:

- lack of initial compaction of the embankment fill
- steep inclined side-slopes

- improper road bed treatment. The embankment is resting on weak and compressible subsoil occurring in the floor of the gully.
- insufficient drainage of the natural water course. Water ponds along the toe of the embankment due to the wrong elevation of the culvert inlet.

(5) The measures required for repairs include:

- extension of the existing culvert by 15 m
- construction of a proper transition from the natural channel to the culvert inlet
- flattening the embankment slopes
- sealing of the shoulders.

The amount of the involved work will be:

- construction of embankment	50.000 m³
- provision of culvert pipes	15 lm
- concrete work	50 m³
- reconstruction of pavement	100 lm
- sealing of shoulders	600 m²

c) Embankment failure at km 33+600

(1) This case is similar to that described above. With the exception that the embankment here is 200 m long. Consequently the amount of the required work will be:

- construction of embankment		100.000 m³
- provision of culvert pipes	20 lm	
- concrete work	50 m³	
- reconstruction of pavement	200 lm	
- sealing of shoulders	1200 m²	

<u>**Road No S 12, Samtredia - Ureki**</u>

(1) The road is partly located in the Kolcheti valley and partly runs along the foothills of the adjacent ridge of Guria. In general the terrain crossed can be characterised as flat with short stretches of undulating terrain. The area belongs to the most humid zone of the country with a mean annual rainfall of approx. 2000 mm. The drainage conditions of the area are poor and during rains parts of the valley are subjected to flooting and the road to overlopping as a consequence.

(2) The Guria ridge consists of tuff conglomerates and sedimentary limestone whilst the soils of the planes are of alluvial origin consisting of silty clays and in less extent of sands and conglomerates.

(3) The embankment along the road generally does not present foundation problems, as a result of their limited height and the advanced consolidation.

(4) The subgrade mainly is made of stony clayey silts. The percentage of gravel and cobbles ranges between 8% and 20%. All material identified fall into HRB group A-4. These materials usually produce high laboratory CBR-values. The in-situ bearing

capacity of the subgrade, however, will be considerably lower because the soils at subgrade level are liable to saturation.

(5) The bituminous pavement consists of a bitumen macadam which has been resealed by an asphalt wearing course. The present thickness of the combined bituminous layer varies from 15 cm to 22 cm. The granular base supporting the macadam is entirely made of natural river gravel. Its thickness ranges between 20 cm and 35 cm.

(6) The damage occurring along the road are attributed to the insufficiency of the drainage system. Details of the damage identified are given in Appendix 6.3.

Construction material

Material type

The following material has been incorporated in pavement during initial construction.

- River gravel
- Conglomerate
- Andesit
- Limestone

The characteristics of these material are described below:

a) River gravel

(1) This is the most commonly occurring material within the project area. Almost all rivers traversing the area create large gravel deposits. They are composed of a variable blend of gravel and cobbles in a matrix of silty sands. The material in non-plastic and coarse grained with a high percentage of oversize (+50 mm) approaching in some cases 60 %. The gravel originating largely from different bedrock and subjected to varying degrees of transportation is composed of rounded to flat aggregates of different rock types and hence of variable soil mechanical and chemical compositions.

(2) River gravels are suitable for the construction of subbase and in some extent for base course. The "as-dug" material, however, contains a large amount of oversized elements and hence should be screened and/or crushed prior to its use. Unfortunately this aspect has been neglected during initial construction.

(3) Crushed gravels produce aggregates suitable for base course construction and for asphalt mixes. Due to the diversity of gravel origin , however, attention should be paid to ensure that the materials are sufficiently durable.

b) Conglomerate

(1) This material is of sedimentary origin and forms deposits of irregular extension. The composition of the material is similar to that of the river gravel with the exception that the matrix in which the stones are embedded consist of plastic clays. The plasticity index of the matrix of fines varies from 10% to 24%.

(2) Generally the material is easily rippable. However some deposits are rather cemented and excavation in such location requires drill and blast operations.

(3) The material has been used to form subbase even base course in some locations. However due to its high plasticity and unfavourable grain size distribution the use of the material in the construction of pavement layers is not recommended.

c) Andesit

This material has been encountered on the southern part of the Tiblisi - Guguti road only. The material is originated from horizontally distributed lava flows. The limits and the extent of the flows are very irregular. The rock is fine grained in texture and hard. Crushed rock has been used in base course construction and in production of aggregates.

d) Limestone

In the project area Limestone has been used for the production of filler only.

Material availability

River gravels suitable for constructions purpose are abundant in the project area and within short haulage distance. However environmental aspect restrict their excavation on places already demarcated for this purpose. The location of those borrow pits are presented in Appendix 6.3.

6.5 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 in the period between April 22th, 1997 and April 30th, 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.

Based on FWD measurements and calculation, sections with recommended uniform overlay thickness are compiled. The calculation also states the residual service life of the road and the proposed service life (15 years). In the case of the study roads the residual pavement life is very low, in many sections less than 2 - 3 years. The low residual life and poor existing bearing capacity require thick overlays in many sections, as shown in Appendix 6.4, Pavement Strength Report.

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 6.4, Pavement Strength Report.

6.6 Road Condition and Roughness

General Description of the Road Condition

The study roads were 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.

S 4: Tbilisi - Red Bridge

Along much of the road length, the road exhibited surface defects such as traverse, longitudinal or alligator cracks, especially on the road edges.
Between km 25 and km 26 the road passes a marshy area with settlements and depressions. In the section km 11 - km 15 and km 17 - km 18 potholes occurred extensively.

S 9: Tbilisi by-pass

Pavement defects in this section were intermittent, in some areas occurring locally and in others over continuous stretches. Damages included settlements, potholes and cracks. In the section km 2 - km 3, km 13 - km 16 and km 19 - 20 showed significant damage.

S 1: Tbilisi - Kashuri

The road section form Tbilisi - Kashuri is a paved road in good - fair condition, but there were long stretches with extensive cracking.

S 6: Tbilisi - Guguti / Armenian border

The road condition varied from fair to bad, with short sections where the pavement is destroyed. The road showed surface defects such as cracks and potholes. The main sections showing pavement damage were km 14 - km 19, km 23 - km 24, km 30 to km 33, km 42 and until the Armenian border.

S 7: Marneuli - Sadakhlo

Pavement defects in this section were along much of its length. Damages included cracks, alligator cracks and potholes. Some parts of the road were complete destroyed.

S 12: Samtredia - Ureki

The pavement surface showed along much of its length, significant damage with short section where the pavement is destroyed. Damages included traverse, longitudinal and alligator cracks, settings and potholes.

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. Some parts 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.

Particular observations are:

<u>Cracks</u> are caused either by
- unsuitable material or under dimensioned gravel layers below the asphalt, or
- because of deformations due to under dimensioned pavement structure, or
- because of wrong choice of bitumen, or
- because of material fatigue

<u>Potholes</u> are resulting from
- wrong granulometric graduation
- wrong and/or overdose of bitumen

Due to the suction effect of the tires, first bitumen and subsequently the aggregates are pulled out of the road surface.

The surface deficiencies are summarised in the table below.

Table 6.6: Deficiencies of surface

Section	Cracks (%)	Alligator Cracks (%)	Potholes (%)	Settle-ments (%)	Rutting <=10mm (%)	Rutting >10mm (%)	Patched Area (%)
S 1, Tbilisi - Kashuri							
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)	0.5	2.8	0.2	0.8	0.0	0.1	0.1
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	0.2	4.3	1.3.	1.5	0.0	4.8	0.0
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)	0.2	2.7	3.9	0.6	0.1	1.5	0.0
S 4, Tbilisi - Red Bridge / Azerbaijan border (km 11+000 - km 57+170)	1.2	19.2	4.7	4.2	0.7	1.2	0.2
S 6, Tbilisi - Marneuli - Guguti / Armenian border							
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	1.0	5.5	9.8	1.5	0.2	0.4	0.0
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	0.6	12.0	6.5	0.8	0.0	0.0	0.0
Subsection: Bolnisi - Guguti / Armenian border (km53+880 - km 99+127)	0.3	13.4	40.0	1.1	0.0	0.1	0.0
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	0.0	30.2	21.9	0.0	0.0	0.0	0.0
S 9, Tbilisi by-pass							
Subsection: west (km 0+000) - km 34+800)	0.7	7.7	5.9	11.5	0.0	0.0	0.4
Subsection: east (km 34+800 - km 49+008)	1.3	7.8	0.5	6.6	0.0	0.0	0.5
S 12, Samtredia - Ureki (km 0+000 - km 56*528)	0.9	15.5	29.6	0.2	0.0	0.6	0.0

Details are shown in Appendix 6.5 and on the straight line diagrams in Appendix 6.6.

Width of the Study Roads

The existing carriageway width of the study roads range from 7.7 m to 10.7 m. The table below shows the average road width

Table: Average Road Width

Section	Average Road Width		
	Carriageway (m)	Shoulder left(m)	Shoulder right(m)
S 1, Tbilisi - Kashuri			
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)	10.55/10.65	2.01	2.00
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	9.22	1.94	2.00
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)	9.63	1.91	1.85
S 4, Tbilisi - Red Bridge / Azerbaijan border (km 11+000 - km 57+170)	8.55	1.82	1.86
S 6, Tbilisi - Marneuli - Guguti / Armenian border			
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	10.35	2.35	2.32
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	8.78	2.23	2.10
Subsection: Bolnisi - Guguti / Armenian border (km53+880 - km 99+127)	7.80	1.89	1.76
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	7.69	2.02	1.87
S 9, Tbilisi by-pass			
Subsection: west (km 0+000) - km 34+800)	10.30	2.83	2.90
Subsection: east (km 34+800 - km 49+008)	10.10	2.78	2.37
S 12, Samtredia - Ureki (km 0+000 - km 56*528)	8.01	2.00	1.96

The study roads are mainly two lane roads except the road section from Tbilisi to the junction S 1/S 3 on the S 1, which is a four lane road.

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 6.7

Curvature

The data of the horizontal curvature characteristic of the existing road were as far as possible 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: Curvature of existing road

Section	Curvature (°/km)
S 1, Tbilisi - Kashuri	
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)	10.9
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	7.1
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)	9.8
S 4, Tbilisi - Red Bridge / Azerbaijan border (km 11+000 - km 57+170)	23.9
S 6, Tbilisi - Marneuli - Guguti / Armenian border	
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	40.4
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	37.1
Subsection: Bolnisi - Guguti / Armenian border (km53+880 - km 99+127)	59.2
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	36.2
S 9, Tbilisi by-pass	
Subsection: west (km 0+000) - km 34+800)	17.1
Subsection: east (km 34+800 - km 49+008)	19.0
S 12, Samtredia - Ureki (km 0+000 - km 56*528)	46.8

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	Average IRI (m/km)
S 1, Tbilisi - Kashuri	
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)	4.3
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	4.7
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)	4.2
S 4, Tbilisi - Red Bridge / Azerbaijan border (km 11+000 - km 57+170)	5.9
S 6, Tbilisi - Marneuli - Guguti / Armenian border	
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	5.7
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	7.7
Subsection: Bolnisi - Guguti /Armenian border (km53+880 - km 99+127)	10.1
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	11.1
S 9, Tbilisi by-pass	
Subsection: west (km 0+000) - km 34+800)	5.0
Subsection: east (km 34+800 - km 49+008)	4.5
S 12, Samtredia - Ureki (km 0+000 - km 56+528)	7.8

The detailed records of the measurements and the resulting mean road roughness for each direction of lane are attached in Appendix 6.8

6.7 Drainage Condition

In total 655 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 6.9 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 6.7: Deficiencies of inspected Culverts

Section	No. of culverts	Deficiencies		
		Silted/ Blocked % of Total	Sour % of Total	Structural Damages % of Total
S 1. Tbilisi - Kashuri				
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)	15	33.3		
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	104	32.7		
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)				
	48	22.9		
S 4. Tbilisi - Red Bridge / Azerbaijan border				
(km 11+000 - km 57+170)	67	64.2		
S 6. Tbilisi - Marneuli - Guguti / Armenian border				
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)				
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	25	72.0		
Subsection: Bolnisi - Guguti / Armenian border (km53+880 - km 99+127)	53	67.9		
	110	58.2		
S 7. Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)				
S 9. Tbilisi by-pass	76	68.4		
Subsection: west (km 0+000) - km 34+800)				
Subsection: east (km 34+800 - km 49+008)				
S 12, Samtredia - Ureki (km 0+000 - km 56*528)	53	43.4		32.1
	24	29.2		
	80	21.3	2.5	

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

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

6.8 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 6.10. 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.

6.9 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 29:

Section	Cumulative no. of ESA in design lane	CBR value for subgrade (mm)	Sub-base thickness (mm)	Road base thickness (mm)	Surfacing thickness (mm)
S 1, Tbilisi - Kashuri					
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)					
Subsection: Junction S 3- Gori junction (km 26+940 - km 84+700)	12,630,037	7.0	170	130	100
Subsection: Gori junction - Kashuri (km 84+700 - 126+670)	16,009,102	6.0	210	130	100
S 4, Tbilisi - Red Bridge / Azerbaijan border (km 11+000 - km 57+170)	1,853,934	6.0	180	90	80
S 6, Tbilisi - Marneuli - Guguti / Armenian border					
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	5,808,140	9.0	150	110	90
Subsection: Marneuli - Bonisi (km 28+840 - km 53+880)	3,043,653	10.0	150	100	80
Subsection: Bolnisi - Guguti / Armenian border (km53+880 - km 99+127)	1,412,255	6.0	170	90	70
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	2,999,596	5.0	220	100	80
S 9, Tbilisi by-pass					
Subsection: west (km 0+000) - km 34+800)	5,525,331	7.5	150	110	90
Subsection: east (km 34+800 - km 49+008)	6,386,673	12.0	150	110	90
S 12, Samtredia - Ureki (km 0+000 - km 56*528)	3,811,716	9.7	150	100	90

The detailed calculation of standard axles are attached in Appendix 6.11.

The pavement design considers the existing base course as sub-base, which will be strengthened by recycled asphalt from the existing pavement to provide the total necessary sub-base thickness. This considers the re-use of the existing pavement layers optimal.

According to the Road Note the sub-base CVR shall be at least 30 %.

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:

S 1, Tbilisi - Kashuri

Chainage		Resealing	Overlay 40 mm	Overlay 75 mm	Overlay 100 mm	Recon-struction
from	to	length (m)	length (m)	length (m)	length (m)	length (m)
Subsection: Tbilisi - Junction S 3 (km 15+000 - km 26+940)						
15.000	17.250		2.250			
17.250	22.750				5.500	
22.750	26.250			3.500		
26.250	26.940					690
Subsection: Junction S 3 - Gori junction (km 26+940 - km 84+700)						
26.940	31.750					4.810
31.750	37.250				5.500	
37.250	45.750					8.500
45.750	48.250			2.500		
48.250	57.250				9.000	
57.250	62.250			5.000		
62.250	65.750					3.500
65.750	68.250			2.500		
68.250	75.750		7.500			
75.750	78.750					3.000
78.750	78.950		200			
78.950	79.050					100
79.050	80.750		1.700			
80.750	81.415				665	
81.415	83.080					1.665
83.080	83.750				670	
83.750	84.700	950				
Subsection: Gori junction - Khasuri (km 84+700 - km 126+670)						
84.700	86.250	1.550				
86.250	86.850			600		
86.850	87.150					300
87.150	91.750			4.600		
91.750	94.750				3.000	
94.750	97.750		3.000			
97.750	100.750			3.000		
100.750	103.250				2.500	
103.250	105.750		2.500			
105.750	109.250				3.500	
109.250	111.250		2.000			
111.250	115.750			4.500		
115.750	120.750		5.000			
120.750	121.790			1.040		
121.790	126.670					4.880
TOTAL		**2.500**	**24.150**	**27.240**	**30.335**	**27.445**

S 4, Tbilisi - Red Bridge / Azerbaijan border

Chainage		Resealing	Overlay 40 mm	Overlay 75 mm	Overlay 100 mm	Recon-struction
from	to	length (m)	length (m)	length (m)	length (m)	length (m)
11.000	11.655				655	
11.655	12.860					1.205
12.860	13.250				390	
13.250	15.360			2.110		
15.360	18.750					3.390
18.750	21.385		2.635			
21.385	21.415					30
21.415	22.140		725			
22.140	25.705					3.565
25.705	26.250				545	
26.250	26.600		350			
26.600	27.730					1.130
27.730	28.250		520			
28.250	32.250					4.000
32.250	32.470				220	
32.470	32.530					60
32.530	32.670				140	
32.670	32.730					60
32.730	33.885				1.155	
33.885	33.915					30
33.915	34.285				370	
34.285	34.315					30
34.315	34.385				70	
34.385	34.415					30
34.415	37.550				3.135	
37.550	37.650					100
37.650	37.750				100	
37.750	42.250			4.500		
42.250	43.750					1.500
43.750	43.950		200			
43.950	44.250					300
44.250	47.250		3.000			
47.250	47.975			725		
47.975	51.895					3.920
51.895	53.250		1.355			
53.250	54.360			1.110		
54.360	54.750					390
54.750	56.180			1.430		
56.180	57.170					990
TOTAL		**0**	**8.785**	**9.875**	**6.780**	**20.730**

S 6, Tbilisi - Marneuli - Bolnisi - Guguti / Armenian border

Chainage		Resealing	Overlay 40 mm	Overlay 75 mm	Overlay 100 mm	Recon-struction
from	to	length (m)	length (m)	length (m)	length (m)	length (m)
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)						
3.000	4.250					1.250
4.250	6.750		2.500			
6.750	8.750					2.000
8.750	10.475		1.725			
10.475	10.525					50
10.525	11.050		525			
11.050	11.150					100
11.150	12.190		1.040			
12.190	12.210					20
12.210	12.250		40			
12.250	14.250					2.000
14.250	14.535			285		
14.535	16.050					1.515
16.050	16.675			625		
16.675	28.300					11.625
28.300	28.840				540	
Subsection: Marneuli - Bolnisi (km 28+840 - km 53+880)						
28.840	29.275				435	
29.275	29.325					50
29.325	31.025				1.700	
31.025	31.175					150
31.175	31.400				225	
31.400	31.645					245
31.645	32.100				455	
32.100	32.300					200
32.300	34.750				2.450	
34.750	35.975			1.225		
35.975	36.025					50
36.025	39.750			3.725		
39.750	41.090				1.340	
41.090	41.110					20
41.110	41.875				765	
41.875	41.925					50
41.925	42.280				355	
42.280	42.365					85
42.365	46.250				3.885	
46.250	49.250					3.000
49.250	52.250			3.000		
52.250	56.250					4.000

Subsection: Bolnisi - Guguti / Armenian border (km 53+880 - km 99+127)						
56.250	56.470				220	
56.470	59.200					2.730
59.200	60.250				1.050	
60.250	69.250					11.000
69.250	69.425			175		
69.425	69.575					150
69.575	70.160			585		
70.160	70.270					110
70.270	70.650			380		
70.650	99.127					28.477
TOTAL		**0**	**5.830**	**10.000**	**13.420**	**66.877**

S 7, Marneuli - Sadakhlo / Armenian border

Chainage		Resealing	Overlay 40 mm	Overlay 75 mm	Overlay 100 mm	Recon-struction
from	to	length (m)	length (m)	length (m)	length (m)	length (m)
0	480					480
480	970			490		
970	7.750					6.780
7.750	11.250		3.500			
11.250	28.920					17.670
28.920	29.100				180	
29.100	29.300					200
29.300	29.440				140	
29.440	30.215					775
30.215	30.350				135	
30.350	34.152					3.802
TOTAL		**0**	**3.500**	**490**	**455**	**29.707**

S 9, Tbilisi Bypass

Chainage		Resealing	Overlay 40 mm	Overlay 75 mm	Overlay 100 mm	Recon-struction
from	to	length (m)	length (m)	length (m)	length (m)	length (m)
Subsection: bypass west (km 0+000 - km 34+800)						
0	2.000		2.000			
2.000	6.250					4.250
6.250	6.475		225			
6.475	6.525					50
6.525	6.920		395			
6.920	8.010					1.090
8.010	9.250		1.240			
9.250	11.250					2.000
11.250	13.000				1.750	
13.000	16.750					3.750
16.750	19.510				2.760	
19.510	23.825					4.315
23.825	24.075				250	
24.075	24.125					50
24.125	25.085				960	
25.085	25.115					30
25.115	26.210				1.095	
26.210	27.660					1.450
27.660	27.750				90	
27.750	33.250					5.500
33.250	33.500			250		
33.500	33.700					200
33.700	34.800			1.100		
Subsection: bypass east (km 34+800 - km 49+008)						
34.800	36.750			1.950		
36.750	38.750		2.000			
38.750	41.750					3.000
41.750	42.190			440		
42.190	42.210					20
42.210	43.875			1.665		
43.875	43.925					50
43.925	44.275			350		
44.275	44.325					50
44.325	47.675			3.350		
47.675	47.725					50
47.725	49.008			1.283		
TOTAL		**0**	**5.860**	**10.388**	**6.905**	**25.855**

S 9, Tbilisi Bypass

Chainage		Resealing	Overlay 40 mm	Overlay 75 mm	Overlay 100 mm	Recon-struction
from	to	length (m)	length (m)	length (m)	length (m)	length (m)
Subsection: bypass west (km 0+000 - km 34+800)						
0	2.000		2.000			
2.000	6.250					4.250
6.250	6.475		225			
6.475	6.525					50
6.525	6.920		395			
6.920	8.010					1.090
8.010	9.250		1.240			
9.250	11.250					2.000
11.250	13.000				1.750	
13.000	16.750					3.750
16.750	19.510				2.760	
19.510	23.825					4.315
23.825	24.075				250	
24.075	24.125					50
24.125	25.085				960	
25.085	25.115					30
25.115	26.210				1.095	
26.210	27.660					1.450
27.660	27.750				90	
27.750	33.250					5.500
33.250	33.500			250		
33.500	33.700					200
33.700	34.800			1.100		
Subsection: bypass east (km 34+800 - km 49+008)						
34.800	36.750			1.950		
36.750	38.750		2.000			
38.750	41.750					3.000
41.750	42.190			440		
42.190	42.210					20
42.210	43.875			1.665		
43.875	43.925					50
43.925	44.275			350		
44.275	44.325					50
44.325	47.675			3.350		
47.675	47.725					50
47.725	49.008			1.283		
TOTAL		0	**5.860**	**10.388**	**6.905**	**25.855**

S 12, Samtredia - Ureki

Chainage		Resealing	Overlay 40 mm	Overlay 75 mm	Overlay 100 mm	Recon-struction
from	to	length (m)	length (m)	length (m)	length (m)	length (m)
0	5.210					5.210
5.210	5.360			150		
5.360	6.550					1.190
6.550	7.050			500		
7.050	18.750					11.700
18.750	19.070				320	
19.070	25.250					6.180
25.250	26.070			820		
26.070	27.750					1.680
27.750	30.750			3.000		
30.750	31.620					870
31.620	32.130			510		
32.130	37.050					4.920
37.050	37.250			200		
37.250	40.925				3.675	
40.925	41.075					150
41.075	43.250				2.175	
43.250	45.250			2.000		
45.250	51.070					5.820
51.070	51.250			180		
51.250	53.960				2.710	
53.960	54.040					80
54.040	54.250				210	
54.250	56.528					2.278
TOTAL		**0**	**0**	**7.360**	**9.090**	**40.078**

7. THE COST OF ROAD MAINTENANCE, AND REHABILITATION 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 Sakavtogza 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 Lari at the exchange rate of 1.27 Lari to the US dollar (July 1997).

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

Description	Unit	Rate US $
Bitumen	ton	130.00
Aggregate	m^3	23.80
Filler	ton	30.00
Sand	m^3	18.00
Gravel	m^3	9.00
Reinforced concrete M 300	m^3	231.08
Plant-mixed concrete M 150	m^3	77.00
Plant-mixed concrete M 300	m^3	103.00
Plant-mixed concrete M 400	m^3	115.00
Traffic sign	no.	32.69
Signpost	no.	150.00
Crash barrier	m	34.85
Marker post	no.	3.00
Km post	no.	10.71
Marking	m	2.54
Fuel (diesel)	litre	0.25
Fuel (petrol)	litre	0.33
Electric power	kw/h	0.09
Labour (includes social security cost, etc.)	month	675.00
Transportation	t/km	0.20

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 $
Resealing	m^2	1.25
Tack coat	m^2	0.60
Overlay 40 mm	m^2	6.00
Overlay 60 mm	m^2	9.91
Overlay 90 mm	m^2	14.08
Reconstruction (depends on the road sections)	m^2	36.25 - 42.89
Patching	m^2	12.12
Clean out of culverts	m	1.92
Shoulder regravelling	m^2	0.75

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

	unit	Size A	Size B	Size C
	m^3	155	86	69
Additional costs for scaffoldings	m^3	75	42	33

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.

unit	Size A	Size B	Size C
m^3	12	11	10

3. Slope protection:

The slope protection is executed in two layers:

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.

unit	Size A	Size B	Size C
m^2	35	35	35

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.

unit	Size A	Size B	Size C
m^2	530	340	240

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

unit	Size A	Size B	Size C
m^2	100	60	45

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

	unit	Size A	Size B	Size C
	m²	45	26	20

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 3,5 mm
6. Wearing surface asphalt concrete thickness 3,5 mm

	unit	Size A	Size B	Size C
	m²	220	122	98

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

	unit	Size A	Size B	Size C
	m²	135	75	60

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 3,5 cm 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	650	360	305

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	75	45	38

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	350	230	170

12. New massive concrete barriers:

Construction of massive 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 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	1800	1440	1000
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	2475	1375	1100
b.) Expansion joint for steel superstructures. Construction of the expansion joint as waterproof joint constructions with **more** as one sealing profile across the total width of the bridge (in the area of sidewalks and carriageway).	m	5900	3280	2625
14. New drainage facilities: Installation standard gullies with shutter and dirt trap in existing waste pipes.	no.	900	900	900
15. Maintenance of bearings: Clean, application of a corrosion protection system and greasing of steel slide bearings.	no.	290	290	290
16. New bearings Removal of old bearings and assembly of new rubber bearings.	no.	1150	1150	1150
17. 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	1450	1450	1450

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

18. 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.

The item also includes the removal of the existing chamber walls

	m	240	240	240

19. All kinds of concrete works:

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

	m³	600	330	265

20. Corrosion protection of steel superstructures:

Repair of local damages of the corrosion protection system of steel structures.

The item does not contain scaffoldings.

	m³	60	60	60

21. 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.

	no.	2325	2325	2325

22. 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.

	m²	2830	1570	1260

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

23. New bridge:

Construction of a new bridge (without demolition works)

	m^2	2250	1250	1000

24. 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)

	m	700	700	700

7.4 Definition of Road Sections for Feasibility Analysis

The study has covered 11 links of 6 main road in Georgia. The total length of road links studied is just under 394 km. The links in the S.1, S.4, S.9 and S.12 roads form part of the main east-west road corridor across Georgia and, on a larger scale, an important component of the road corridor between the Caspian Sea and points east and the Black Sea and Turkey and central and western Europe to the west. The S.6 and S.7 roads form part of the main international road links between Tbilisi and Armenia, in which context the S.7 is the more important access route to Armenia. The roads links studied are listed below.

Road No.	Location: Start	Location: Finish	Road length (km)
S.1	Tbilisi	S1 / S3 road jct.	11.9
S.1	S1 / S3 road jct.	Gori jct.	57.8
S.1	Gori jct.	Khashuri	42.0
S.4	Tbilisi	Red Bridge border post (Azerbaijan border)	46.2
S.6	Tbilisi	Marneuli	25.8
S.6	Marneuli	Bolnisi	25.0
S.6	Bolnisi	Guguti border post (Armenian border)	45.3
S.7	Marneuli	Sadakhlo border post (Armenian border)	34.2
S.9	Tbilisi Bypass west		34.8
S.9	Tbilisi Bypass east		14.2
S.12	Samtredia	Ureki	56.5
	Total East - West Corridor		263.4
	Total North - South routes		130.3
	TOTAL ROADS STUDIED		393.7

7.5 Definition of Road Maintenance, Rehabilitation Options Analysed

The number of options or strategies analysed were limited to the following:

- Do minimum ("without project" situation). This involves routine maintenance and patching and may involve reconstructing the road when future pavement deterioration reaches the point where there is a danger of complete pavement destruction. This point has been assumed to be reached 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 overlay and reconstruction proposals were not defined as mutually exclusive alternatives, but rather as solutions considered to be appropriate for specific sub sections on purely engineering grounds.

7.6 The Costs of 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 proposed rehabilitation measures for each section are summarised in Table 7.1.

Table 7.1 SUMMARY OF THE COSTS OF ROAD IMPROVEMENT OPTIONS

Road No.	Engineering section	Location start	Location finish	Road length (km)	Project Description	Project Cost (US$ million)	Project Cost (US$ / km)
S.1	S11.1	Tbilisi	S1 / S3 road jct.	11.25	Overlay	1.584	140,800
S.1	S11.2	Tbilisi	S1 / S3 road jct.	0.69	Reconstruction	0.373	540,580
				11.94		1.957	163,903
S.1	S12.1	S1 / S3 road jct.	Gori jct.	36.19	Overlay	4.235	117,037
	S12.2	S1 / S3 road jct.	Gori jct.	21.58	Reconstruction	10.355	479,954
				57.76		14.59	252,597
S.1	S13.1	Gori jct.	Khashuri	36.79	Overlay	3.889	105,708
	S13.2	Gori jct.	Khashuri	5.18	Reconstruction	2.557	493,629
				41.97		6.446	153,586
S.4	S41.1	Tbilisi	Red Bridge border post	25.44	Overlay	2.556	100,472
	S41.2	Tbilisi	Red Bridge border post	20.73	Reconstruction	7.827	377,569
				46.17		10.383	224,886
S.6	S6.1	Tbilisi	Marneuli	7.28	Overlay	0.655	89,973
	S6.2	Tbilisi	Marneuli	18.56	Reconstruction	9.332	502,802
				25.84		9.987	386,494
S.6	S6.1	Marneuli	Bolnisi	19.56	Overlay	2.653	135,634
	S6.2	Marneuli	Bolnisi	5.48	Reconstruction	2.246	409,854
				25.04		4.899	195,647
S.6	S63.1	Bolnisi	Guguti border	2.41	Overlay	0.281	116,598
	S63.2	Bolnisi	Guguti border	42.84	Reconstruction	14.541	339,450
				45.25		14.822	327,580
S.7	S71.1	Marneuli	Sadakhlo border	4.45	Overlay	0.311	69,966
	S71.2	Marneuli	Sadakhlo border	29.71	Reconstruction	10.095	339,819
				34.15		10.406	304,697
S.9	S91.1	Tbilisi Bypass west		12.12	Overlay	1.762	145,440
	S91.2	Tbilisi Bypass west		22.69	Reconstruction	11.837	521,799
				34.8		13.599	390,776
S.9	S92.1	Tbilisi Bypass east		11.04	Overlay	1.288	116,688
	S92.2	Tbilisi Bypass east		3.17	Reconstruction	1.593	502,524
				14.21		2.881	202,773
S.12	S121.1	Samtredia	Ureki	16.45	Overlay	2.007	122,006
	S121.2	Samtredia	Ureki	40.08	Reconstruction	14.986	373,921
				56.53		16.993	300,612

Source: Consultants' estimates

A detailed cost breakdown by section and cost item is given in Appendix 7.3.

7.7 Road Costs in the Absence of the Specified Improvement Options

In the economic analysis the costs taken into account over the life cycle of the specified road maintenance and rehabilitation 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 of the specified maintenance, and rehabilitation 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 maintenance and rehabilitation 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 categories 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 travel 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 and rehabilitation projects.

Table 7.2: Summary of Section Costs

Section	Length km	Costs in Million US $						Total Million US $	Total/km Million US $
		General Items	Earth-works	Drainage	Bridges	Pavement	Marking & Safety		
S 1, Tblilisi - Kashuri									
Subsection: Tbilisi - Junction S3 (km 15+000 - km 26+940)	11,94	843.422	65.998	26.028	5.179.284	2.980.336	182.571	9.277.639	777.022
Subsection: Junction S3 - Gori junction (km 26+940 - km 84+700)	57,76	1.515.305	145.641	125.738	2.501.296	11.848.368	532.011	16.668.359	288.580
Subsection: Gori junction - Khashuri (km 84+700 - 126+670)	41,97	850.947	575.970	91.028	1.921.677	5.534.222	386.573	9.360.417	223.026
S 4, Tbilisi - Red Bridge/Azerbaijan border (km 11+000 - km 57+170)	46,17	1.015.339	18.543	100.595	1.002.880	8.606.111	425.258	11.168.726	241.904
S 6, Tbilisi - Marneuli - Guguti / Armenian border									
Subsection: Tbilisi - Marneuli (km 3+000 - km 28+840)	25,84	781.249	256.694	56.719	377.736	6.883.338	238.005	8.593.741	332.575
Subsection: Marneuli - Bolnisi (km 28+840 - km 53+880)	25,04	497.265	85.081	55.437	904.792	3.696.702	230.636	5.469.913	218.447
Subsection: Bolnisi - Guguti / Armenian border (km 53+880 - km 99+127)	45,25	1.092.172	178.917	99.865	414.922	9.811.265	416.757	12.013.898	265.518
S 7, Marneuli - Sadakhlo / Armenian border (km 0+000 - km 34+152)	34,15	918.415	135.123	74.957	1.815.840	6.843.662	314.564	10.102.561	295.812
S 9, Tbilisi bypass									
Subsection: west (km 0+000 - km 34+800)	34,80	1.581.861	1.821.125	81.001	3.145.054	10.450.900	320.533	17.400.474	500.014
Subsection: east (km 34+800 - km 49+008)	14,21	459.611	48.676	31.064	1.779.857	2.605.649	130.866	5.055.723	355.836
S 12, Samtredia - Ureki (km 0+000 - km 56+528)	56,53	1.617.064	246.382	122.636	1.820.339	13.460.618	520.663	17.787.702	314.671

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 REHABILITATION OPTIONS

8.1 General

This chapter sets out the results of the economic analysis of the road rehabilitation projects studied on selected road links on the S.1 and S.12 roads in Georgia's main east-west transport corridor and on the north south routes between Tbilisi and the Armenian border. The rehabilitation projects proposed comprise overlays and reconstruction of selected sections within each link. The economic analysis is in the form of a cost-benefit analysis of each rehabilitation option based on the use of the HDM III model.

The rehabilitation options being evaluated are overlaying and reconstruction. Within a given link, the individual sub sections for which overlays or reconstruction have been proposed on the basis of engineering analysis, are not necessarily contiguous. For the purpose of economic analysis, therefore, it has been necessary to combine them into overlay packages and reconstruction packages. The rehabilitation options for each link comprise a collection of sub links for overlay and a collection of sub links for reconstruction. It has been necessary to adopt this approach of combining sub sections for overlay and sub sections for reconstruction into combined overlay and reconstruction packages within a link in order to keep the scope of the economic analysis manageable. Individual sub sections for overlay or reconstruction are on average only just over 1 km long and the individual analysis of each sub section would have required nearly 390 runs of the HDM III model which, given the extensive data input requirements, would have been impractical.

The inputs for the economic analysis of the overlay and reconstruction packages within each link also involved analysing the road characteristics of the relevant sub sections and taking weighted averages of the required input parameters. The weighting was based on length in km. The process of weighted averaging is not thought to have distorted the input data on road characteristics. In the case of pavement roughness, for example, a vital input for the HDM III analysis, the weighted average and standard deviation for IRI data set out in Appendix Table A.8.1 indicate an acceptable level of variation about mean roughness for both overlay and reconstruction sections.

These weighted averages of the different types of data on road characteristics were the input data for the respective overlay and reconstruction packages analysed using HDM III.

An important part of the economic analysis is the sensitivity analysis, particularly for those options where the economic feasibility is shown to be marginal on the basis of best estimates for input data. An analysis of the results of the economic analysis set out in Table 8.1 shows that the economic feasibility of the reconstruction option proposed on engineering grounds is at best only marginal. The sensitivity analysis therefore concentrated on the two links where the economic feasibility of reconstruction was most marginal and examined the sensitivity of the results to assumed variations in base year AADT, traffic growth rates and initial capital costs.

8.2 Results of the Economic Analysis

The results of the economic analysis of the various road rehabilitation projects are summarised in Table 8.1. It is important to emphasise at this stage that the "requirement" for overlays and reconstruction was defined on the basis of engineering analysis alone. The results of the economic analyses make clear that, particularly for expensive reconstruction projects, requirement defined in purely engineering terms is not necessarily the same as economic priority based on cost-benefit analysis results.

The results of the economic analysis show that the proposed overlay works are feasible for immediate implementation on all but two of the road links studied. The two exceptions are the eastern and western parts of the Tbilisi bypass where present pavement roughness levels for the sections proposed for overlaying are below IRI 5 m/km. Very few of the proposed reconstruction packages on the links studied achieve economic feasibility as defined by a 15 per cent economic internal rate of return (EIRR) or a positive Net Present Value (NPV) at a 15 per cent discount rate and this suggests that they are premature. The exceptions are the link between Tbilisi and the S1/S3 road junction and the Marneuli-Sadakhlo (Armenian border) link. On the former, existing roughness of IRI 4.5 m/km is quite high in relation to the AADT of nearly 10,000 vehicles and the reconstruction option is justified. On the Marneuli-Sadakhlo link the road is in very poor condition as reflected in pavement roughness levels of over IRI 11 m/km and, even with AADT of just under 2,000, reconstruction has a high engineering and economic priority. Elsewhere, average reconstruction costs of over US$ 405,000 per km and generally low traffic levels (except on the S.1 road west of Tbilisi) mean that reconstruction options have a relatively low economic priority. On the S.1 links between the S.1 / S.3 junction and Gori junction and between Gori junction to Khashuri the economic feasibility of reconstruction is marginal, largely because the existing pavement roughness is less than IRI 4.5 m/km.

In Table 8.2 the overlay and reconstruction packages are set out in descending order of economic priority as measured by Net Present Value to Initial Cost (NPV / Cost). The various packages have sorted into three groups based on descending NPV / Cost. The first group are economically feasible for immediate implementation, having positive NPVs and EIRRs of 15 per cent and over. The total length of these sections is 190.2 km and the total initial cost of the proposed road works would be US$ 28.64 million. The second group comprise what could be described as marginal projects and have EIRRs between 10 and 15 per cent. These sections amount to 68.5 km and the total cost of the road works would be US$ 25.29 million. The final group is made up entirely of reconstruction proposals with EIRRs of less than 10 per cent and includes sections totalling 135 km. The total cost of these road works would be US$ 53 million and the negative NPV would amount to US$-15.5 million.

In terms of contract packaging it is probably more realistic to consider combined overlay and reconstruction projects at the link level or for groups of links. At the link level, rehabilitation projects comprising a combination of overlays and reconstruction on selected sub sections have overall EIRRs of over 15 per cent the following road links:

- S.1 (Tbilisi - S.1 / S.2 junction) - overall EIRR 33.7%
- S.1 (S.1 / S.3 junction - Gori junction) - overall EIRR 22.9 %. Here the marginal feasibility of reconstruction sections is subsidised by the very high returns to the overlay sections.
- S.1 (Gori junction - Khashuri) - overall EIRR 25.8 %. Here the marginal feasibility of reconstruction sections is also subsidised by the very high returns to the overlay sections.
- S.6 (Tbilisi - Marneuli) - overall EIRR 21.8 % - largely because of the very high returns on the overlay sections.
- S.6 (Marneuli - Bolnisi) - overall EIRR 40 % - almost entirely due to the very high returns on the overlay sections.
- S.7 (Marneuli - Sadakhlo) - overall EIRR 23.8 % - both the overlay and reconstruction components have a high economic priority and the urgency of rehabilitation is enhanced by the road's international importance as part of the main road link between Tbilisi and Armenia.

It will be noted that on many of these links the majority of the reconstruction projects would be subsidised by the overlay projects.

There have been no proposals in this study for widening the selected roads in Georgia from 2 to 4 lanes. On certain roads with AADT in excess of 7,000 vehicles there are already 4 lane sections, particularly on the approaches to Tbilisi. Although the highway design categories inherited from the Soviet Union specify an AADT of 7,000 vehicles as the threshold for widening from 2 to 4 lanes, this is considered to be far too low in most western European countries. Engineering and economic analyses of widening projects which have recently been undertaken in the Ukraine and Azerbaijan suggest that reconstruction plus widening from 2 to 4 lanes requires a base year AADT of 11,000 - 12,000 vehicles to be economically justified. Apart from the link between Tbilisi and the S.1 / S.3 junction, most of which is already of 4 lane standard, none of the roads studied have base year AADT levels anywhere near the 11,000 - 12,000 vehicle threshold at which widening to 4 lanes might be realistic in economic terms.

Table 8.1 GEORGIA - SUMMARY OF THE ECONOMIC ANALYSIS RESULTS FOR ROAD IMPROVEMENT PROJECTS

Road	Engineering	Location		Road	Pavement	No.of	Surface	Structural No.		Pavement	Base	Project	Project Cost		Economic Analysis Results		
no.	section	start	finish	length (km)	width (m)	lanes	type	Existing	Improved	Roughness IRI (m/km)	Year AADT	Description	(US$ million)	(US$ / km)	NPV (US$ mn.)	NPV / Cost	IRR (%)
S.1	S11.1	Tbilisi	S1 / S3 road jct.	11,25	10,60	2/4	AC	4,60	5,59	4,3	9.106	Overlay	1,584	140.800	2,85	1,80	37,0
S.1	S11.2	Tbilisi	S1 / S3 road jct.	0,69	10,60	2/4	AC	3,68	6,21	4,5	9.106	Reconstruction	0,373	540.580	0,04	0,09	16,6
				11,94									1,957	163.903	2,89	1,47	33,7
S.1	S12.1	S1 / S3 road jct.	Gori jct.	36,19	9,22	2	AC	4,71	5,68	4,4	5.712	Overlay	4,235	117.037	5,09	1,20	28,5
	S12.2	S1 / S3 road jct.	Gori jct.	21,58	9,22	2	AC	3,64	6,00	5,0	5.712	Reconstruction	10,355	479.954	-1,12	-0,11	12,9
				57,76									14,590	252.597	3,97	0,27	22,9
S.1	S13.1	Gori jct.	Khashuri	36,79	9,63	2	AC	4,86	5,60	4,2	6.238	Overlay	3,889	105.708	5,28	1,36	27,6
	S13.2	Gori jct.	Khashuri	5,18	9,63	2	AC	4,86	5,58	4,4	6.238	Reconstruction	2,557	493.629	-0,37	-0,14	13,0
				41,97									6,446	153.586	4,91	0,76	25,8
S.4	S41.1	Tbilisi	Red Bridge border post	25,44	8,55	2	AC	3,89	4,88	5,5	1.359	Overlay	2,556	100.472	0,16	0,06	15,9
	S41.2	Tbilisi	Red Bridge border post	20,73	8,55	2	AC	3,85	4,81	6,2	1.359	Reconstruction	7,827	377.569	-3,23	-0,41	5,4
				46,17									10,383	224.886	-3,07	-0,30	9,4
S.6	S6.1	Tbilisi	Marneuli	7,28	10,35	2/4	AC	4,32	5,14	6,0	4.285	Overlay	0,655	89.973	1,40	2,14	48,4
	S6.2	Tbilisi	Marneuli	18,56	10,35	2/4	AC	3,41	5,47	6,3	4.285	Reconstruction	9,332	502.802	-1,29	-0,14	11,4
				25,84									9,987	386.494	0,11	0,01	21,8
S.6	S6.1	Marneuli	Bolnisi	19,56	8,78	2	AC	3,70	4,87	8,0	2.724	Overlay	2,653	135.634	2,53	0,95	48,5
	S6.2	Marneuli	Bolnisi	5,48	8,78	2	AC	3,37	5,56	6,5	2.724	Reconstruction	2,246	409.854	-0,49	-0,22	9,6
				25,04									4,899	195.647	2,04	0,42	40,0
S.6	S63.1	Bolnisi	Guguti border	2,41	7,80	2	AC	4,10	4,83	8,1	763	Overlay	0,281	116.598	0,15	0,53	31,5
	S63.2	Bolnisi	Guguti border	42,84	7,80	2	AC	3,23	5,52	10,2	763	Reconstruction	14,541	339.450	-2,40	-0,17	6,1
				45,25									14,822	327.580	-2,25	-0,15	7,5
S.7	S71.1	Marneuli	Sadakhlo border	4,45	7,69	2	AC	3,60	4,19	9,6	1.833	Overlay	0,311	69.966	0,72	2,32	95,0
	S71.2	Marneuli	Sadakhlo border	29,71	7,69	2	AC	2,83	5,12	11,4	1.833	Reconstruction	10,095	339.819	0,99	0,10	20,3
				34,15									10,406	304.697	1,71	0,16	23,8
S.9	S91.1	Tbilisi Bypass west		12,12	10,30	2	AC	3,63	4,76	4,6	921	Overlay	1,762	145.440	-0,41	-0,23	11,5
	S91.2	Tbilisi Bypass west		22,69	10,30	2	AC	3,29	4,93	5,2	921	Reconstruction	11,837	521.799	-5,64	-0,48	3,8
				34,80									13,599	390.776	-6,05	-0,44	5,6
S.9	S92.1	Tbilisi Bypass east		11,04	10,10	2	AC	4,82	5,55	4,4	2.921	Overlay	1,288	116.688	-0,09	-0,07	13,8
	S92.2	Tbilisi Bypass east		3,17	10,10	2	AC	4,37	5,55	5,2		Reconstruction	1,593	502.524	-0,54	-0,34	8,8
											2.921						
				14,21									2,881	202.773	-0,63	-0,22	11,2
S.12	S121.1	Samtredia	Ureki	16,45	8,01	2	AC	3,92	5,04	7,7	1282	Overlay	2,007	122.006	1,24	0,62	31,5
	S121.2	Samtredia	Ureki	40,08	8,01	2	AC	3,59	5,11	7,8	1282	Reconstruction	14,986	373.921	-3,18	-0,21	5,5
				56,53									16,993	300.612	-1,94	-0,11	10,4

Source: Consultants' estimates

Table 8.2 GEORGIA - SUMMARY OF THE ECONOMIC PRIORITY OF OVERLAY AND RECONSTRUCTION SECTIONS

Road no.	Engineering section	Location start	Location finish	Road length (km)	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 (%)
S.7	S71.1	Marneuli	Sadakhlo border	4,45	9,6	1.833	Overlay	0,311	69.966	0,72	2,32	95,0
S.6	S6.1	Tbilisi	Marneuli	7,28	6,0	4.285	Overlay	0,655	89.973	1,40	2,14	48,4
S.1	S11.1	Tbilisi	S1 / S3 road jct.	11,25	4,3	9.106	Overlay	1,584	140.800	2,85	1,80	37,0
S.1	S13.1	Gori jct.	Khashuri	36,79	4,2	6.238	Overlay	3,889	105.708	5,28	1,36	27,6
S.1	S12.1	S1 / S3 road jct.	Gori jct.	36,19	4,4	5.712	Overlay	4,235	117.037	5,09	1,20	28,5
S.6	S6.1	Marneuli	Bolnisi	19,56	8,0	2.724	Overlay	2,653	135.634	2,53	0,95	48,5
S.12	S121.1	Samtredia	Ureki	16,45	7,7	1282	Overlay	2,007	122.006	1,24	0,62	31,5
S.6	S63.1	Bolnisi	Guguti border	2,41	8,1	763	Overlay	0,281	116.598	0,15	0,53	31,5
S.7	S71.2	Marneuli	Sadakhlo border	29,71	11,4	1.833	Reconstruction	10,095	339.819	0,99	0,10	20,3
S.1	S11.2	Tbilisi	S1 / S3 road jct.	0,69	4,5	9.106	Reconstruction	0,373	540.580	0,04	0,09	16,6
S.4	S41.1	Tbilisi	Red Bridge border post	25,44	5,5	1.359	Overlay	2,556	100.472	0,16	0,06	15,9
				190,21				28,64		20,45	0,71	
S.9	S92.1	Tbilisi Bypass east		11,04	4,4	2.921	Overlay	1,288	116.688	-0,09	-0,07	13,8
S.1	S12.2	S1 / S3 road jct.	Gori jct.	21,58	5,0	5.712	Reconstruction	10,355	479.954	-1,12	-0,11	12,9
S.6	S6.2	Tbilisi	Marneuli	18,56	6,3	4.285	Reconstruction	9,332	502.802	-1,29	-0,14	11,4
S.1	S13.2	Gori jct.	Khashuri	5,18	4,4	6.238	Reconstruction	2,557	493.629	-0,37	-0,14	13,0
S.9	S91.1	Tbilisi Bypass west		12,12	4,6	921	Overlay	1,762	145.440	-0,41	-0,23	11,5
				68,47				25,29		-3,28	-0,13	
S.6	S63.2	Bolnisi	Guguti border	42,84	10,2	763	Reconstruction	14,541	339.450	-2,40	-0,17	6,1
S.12	S121.2	Samtredia	Ureki	40,08	7,8	1282	Reconstruction	14,986	373.921	-3,18	-0,21	5,5
S.6	S6.2	Marneuli	Bolnisi	5,48	6,5	2.724	Reconstruction	2,246	409.854	-0,49	-0,22	9,6
S.9	S92.2	Tbilisi Bypass east		3,17	5,2	2.921	Reconstruction	1,593	502.524	-0,54	-0,34	8,8
S.4	S41.2	Tbilisi	Red Bridge border post	20,73	6,2	1.359	Reconstruction	7,827	377.569	-3,23	-0,41	5,4
S.9	S91.2	Tbilisi Bypass west		22,69	5,2	921	Reconstruction	11,837	521.799	-5,64	-0,48	3,8
				134,98				53,03		-15,48	-0,29	

Source: Consultant's estimates.

8.3 Results of the Sensitivity Analysis

For the reasons discussed above, the sensitivity analysis was concentrated on the rehabilitation proposals whose economic feasibility appears to be the most marginal.These are the proposals for reconstruction on the two links S.1/S.3 junction - Gory junction and Gori junction - Khashuri on the S.1 road west of Tbilisi. The sensitivity analysis covered the potential effect on project EIRRs of the following assumed changes in capital costs and traffic.

- Initial costs: -30%, -20%, -10%, +10%, +20% and +30%
- Base Year AADT -30%, -10%, +10% and +30%
- Traffic growth rates Optimistic assumption implying traffic growth approximately 23% higher than the best estimate prediction and a pessimistic assumption implying traffic growth around 18% lower than the best estimate prediction.

The results of the sensitivity analyses are summarised in Table 8.3 and illustrated in Figures 8.1 - 8.3. These results show that for the EIRR for reconstruction to reach the economic feasibility threshold of 15 per cent, initial costs on the two links would have to be 20 per cent lower than estimated, base year AADT would need to be 20 - 30 per cent higher than estimated and traffic growth would need to exceed the Consultant's high growth scenario. The results show that the EIRRs are most sensitive to changes in initial capital costs and then to changes in base year AADT. They are slightly less sensitive to changes in traffic growth assumptions.

The results of the economic analysis show that the economic feasibility of the reconstruction proposals on the following three links is marginal.

- S1 / S3 junction - Gori junction
- Gori junction - Khashuri
- Tbilisi - Marneuli

In other words, the EIRRs for reconstruction on these links lie between 11 and 13 per cent and, if the economic feasibility threshold is taken to be 15 per cent, the proposals are slightly premature. A brief analysis has been undertaken to establish when implementation of reconstruction would be justified and the results are set out in Table 8.4. The optimum timing for the implementation of reconstruction on these three links would be between the years 2000 and 2002. These are the years when the EIRRs of the respective reconstruction proposals reach 15 per cent and their NPVs become positive. The implication of this analysis is that the reconstruction proposals on other links where the EIRRs are less than 10 per cent are significantly premature. It may be that on these links an initial overlay followed by further strengthening measures at a later date may be a more promising solution in economic terms.

Table 8.3 SUMMARY OF SENSITIVITY ANALYSIS RESULTS

Variation from Base Case Input Values (%)		S1/S3 Junction - Gori Junction			S1.Gori Junction - Khashuri		
		IRR (%)	% change in IRR	% change per 1% in input value	IRR (%)	% change in IRR	% change per 1% in input value
Initial Costs							
Base Case -	30	17,6	36,4	1,2	16,4	26,2	0,9
Base Case -	20	15,8	22,5	1,1	15,0	15,4	0,8
Base Case -	10	14,2	10,1	1,0	13,9	6,9	0,7
Base Case		**12,9**	**0,0**		**13,0**	**0,0**	
Base Case +	10	11,7	-9,3	-0,9	12,1	-6,9	-0,7
Base Case +	20	10,6	-17,8	-0,9	11,4	-12,3	-0,6
Base Case +	30	9,6	-25,6	-0,9	10,7	-17,7	-0,6
Base AADT							
Base Case -	30	10,0	-22,5	-0,7	9,9	-23,8	-0,8
Base Case -	10	12,2	-5,4	-0,5	11,8	-9,2	-0,9
Base Case		**12,9**	**0,0**		**13,0**	**0,0**	
Base Case +	10	14,4	11,6	1,2	13,5	3,8	0,4
Base Case +	30	16,3	26,4	0,9	15,0	15,4	0,5
Traffic Growth							
Low assumption	-18,2	12,0	-7,0	0,4	11,3	-12,4	0,7
Base Case		**12,9**	**0,0**		**12,9**	**0,0**	
High assumption	23,6	14,7	14,0	0,6	14,0	8,5	0,4

Source: Consultant's estimates

Table 8.4 OPTIMUM TIMING OF RECONSTRUCTION - SELECTED LINKS

Year	Year No.	RECONSTRUCTION - OPTIMUM TIMING											
		S.1 / S.3 JCT. - GORI JCT.			S.1 GORI JCT. - KHASHURI				TBILISI - MARNEULI				
		Implementation Year			Implementation Year				Implementation Year				
		1998	1999	2000	1998	1999	2000	2001	1998	1999	2000	2001	2002
NPV @ 15%		-1,122	-0,464	0,052	-0,367	-0,175	-0,021	0,100	-1,292	-0,802	-0,428	-0,156	0,027
IRR (%)		12,9%	13,9%	15,1%	13,0%	13,9%	14,8%	15,9%	11,4%	12,3%	13,2%	14,2%	15,2%

Source: Consultant's estimate

FIGURE 8.1 SENSITIVITY OF IRR TO CHANGES IN INITIAL CAPITAL COSTS

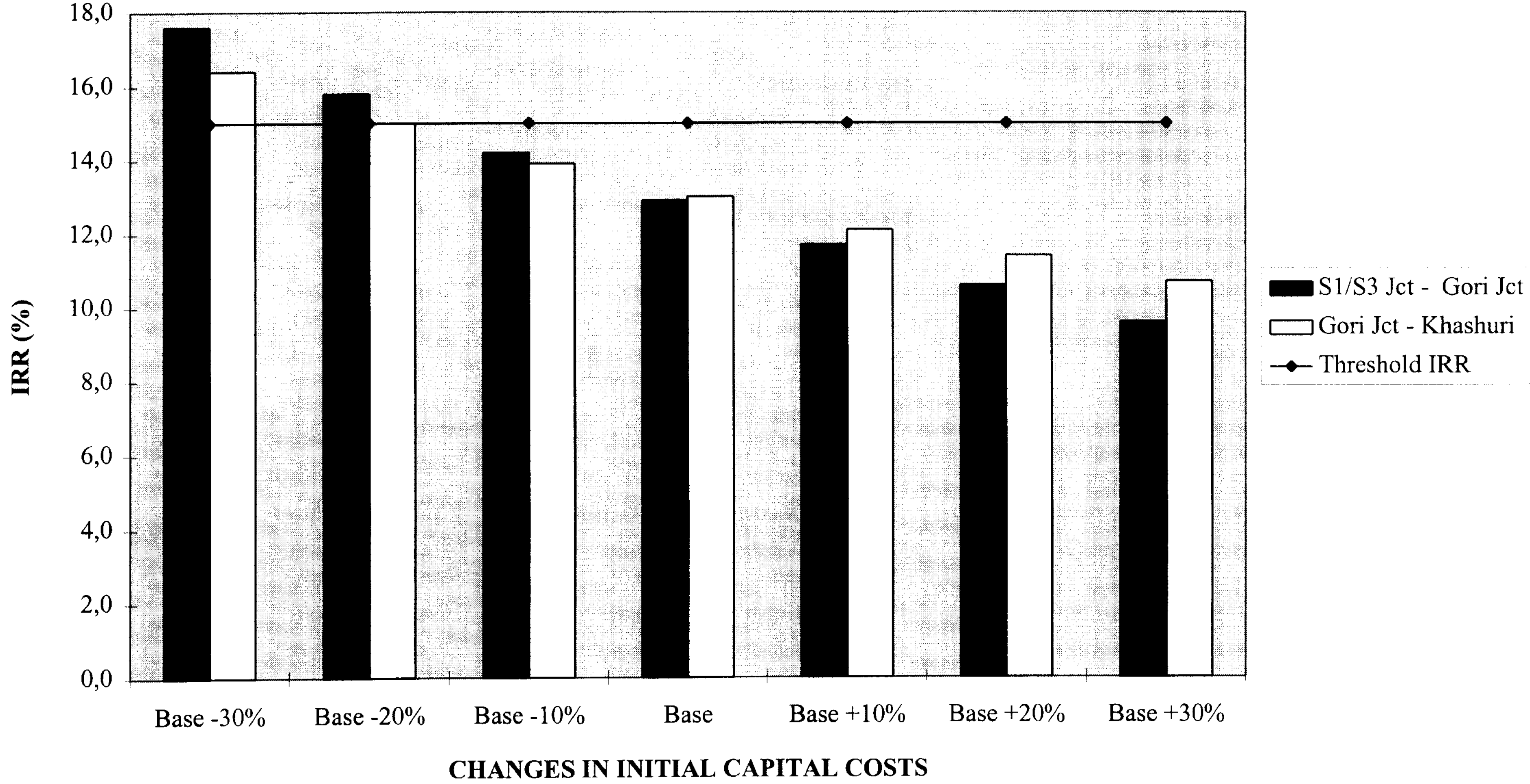

FIGURE 8.2 SENSITIVITY OF IRR TO CHANGES IN BASE YEAR TRAFFIC

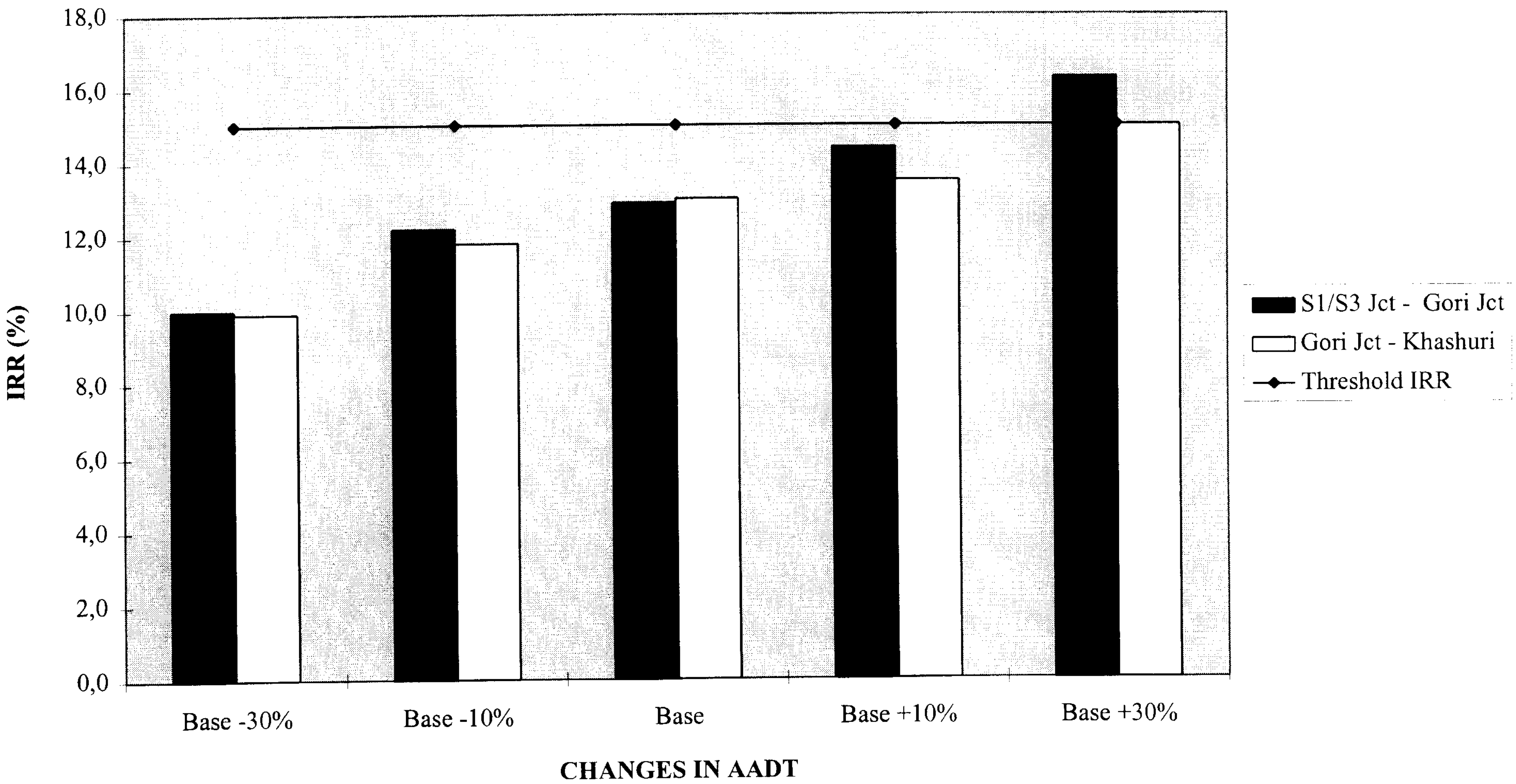

FIGURE 8.3 SENSITIVITY OF IRR TO TRAFIC GROWTH ASSUMPTIONS

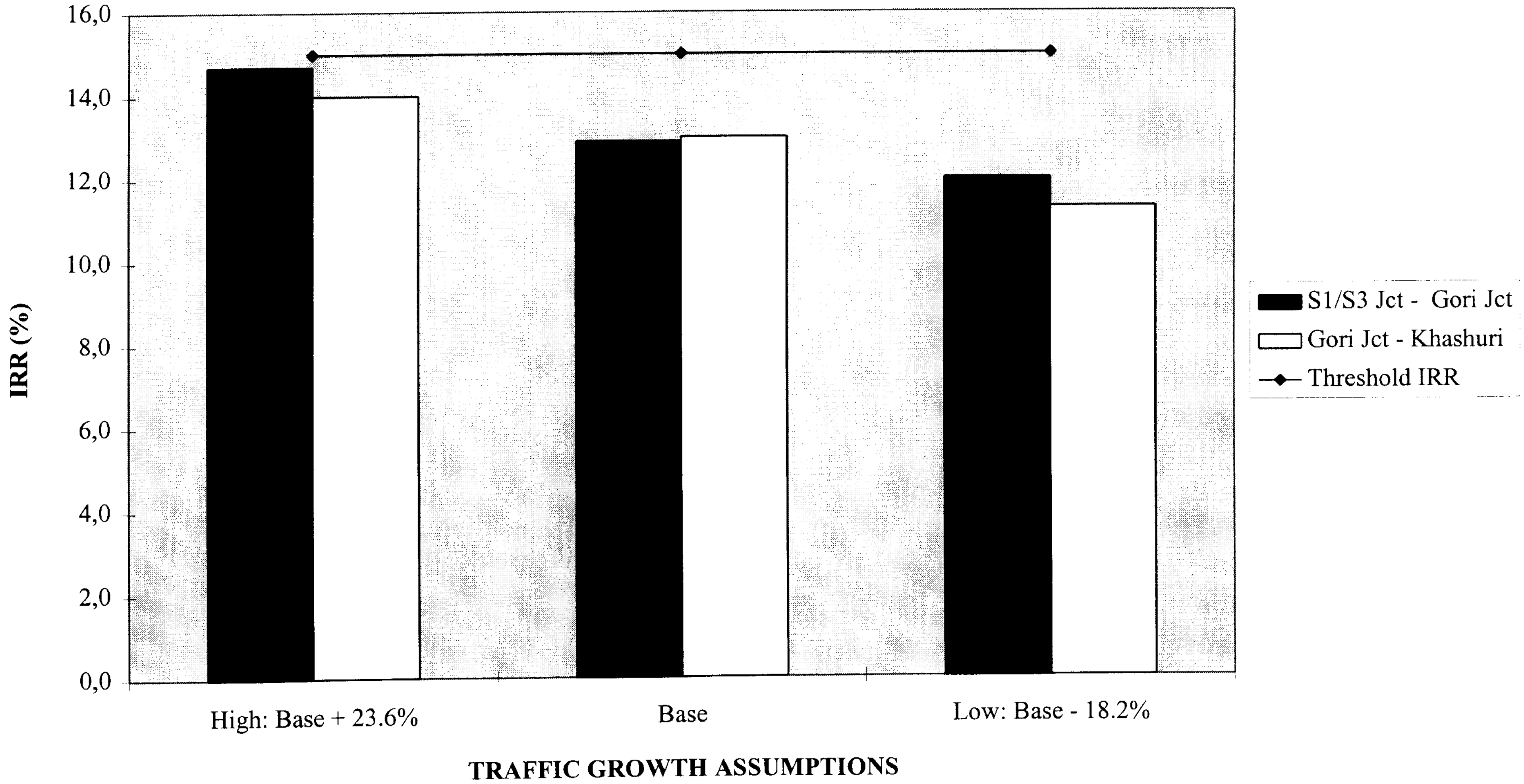

Table A.8.1 NUMBER OF SUB SECTIONS FOR OVERLAY AND RECONSTRUCTION BY LINK

Road No.	Location Start	Location Finish	Treat-ment	Length km	Sub Sections No.	Sub Sections Average length (km)	Pavement Roughness Weighted Average IRI (m/km)	Standard Deviation IRI (m/km)	Coefficient of Variation (%)
S1	Tbilisi	S1/S3 junction	Overlay	11,250	11	1,00	4,29	0,545	12,7
	Tbilisi	S1/S3 junction	Reconstruction	0,690	1	1,00	4,50	-	
S1	S1/S3 junction	Gori junction	Overlay	36,185	35	1,00	4,45	0,832	18,7
	S1/S3 junction	Gori junction	Reconstruction	21,575	23	1,00	5,03	0,894	17,8
S1	Gori junction	Khashuri	Overlay	36,790	36	1,00	4,20	0,597	14,2
	Gori junction	Khashuri	Reconstruction	5,180	6	0,95	4,36	1,233	28,3
S4	Tbilisi	Red Bridge bp	Overlay	25,440	23	1,08	5,47	1,122	20,5
	Tbilisi	Red Bridge bp	Reconstruction	20,730	20	1,07	6,16	1,505	24,4
S6	Tbilisi	Marneuli	Overlay	7,280	9	0,88	5,97	1,719	28,8
	Tbilisi	Marneuli	Reconstruction	18,560	21	0,84	6,30	1,952	31,0
S6	Marneuli	Bolnisi	Overlay	19,560	20	0,98	8,00	2,921	36,5
	Marneuli	Bolnisi	Reconstruction	5,480	6	1,02	6,51	1,651	25,4
S6	Bolnisi	Guguti bp	Overlay	2,410	2	1,10	8,05	0,544	6,8
	Bolnisi	Guguti bp	Reconstruction	42,837	40	1,07	10,20	2,935	28,8
S7	Marneuli	Sadakhlo	Overlay	4,445	5	1,00	9,60	2,948	30,7
	Marneuli	Sadakhlo	Reconstruction	29,707	29	1,01	11,41	3,235	28,4
S9	Tbilisi bypass west		Overlay	12,115	10	1,13	4,57	1,750	38,3
	Tbilisi bypass west		Reconstruction	22,685	23	1,03	5,16	1,583	30,7
S9	Tbilisi bypass east		Overlay	11,038	11	0,98	4,35	1,049	24,1
	Tbilisi bypass east		Reconstruction	3,170	3	1,03	5,19	1,570	30,3
S12	Samtredia	Ureki	Overlay	16,450	15	1,07	7,66	3,390	44,3
	Samtredia	Ureki	Reconstruction	40,078	38	1,06	7,79	2,523	32,4
					387	1,01			

Source: Consultant's estimate

9. RECOMMENDATIONS AND CONCLUSION

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

The existing traffic level on the study roads range from less than 1,000 to more than 9,000 AADT. The highest traffic flows are on the S 1 road section between Tbilisi and the junction to Vladikavkaz with about 9,000 vehicles per day. Here the traffic from Russia joins the east-west traffic flows. The daily traffic on the S 1 towards Kashuri remains at the level of more than 5,000 vehicles. Apart from the Tbilisi - Marneuli road link (about 4,000 ADT), average daily traffic levels on the other study road links were below 3,000 vehicles: Foreign vehicles account for less than 5 % of the total traffic flow on most of the study roads. However, the international traffic consists predominantly of heavy vehicles with 3 or more axles.

The traffic forecast indicates an overall rate of traffic growth of 4.8 % per year between 1990 and 2010 and 6.7 % per year thereafter. The heavy trick traffic is assumed to grow more rapidly than the traditional light - medium truck traffic.

The estimated volume capacity ratios suggest that capacity constraints will not be experienced before 2015. Immediate activities to widen the study roads would be premature.

The road condition of the study roads differs in large variations. Some sections of the road are still in an acceptable condition, whilst others have already reached a critical phase with typical indications such as cracks, potholes, deep permanent depressions or are already destroyed. For road sections with severe damages and/or where the pavement has reached the end of its service life reconstruction of the pavement is required. In cases where the pavement is in a fair condition with minor damages and where the bearing capacity needs a reinforcement an overlay is recommended. The necessary overlay thickensses were identified by Falling Weight Deflectometer surveys and evaluation.

The results of the economic analysis show that most of the proposed overlay works are feasible for immediate implementation, whereas a few of the reconstruction works are premature. In practice it is more realistic to consider combined overlay and reconstruction projects at the link level, whereby the reconstruction works subsided by the overlay works. Economically feasible for immediate implementation are the following road links

- S 1, Tbilisi - Kashuri (EIRR 22.9 % - 33.7 %)
- S 6, Tbilisi - Marneuli (EIRR 21.8 % - 40.0 %)
- S 7, Marneuli - Sadkhlo (EIRR 23.9 %)

For the other road sections reconstruction is premature and should not be implemented before the year 2000 at the earliest.