E U R O P E A N   U N I O N - T A C I S

Technical Assistance to the Southern Republics of the CIS

and Georgia - TRACECA

TRADE AND TRANSPORT SECTORS

IMPLEMENTATION OF PAVEMENT MANAGEMENT SYSTEMS

PROJECT NO.: TELREG 9305

REVIEW OF ROAD DESIGN STANDARDS

JANUARY 1997

KOCKS CONSULT GMBH
Consulting Engineers
Koblenz / Germany

in association with

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

PHØNIX
Pavement Consultants
Vejen / Denmark

COVER PAGE 1

REVIEW OF ROAD DESIGN STANDARDS

REPORT COVER PAGES

Project Title	:	Traceca Project - Implementation of Pavement Management Systems
Project Number	:	TELREG 9305
Country	:	The Southern Republics of the CIS and Georgia

		Local Operator	EC Consultant
Name	:	Concern **UZAVTOYUL**	KOCKS CONSULT GMBH Consulting Engineers
Address	:	68 'a' Pushkin Street 700000 Tashkent UZBEKISTAN	Stegemannstraße 32 - 38 56068 Koblenz GERMANY
Tel. number	:	(3712) 682526 and 361595	xx49 - 261 - 1302-0 (operat.) xx49 - 261 - 1302-143 (direct)
Fax number	:	(3712) 682711	xx49 - 261 - 1302 - 152
Telex number	:	--	862807
E-mail	:		kocks@t-online.de
Contact person	:	Vohid Normatovich Azamov, State Road Inspector	Werner P. Weiler, Project Director
Signatures	:		

Name	:	Ministry of Transport (MoT), State Institute of Road Design **KYRGYZDORTRANSPROJEKT** (K)	KOCKS CONSULT GMBH Consulting Engineers
Address	:	42 Isanov Street (MoT) Bishkek 720079 KYRGYZSTAN	
Tel. number	:	(3312) 216674 (MoT) or 444187 (K)	
Fax number	:	(3312) 213667 (MoT) or 444193 (K)	
Telex number	:	--	
Contact person	:	Akunov Kuwan Akunowitsch, Head of Roads Department (MoT) Levan M. Alibegashvili, Director (K)	
Signatures	:		

COVER PAGE 2

REVIEW OF ROAD DESIGN STANDARDS

		Local Operator	EC Consultant
Name	:	Ministry of Transport & Communications, Department of Highways (DoH), Joint-stock company **KAZDORNII** (K)	KOCKS CONSULT GMBH Consulting Engineers
Address	:	9 Emtsov Street Almaty, 480061 KAZAKHSTAN	
Tel. number	:	(3272) 324769 (DoH) or 400447 (K)	
Fax number	:	(3272) 324449 (DoH) or 400819 (K)	
Telex number	:	--	
Contact person	:	Amangeldy N. Yelgonov, Dept.Director (DoH) Oleg A. Krasikov, Deputy Director (K)	
Signatures	:		

Name	:	State Concern **AZERAVTOYOL**	KOCKS CONSULT GMBH Consulting Engineers
Address	:	72 A, Hadjihekov Street 370010 Baku AZERBAIJAN	
Tel. number	:	(8922) 933556	
Fax number	:	(8922) 930045	
Telex number	:	142272 YOL	
Contact person	:	Shahin H. Hasanov, Vice President and Project Manager for TRACECA-PMS	
Signatures	:		

COVER PAGE 3

REVIEW OF ROAD DESIGN STANDARDS

	Local Operator	EC Consultant
Name :	Concern **TURKMENAUTOELLARI**	KOCKS CONSULT GMBH Consulting Engineers
Address :	744000 Ashgabat TURKMENISTAN	
Tel. number :	(3632) 245487	
Fax number :	(3632) 255379 and 511678	
Telex number :	--	
Contact person :	Vladimir Volodin, Vice President	
Signatures :		

Name :	State Concern of Roads, **SAKAVTOGSA**	KOCKS CONSULT GMBH Consulting Engineers
Address :	29a Gagarin Street 380060 Tbilisi GEORGIA	
Tel. number :	(99532) 376604	
Fax number :	(99532) 376458	
Telex number :	212189	
Contact person :		
Signatures :		

COVER PAGE 4

REVIEW OF ROAD DESIGN STANDARDS

		Local Operator	EC Consultant
Name	:	**Armenian Road Directorate** (ARD)	KOCKS CONSULT GMBH Consulting Engineers
Address	:	Yerevan ARMENIA	
Tel. number	:	(3742) 586601	
Fax number	:	(3742) 151876 or 151830	
Telex number	:	212189	
Contact person	:	Nikolai Elarian, Director (ARD)	
Signatures	:		

Name	:	Ministry of Transport and Roads **TADJIKGIPROTRANSSTROY**	KOCKS CONSULT GMBH Consulting Engineers
Address	:	Ayni Street 14 734042 Dushanbe TADJIKISTAN	
Tel. number	:	(3772) 215380 or 212020	
Fax number	:	(3772) 212003	
Telex number	:		
Contact person	:	Mirzoev Timur Dodojenovia	
Signatures	:		

KOCKS
INGENIEURE

COVER PAGE 5

REVIEW OF ROAD DESIGN STANDARDS

Date of report : 30. January 1997

Reporting period : 20. December 1995 to 20 December 1996

Author of report: Hans U. Zimmermann, Asphalt Specialist (Kocks Consult GmbH)
Ulrich Willems, Highway Engineer & Team Leader (Kocks Consult GmbH)

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

TABLE OF CONTENTS

1. INTRODUCTION

This report on the Review of Road Design Standards in one of the reports being produced under the European Union - Tacis sponsored TRACECA Project for the Implementation of Pavement Management Systems. The Project covers eight states of the south of the former Soviet Union which are five states in Central Asia

- Kazakhstan
- Kyrghyzstan
- Tadjikistan
- Turkmenistan
- Uzbekistan

and another three states in the Caucasus area

- Armenia
- Azerbaijan
- Georgia.

The introduction of the Terms of Reference already describes a number of deficiencies which were also encountered during the Consultant's studies and review like

- low standard/quality of road construction (e. g. laying techniques, compaction, mix design, workmanship)
- modern Western performance criteria, technical specifications and implementation technologies are little known in the region
- high nominal standards (e. g. design speed of 150 km/h)
- road safety is inadequate

During the Consultant's activities in the project area the above listed deficiencies were further studied, detailed and discussed in a number of meetings and seminars in each of the eight recipient states with the two main headings:

BITUMINOUS BOUND MATERIALS

REVIEW OF METHODS, TECHNOLOGIES AND RELATED STANDARDS IN THE RECIPIENT STATES AND COMPARISON WITH EUROPEAN AND OTHER WESTERN METHODS, TECHNOLOGIES AND STANDARDS

ROAD DESIGN AND ROAD SAFETY

REVIEW OF RELEVANT ROAD DESIGN AND ROAD SAFETY STANDARDS FOR THE TRACECA ROADS (MAGISTRALE) IN THE RECIPIENT STATES AND COMPARISON WITH WESTERN EUROPEAN STANDARDS

In this report under the same headings the topics of the seminars are summarised and the review/analysis of the relevant standards is detailed.

2. BITUMINOUS BOUND MATERIALS

2.1. Pavement Design

2.1.1 Design Philosophies

The pavement design of a road general depends on:

- planned design life
- traffic volume (traffic forecast)
- road category

Taking into consideration the above basic design factors the main aim of the pavement design should be to achieve

- riding comfort acceptable to road users
- economy (implementation and life time)
- limited surface deflection

In the former Soviet Union Standards (SUS) the governing factor for pavement design is the so-called stiffness modulus of the pavement structure, comprising the different pavement layers (e. g. subbase, base course, asphalt concrete). With this stiffness modulus the total pavement thickness and the allowable deflection is specified. The stiffness modulus is calculated under consideration of E-moduli of the respective pavement layers. Based on researches the SUS specifies the E-moduli, which then are used without further verification for the design and on site. The criteria for determination of asphalt layer thickness is the limit on the tensile stress at the bottom of the asphalt layer.

In European/Western standards (E/WS) the pavement design is based on tolerable stresses induced in the subgrade by traffic load. The different subgrade materials and their behaviour are considered with the respective subgrade bearing capacity (e. g. CBR, plate load test) leading to the total pavement thickness. The total pavement thicknesses result from standardised pavement layer thicknesses which have been empirically determined. In addition the materials requirements are specified and have to be verified on site by regular testing to ensure the required bearing capacity of each layer. The criteria for determination of asphalt layer thickness is to provide a satisfactory service over the planned design life period of the pavement, taking into consideration the effects (climate, traffic) on the road surface.

The main differences between the SUS pavement design and E/WS pavement design are:

Requirement	SUS Design	E/WS Design
pavement deformation is limited by	stiffness modulus of the pavement structure	stress on subgrade
asphalt layer thickness is determined by	tensile stress at bottom of asphalt layers	limitation of deterioration resulting in acceptable surface condition

In summary the SUS design procedure is a method using theoretical material values. Although an adequate stiffness of a road structure is an important requirement, this does not necessarily translate into a well designed road, comfortable to use and economic in construction and maintenance.

The E/WS design procedure is based on empirical factors which are the results of practical experience with specified control of each pavement layer on site.

2.1.2 Characterisation of pavement layers

The surface course or wearing course is the top layer of an asphalt pavement and should be constructed of dense asphalt concrete. Between surface course and base course a more porous asphalt layer the so called binder course is placed. The binder course should be an asphalt mixture with a high stability and shear strength.

Below the binder the base course (road base) is the main load spreading layer of the pavement. It will normally consist of crushed stone or suitable natural gravel. For roads with high traffic load the base course can be a bituminous treated layer with high compressive strength for the total layer thickness or for the upper part combined with a lower base course layer of cement or lime treated or untreated gravel sand mixture.

The subbase is the second load spreading layer underlying the base course. It normally consists of a material of lower quality than the base course such as a natural gravel-sand mixture. This layer also serves as a separating layer preventing contamination of the base course by subgrade material during construction. Base course and subbase have to be frost-resistant.

The subgrade (existing natural ground or embankment fill) should be compacted to fulfil the requirements of a sufficient bearing capacity.

2.1.3 Assessment of existing design methods in comparisation with western design procedures

In the example below a pavement designed to SUS is recalculated and compared with an E/WS design method. The SUS design provides a service life of the pavement of 15 years. Less than 6 years service life for the same pavement is the result of the recalculation with the E/WS method, the empirical method of AASHTO (American Association of State Highway and Transport Officials).

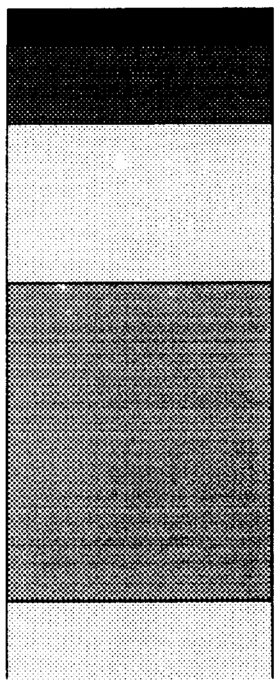
Design with SUS (VSN 46 - 72)

Design Traffic: 1342 equivalent standard vehicles per day in day in design lane

Initial traffic assuming 1.5 % growth = 1073 vpd

Accumulated $ESAL_{80} = 7.02 \times 10^{6}$ (15 years)

DESIGN SOLUTION
according to VSN 46 - 72



Wearing course 50 mm	$E_1 = 1500\ MN/m^2$
Binder course 80 mm	$E_2 = 1000\ MN/m^2$
Granular base 120 mm (crushed, cement treated)	$E_3 = 600\ MN/m^2$
Granular subbase 400 mm	$E_4 = 200\ MN/m^2$
Subgrade	$E_5 = 28\ MN/m^2$

Recalculation by AASHTO Method

The relation for the number of $ESAL_{80}$ is as follows :

$$\text{Log } ESAL_{80} = Z_R\ S_o + 9{,}36 \log (SN + 1) - 0.20 + \frac{\log ((PSI /(4.2-1.5)))}{0.4 + (1094/ (SN +1)^{5.15}}) + 2.32 \log M_R - 8.07$$

Z_R = - 1.645 (Normal deviate for 35 % reliability level)

S_o = 0.45 (Standard deviation)

$M_R = 5\ 10^{3}$ for example 1 (Subgrade resilient modulus)

PSI = 4.2 - 2.5 = 1.7 (Change in the present serviceability index)

PSI = 4.2 Construction Quality common in USA

PSI = 2.5 Minimum acceptable PSI

Log $ESAL_{80}$ = - 0.740 + 7.083 - 0.396 + 8.582 - 8.07 = 6.459

$ESAL_{80}$ = 2.88 * 10^6 (Number of passes by Equivalent Standard Axle Load)

Design Traffic : 1342 equivalent standard axle loads per day in design lane (assumption)

= 2,88 * 10^6 / 1342 = 2146

2146 / 365 = 5.8 years Design life according AASHO

2.1.4 Assessment and recommendation

The SUS design is a theoretical procedure. It is recommended to use a method mo^re based on values of experience and empirical studies as demonstrated in the above example. Specially the present practice with computation using the stiffness modulus and the tensile stress at the bottom of the asphalt layers should be discarded. If it is necessary to use still the SUS then more attention has to be paid to the bearing capacity of the subgrade (testing of CBR, moisture content, grading). For roads with a high traffic load, as the magistrale are, the upper layer of the base course (road base) should always be a bituminous layer. The thickness of all frost resistance layers should be reconsidered according to local conditions and experience.

For the asphalt concrete itself it is recommended to reduce the maximum grain size of the aggregates and to use as binder a destillation bitumen.

2.2 Materials

Asphalt concrete is a mixture of sand, aggregates and bitumen. A mineral powder is added as filler to provide a sufficient quantity of fine material, which can be also cement or crushed limestone. Between bitumen and aggregates a sufficient adhesion is required. The value of adhaesion depends on the kind of bitumen and the aggregate.

Aggregates
The maximum grain size of the aggregates is of great importance for the mechanical values of the asphalt and directly related to thickness of asphalt layers.

Bitumen
The bitumen used in Western European countries for road construction is named according the average penetration value. For example B65 means B for Bitumen, 65 for 65 1/10 mm medium penetration (max/min limits of penetration 50/75). Bitumen in Europe is produced by a two step destillation procedure (atmospheric and vaccuum destillation).

The following types of bitumen are available B15, B25, B45, B65, B80, B200, B300.

For road construction (rolled asphalt) bitumen B65 and B80 is preferably used, and Bitumen B200, B300 for road surface treatment

Natural asphalt (bitumen) is found in Azerbaijan, Turkmenistan.

Asphalt job mix design criteria and laboratory testing
The asphalt job mix design provides the optimum values for
- density
- air voids content
- bitumen content
- stability and flow value

standard laboratory tests for bitumen carried out on construction site
- penetration
- softening point
- breaking point
- ductility

Assessment and recommendation
Existing laboratory equipment in the eight recipient states was produced in the former Soviet Union and complies with the relevant SUS.

Main laboratory testing procedures for aggregates, sand, bitumen and asphalt is done according the SUS which differ only little to European/western tests standards. The Marshall test is widely known, but not used due to lack of equipment and missing requirement for limitations.

2.3 Quality Control

The aim of quality control in production and implementation is to maintain a constant level of quality which in the long term results in a cost reduction

Regular testing of the product quality shall be done by the manufacturer before delivery to customers (testing as a measure of self controlling). Furthermore sample controlling and testing shall be carried out by an independent institution to supervise the manufactuer's testing in order to assure constantly the quality of the product/materials.

When materials are used for construction field and laboratory testing is required to assure that the materials used and the workmanship comply with the relevant standards and specifications. The usual approach on a construction site is that the contractor carries out own testing throughout the period of execution of works. The test results are to be submitted to the (independent) supervisor for verification and the supervisor will do own testing.

In the recipient states the European/western approach for quality control and the independent supervision of works is not existing and thus very often the materials and construction requirements of the existing standards and specifications are not achieved resulting in poor quality implementation and short service life with high maintenance costs. Therefore a quality control, a quality assurance system should be introduced which will support the durability of construction and encourage the countries' economy.

2.4 Asphalt Production and Pavement Placing Techniques

Asphalt products for road construction

There are generally two different types of asphalt mixtures used for road construction:

(i) rolled asphalt (with air voids)

The asphalt is placed and compacted at maximum density and there are still air voids not filled with bitumen. The specified temperature for placing hot asphalt mixtures is 120 - 180°C and compaction has to be completed before the temperature drops below 90°C.

In Europe the use of cold asphalt mixtures is restricted to special cases or locations (islands, moutainous regions, temporary repairs).

(ii) Mastic asphalt (without air viods)

In the asphalt mixture there are no air voids and therefore after placing no compaction is necessary. The specified paving temperature temperature is 220 - 240 °C.

Overheating of bitumen will result in a poor quality asphalt mixture and therefore the maximum admissible temperatures of bitumen for asphalt mixtures are specified:

Type of Bitumen	max. Temperature [°C]
B45	190
B65	180
B80	180

Lowest and highest temperatures for asphalt mixtures in °C leaving the mixer:

(i) SUS (GOST)

Type of Bitumen	Temperature of Asphalt [°C]
BND 40 / 60 BND 60 / 90 BND 90 / 130 BN 60 / 90 BN 90 / 130	140 - 160

Note: The maximum temperature may be 10 °C higher if the asphalt is placed at air temperatures below 5 °C.

(ii) E/WS (ZTV - Asphalt, German Standard)

Typ of Bitumen	Temperature of Asphalt for Binder Layer [°C]	Temperature of Asphalt for Surface Course [°C]
B45	130 - 190	140 - 190
B65	120 - 180	130 - 180
B80	120 - 180	130 - 180

Note: Surface course should not be placed at air temperatures below 3°C, Asphalt binder course not below 0 °C.

Asphalt mixing plants

A mixing plant for asphalt production shall be designed and operated so as to produce mixtures according to the Job-Mix-Formula. There are general two types of mixing plants used for asphalt production:

- Batch mixing plants
- Continuous mixing plants

Asphalt placing and compacting procedures

Placing of asphalt is done with an asphalt finisher (paver), normal working width 6 m to 8 m, which achieve a so-called precompaction of about 90% of required density. Paving speed is depending on kind, width and thickness of asphalt layers ranging from about 1.0 m/min. (surface course) to 2.5 m/min (binder course, base course).

Compacting of asphalt with tandem steel roller (vibration possible) and pneumatic roller.

Assessment and recommendation

In the recipient states the mixing equipment is of Soviet Union or east German origin. Most of the mixing plants are out of operation since a number of years by various reasons. Due to the lack of operating mixing plants and long haulage distances the use of cold mix asphalt became common for maintenance and repair works. Compacting was and is still done with static steel rollers. Pneumatic rollers and rollers with vibration possibility have not been encountered in the recipient states.

The existing mixing plants could produce a good quality asphalt, but this depends on the condition of the equipment and it is difficult to purchase spare parts. A similar problem for spare parts appears for asphalt placing equipment (pavers, rollers).

With regard to the above problems and the superiority of E/WS asphalt placing equipment some of the recipient states have started to use E/WS equipment to achieve a better quality in pavement construction. However, it is recommended to provide appropriate training for those equipment so that their possibilities are understood and can be fully utilised.

2.5 Rehabilitation of Asphalt Pavement

The deterioration of a pavement manifests itself by various signs of appearance or indicators which can be associated with the probable causes of the failure or imperfection. To determine if and to which extend rehabilitation measures are necessary as a first step an assessment of the road condition is required.

An assessment of road condition should include the following:

(i) surface condition
A visual condition survey of an asphalt pavement shall describe the types of pavement distress relating them to the likely causual factors. The visible manifestations related to pavementdistress generally fall into one of the following broad categories:

- cracking
- distortion
- disintegration
- skid resistance

(ii) bearing capacity
Special equipment is used to asses the actual bearing capacity. The Benkelman beam is widely known but the results of the measurements cannot be related to the different pavement layers. The Falling Weight Deflectometer (FWD) is a fast and most advanced method to collect relevant data from actual deflection measurements and following calculations give distinguished results for the different pavement layers.

(iii) pavement composition
Sampling and laboratory testing of the existing asphalt pavement reveals the actual condition of aggregates and bitumen as well as the used basecourse and subbase material.

(iv) pavement structure condition
After a certain time depending for example on traffic load and climatic conditions all pavements need maintenance and repairs to keep a certain level of ride comfort. If maintenance of a pavement is neglected for a longer period the deterioration of the road may accelerate. The pavement condition is quickly getting worse and is then unacceptable to road users. The high degree of deterioration of a neglected pavement results in destruction requiring an expensive reconstruction in the end. A permanent maintenance and repair of smaller deficiencies will extend the life time of a pavement and keeps the surface in good condition.

Assessment and Recommendation

During the road inspections carried out in the 8 recipient states very different quality of road maintenance/repair/rehabilitation works was observed ranging from good to very poor. Cases were observed where on the one hand cold asphalt was dropped into water filled potholes but also on the other hand proper edge cutting with preparation for receiving the asphalt and following compaction. Furthermore placing of asphalt concrete layers was carried out by pavers but without grade control or the materials was spread by graders. In only a few cases the resulting surface condition, in particular the road roughness, was satisfactory. When the above described deficiencies were discussed in the seminars with the specialists of the recipient institutes the main reason given was that maintenance is mostly done according to financial possibilities/constraints and not according to technical requirements.

In summary the existing methodology as well as the equipment is in most of the recipient states unsatisfactory. As already described in the sub-chapter above some of the states have started to purchase modern European/western equipmnet and it is recommended to carry out training for operators, foremen, site engineers etc. to achieve an advanced knowledge in the methodology and techniques for road maintenance and rehabilitation works and for an optimum utilisation of the equipment.

2.6 Recycling Techniques and Methods for Asphalt Concrete

Cold and hot recycling

Cold recycled (cut/milled and pulverised) asphalt pavement can only be used for lower layers as base course or as binder course when adding bitumen emulsion and/ or cement or cement suspension. Depending on the traffic load and to achieve the required surface properties the compacted recycled road base is subsequently covered with a bituminous surface layer. Depending on laboratory testing results of the existing asphalt concrete hot recycled asphalt pavement may be used also for surface course with or without adding new materials.

Conventional methods

Deteriorated asphalt pavement is cut or milled and transported to a mixing plant. There the material is pulverised, heated and mixed with or without adding new aggregates and bitumen. The asphalt mixture is then transported to the construction site and placed on the road. This method is used when a mixing plant is close to the site since additional transport of removed asphalt pavement to the mixing plant and of the newly mixed material back to the road construction site has to be considered.

Mix in place recycling

The mix-in-place recycling is a very promising and economical method for the reconstruction of damaged asphalt roads. With this method the material of deteriorated roads is recycled in place and immediately used for the new pavement construction.

- Objectives of this method
  - Rehabilitation of road surface
  - Improvement of load bearing capacity
  - Improvement of frost resistance

- Advantages of this method
  - Avoidance of waste road construction material
  - Saving of natural resources
  - Environmental friendly
  - Reduction of material transports resulting in avoidance of traffic load burden on other rural/public roads in the area usually used for haulage

This construction method is characterised by a recycling equipment which cuts/mills and pulverises the existing road material if necessary including the unbound road base and subsequently mixes the crushed material with cement or bituminous binder agents. At this time available recycling equipment can be used on asphalt layers with a thickness of up to 15 cm. The following methods and techniques are used:

- Reshape: Deteriorated surface course/asphalt pavement will be heated, loosened and the hot material placed without adding material.
- Repave: The loosened and hot replaced material is immediately covered with a new hot asphalt layer containing only new material.
- Remix: Deteriorated surface course/asphalt pavement will be heated, loosened and new material (asphalt mixture or only bitumen) has to be added to get a mixture according the job mix design.

Assessment and Recommendation

Modern asphalt recycling techniques are requiring special equipment and a well trained labour force. In addition in all recipient states the budget for road maintenance and road repair is very limited so that recycling of asphalt concrete, if any, as for example in Uzbekistan and Kazakstan is very rare and done by specialised European/western companies.

However, the specialists of the recipient institutes met in the seminars are very interested in this modern and economical road/pavement rehabilitation technology. When the recycling technology is introduced it should be accompanied by special seminars and training not only for the use of equipment but also for technicians and engineers who have to do the laboratory testing of the existing pavement materials as well as the job mix design for the re-use.

3. ROAD DESIGN AND ROAD SAFETY

3.1 Road Design Standards

3.1.1 General

The standard for the geometrical design of roads and highways in the TRACECA states was developed in the former Soviet Union. In some of the states researches are ongoing for modification of this standard towards the development of national standards, which may consider local requirements as well as harmonisation with western European standards. However, no new standard has been published yet and the Soviet Union road standard (SNIP) is still in use.

For comparison with an western European standard the German standard for road and highway design is used and was presented in the seminars respectively.

The TRACECA Project includes selected international road links in the eight recipient states which in most cases are the so-called magistrale with the highest standard, but also with the next lower category of standard reflecting the requirements of lower traffic volume. The details of road design standards described in the following therefore cover these categories of the TRACECA roads.

3.1.2 Road Categories and Design Speeds

For an better overview all road categories and related design speeds are listed in the tables below. The relevant parameters of the Soviet Union road standard (SUS) are given in Table 3.1 and of the European/German road standard (E/GS) in Table 3.2. Categories not applicable for the TRACECA roads are shaded.

Apparent are the relative high design speeds of the SUS and the subdivision of the group category/road category with particulars of the E/GS. During seminars in the recipient institutes the scientific/research background of the two standards was discussed and some approaches were found as different, however, to discuss and evaluate all the differences of the development of the standards would be beyond the scope of the Project.

As discussed in the seminars the SUS design speed of 150 km/h has been used in flat terrain only (e.g. steppe of Kazakhstan) or not at all (e.g. Azerbaijan, Georgia, Kyrgyzstan, Uzbekistan) since the requirements are very high and the various constraints would have made the implementation to expensive. Considering this approach in the design practice, the differences of the two standards are marginal only.

Table 3.1: Soviet Union Road Standard 2.05.02-85, 1986

CATEGORY	DESIGN SPEED [Km/h]		
	GENERAL	WINDING TERRAIN	MOUNTAIN. TERRAIN
I - a	150	120	80
I - b	120	100	60
II	120	100	60
III	100	80	50
IV	80	60	40
V	60	40	30

Table 3.2: German Standard RAS-Q, 1982/1996

CATEGORY				DESIGN SPEED [km/h]
GROUP CATEGORY		ROAD CATEGORY		
A	MAGISTRALE, outside populated areas	**A I**	long distance/international link	90 - 120
		A II	regional link	80 - 120
		A III	interurban link	60 - 80 (100)
		A IV	major infrastructure link	60 - 80
B	HIGHWAYS, around or through towns	**B II**	major highway	(60) 70 - 80
		B III	main highway	(50) 60 - 70
		B IV	highway	50 - 60
C	MAJOR URBAN ROADS	**C III**	major road (highway)	50 (- 70)
		C IV	main road	(40) 50 (60)
D	URBAN MAIN ROADS	**D IV**	main road	40 - 50
		D V	main street	none
E	URBAN ACCESS ROADS	**E V**	street	none
		E VI	lane	none

Values in (...) = Exceptions

3.1.3 Geometrical Design Elements

Based on the selected road category and the design speed respectively the geometrical elements for the road design are defined.

The main parameters for ***horizontal and vertical alignment*** are summarised in Table 3.3 for the SUS and for the E/GS in Table 3.4. When as described above the requirements of the SUS design speed 150 km/h is not taken into consideration the two standards are very similar with more particulars given in the E/GS.

Table 3.3: Soviet Union Road Standard 2.05.02-85, 1986

DESIGN SPEED	MAX. GRADI - ENT	MINIMUM VERTICAL CURVE Radius Crest Curve	Radius Sag Curve general	mountain.	MINIMUM HORIZONTAL CURVE general Radius	Crossfall	mountainous Radius	Crossfall
150 km/h	3.0 %	30000 m	8000 m	4000 m	1200 m	2 - 3 %	1000 m	2 - 3 %
120 km/h	4.0 %	15000 m	5000 m	2500 m	800 m	3 - 4 %	600 m	5 - 6 %
100 km/h	5.0 %	10000 m	3000 m	1500 m	600 m	5 - 6 %	400 m	6 %
80 km/h	6.0 %	5000 m	2000 m	1000 m	300 m	6 %	250 m	6 %
60 km/h	7.0 %	2500 m	1500 m	600 m	150 m	6 %	125 m	6 %

Table 3.4: German Standard RAS-L-1, 1984, for Road Category A

DESIGN SPEED	MAX. GRADI - ENT	MINIMUM VERTICAL CURVE Radius Crest Curve	Radius Sag Curve	MINIMUM HORIZONTAL CURVE Radius and minimum Crossfall	Radius and maximum Crossfall
120 km/h	4.0 %	20000 m	10000 m	3000 m & 2.5 %	800 m 7 % (8 %)
100 km/h	4.5 %	10000 m	5000 m	1800 m & 2.5 %	500 m 7 % (8 %)
90 km/h	5.0 %	7000 m	3500 m	1400 m & 2.5 %	380 m 7 % (8 %)
80 km/h	6.0 %	5000 m	2500 m	1100 m & 2.5 %	280 m 7 % (8 %)
70 km/h	7.0 %	3500 m	2000 m	800 m & 2.5 %	200 m 7 % (8 %)
60 km/h	8.0 %	2750 m	1500 m	500 m & 2.5 %	135 m 7 % (8 %)

Values in (...) = Exceptions

With the determined road category and the respective traffic volume both standards define the main parameters for the ***road cross section*** which are summarised in Table 3.5 for the SUS and for the E/GS in Table 3.6.

Again and as described for other parameters before the two standards for the road cross section are very similar and adequate with the exception of the decision point from two to four lanes in the SUS which requires at least four lanes for a traffic volume of above 14,000 vehicles per day. In the highest category A I of the E/GS and for up to 27,000 vehicles/day the 1982 RAS-Q standard required two lanes only which with regard to traffic flow and road safety recently has been revised (RAS-Q 1996, published on 15.08.96) to three lanes.

Table 3.5: Soviet Union Road Standard 2.05.02-85, 1986

CAT	TRAFFIC VOLUME (ADT) NORMAL + WINDING	DIFFIC. TERRAIN	LANES NO.	WIDTH	SHOULDER TOTAL (PAVED)	MEDIAN TOTAL (PAVED)	TOTAL ROAD WIDTH
I-a	> 80000	> 70000	8	3.75 m	3.75 m (0.75m)	6.00 m (1.00m)	43.50 m
	> 40000 ≤ 80000	> 34000 ≤ 70000	6	3.75 m	3.75 m (0.75m)	6.00 m (1.00m)	36.00 m
	> 14000 ≤ 40000	> 14000 ≤ 34000	4	3.75 m	3.75 m (0.75m)	6.00 m (1.00m)	28.50 m
I-b	> 80000	> 70000	8	3.75 m	3.75 m (0.75m)	5.00 m (1.00m)	42.50 m
	> 40000 ≤ 80000	> 34000 ≤ 70000	6	3.75 m	3.75 m (0.75m)	5.00 m (1.00m)	35.00 m
	> 14000 ≤ 40000	> 14000 ≤ 34000	4	3.75 m	3.75 m (0.75m)	5.00 m (1.00m)	27.50 m
II	6000 - 14000		2	3.75 m	3.75 m (0.75m)	- -	15.00 m
III	2000 - 6000		2	3.50 m	2.50 m (0.75m)	--	12.00 m
IV	200 - 2000		2	3.00 m	2.00 m (0.50m)	--	10.00 m
V	< 200		1	(2.25 m)	1.75 m (--)	--	8.00 m

Table 3.6: German Standard RAS-Q, 1996

ROAD CAT.	TRAFFIC VOLUME (ADT) [veh./day]	LANES NO	WIDTH	SHOULDER TOTAL (PAVED)	MEDIAN TOTAL (PAVED)	TOTAL ROAD WIDTH	NOTE
A I	45000 - 61000	6	3.75 m 3.50 m	4.50 m (3.00 m)	5.00 m (2x0.75m)	35.50 m	i
	29000 - 39000	4	3.75 m	4.75 m (3.25 m)	5.00 m (2x0.75m)	29.50 m	
	14000 - 27000	3	3.75 m 3.50 m 3.25 m	1.75/2.75 m (0.25 m)	0.50 m (0.50 m)	15.50 m	ii
A II	54000 - 66000	6	3.50 m	4.00 m (2.50 m)	4.00 m (2x0.50m)	34.00 m	
	35000 - 42000	4	3.50 m	4.00 m (2.50 m)	4.00 m (2x0.50m)	26.00 m	
	22000 - 27000	3	3.75 m 3.50 m 3.25 m	1.75/2.75 m (0.25 m)	0.50 m (0.50 m)	15.50 m	ii
	14000 - 21000	2	3.50 m	1.75 m (0.25 m)	--	10.50m	
A III	33000 - 42000	4	3.25 m	2.00 m (0.50m)	3.00 m (2x0.50m)	20.00 m	
	11000 - 21000	2	3.00 m	1.75 m (0.25m)	--	9.50 m	
A IV	11000 - 14000	2	3.00 m	1.75 m (0.25m)	--	9.50 m	

NOTES: (i) total width of 35.50 m with width of right lane 1 x 3.75 m and left lanes 2 x 3.50 m

(ii) total width of 15.50 m:
- no. of lanes 3 (2+1 alternating)
- width of single (1) lane 1 x 3.75 m with shoulder 2.75 m (0.25m paved)
- width of double (2) lanes 1 x 3.50 m (right) + 1 x 3.25 m (left) with shoulder 1.75 m (0.25m paved)
- width of "median" 0.50 m (paved)

3.2 Road Safety and Road Design Aspects

3.2.1 Preliminary Remarks

Road and traffic safety is based on the three 'E' which can be described as:

Engineering	(e. g. standards for road design and traffic engineering, control of quality in implementation, supervision of works for and maintenance of a good/safe road condition)
Education	(e. g. education of pedestrians and motorists, training, public promotion)
Enforcement	(e. g. laws and regulations, police, justice)

and is a complex process where dynamic, visual, geometrical, drainage and psychological requirements need to be optimised.

In the following those aspects concerning road safety and related road design details are described which were presented and discussed in the seminars held in the recipient states.

3.2.2 Technical Aspects of Road Safety and Road Design

- **Sequence of Radii for horizontal Alignment**

  The relation of the radii of horizontal curves in the road alignment is specified in both standards, the SUS as well as the E/GS. The aim is to achieve a relative constant travelling speed resulting in safety for the road users (avoidance of unexpected narrow curves). In cases where constraints do not allow to follow the requirements of the standard(s) extensive signalisation is necessary.

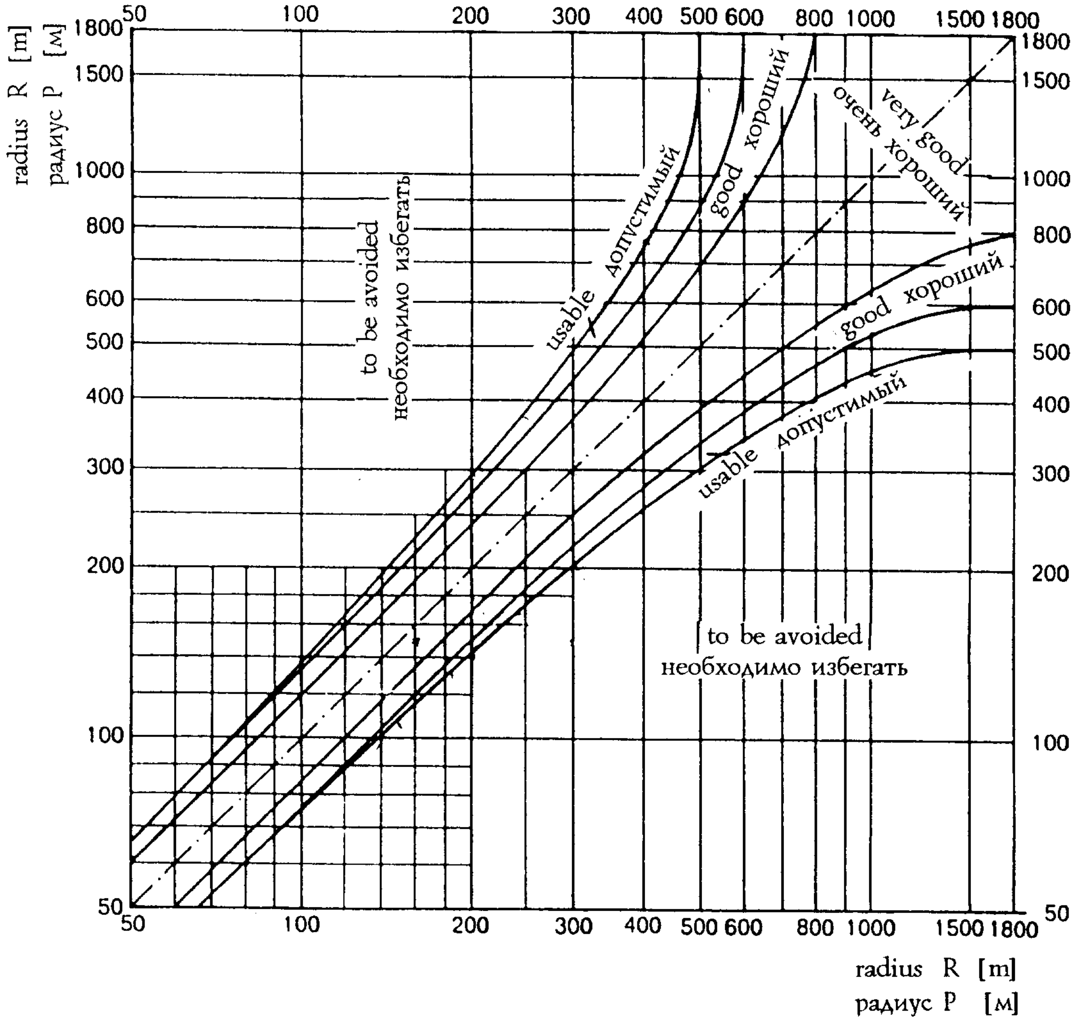
  In sub-chapter 4.3.3 of the SUS (SNIP 2.05.02 - 85) the relation of radii is specified as

  $$R_1 : R_2 = 1 : (\text{maximum } 1.3)$$

  which is considered as to rigid and not reflecting the requirements of moving vehicle dynamics.

  The suitability of the sequence of radii in the E/GS (RAS-L-1, 1984) is determined according to the diagramm below and improvement of the SUS is recommended.

Sequence of Radii for Horizontal Curves, RAS-L-1, 1984



- **Length of straight Road Section and minimum Radius of Curve after straight Road Section**

  At long straight road section it is rather difficult for drivers to assess distance and speed of approaching vehicles. Furthermore for the safety of road users it is important to decide on an appropriate radius after a straight section of road, where vehicles may build up speed. The SUS (SNIP) specifies maximum 5 km length of straight and should be complemented by the requirements of the E/GS for the radius after a straight road section as summarised in table 3.7 below.

Table 3.7: German Standard RAS-L-1, 1984

ROAD CATEGORY	LENGTH OF STRAIGHT	MINIMUM RADIUS
A I, A II	L ≥ 600 m	min R > 600 m
	L < 600 m	min R > L
A III, A IV, B II	L ≥ 500 m	min R > 500 m
	L < 500 m	min R > L

- **Junctions incl. Approaches and Slowing Down/Acceleration Lanes**

  For Junctions and intersections one of the main design requirement is safety for the road users which can be achieved when the junction/intersection system

  - provides adequate visibility
  - is easy to understand
  - is designed for appropriate speed
  - is furnished with adequate horizontal and vertical signalisation (road markings and traffic signs)

  Those requirements are of high importance especially for non-local drivers, who also need information signs for orientation and decision which direction to take well ahead of the junction.

  The priority in the SUS for junctions at grade is to achieve a relative high speed for vehicles entering and moving in the junction. The resulting relative big radii used in those junctions lead to large islands and a large area for the entire junction itself with the consequence of a reduced visibility.

  In comparison the E/GS has relative small radii in the junction with small islands resulting in a good visibility. To achieve a speed of entering vehicles with little difference to the through traffic acceleration lanes are provided.

  In summary the E/GS with constructural measures reducing the speed in the junction approach and providing good visibility which both make the 'system' of the junction clearly understandable has advantage in traffic safety and therefore the SUS should be improved accordingly.

  The SUS for grade separated junctions/intersections including clover leaves is very similar to the E/GS. During field visits in the course of the seminars several cases were observed where the SUS has been modified and shorter slowing down/acceleration lanes were constructed. This modification was explained with budget constraints and the relative low traffic volume at the time of the implementation. The theory is to provide the necessary slowing down/acceleration lanes when the traffic volume has reached a certain level and the full standard is required.

- **Signalisation**

  The SUS for road and traffic signs is in line with western European/international standards and modification is considered not to be necessary. In many cases the information signs were encountered with description in Latin letters in addition to the Cyrillic, which is appreciated by foreign road users and which should be shown on all informative signs along the international, the TRACECA roads. However, the quality of materials should be improved, especially the brightness of reflective material and/or the workmenship should be better controlled.

  The same applies for road marking. The SUS is appropriate and the materials/quality should be improved. Some modification/additions should be considered to increase traffic safety as for example on two lane roads arrows in the centreline ahead of a continous centreline marking (non overtaking). In general road marking has been neglected in the TRACECA states for some time by various reasons - budget constraints for maintenance, broken down equipment, supply of paint abandoned etc.

In the TRACECA states marker posts are used at junctions, bridge approaches, railway crossings and at culvert locations only. According to the SUS the posts are white with a black stripe, reflective material or reflectors are not used. The existing standard is considered as not appropriate and should be improved: size of post and use of reflectors. Marker posts are a very important component of road safety, especially in the darkness they provide together with an appropriate road marking the best possible guidance for road users. It is understood that the provision of marker post for the entire road network in the TRACECA states would be rather costive, but it is recommended that marker posts with an appropriate spacing (say 50 to 75 m) along the international, the TRACECA roads are successively installed when road sections are improved/rehabilitated.

- **Safety for Town Passages with high Traffic Volume**

The magistrale, the TRACECA roads inspected often run through towns and villages which is inconvenient for both the road users as well as the inhabitants. For the latter besides environmental inconvenience (exhaust gases, noise) the traffic on the magistrale form a danger for crossing vehicles and pedestrians. Low speed in the town passages resulting in longer travelling time (economic losses) is the inconvenience for drivers together with the potential high danger of an accident.

A by-pass for those towns and villages would be the best solution for the above problems. As in Europe also in the TRACECA states it takes several years up to decades to prepare such a by-pass project - feasibility, financing, land acquisition etc. - and until the implementation. Therefore it is necessary to implement measures for immediate improvement of the traffic safety and if possible for mitigation of the other inconveniences.

In the meetings and seminars held in the recipient it carried out that the local engineers/specialists are familiar with and aware of the required safety improvements but financing is not available possibly because other projects have a higher priority. The following measures were discussed and include also low-cost solutions which can produce considerable improvement:

(i) Where sufficient space can be made available private accesses to the magistrale should be abandoned and collected with a parallel minor road which then enters into the magistrale with a proper junction (= reduction of danger points).

(ii) Provision of safe pedestrian crossings
   - subways or bridges (= very expensive)
   - traffic lights (= expensive)
   - prefabricated islands bolted on the road surface as safety waiting zone after crossing of one lane and before crossing the other (= low cost and quickly implemented)

(iii) Adequate road marking and traffic signs (= minimum requirement)

(iv) Sensibly determined/useful speed limits which will be understood and accepted by drivers:

- when the houses/village is situated on one side of the road only there is hardly any crossing traffic (vehicles and pedestrians) and the village name signboards which require a speed of 50 or 60 km/h should be removed and a speed of 70 or 80 km/h should be allowed by traffic signs (= improvement of traffic flow, reduction of travelling time)

- village name signboards which very often are placed several hundred meters before the first houses appear (leads to disregarding of the 50/60 km/h limit) should be relocated close to the real village entrance, where necessary the approach can be provided with a first speed limit of 70 or 80 km/h (= improvement of traffic flow, reduction of travelling time).

- **Emergency Escape Lanes at extended Descends**

The SNIP does not include such a standard. Due to the nature of the terrain and the necessity local standards were developed in for example Kazakhstan and Kyrgyzstan which are appropriate.

- **Winter Maintenance**

In those TRACECA states where winter conditions are experienced the aim and the requirements of winter maintenance are well known by the engineers/specialists of the institutes and departments in the recipient states. Presently the problem is that a reduced scope of winter maintenance can be carried out only due to budget constraints and equipment at the end of service life. In most cases application of salt or grit is done by throwing the material by shovel from a moving truck.

In meetings and seminars (and during the Study Tour to Europe in November 1996) European methods and technologies were presented and possible development/improvements discussed which can be summarised as

- updating/upgrading of winter maintenance management plans

- introduction of modern/economically working equipment for removal of snow and for application of grit/salt (including the benefit for the environment)

3.2.3 Non Technical Aspects of Road Safety

- **Public Promotion/Information Programmes**

The above sub-chapters present and discuss a number of technical safety measures which are the one part of road and traffic safety. The other part which is assumed to be the more difficult one is the so-called human factor, which includes all participants in the public traffic from vehicle drivers to pedestrians. Technical safety measures may not provide the planned results when the human factor fails. It has been experienced for example when a bad road was rehabilitated and had received a smooth surface, all necessary signalisation and safety measures (road marking, marker posts etc.) the number of accidents increased because drivers tended to overspeed.

Risky behaviour may in many cases result from lack of discipline but also from not understanding or accepting measures and regulations. Therefore public promotion/information programmes are of high importance to provide the necessary background information for understanding and acceptance to increase safety. But also to enhance the understanding of one another like pedestrians and drivers as for example:

- pedestrians must understand that a car with a speed of, say, 50 km/h cannot come to a full stop within 10 metres.
- drivers have to control/keep the allowable maximum speed, if necessary reduce it, to give pedestrians a chance to cross safely the road
- etc.

Before independence of the TRACECA states public promotion/information programmes existed (e. g. on TV, radio) but only a few are left like the education/training of primary school pupils. It is therefore recommended to re-activate or initiate those programmes - on TV and radio, with brochures, advertisement etc. - which in Europe are running since decades and always have to continue.

- **Enforcement of Regulations**

During the seminars in the recipient institutes the decreasing discipline and the increase of violation of traffic regulations was put into discussion as another problem of road safety aspects. Besides the above mentioned public promotion/information programmes for education possibilities to control and discipline road users repeatedly violating regulations were discussed. As an example the system in force in Germany was presented as described below.

- **Point System for Violation of Traffic Regulations (Germany)**

In addition to fines a central register has been installed for supervising repeated violations. Registration is done for all fines above 55 US$. Samples of the point system are shown in the table below.

VIOLATION	POINTS	NOTE
Exceeding of speed limit in towns		
21 - 25 km/h	●	
26 - 30 km/h	●●●	
31 - 40 km/h	●●●	
41 - 50 km/h	●●●●●	i
51 - 60 km/h	●●●●●	i
> 60 km/h	●●●●●●	ii
Driving under the influence of alcohol		
0.8 - 1.1 °/oo	●●●●	
> 1.1 °/oo	●●●●●●●	
Exceeding technical vehicle check > 8	●●	
months	●●●●●●	
Driving without valid driving licence	●●●●●●	
Driving without valid third party insurance	●●●●●●	
Misuse of number plate		
Bad signalisation of broken down vehicle	●●	
Worn out tyres (< 1.6 mm)	●●●●	
Disappearance of accident site	●●●●●●●	
Dangerous overtaking	●●	
Disregarding NO OVERTAKING sign	●●●●	
Disregarding STOP sign	●●●	
Disregarding RED traffic light	●●●	
Insufficient space to vehicle in front	●●●●	
Aggressive closing up and use of flashing	●●●●●●●	
light	●●●	
Driving without light in fog or heavy rain	●●●●	
Turning or reversing on a motorway	●●●	
Right-hand side overtaking outside towns		

NOTES: (i) One month confiscation of driving licence in addition
(ii) Two months confiscation of driving licence in addition

Action is taken by the central register department at a

SUM OF 9 POINTS: A warning letter is issued and advise is given to attend a training course, which attendance results in the deletion/reduction of 4 points.

SUM OF 14 POINTS: The theoretical and in some cases the practical examination test for the driving licence has to be repeated.

SUM OF 18 POINTS: A medical - psychological examination is required. Non-appearance is equal to not being qualified for a driving licence, which will then be confiscated.

- **Violation of Load Regulations (Germany)**

For vehicles with a gross weight of >7.5 tons the following fines apply when the maximum gross weight or the allowable maximum axle load is exceeded.

EXCESS	> 5 %	FINE	70 US$
	> 10 %		80 US$
	> 15 %		90 US$
	> 20 %		140 US$
	> 25 %		200 US$
	> 30 %		270 US$

In cases with an excess of >30 % unloading might be required.

- **Legislation**

In the meetings and seminars further questions and problems concerning road/traffic safety were discussed which can only be controlled by appropriate legislation as demonstrated in the above paragraphs with possibilities for enforcement of regulations.

Two highlighted problems are given below:

After independence in some of the recipient states it became somehow rather easy to get a driving license. The training is not any more comprehensive enough and many drivers drive vehicles (e. g. trucks) which class they have not acquired with their driving license.

Another growing problem is the import of right-hand steering vehicles. Since the driver has a considerably reduced sight, overtaking other vehicles becomes dangerous. Also right-hand steering vans and mini buses have the doors for passengers on the left side, the road side respectively resulting in a danger for leaving/entering passengers especially children.

4. CONCLUSION AND RECOMMENDATION

4.1 Bituminous Bound Material

The low standard and the low quality of road construction respectively encountered in most of the eight recipient states is mainly caused by:

- an inadequate pavement design methodology
- use of sub-standard materials
- poor workmanship
- inadequate equipment

A modification/improvement of the pavement design is recommended in order to base the design on empirical data which are results of practical experience. Together with a longer service life of the pavement a more economical construction and maintenance can be expected.

However, an improved design methodology will not automatically improve the quality of the roads. Two of the above reasons for the present low quality of the roads can be summarised as the problem of quality and quality control. In the former Soviet Union the supervision of works was not functioning and although the testing procedures for materials differ only little to European/western test standards substandard/low quality materials have been used for construction. Even when good quality materials were available the specified standards were not achieved due to poor workmanship. A quality control/assurance system should be introduced which is essential for the durability of all road components (pavement, earthworks, bridges, etc.) and should include the testing of materials as well as the supervision of construction works. Furthermore training of all levels of staff involved in road construction and road maintenance works is necessary.

On the equipment side the situation deteriorated during the past years mainly due to lack of spare parts (may be funds as well) and associated maintenance. In some states modern European/western equipment was already introduced to improve the situation. Appropriate training in the use of this equipment is recommended. In this context special seminars and training for the new recycling technology is recommended which should range from testing of existing pavement material, pavement design for re-used materials to the operation of equipment.

4.2 Road Design and Road Safety

The road design standard presently used in the TRACECA states, the Soviet Union road standard (SNIP), is as far as reviewed in the course of the Project in most aspects adequate. Under consideration of economical and safety aspects some modifications are recommended which should be introduced in the current standard or in the national standards under preparation:

- deletion of the design speed of 150 km/h and its related design parameters
- introduction of a road cross section with three lanes (2+1 alternating) for a traffic volume of 14,000 to 27,000 vehicles per day
- improvement of road design standards for junctions and horizontal alignment
- improvement of signalisation
- improvement of safety in town passages

- reactivation/implementation of public promotion/information programmes for road/traffic safety
- amendments/additions of legislation if and where necessary

It should be noted that the three lane (2+1 alternating) cross section was encountered in a section of one of the TRACECA roads, namely in town/village passages of the M 39 in Kyrgyzstan west of Bishkek to Kara Balta and the border with Kazakhstan. This local standard should be reviewed with regard to results and findings described above.