Tacis

TRACECA

Telecommunications network for the Caucasian railways

Feasibility study

CIE CONSULT

UIC

Executive summary

This document is the final version of the feasibility study for the 'Telecommunication network for the Caucasian railways'. It is an extract from the final report of the 'Central Asian Railways Restructuring - Module E : Telecommunications' project.

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This feasibility study was carried out taking account of the other studies for the Traceca railways.

For the UIC :

André Michel
Director of Administration

1. Introduction

This feasibility study on interconnection of telecommunications systems in TRACECA countries is part of the Central Asian Railways Restructuring study consisting of Module E.
This project is financed by Tacis/Traceca in collaboration with the European Bank for Reconstruction and Development (EBRD).

The results of the UIC feasibility study will enable the best target solution to be determined from a technico-economic point of view.

The technical feasibility study conducted by Mr Moretti (Tractebel) has demonstrated that the Caucasus telecommunication railway project is a technically viable option to provide the railways of the three Caucasian countries with a modern and efficient telecommunications system, that can in a realistic way not only fulfil their immediate demands, but also those resulting from a future rise in railway traffic.

In order to speed up the renovation process of the Caucasian Railways, a **minimum pilot project** will also be presented.

In a global context, the Trans Asia Europe (TAE) project is to install telecommunications links between Shanghai and Frankfurt. The Frankfurt-Ukraine and Shanghai-Central Asia links are well advanced, but the Caucasus part is still missing, therefore the Caucasian railways telecommunication pilot project could be the missing link of the TAE project. Another project, via Iran-Turkey-Armenia is now investigated by competitors so the pilot project should be started as soon as possible to avoid loosing these potential external telecommunications revenues.

This part is the executive summary.

Chapter one presents the detailed recommendations with an economic study.
Chapter two includes general recommendations and the methodology used to draw up the detailed recommendations.
Chapter three contains a survey of existing facilities.

2. Executive Summary

2.1 Telecommunications Inventory

There was a time when telecommunications facilities at the Central Asian and Caucasian railways amply fulfilled railway operating requirements. This is no longer the case.

In general, switching equipment, dedicated lines and transmissions employ analog technology, while aerial lines and copper cables make up the tangible transmission media. The primary power source for the various installations is the public electricity grid, with the secondary power supply being provided by the railway.

Telecommunications installations comply with standards (GOST) and OSJD leaflets on railway applications. They are the result of mass production with little or no innovation on the general telecommunications front, but admittedly display certain simplifications authorised for private networks. All installations were supplied by the former Soviet Union and are thus uniform across the entire Caucasian railway network.

Today, production of this telecommunications equipment has been halted, making it difficult to maintain the worn-out installations in working order. Some were damaged during the civil war or through theft. In the absence of spare parts, some installations are dismantled to repair others. Given the slump in train numbers, the telecommunications facilities can still cope with the traffic volume, albeit with frequent train delays. At some stage, this deterioration in railway telecommunications will culminate in a crisis in general transport conditions on certain lines.

Over the past few years, some installations have been upgraded to digital technology. These had been shut down for the reasons listed above.
There is a need to train local teams prior to the use of new technology.
Attempts in Georgia to sling optical fibre cables between OHL masts clearly illustrates the need to train local teams prior to the use of new equipment.
In Central Asia, the railways' response to the insufficient transmission capacity has been to install Hertzian links or lease channels from public telecommunications services.

Upgrading programmes are undermined by the railways' lack of finance. The current tendency to replace faulty installations at minimum cost could result in a hotchpotch of different equipment and ruin all attempts to harmonise technology between the railways. Incompatibility would be the result. Help would be required to draw up a basis for technical harmonisation in the various telecommunications sectors.

A detailed survey of existing facilities is given in chapter three.

2.2 General Telecommunications Recommendations

Chapter two of this report contains preliminary recommendations and basic costs intended for use in drawing up the action and investment plan.

- The project description comprises an outline of the general context and the financial and legal aspects.
- The outline contains a rough investment model and explains that a precise and detailed account of the needs of the railways concerned is not currently available. This will be required in order for projects of an operational nature to be possible.

- This is followed by a detailed list of the services to be provided by the telecommunications networks under the headings Signalling, Railway Operations and Applications.

  Each of the above categories is defined and the telecommunications services required are set out.

- A technical proposal outlines technological developments and the main aspects of network architecture.

  A list of technical specifications is proposed and classified as follows:
  - mandatory,
  - recommendatory,
  - informatory.

  The specifications deal with:
  - telecommunications for signalling and railway operations,
  - transmission cables (type, laying, connection, capacity),
  - the actual telecommunications network (digital transmission equipment, redundancy, management, synchronisation),
  - integration or not of the telecommunications network,
  - energy supply sources.

It is important to note that these technical specifications are generic: they are generally valid but do not govern implementation of specific projects.

This type of specification should be drawn up after a precise and detailed account has been obtained of the needs of the railways concerned.

- The figures for basic costs are approximate. They may be used as a starting point for the future action and investment plan.

  Nonetheless, these figures are average values, affected by a number of variable factors.
  Only the invitation to tender (and ensuing negotiations) will enable definitive prices to be established.

2.3 Caucasus Telecommunications Recommendations

2.3.1 Technical Study

Applying the general guidelines outlined in Chapter two to the Caucasian railways produced the following recommendations.

2.3.1.1 Backbone network

A **backbone network proposal** has been drafted for each of the three Caucasian countries, outlining:

- why specific options were taken for a given country,
- general diagram of the backbone network,
- **investment tables** for two network configurations:
  -- without back-up of incoming railway control centre circuits,
  -- with partial back-up of incoming railway control centre circuits.

This data is taken as a basis for the economic study.

The backbone network takes in the following sections:
In Armenia : Ayrum (Georgian border) - Yerevan - Razdan, i.e. 369 km.
In Azerbaïjan : Beyuk-Kasik (Georgian border) - Bakou, i.e. 503 km.
In Georgia : Poti/Batumi - Tbilisi - Sadakhlo (Armenian border)/ Gardabani (Azerbaijani border), i.e. 550 km.

2.3.1.2 Secondary network

A **simplified proposal for secondary railway networks** rounds off the technical study. This is organised along similar lines to the backbone network proposal (justification of options selected, general diagrams, investment tables).

2.3.1.3 Conclusions

The main **conclusions** are as follows:

- It is recommended that a firm decision be made to opt for **optical fibre cables** and **digital transmission** techniques.

Where the backbone telecom network is concerned, it is recommended that use be made of cables with 24 optical fibres, 12 of which would be employed for railway applications and 12 by possible future telecom operators. This cable will be buried to ensure reliability and a long life cycle.

Comparison of laying methods for optical fibre cable :

Method of laying	Aerial		Buried	
	Pro	Con	Pro	Con
Ease of laying	X		X (earth)	X (rocks)
Mechanical protection		X	X	
Sensitivity to wind, trees, snow, etc.		X	X	
Risk of vandalism		X	X	
Effects of catenary poles condition		X	X	
Bullet-proof tests		X	X	
Price of cable		X	X	
Speed of laying	X			X
Laying price	X			X

- It is recommended that the basis of the backbone networks should be SDH technology (synchronous 155 Mbit/s STM1 add/drop multiplexers) supplemented by distribution telecom networks using drop-and-insert PCM (2 Mbit/s add/drop multiplexers with an 8 Mbit/s ADM8 transport medium and 2 Mbit/s add/drop multiplexers with a 2 Mbit/s ADM2 transport medium). These telecom networks are linear and in this respect they reflect the topology of the railway networks.

- It is recommended that telecom networks be provided at least partially with back-up, without seeking full redundancy for all the various installations, this not being economically justified. The solution whereby incoming control centre circuits are provided with back-up would be preferable but seems unfeasible, given that the public telecom operators do not appear to be able to supply the necessary external cables.

- It would also be advisable to replace the automatic administrative telephone switches with digital equipment.

- The technology to be adopted for the secondary railway telecom networks should consists of a 6-fibre cable and drop-and-insert PCM.

Given the high cost of investment, it is not recommended that secondary networks be systematically equipped but rather that this be done in relation to actual operating needs. However it should be borne in mind that the equipment recovered when replacing the backbone will be available for use in maintaining these secondary lines and this will make it possible to defer investments for them.

2.3.2 Investments

2.3.2.1 Budget for the recommendations

The recommendation that an optical fibre network be installed with SDH and PCM multiplexers, operational telephony and administrative telephone switches would give the following budget:

	EU Investment (MECU)	Railway Investment (MECU)
Total	18.33	2.55

European Union investment covers:
- the cable and its fittings
- supervision of staking out operations and cable laying
- cable connections
- transmission equipment
- PABX
- power supply
- spares
- training

The railways' investment covers:
- staking out
- civil engineering
- cable laying
- rewiring buildings and installing subscriber telephones

The cost calculated is ten times lower than that of similar work in western Europe because of manpower cost differences.

2.3.2.2 Pilot Project

In order to focus on top priority investments that are vital to the railways, and to quickly initiate a preliminary project which would demonstrate the viability of the whole project, a pilot project should be set up.

The pilot project should focus on the main line linking Baku to Poti (through Tbilisi) and to Yerevan, thus entailing the knock-on effects on the backbone proposal :
- Omission of the Samtredia/Batumi section in Georgia
- Omission of the Yerevan/Razdan section in Armenia
- Completion of the whole backbone whilst only installing equipment in 70% of small stations (in relation to the categories in the UIC technical study).
- Inclusion of all PABX but with only 75% of the original capacity

N.B.: not renewing the equipment in 30 to 50% of stations was already a recommendation in the CIE-Consult report on Georgia for the EBRD.

The pilot backbone network takes in the following sections:

In Armenia : Ayrum (Georgian border) - Yerevan, i.e. 309 km.
In Azerbaïjan : Beyuk-Kasik (Georgian border) - Bakou, i.e. 503 km.
In Georgia : Poti - Tbilisi - Sadakhlo (Armenian border)/ Gardabani (Azerbaijani border), i.e. 444 km.

The investment requirement would be as follows:

	EU Investment (MECU)	Railway Investment (MECU)
Total	14.8	2.2

There is quite a substantial degree of uncertainty in the Railway investment figure, as it mainly covers civil engineering which will depend on local costs. And this figure only approximate the work that would be done by the railways themselves. If the civil engineering is undertaken by an external company and paid by the railways, the amount may be much higher.

2.3.3 Economic study

The economic study is composed of a comparison between two scenarios over 20 years.

- Reference scenario, in which the project does not go ahead. The current maintenance budget continues to apply, with an increase of 2% per annum. Locomotives are procured to offset delays caused by telecommunications failures (5 minutes per 6.4 km section per day for all trains in the country concerned).

- Project scenario, in which the investments are made in each of the countries concerned. Operating costs amount to 2% of investment in equipment and maintenance is 1FRF/m of cable laid.
  Cables have a lifespan of 50 years and equipment of 20 years.

  Revenue may be expected from hiring out surplus system capacity to telecom operators. This revenue is taken into account in Armenia from the second year, since the law already allows for this eventuality. In Azerbaijan and in Georgia, the necessary legal framework does not yet exist and as a result revenue is only expected to be earned six years after the start of the project.

The following table shows the corresponding internal rates of return:

	Overall	Armenia	Azerbaijan	Georgia
IRR	21 %	19 %	32 %	16 %

Results will be heavily dependent on revenue earned from leasing excess system capacity. Among the many advantages of this investment, only this revenue has been able to be estimated. But the internal benefits would be sufficient in themselves to justify the project as part of the railway restructuring process.

Despite the rather pessimistic assumptions and a reference situation where the cost of maintenance has probably been underestimated, the internal rates of return of the proposed projects are high (about 20%). They would require changes in the telecommunications legislation in Georgia and Azerbaijan in the next five years.

Chapter 1

Caucasus - Recommendations and economic study

Caucasus - Recommendations and economic study

Contents

Caucasus - Recommendations and economic study

1. Telecommunications

The material enclosed contains the action and investment plan for Module E of the TRACECA project for the countries in the Caucasian area: Georgia, Azerbaijan and Armenia.

It consists of a technical study and an economic study.

1.1 Summary

1.1.1 Preface

1.1.1.1 Context and strategy

In Chapter 2, section 1 the **context** of the study is set out and in section 2, the **method** selected and the **general technical options** underlying the study of telecommunications network architecture.

The **context** is essentially as follows:

- Independent railway telecom networks have been envisaged for each country, with PABX being used to interconnect these countries with each other and with Europe.

- Major importance has been attached to specific railway telecom facilities used for railway operations and ensuring the safety of railway movements. In particular, these require a process of collection-distribution between the Control Centre, which is in charge of the supervision of railway lines as a whole, and the stations dotted along the line.

The **study strategy** selected is based on a distinction between a backbone telecom network, and a secondary telecom network, the backbone being for main railway trunk lines and the spokes being for the secondary lines branching off from these main line routes.

1.1.1.2 Block diagrams

Explanations and a set of **block diagrams** are provided in support of the general technical options selected and describe the rules for positioning the various parts that go to make up a telecom network. These constitute Chapter 2, section 3.

1.1.1.3 Financial data

Financial data given in Chapter 2, section 1.4 provides details of and a justification for the basic costs of the different parts of the telecom networks.

1.1.2 Technical study

The general recommendations of Chapter 2, applied to the railways in the Caucasian area, culminate in the following recommendations.

Caucasus - Recommendations and economic study

1.1.2.1 Backbone network

A **proposal for a backbone network** is given for each of the three countries in the Caucasian area. These consist of:

- a document setting out the reasons for the specific options selected for a particular country,
- the general architecture of the backbone network (Appendix 1),
- **investment tables** (Appendix 2) for two different network configurations:
  -- without back-up of incoming railway control centre circuits,
  -- with partial back-up of incoming railway control centre circuits.

This data will subsequently be used as a basis for the economic study.

The backbone includes the following sections:
In Armenia: Ayrum (Georgian border) - Yerevan - Razdan, i.e. 369 km.
In Azerbaijan: Beyuk-Kasik (Georgian border) - Baku, i.e. 503 km.
In Georgia: Poti/Batumi - Tbilisi - Sadakhlo (Armenian border)/Gardabani (Azerbaijan border), i.e. 550 km.

1.1.2.2 Secondary network

A **simplified proposal for railway secondary networks** completes the technical study. This is organised along similar lines to the backbone network proposal (justification of solutions selected, general diagrams, investment tables). The corresponding diagrams and appendices are given as Appendices 3 and 4.

1.1.2.3 Conclusions

The following are the main **conclusions**:

- It is recommended that a firm decision be made to opt for **optical fibre cables** and **digital transmission** techniques.
Where the backbone telecom network is concerned, it is recommended that use be made of cables with 24 optical fibres, 12 of which would be employed for railway applications and 12 by possible future telecom operators. This cable will be buried to ensure reliability and a long life cycle.

Comparison of laying methods for optical fibre cable :

Method of laying	Aerial		Buried	
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Ease of laying	X		X (earth)	X (rocks)
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Sensitivity to wind, trees, snow, etc.		X	X	
Risk of vandalism		X	X	
Effects of catenary poles condition		X	X	
Bullet-proof tests		X	X	
Price of cable		X	X	
Speed of laying	X			X
Laying price	X			X

- It is recommended that the basis of the backbone network should be SDH technology (synchronous 155 Mbit/s STM1 add/drop multiplexers) supplemented by telecom distribution networks using drop-and-insert PCM (2 Mbit/s add/drop multiplexers with an 8 Mbit/s ADM8 transport medium and 2 Mbit/s add/drop multiplexers with a 2 Mbit/s ADM2 transport medium).
These telecom networks are linear and in this respect they reflect the topology of the railway networks.

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- It would also be advisable to replace the automatic administrative telephone switches with digital equipment.

- The technology to be adopted for the railway secondary networks should consists of a 6-fibre cable and drop-and-insert PCM.
Given the high cost of investment, it is not recommended that secondary networks be systematically equipped but rather that this be done in relation to actual operating needs. However it should be borne in mind that the equipment recovered when replacing the backbone will be available for use in maintaining these secondary lines and this will make it possible to defer investments for them.

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The railways' investment covers:
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- rewiring buildings and installing subscriber telephones

The cost calculated is ten times lower than that of similar work in western Europe because of manpower cost differences.

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In order to focus on top priority investments that are vital to the railways, and to quickly initiate a preliminary project which would demonstrate the viability of the whole project, a pilot project should be set up.

Caucasus - Recommendations and economic study

The pilot project should focus on the main line linking Baku to Poti (through Tbilisi) and to Yerevan, thus entailing the knock-on effects on the backbone proposal :

- Omission of the Samtredia/Batumi section in Georgia
- Omission of the Yerevan/Razdan section in Armenia
- Completion of the whole backbone whilst only installing equipment in 70% of small stations (in relation to the categories in the UIC technical study).
- Inclusion of all PABX but with only 75% of the original capacity

N.B.: not renewing the equipment in 30 to 50% of stations was already a recommendation in the CIE-Consult report on Georgia for the EBRD.

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In Georgia : Poti - Tbilisi - Sadakhlo (Armenian border)/ Gardabani (Azerbaijani border), i.e. 444 km.

The amount of investment would be as follows:

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There is quite a substantial degree of uncertainty in the Railway investment figure, as it mainly covers civil engineering which will depend on local costs. And this figure only approximate the work that would be done by the railways themselves. If the civil engineering is undertaken by an external company and paid by the railways, the amount may be much higher.

1.1.4 Economic study

The economic study is composed of a comparison between two scenarios over 20 years.

- Reference scenario, in which the project does not go ahead. The current maintenance budget continues to apply, with an increase of 2% per annum. Locomotives are procured to offset delays caused by telecommunications failures (5 minutes per 6.4 km section per day for all trains in the country concerned).

- Project scenario, in which the project is implemented in each of the countries concerned within a twelve-month period. Operating costs amount to 2% of investment in equipment and maintenance is 1FRF/m of cable laid. Cables have a useful life of 50 years and equipment of 20 years.

  Revenue may be expected from hiring out surplus system capacity to telecom operators. This revenue is taken into account in Armenia from the second year, since the law already allows for this eventuality. In Azerbaijan and in Georgia, the necessary legal framework does not yet exist and as a result revenue is only expected to be earned six years after the start of the project.

The following table shows the corresponding rates of return:

	Overall	Armenia	Azerbaijan	Georgia
IRR	21 %	19 %	32 %	16 %

Results will be heavily dependent on revenue earned from hire of excess system capacity. Among the many advantages of this investment, only this revenue has been able to be estimated. But the internal benefits would be sufficient in themselves to justify the project as part of the railway restructuring process.

Despite the rather pessimistic assumptions and a reference situation where the cost of maintenance has probably been underestimated, the internal rates of return of the projects proposed are high (about 20%). They would require changes in the telecommunications legislation in Georgia and Azerbaijan in the next five years.

1.2 Technical study

The diagrams and investment tables are given in Appendices 1 and 2.

1.2.1 Backbone Network, Armenia

1. The backbone network consists of the Ayrum-Yerevan-Razdan line.

5 STM1 are located on the line in:
- Vanadzor, Gyumri, Macis, Erevan et Razdan.

A 14 km local loop is located on the Yerevan-Macis section.

2. The total length of the Ayrum-Yerevan-Razdan backbone is 369 km (including local loop).

3. The PABX is located in Yerevan.

4. There is a total of 40 stations, which may be broken down as follows:
   - 8 large or medium-size stations, warranting telephone equipment suitable for an average stations. These are:
     -- Ayrum, Samain, Vanadzor, Gyumri, Masis, Yerevan-Fret, Yerevan-Passagers and Razdan,
   - 32 less-important stations, warranting telephone equipment suitable for a small station.

5. The traffic and energy (sub-systems, OHL) control room is located in Yerevan.

6. A single technical facilities room (including power supply, air conditioning, protection systems, wiring racks, etc.) is located in Yerevan for the control room station equipment, the PABX and the digital transmission equipment - STM1 and ADM.

7. The distribution networks are made up of 8 Mbits/s ADM (drop-and-insert PCM add/drop multiplexers).
(See Chapter 2, section 2 : Method)

From the rules in the Method sub-section and figure AIP.1, it may be extrapolated that 10 links need to be set up for the distribution network, i.e. the following ADM distribution:
- 40 for the stations,
- 10 to the Yerevan control room.

Thus a total of 50 ADM for a network without back-up of links between control centres and stations.

8. An SDH network management unit (STM1) is located in Yerevan.

9. Two distribution network management units (ADM) are each located in Yerevan and in Gyumri respectively, which are considered the telecom centres of excellence of Armenia.

10. As regards power supply:
    - power supply to the PABX, STM1 and ADM of the Yerevan control room is included in the technical facilities room,
    - the 8 large stations listed under point 4 and the corresponding STM1 and ADM are fed by 8 medium capacity power supply lines,
    - the 32 small stations listed under point 4 and the corresponding ADM are fed by 32 modest capacity power supply lines.

11. Back-up

It is assumed that there is a flattened transmission loop providing partial back-up in every case.

Total back-up for the main rail operating links (operations control and power control) on the Yerevan-Vanadzor line can be provided by an external network (for example the public network). That arrangement would involve installing 10 additional ADM in Vanadzor.
It also requires 1 additional medium capacity power supply line in Vanadzor.

1.2.2 Backbone Network, Azerbaijan

1. The backbone network consists of 9 STM1 located in:
- Akstafa, Gyandja, Evlakh, Udzari, Kyurdamir, Kazi-Magomed, Alyatl, Baladjari and Bakou
The backbone network runs from Beyuk-Kasik (border with Georgia) to Bakou.

A 9 km local loop is located in Bakou.

2. The total length of the backbone is 503 km (including the local loop).

3. The PABX is located in Bakou.

4. There is a total of 50 stations, which may be broken down as follows:
  - 12 large and medium-size stations, warranting telephone equipment suitable for an average station. These are:
    -- Beyuk-Kasik, Akstafa, Gyandja, Evlakh, Udzari, Kyurdamir, Kazi-Magomed, Alyatl, Baladjari and 3 x Bakou.
  - 38 less important stations, warranting telephone equipment suitable for a small station.

5. The traffic and energy (sub-stations, OHL) control room is located in Bakou.

6. A single technical facilities room (including power supply, air conditioning, protection systems, wiring racks, etc.) is located in Bakou for the control room station equipment, the PABX and the digital transmission equipment - STM1 and ADM.

7. The distribution networks are made up of 8 Mbits/s ADM (drop-and-insert PCM add/drop multiplexers).
(See Chapter 2, section 2 : Method)

From the rules in the Method sub-section and figure AIP.2, it may be extrapolated that 14 links need to be set up for the distribution network, i.e.; the following ADM distribution:
  - 50 for the stations,
  - 14 to the Bakou control room.
Thus a total of 64 ADM for a network without back-up of links between control centres and stations.

8. An SDH network management unit (STM1) is located in Bakou.

9. Two distribution network management units (ADM) are located in Bakou and in Gyandja respectively, which are considered the telecom centres of excellence of Azerbaijan.

10. As regards power supply:
  - power supply to the PABX, STM1 and ADM of the Bakou control room is included in the technical facilities room.
  - the 12 large stations listed under point 4 and the corresponding STM1 and ADM are fed by 12 medium capacity power supply lines.
  - the 38 small stations listed under point 4 and the corresponding ADM are fed by 38 modest capacity power supply lines.

11. Back-up

It is assumed that there is a flattened transmission loop providing partial back-up in every case.

Total back-up for the main rail operating links (operations control and energy control) on the Bakou-Gyandja line can be provided by an external network (for example the public network). That arrangement would involve 14 additional ADM being installed in Gyandja.
It also requires 1 additional medium capacity power supply line in Gyandja.

1.2.3 Backbone Network, Georgia

1. The backbone network consists of 7 STM1 installed in:
   - Poti, Batumi, Samtrediya, Zestafoni, Khashuri, Gori and Tbilisi.

Apart from the Poti-Tbilisi main line and the Batumi-Samtrediya secondary line, the network includes secondary lines running to the borders with Azerbaijan and Armenia, i.e. the Tbilisi-Gardabani and Tbilisi-Sadakhlo lines.

A 9 km local loop is located in Tbilisi.

2. The total length of the backbone is 550 km (including the local loop).

3. The PABX is located in Tbilisi.

4. There is a total of 69 stations, which may be broken down as follows:
   - 15 large and medium-size stations, warranting telephone equipment suitable for an average stations. These are:
     -- Poti, Senaki, Batumi, Samtredyia, Kutasi, Zestafoni, Khashuri, Gori, 3 x Tbilisi (-UZL., -PASS. and -SORT.), Marauli, Sadakhlo, Rustavi and Gardabani.
   - 54 less important stations, warranting telephone equipment suitable for a small station.

5. The traffic and energy (sub-stations, OHL) control room is located in Tbilisi.

6. A single technical facilities room (including power supply, air conditioning, protection systems, wiring racks, etc.) is located in Tbilisi for the control room station equipment, the PABX and the digital transmission equipment - STM1 and ADM.

7. The distribution networks are made up of 8 Mbits/s ADM (drop-and-insert PCM add/drop multiplexers).
(See Chapter 2, section 2: Method)

From the rules in the Method sub-section and figure AIP.1, it may be extrapolated that 17 links need to be set up for the distribution network, i.e. the following ADM distribution:
   - 69 for the stations,
   - 17 to the Tbilisi control room.
Thus a total of 86 ADM for a network without back-up of links between control centres and stations.

8. An SDH network management unit (STM1) is located in Tbilisi.

9. Two distribution network management units (ADM) are located in Tbilisi and in Samtredyia respectively, which are considered the telecom centres of excellence of Georgia.

10. As regards power supply:
   - power supply to the PABX, STM1 and ADM of the Tbilisi control room is included in the technical facilities room.
   - the 15 large stations listed under point 4 and the corresponding STM1 and ADM are fed by 15 medium capacity power supply lines.
   - the 54 small stations listed under point 4 and the corresponding ADM are fed by 54 small capacity power supply lines.

11. Back-up

It is assumed that there is a flattened transmission loop providing partial back-up in every case.

Total back-up for the main rail operating links (operations control and energy control) on the Tbilisi-Samtredyia line can be provided by an external network (for example the public network). That arrangement would involve 17 additional ADM in Samtredyia.
It would also require 1 additional medium capacity power supply line in Samtredyia.

1.2.4 Telecom switches for office telephones

In order to enhance the impact of the renovation of the telecommunications network, it is proposed to replace all or some of the telecom switches serving office telephones.

The telecom switches (PABX) involved and the number of subscribers in each case are:

In Armenia :

Yerevan	2 000
Masis	200
Gyumri	1 500
Sananin	200
Ayrum	100
Vanadzor	200

In Azerbaïjan

Baku	3 000
Alyat	100
Kazi Magomed	200
Kyurdamir	200
Baladjari	2 100
Gyandja	2 300

In Georgia

Tbilisi	4 300
Kashuri	1 500
Zestafoni	380
Gori	200
Samtredia	2 000
Senaki	50
Poti	200
Batumi	500

The PABX for the capitals (Yerevan, Baku and Tbilisi) will replace the PABX advocated for the Backbone part.

PABX covering over 500 telephones need the same type of control room as that advocated for the PABX in the Backbone part.

Inter-PABX links are based on channels carrying 2Mbits/s.

Inter-PABX links (channels @ 2Mbits/s)			
	Armenia	**Azerbaïjan**	**Georgia**
Number of channels	7	12	12

The investment tables are given in Appendix 5.

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1.2.5 Railway secondary line architecture and investment

The diagrams and investment tables figure in Appendices 3 and 4.

1.2.5.1 General

- Figures AIP.4 to AIP.6 illustrate the railway secondary line networks in Georgia, Azerbaijan and Armenia.

- The kilometre length and number of stations is stated for each line.

- The following table summarises the main characteristics for the secondary network and the same characteristics for the backbone network:

	Secondary lines			Backbone	
	Number of secondary lines	Kilometres	Number of stations	Kilometres	Number of stations
Georgia	9	934	92	550	69
Azerbaïjan	8	1 354	113	503	50
Armenia	5	409	26	369	40
Total	**22**	**2 697**	**231**	**1 422**	**159**

It is thus evident that the figures for line length and station numbers are substantially higher for the secondary lines than for the backbone networks.

1.2.5.2 Architecture of secondary line telecommunications networks

- Unlike the architecture of the backbone network, that of the secondary line telecom networks has not been studied in detail. The proposal made should be seen as a preliminary outline.

- The secondary lines have been dealt with separately from the backbone networks. Integration in the backbone network could be looked into later, depending on actual operating needs. There is in any case no impact on investment.

- A cable with 6 optical fibres has been chosen (2 for the distribution network, 2 for any back-up or another service, 2 spare fibres), procuring a 15 % saving across the board on the cost of type D cable laying (buried).

- The basic architecture is a linear PCM drop-and-insert network, in line with block diagram SP17.

- ADM network management specifically for the secondary line is installed for secondary lines over 90 km long.
There are no plans to install network management equipment on site at the beginning of the line for shorter secondary lines. Instead, maintenance engineers will work using a portable computer.

- Station installations and medium capacity power supply lines are provided at origin points considered important (major railway hubs and/or long secondary lines). In all other cases, equipment suitable for small stations and low capacity power supply lines are installed.

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- It has been decided not to provide back-up for secondary line control circuits.

1.2.5.3 Investment

- An approximate estimate of the cost of equipping all the secondary lines with fibre optic cables and digital transmission equipment in each country is given in the secondary line **investment tables**.

N.B.: As stated above, no detailed technical study has been carried out for each secondary line. The quantities stated should be considered as rough estimates.

- The following table summarises the estimated investment figures and shows the investment figures for backbone networks without back-up.

Investment summary table (EU)

	Secondary lines	Backbone	Backbone	Total
		(without back-up of links between control centres and stations)	(with back-up of links between control centres and stations)	(with back-up of links between control centres and stations)
Armenia	2.55	3.90	4.04	6.59
Azerbaïjan	7.80	5.03	5.22	13.02
Georgia	5.76	5.79	6.02	11.78
Total (MECU)	**16.11**	**14.73**	**15.28**	**31.39**

Investment summary table (railway)

	Secondary lines	Backbone	Backbone	Total
		(without back-up of links between control centres and stations)	(with back-up of links between control centres and stations)	(with back-up of links between control centres and stations)
Georgia	0.46	0.53	0.53	0.99
Azerbaïjan	1.54	0.72	0.72	2.26
Armenia	1.06	0.79	0.79	1.85
Total (MECU)	**3.06**	**2.04**	**2.04**	**5.1**

1.2.5.4 Conclusion

It is absolutely clear that the scope of the TRACECA project pilot phase in the Caucasus is not to cover the investment on all secondary lines and that secondary line upgrading will have to be carried out step by step as circumstances allow.

1.3 Economic study

1.3.1 Introduction

This section outlines the economic and financial evaluation of the project to install telecommunications networks serving the Caucasian railways of Armenia, Azerbaijan and Georgia. A commonly used alternative for the project title is: "Caucasus Telecom Railways Line (CTRL)".
First an explanation is given as to the method applied followed by a run-down of the different scenarios, the results of internal rate of return (IRR) calculations and an analysis of IRR variations.

The support received from Mr Roussel (Systra) throughout this study has been particularly appreciated.

The data used in the analyses are taken from existing Tacis/Traceca reports and from two studies completed by CIE-Consult for the EBRD.

1.3.1.1 Direct benefits

These benefits, some of which are quantified in this economic study, comprise:
- improvement of rail traffic safety levels, in particular in Armenia and Georgia,
- stripping away of some speed restrictions on certain sections,
- practical elimination of the numerous telecommunications-related delays,
- optimal use of rolling stock,
- installation of powerful communications links between railways in the region,
- better maintenance,
- creation of a new revenue source, i.e. leasing of excess capacity in the telecommunications network.

1.3.1.2 Indirect benefits

Although it is difficult to quantify such advantages, they constitute key factors in reviving the railways in question, in particular with respect to competition. They include:
- creation of the infrastructure required for the installation of MIS systems (essential basis for restructuring),
- creation of the infrastructure necessary to fit the real-time freight tracking systems requested by customers
- provision of a basis for creating interfaces with other transport providers
- regional and international co-operation project.

1.3.2 Method

The economic evaluation was carried out for a period of 20 years in $ US (constant values). The approach taken was to compare the current situation (the reference situation) without the investment project with the situation if the project is implemented (project situation). In each case, income and expenditure are compared and the internal rate of return from the project is estimated for each country.

1.3.3 Reference situation: project not implemented

The reference situation is defined by calculating current telecommunications maintenance and operating costs and the investment required to reduce traffic delays caused by telecommunications incidents. The solution envisaged to lessen these delays is to purchase additional locomotives.

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1.3.3.1 Maintenance and operating costs

These are calculated on the basis of available data regarding the current situation at the various railways in the countries examined. The main items taken were salary payments and costs, expenditure on materials and repairs and any other telecommunications and signalling costs. In the absence of a breakdown per sector, it was assumed that 40% of telecom and signalling department staff and costs are employed solely for telecommunications purposes.

The figures used for Armenia ('97 staff and '96 costs) and Georgia ('96 costs) are taken from the Tewet study (Joint venture for the Caucasian railways), and the (ADDY) source used for those relating to Azerbaijan ('96 staff and costs) is the CIE-Consult study (EBRD Project Identification report, Azerbaijan Railways.

Costs in US $ 1,000	ARMENIA	AZERBAIJAN	GEORGIA
salaries and operating costs	80	1,250	508
materials	32	251	61
repairs(*)	27		396
other costs	4	914	36
Total	**144**	**2,415**	**1,002**

(*) no information available for the Azerbaijan 'repairs entry

These amounts correspond to investments for one kilometre of cable and it is assumed that 40% of staff work purely on telecommunications activities.

	ARMENIA	AZERBAIJAN	GEORGIA
Line length in km	798	2,117	1,575
Km of cable invested	309	503	444
Telecommunications + signalling staff	304	2,086	1,100
Telecommunications staff	122	834	440

Annual maintenance and operating expenditure is given in the following table in US $1,000.

	ARMENIA	AZERBAIJAN	GEORGIA
Maintenance and operating costs	27	230	113

These costs seem to be too low for the material fitted, most likely because available funds for repairs are lacking and certain outdated spare parts cannot be replaced.

The age-related increase in costs was estimated to be 2% per annum.

1.3.3.2 Delays

Delays are caused by obsolete material.

According to the CIE-Consult Study on Georgia (EBRD Project identification report, Georgian railways), the delay observed (aggregate for all trains) is 5 minutes per day and per 6.4 km section. This statistic was applied to each country and adjusted by annual rates of increase in daily delays corresponding to the specific features of the three countries selected for the study.

	ARMENIA	AZERBAIJAN	GEORGIA
Rate of increase in delays	5%	2%	3%

The (book) life of an electric locomotive was set as 25 years, and the residual value is brought to account in the final year of the study (2019).

Caucasus - Recommendations and economic study

The following estimates were taken from various past studies in order to gauge the number of hours for which a locomotive is worked annually:

	ARMENIA	AZERBAIJAN	GEORGIA
km/year/locomotive	70,000 km	100,000 km	100,000 km
mean speed	40 km/h	40 km/h	40 km/h
hrs/year /locomotive	1,750	2,500	2,500

Locomotive requirements are gauged on the basis of annual delays recorded for each country and annual operating hours per locomotive.
The tables are presented in full in Appendix 6.

Locomotive requirements per country are as follows:

ARMENIA

Investment years	2000	2011
Number of locomotives	1	1
Cost (US$ m)	3	3
Residual value (US$ m)	0.72	2.04

AZERBAIJAN

Investment year	2000
Number of locomotives	2
Cost (US$ m)	6
Residual value (US$ m)	1.44

GEORGIA

Investment years	2000	2006
Number of locomotives	1	1
Cost (US$ m)	3	3
Residual value (US$ m)	0.72	1.44

1.3.4 The project

The project situation is determined by investments, operating and maintenance costs and income from leasing of excess capacity in the telecommunications network (PCM channels and dark fibres).

1.3.4.1 Investments

The amount taken corresponds to aggregate investments funded by the EU and the railways, scheduled for disbursement in 2000.

in millions of US $	ARMENIA	AZERBAIJAN	GEORGIA	Total
Aggregate investment	**4.47**	**7.18**	**7.06**	**18.70**
EU share of total investment	3.90	6.22	6.17	**16.29**

A full breakdown is given in Appendices 2 and 5.

Lifespan is assumed to be 50 years for cables and 20 years for equipment.

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1.3.4.2 Maintenance and operating costs

Maintenance and operating costs were estimated as follows:

- equipment: 2 % of total investment in equipment (the corresponding figure for western Europe is 4%),
- cables: 1 FRF/m of laid cable.

The results are set out in the tables below:

in millions of US $	ARMENIA	AZERBAIJAN	GEORGIA
Cable length in km	309	503	444
Total investment	4.47	7.17	7.06
% thereof for equipment	2.04	3.21	3.41
Operating costs (O)	0.04	0.06	0.07
Cable maintenance (M)	0.05	0.08	0.07
Total M+O	**0.09**	**0.15**	**0.14**

1.3.4.3 Revenue from lease of excess transmission capacity

The technical recommendations specified a level of capacity superior to the needs of the railways alone, thus creating a leasing option.

There are two types of excess capacity:

- the SDH/STM-1 installations comprising 63 PCM channels operating at 2Mbits/s.
- twelve fibres (six pairs) reserved for telecom needs (dark fibres).

1.3.4.3.1 PCM capacity

This type of capacity is likely to be of most interest to GSM operators and companies wishing to create IT links between different locations.

Tariff estimates are based on France Télécom rates and calculated for a 2Mbits/s link over 150km, i.e. 0.054 million US $/year. In order to create a realistic scenario, this rate was divided by four, producing 0.014 million US $/year for this study.

The technical recommendations include installing STM-1 equipment providing sixty-three 2Mbits/s channels. The following table summarises railway needs and the number of channels available for leasing.

	Armenia	Azerbaïjan	Georgia
recommended no. of channels	11	15	18
links between PABX systems	7	12	12
with 50% spare capacity	27	41	45
Total available	**63-27= 36**	**63-41= 22**	**63-45= 18**

Given that existing telecommunications legislation in Armenia has already been adapted accordingly, leasing revenue is accounted for as of 2003. In the other two countries, no income is calculated before 2005 to allow time for legislation to be altered.

In the first year, it is assumed that 10% of total capacity is leased with an additional 10% being added each year.

1.3.4.3.2 Dark fibres

This type of capacity will be of use to European and worldwide telecommunications operators who, while reluctant to invest in cables, will have the means and opportunity to install the electronic technology necessary to use the optical fibres surplus to railway needs.

Of the 24 fibres specified in the technical recommendation, 6 will be put to use immediately, 6 will be reserved for future railway needs and 12 will be set aside for leasing.

The income estimates are based on the rates charged by RATP and French motorways, i.e. 8 to 20 FRF/m/year (6FRF = 1US$) per fibre pair. More realistic rates were taken for this study, i.e.:

- 0.5 US $/m/year for Armenia (which feeds the Europe/Asia link)
- 1 US $/m/year for the other two countries (which are on the Europe/Asia link).

Leasing commences in 2007, with two pairs of fibres being leased in the first year and another two pairs being added biennially.

1.3.4.3.3 Telecom switches (PABX)

It would appear that some of the subscribers served by the railway telecom switches are third parties, e.g. forwarding agents, who must pay a subscription for this service. However, given the poor quality of lines, subscription fees are no longer charged.

The same service is provided to the homes of railway employees free of charge, although it is likely that a subscription fee will be levied as part of the move towards a market economy.

Hence, replacing the PABX systems would generate revenue which unfortunately can not be quantified for want of exact data.

1.3.5 Results

Based on the two distinct scenarios developed above the following internal rates of return may be calculated per country:

	Overall	Armenia	Azerbaijan	Georgia
IRR	21 %	19 %	32 %	16 %

The results are given in tabular form in Appendix 6.

1.3.6 Rate of variation

It is interesting to note how the rates of return are affected by a +/- 10 % variation in project investment

The reference situation remains unchanged, with only operating and maintenance costs (and the residual value) varying in response to an adjustment in investment).

	Overall	Armenia	Azerbaïjan	Georgia
IRR (inv +10%)	18 %	17 %	25 %	15 %
IRR (inv -10%)	25%	23 %	52 %	18 %

The tables used for the calculations are given in Appendix 6.

1.3.7 Economic study based solely on telecommunications revenue

The internal rates of return calculated on the basis of revenue from dark fibre and PCM channel leasing alone are as follows:

	Overall	Armenia	Azerbaijan	Georgia
IRR	10%	8%	11%	9%
IRR (inv + 10%)	11%	7%	11%	15%
IRR (inv -10%)	13%	9%	12%	19%

The income generated by leasing excess telecommunications network capacity alone justifies the project. However, it is vital that:

- the governments of Azerbaijan and Georgia undertake to amend telecommunications legislation to enable the railways to compete against the existing national operator;
- agreements be signed apace with telecommunications operators and with companies managing the underwater cables in the Black and Caspian Seas.

1.3.8 Sensitivity to revenue variation

Given the project's heavy reliance upon revenue generated by leasing excess telecommunications network capacity, the following results illustrate the project's sensitivity to their variations :

	Overall	**Armenia**	**Azerbaïjan**	**Georgia**
IRR (revenues +10%)	22 %	20 %	33 %	17 %
IRR (revenues -10%)	20 %	18 %	31 %	15 %

The tables used for the calculations are given in Appendix 6.

1.3.9 First Year Benefit Ratio

The First Year Benefit Ratio (FYBR) is an indicator for gauging most opportune period for project implementation. The FYBR is defined as the ratio of the discounted benefits of the project in the first year of normal operation, divided by the total discounted project costs from project start to the first year of normal operation.

The table below summarises the FYBR for the three countries involved in the optical cable project. Provided the implementation starts in 2000, the project will become fully operational (i.e. dark fibres are leased out) in 2007.
The discount rate applicable to the Caucasus is 8 %.

	Overall	**Armenia**	**Azerbaïjan**	**Georgia**
FYBR	19 %	10.5 %	72.2 %	12.8 %

The very high rate for Azerbaïjan is explained by the significantly lower maintenance costs in the project scenario (S1) as compared to the reference scenario (S0).

From these FYBR figures, it appears that the Caucasian telecommunications market is ready to absorb the optical cable's spare transmission capacity. From a market point of view, the project implementation should therefore not be delayed.

1.3.10 Conclusion

The results obtained rely heavily upon revenue generated by leasing excess telecommunications network capacity. While there are many benefits to be derived from such investment, leasing revenue is the only one which can be quantified, although other internal spin-offs would suffice to justify implementing the project as part of the restructuring of the three railways.

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Although experience has shown that this type of project can be expected to bring about savings in maintenance expenditure, the assumption does not hold true here. Current expenditure is most likely underestimated and/or maintenance work neglected for want of spare parts.

The project is expected to produce lower operating costs and increased revenue (freight and passenger) by enhancing train punctuality.

Chapter 1

Caucasus - Recommendations and economic study
Appendix 1 - Backbone network diagrams

Appendix 1 - Backbone network diagrams

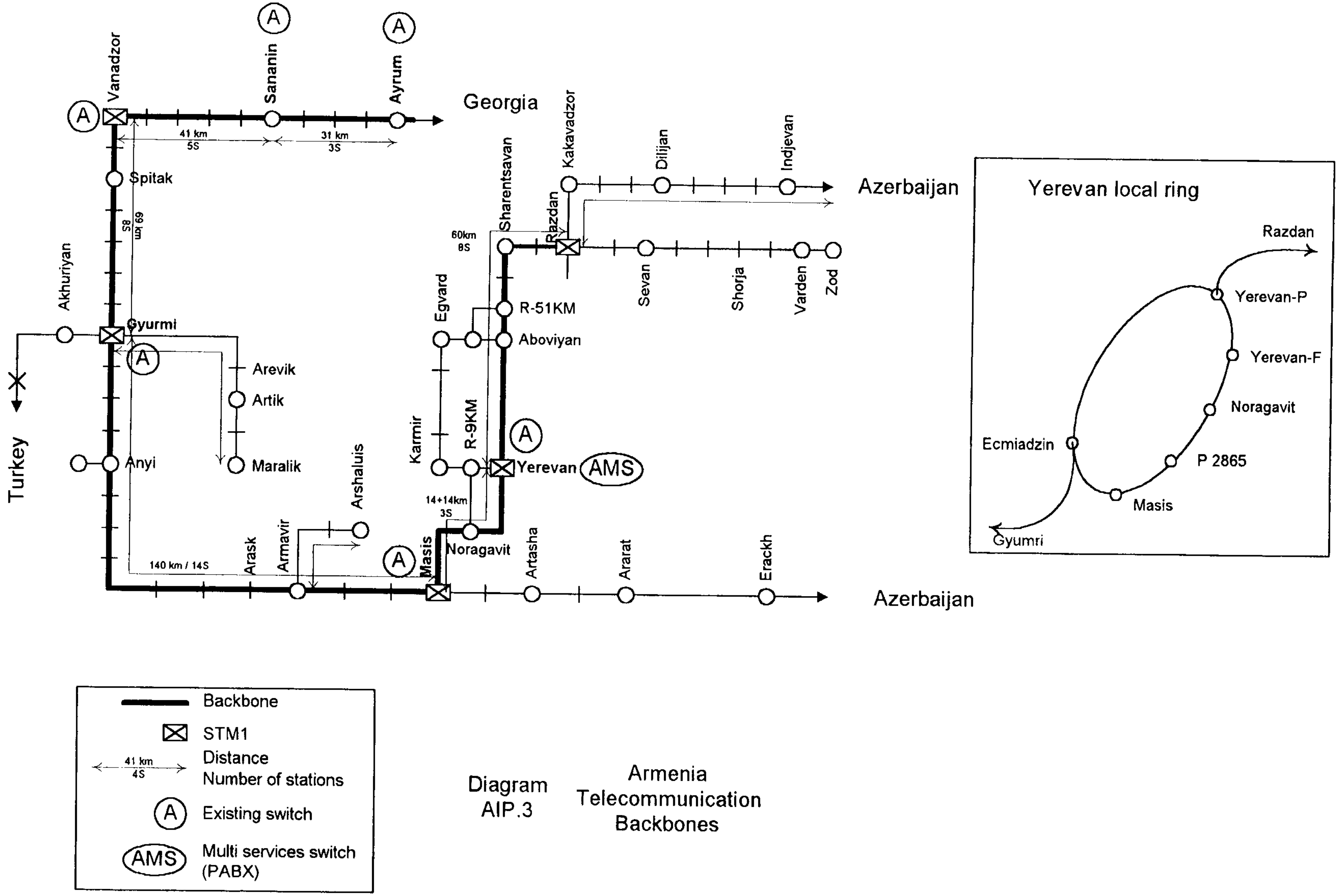


Diagram AIP.3

Armenia Telecommunication Backbones

Appendix 1 - Backbone network diagrams

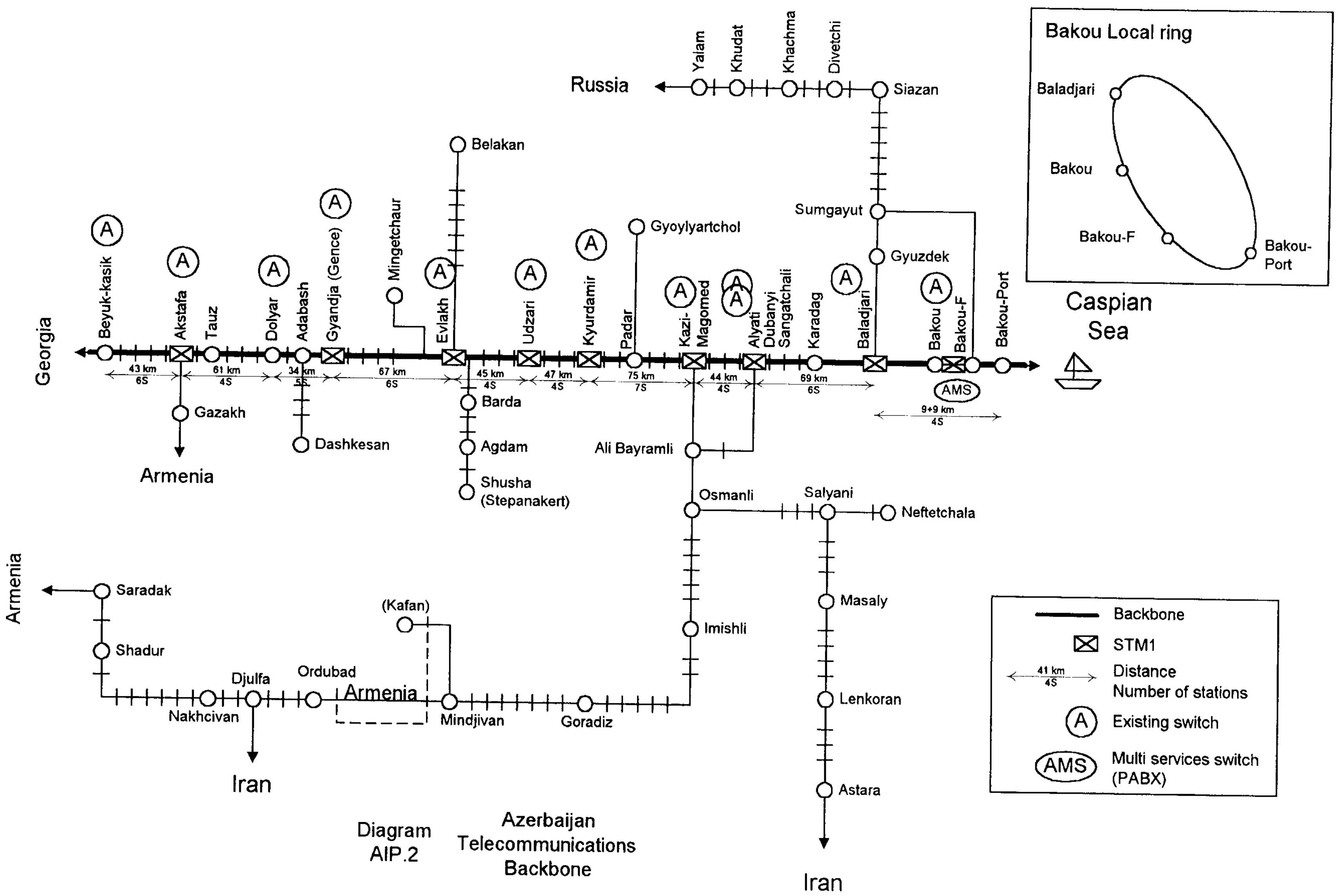


Diagram AIP.2

Azerbaijan Telecommunications Backbone

Appendix 1 - Backbone network diagrams

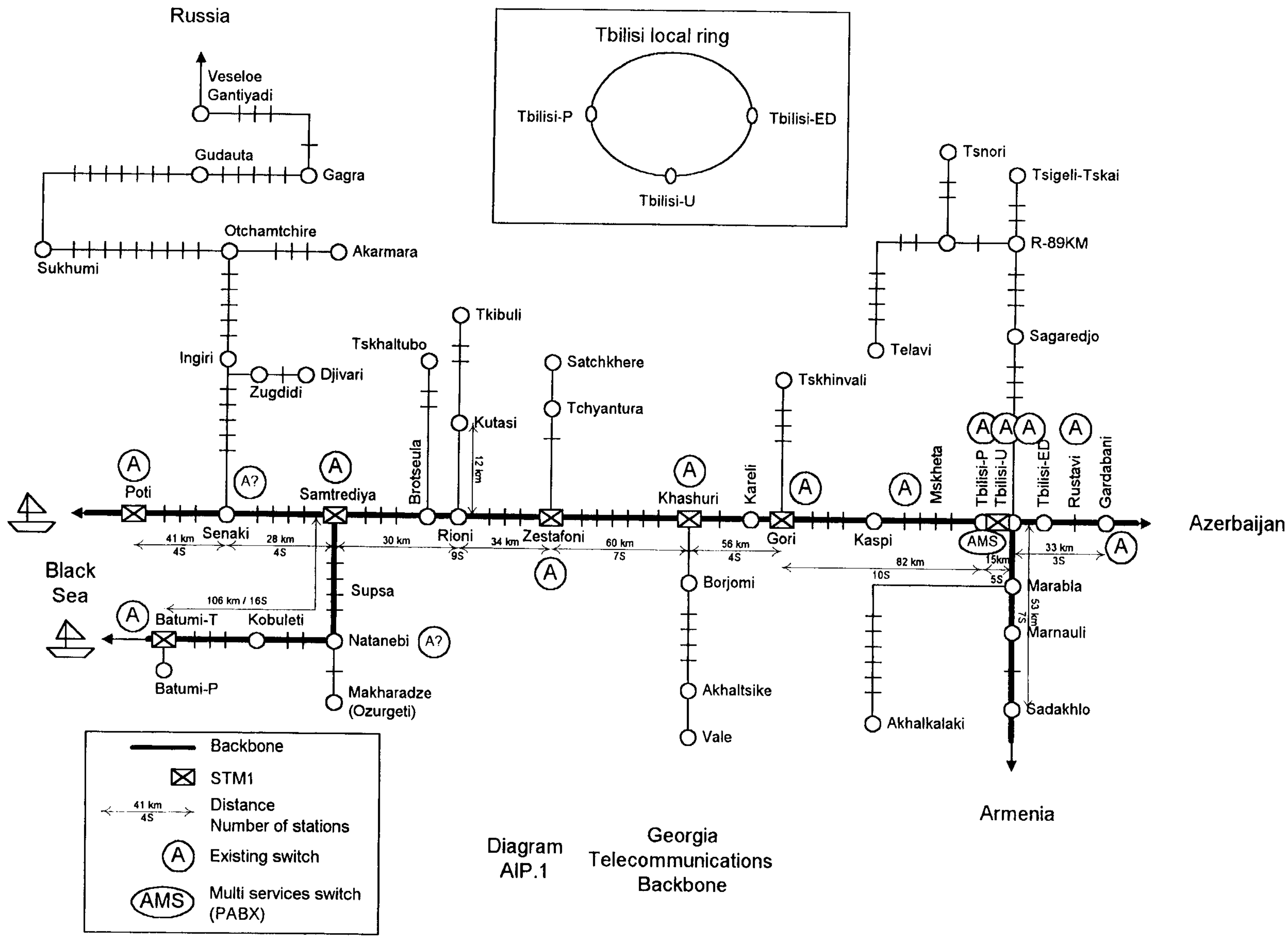


Diagram AIP.1

Georgia Telecommunications Backbone

Chapter 1

Caucasus - Recommendations and economic study
Appendix 2
Investment tables for the backbone networks

Pilot project - Backbone network - Summary - 17/02/99

	EU Investment (Millions of ECU)	Railway investment (Millions of ECU)	Total
Armenia	3,15	0,44	3,60
Azerbaijan	4,72	0,72	5,44
Georgia	4,53	0,64	5,17
Total	**12,40**	**1,81**	**14,21**

Pilot project - Backbone network, ARMENIA
(V0.8 17/02/99)

Item No.	Item description	Comments	Length	Number	Unit price	Total	EU total	Total railway investment (adjusted to reflect local labour costs)
			in km	of units	(in thousands of FRF)	(millions of FRF)	(millions of ECU)	(millions of ECU)
	cabling	supplies	309		20,5	6,33	0,96	
	cabling	supervision of staking-out work	309		2	0,62	0,09	
	cabling	installing links	309		4	1,24	0,19	
	cabling	staking out, civil engineering and laying (including labour)	309		95	29,36		0,44
1	total expenditure on cabling				121,5	37,54	1,24	0,44
	large and medium-sized stations			7				
	smaller stations			17				
	total stations			24				
	number of links	(distribution network)		6				
	number of SDH nodes			4				
2.1	STM1 equipment			4	130	0,52	0,08	
2.2	hooking up STM1 equipment			4	14	0,06	0,01	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			30	64	1,92	0,29	
5.2	hooking up ADM equipment			30	8	0,24	0,04	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		17	15	0,26	0,04	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		7	72	0,50	0,08	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		7	220	1,54	0,23	
11.2	hooking up	(30 lines)		7	21	0,15	0,02	
12.1	small station equipment	(6 lines)		17	44	0,75	0,11	
12.2	hooking up	(6 lines)		17	4	0,07	0,01	
13	spares	(10% of items (2-12)				0,99	0,15	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				49,17	3,00	0,44
15	provision for contingencies	5% of aggregate investment (items 1-14)				2,46	0,15	
		AGGREGATE TOTAL of items 1-15				51,63	3,15	0,44

Pilot project - Backbone network, AZERBAIJAN
(V0.8 17/02/99)

Item No.	Item description	Comments	Length	Number	Unit price	Total	EU total	Total railway investment (adjusted to reflect local labour costs)
			in km	of units	(in thousands of FRF)	(millions of FRF)	(millions of ECU)	(millions of ECU)
	cabling	supplies	503		20,5	10,31	1,56	
	cabling	supervision of staking-out work	503		2	1,01	0,15	
	cabling	installing links	503		4	2,01	0,30	
	cabling	staking out, civil engineering and laying (including labour)	503		95	47,79		0,72
1	total expenditure on cabling				121,5	61,11	2,02	0,72
	large and medium-sized stations			12				
	smaller stations			27				
	total stations			39				
	number of links	(distribution network)		10				
	number of SDH nodes			9				
2.1	STM1 equipment			9	130	1,17	0,18	
2.2	hooking up STM1 equipment			9	14	0,13	0,02	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			49	64	3,14	0,48	
5.2	hooking up ADM equipment			49	8	0,39	0,06	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		27	15	0,41	0,06	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		12	72	0,86	0,13	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		12	220	2,64	0,40	
11.2	hooking up	(30 lines)		12	21	0,25	0,04	
12.1	small station equipment	(6 lines)		27	44	1,19	0,18	
12.2	hooking up	(6 lines)		27	4	0,11	0,02	
13	spares	(10% of items (2-12)				1,41	0,21	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				77,45	4,50	0,72
15	provision for contingencies	5% of aggregate investment (items 1-14)				3,87	0,22	
		AGGREGATE TOTAL of items 1-15				81,33	4,72	0,72

Pilot project - Backbone network, GEORGIA
(V0.8 17/02/99)

Item No.	Item description	Comments	Length in km	Number of units	Unit price (in thousands of FRF)	Total (millions of FRF)	EU total (millions of ECU)	Total railway investment (adjusted to reflect local labour costs) (millions of ECU)
	cabling	supplies	444		20,5	9,10	1,38	
	cabling	supervision of staking-out work	444		2	0,89	0,13	
	cabling	installing links	444		4	1,78	0,27	
	cabling	staking out, civil engineering and laying (including labour)	444		95	42,18		0,64
1	total expenditure on cabling				121,5	53,95	1,78	0,64
	large and medium-sized stations			14				
	smaller stations			27				
	total stations			41				
	number of links	(distribution network)		10				
	number of SDH nodes			6				
2.1	STM1 equipment			6	130	0,78	0,12	
2.2	hooking up STM1 equipment			6	14	0,08	0,01	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			51	64	3,26	0,49	
5.2	hooking up ADM equipment			51	8	0,41	0,06	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		27	15	0,41	0,06	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		14	72	1,01	0,15	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		14	220	3,08	0,47	
11.2	hooking up	(30 lines)		14	21	0,29	0,04	
12.1	small station equipment	(6 lines)		27	44	1,19	0,18	
12.2	hooking up	(6 lines)		27	4	0,11	0,02	
13	spares	(10% of items (2-12)				1,44	0,22	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				70,66	4,31	0,64
15	provision for contingencies	5% of aggregate investment (items 1-14)				3,53	0,22	
		AGGREGATE TOTAL of items 1-15				74,19	4,53	0,64

Investment in backbone networks (Caucasus) - without back-up of the links between control centre and stations - Summary - 17/02/99

	EU Investment (Millions of ECU)	Railway investment (Millions of ECU)	Total
Armenia	3,90	0,53	4,43
Azerbaijan	5,03	0,72	5,75
Georgia	5,79	0,79	6,59
Total	**14,73**	**2,05**	**16,77**

Investment in backbone network, ARMENIA (without back-up of the links between control centre and stations)
(V0.8 17/02/99)

Item No.	Item description	Comments	Length in km	Number of units	Unit price (in thousands of FRF)	Total (millions of FRF)	EU total (millions of ECU)	Total railway investment (adjusted to reflect local labour costs) (millions of ECU)
	cabling	supplies	369		20,5	7,56	1,15	
	cabling	supervision of staking-out work	369		2	0,74	0,11	
	cabling	installing links	369		4	1,48	0,22	
	cabling	staking out, civil engineering and laying (including labour)	369		95	35,06		0,53
1	total expenditure on cabling				121,5	44,83	1,48	0,53
	large and medium-sized stations			8				
	smaller stations			32				
	total stations			40				
	number of links	(distribution network)		10				
	number of SDH nodes			5				
2.1	STM1 equipment			5	130	0,65	0,10	
2.2	hooking up STM1 equipment			5	14	0,07	0,01	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			50	64	3,20	0,48	
5.2	hooking up ADM equipment			50	8	0,40	0,06	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		32	15	0,48	0,07	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		8	72	0,58	0,09	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		8	220	1,76	0,27	
11.2	hooking up	(30 lines)		8	21	0,17	0,03	
12.1	small station equipment	(6 lines)		32	44	1,41	0,21	
12.2	hooking up	(6 lines)		32	4	0,13	0,02	
13	spares	(10% of items (2-12)				1,26	0,19	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				59,58	3,72	0,53
15	provision for contingencies	5% of aggregate investment (items 1-14)				2,98	0,19	
		AGGREGATE TOTAL of items 1-15				62,56	3,90	0,53

Investment in backbone network, AZERBAIJAN (without back-up of the links between control centre and stations)
(V0.8 17/02/99)

Item No.	Item description	Comments	Length	Number	Unit price	Total	EU total	Total railway investment (adjusted to reflect local labour costs)
			in km	of units	(in thousands of FRF)	(millions of FRF)	(millions of ECU)	(millions of ECU)
	cabling	supplies	503		20,5	10,31	1,56	
	cabling	supervision of staking-out work	503		2	1,01	0,15	
	cabling	installing links	503		4	2,01	0,30	
	cabling	staking out, civil engineering and laying (including labour)	503		95	47,79		0,72
1	total expenditure on cabling				121,5	61,11	2,02	0,72
	large and medium-sized stations			12				
	smaller stations			38				
	total stations			50				
	number of links	(distribution network)		14				
	number of SDH nodes			9				
2.1	STM1 equipment			9	130	1,17	0,18	
2.2	hooking up STM1 equipment			9	14	0,13	0,02	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			64	64	4,10	0,62	
5.2	hooking up ADM equipment			64	8	0,51	0,08	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		38	15	0,57	0,09	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		12	72	0,86	0,13	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		12	220	2,64	0,40	
11.2	hooking up	(30 lines)		12	21	0,25	0,04	
12.1	small station equipment	(6 lines)		38	44	1,67	0,25	
12.2	hooking up	(6 lines)		38	4	0,15	0,02	
13	spares	(10% of items (2-12)				1,58	0,24	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				79,40	4,79	0,72
15	provision for contingencies	5% of aggregate investment (items 1-14)				3,97	0,24	
		AGGREGATE TOTAL of items 1-15				83,37	5,03	0,72

Investment in backbone network, GEORGIA (without back-up of the links between control centre and stations)
(V0.8 17/02/99)

Item No.	Item description	Comments	Length	Number	Unit price	Total	EU total	Total railway investment (adjusted to reflect local labour costs)
			in km	of units	(in thousands of FRF)	(millions of FRF)	(millions of ECU)	(millions of ECU)
	cabling	supplies	550		20,5	11,28	1,71	
	cabling	supervision of staking-out work	550		2	1,10	0,17	
	cabling	installing links	550		4	2,20	0,33	
	cabling	staking out, civil engineering and laying (including labour)	550		95	52,25		0,79
1	total expenditure on cabling				121,5	66,83	2,21	0,79
	large and medium-sized stations			15				
	smaller stations			54				
	total stations			69				
	number of links	(distribution network)		17				
	number of SDH nodes			7				
2.1	STM1 equipment			7	130	0,91	0,14	
2.2	hooking up STM1 equipment			7	14	0,10	0,01	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			86	64	5,50	0,83	
5.2	hooking up ADM equipment			86	8	0,69	0,10	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		54	15	0,81	0,12	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		15	72	1,08	0,16	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		15	220	3,30	0,50	
11.2	hooking up	(30 lines)		15	21	0,32	0,05	
12.1	small station equipment	(6 lines)		54	44	2,38	0,36	
12.2	hooking up	(6 lines)		54	4	0,22	0,03	
13	spares	(10% of items (2-12)				1,90	0,29	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				88,67	5,52	0,79
15	provision for contingencies	5% of aggregate investment (items 1-14)				4,43	0,28	
		AGGREGATE TOTAL of items 1-15				93,10	5,79	0,79

Investment in backbone networks (Caucasus) - with back-up of the links between control centre and stations - Summary - 17/02/99

	EU Investment (Millions of ECU)	Railway investment (Millions of ECU)	Total
Armenia	4,04	0,53	4,57
Azerbaijan	5,22	0,72	5,94
Georgia	6,02	0,79	6,81
Total	**15,28**	**2,05**	**17,33**

Investment in backbone network, ARMENIA (with back-up of the links between control centre and stations)
(V0.8 17/02/99)

Item No.	Item description	Comments	Length	Number	Unit price	Total	EU total	Total railway investment (adjusted to reflect local labour
			in km	of units	(in thousands of FRF)	(millions of FRF)	(millions of ECU)	(millions of ECU)
	cabling	supplies	369		20,5	7,56	1,15	
	cabling	supervision of staking-out work	369		2	0,74	0,11	
	cabling	installing links	369		4	1,48	0,22	
	cabling	staking out, civil engineering and laying (including labour)	369		95	35,06		0,53
1	total expenditure on cabling				121,5	44,83	1,48	0,53
	large and medium-sized stations			8				
	smaller stations			32				
	total stations			40				
	number of links	(distribution network)		10				
	number of SDH nodes			5				
2.1	STM1 equipment			5	130	0,65	0,10	
2.2	hooking up STM1 equipment			5	14	0,07	0,01	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			60	64	3,84	0,58	
5.2	hooking up ADM equipment			60	8	0,48	0,07	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		32	15	0,48	0,07	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		9	72	0,65	0,10	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		8	220	1,76	0,27	
11.2	hooking up	(30 lines)		8	21	0,17	0,03	
12.1	small station equipment	(6 lines)		32	44	1,41	0,21	
12.2	hooking up	(6 lines)		32	4	0,13	0,02	
13	spares	(10% of items (2-12)				1,34	0,20	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				60,46	3,85	0,53
15	provision for contingencies	5% of aggregate investment (items 1-14)				3,02	0,19	
		AGGREGATE TOTAL of items 1-15				63,48	4,04	0,53

Investment in backbone network, AZERBAIJAN (with back-up of the links between control centre and stations)
(V0.8 17/02/99)

Item No.	Item description	Comments	Length in km	Number of units	Unit price (in thousands of FRF)	Total (millions of FRF)	EU total (millions of ECU)	Total railway investment (adjusted to reflect local labour (millions of ECU)
	cabling	supplies	503		20,5	10,31	1,56	
	cabling	supervision of staking-out work	503		2	1,01	0,15	
	cabling	installing links	503		4	2,01	0,30	
	cabling	staking out, civil engineering and laying (including labour)	503		95	47,79		0,72
1	total expenditure on cabling				121,5	61,11	2,02	0,72
	large and medium-sized stations			12				
	smaller stations			38				
	total stations			50				
	number of links	(distribution network)		14				
	number of SDH nodes			9				
2.1	STM1 equipment			9	130	1,17	0,18	
2.2	hooking up STM1 equipment			9	14	0,13	0,02	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			78	64	4,99	0,76	
5.2	hooking up ADM equipment			78	8	0,62	0,09	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		38	15	0,57	0,09	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		13	72	0,94	0,14	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		12	220	2,64	0,40	
11.2	hooking up	(30 lines)		12	21	0,25	0,04	
12.1	small station equipment	(6 lines)		38	44	1,67	0,25	
12.2	hooking up	(6 lines)		38	4	0,15	0,02	
13	spares	(10% of items (2-12)				1,69	0,26	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				80,59	4,97	0,72
15	provision for contingencies	5% of aggregate investment (items 1-14)				4,03	0,25	
		AGGREGATE TOTAL of items 1-15				**84,62**	**5,22**	**0,72**

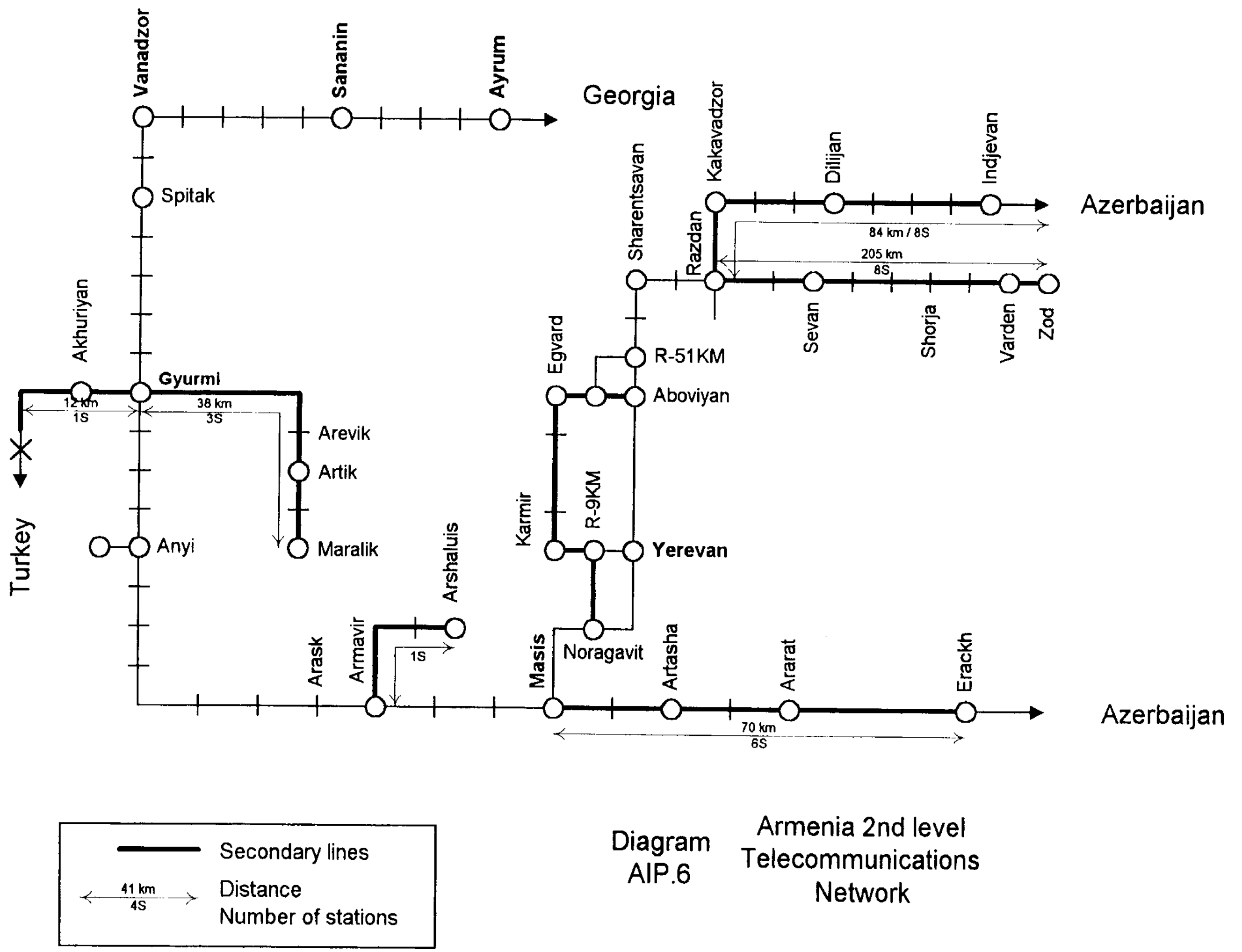
Investment in backbone network, GEORGIA (with back-up of the links between control centre and stations)
(V0.8 17/02/99)

Item No.	Item description	Comments	Length in km	Number of units	Unit price (in thousands of FRF)	Total (millions of FRF)	EU total (millions of ECU)	Total railway investment (adjusted to reflect local labour (millions of ECU)
	cabling	supplies	550		20,5	11,28	1,71	
	cabling	supervision of staking-out work	550		2	1,10	0,17	
	cabling	installing links	550		4	2,20	0,33	
	cabling	staking out, civil engineering and laying (including labour)	550		95	52,25		0,79
1	total expenditure on cabling				121,5	66,83	2,21	0,79
	large and medium-sized stations			15				
	smaller stations			54				
	total stations			69				
	number of links	(distribution network)		17				
	number of SDH nodes			7				
2.1	STM1 equipment			7	130	0,91	0,14	
2.2	hooking up STM1 equipment			7	14	0,10	0,01	
3	SDH management			1	700	0,70	0,11	
4.1	synchronisation	clock		1	100	0,10	0,02	
4.2	synchronisation	SSU		1	75	0,08	0,01	
4.3	synchronisation	GPS		1	25	0,03	0,00	
5,1	ADM equipment			103	64	6,59	1,00	
5.2	hooking up ADM equipment			103	8	0,82	0,12	
6	ADM management			2	100	0,20	0,03	
7.1	AMS (PABX)	(equipment and management)		1	1400	1,40	0,21	
7.2	AMS (PABX)	(technical facilities, power supply, etc.)		1	600	0,60	0,09	
8	low-capacity power supply	(ADM, low-capacity station centre)		54	15	0,81	0,12	
9	medium-capacity energy supply	(STM1, medium-capacity station centre)		16	72	1,15	0,17	
10.1	large station and control centre equipement	(4-regulator control centre)		1	740	0,74	0,11	
10.2	hooking up	(4-regulator control centre)		1	80	0,08	0,01	
11.1	medium station equipment	(30 lines)		15	220	3,30	0,50	
11.2	hooking up	(30 lines)		15	21	0,32	0,05	
12.1	small station equipment	(6 lines)		54	44	2,38	0,36	
12.2	hooking up	(6 lines)		54	4	0,22	0,03	
13	spares	(10% of items (2-12)				2,03	0,31	
14	training			1	728	0,73	0,11	
		Total of items (1-14)				90,10	5,73	0,79
15	provision for contingencies	5% of aggregate investment (items 1-14)				4,50	0,29	
		AGGREGATE TOTAL of items 1-15				94,60	6,02	0,79

Chapter 1

Caucasus - Recommendations and economic study
Appendix 3 - Network of secondary railway lines

Appendix 3 - Network of secondary lines



Appendix 3 - Network of secondary lines

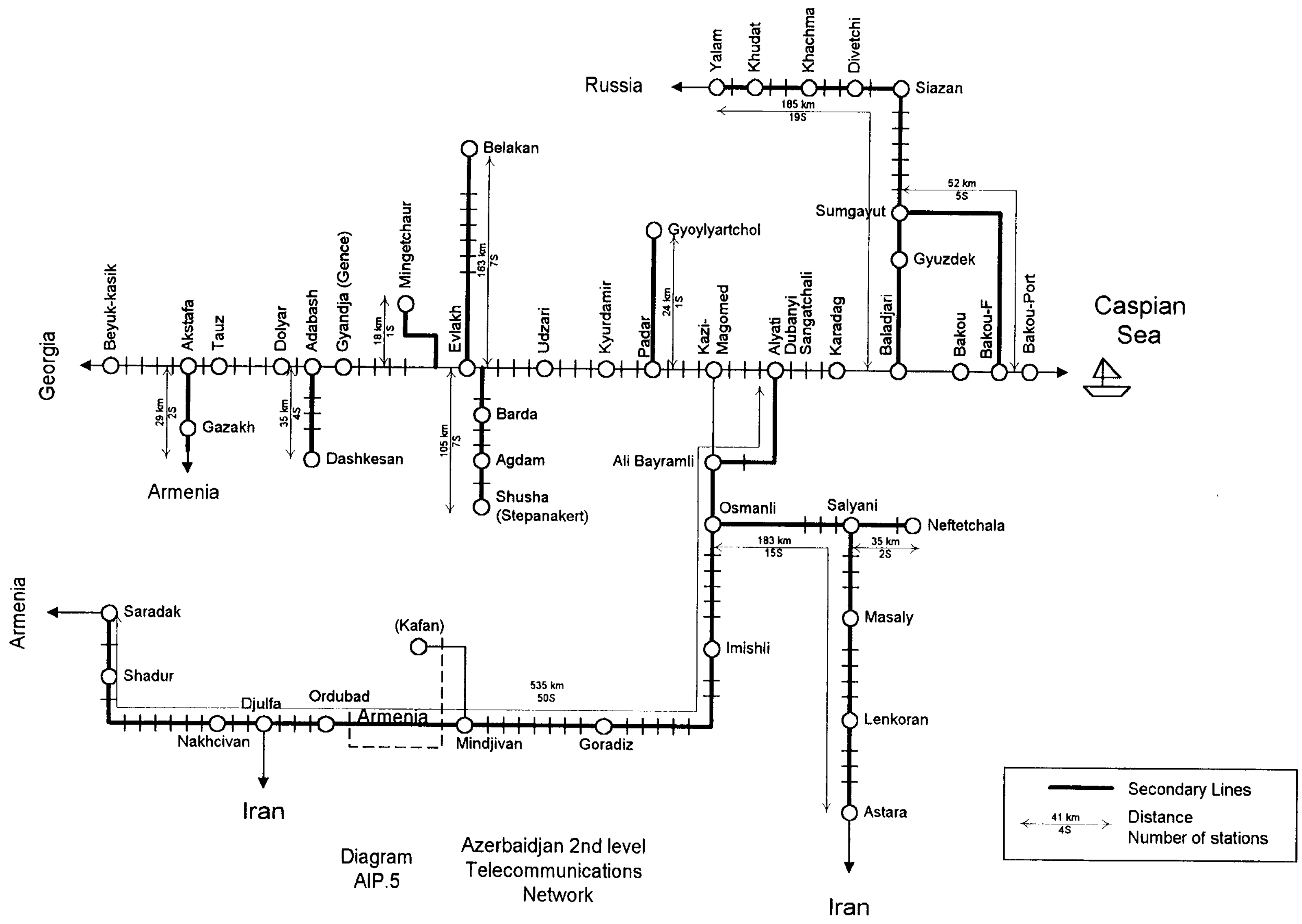


Diagram
AIP.5

Azerbaidjan 2nd level
Telecommunications
Network

Appendix 3 - Network of secondary lines

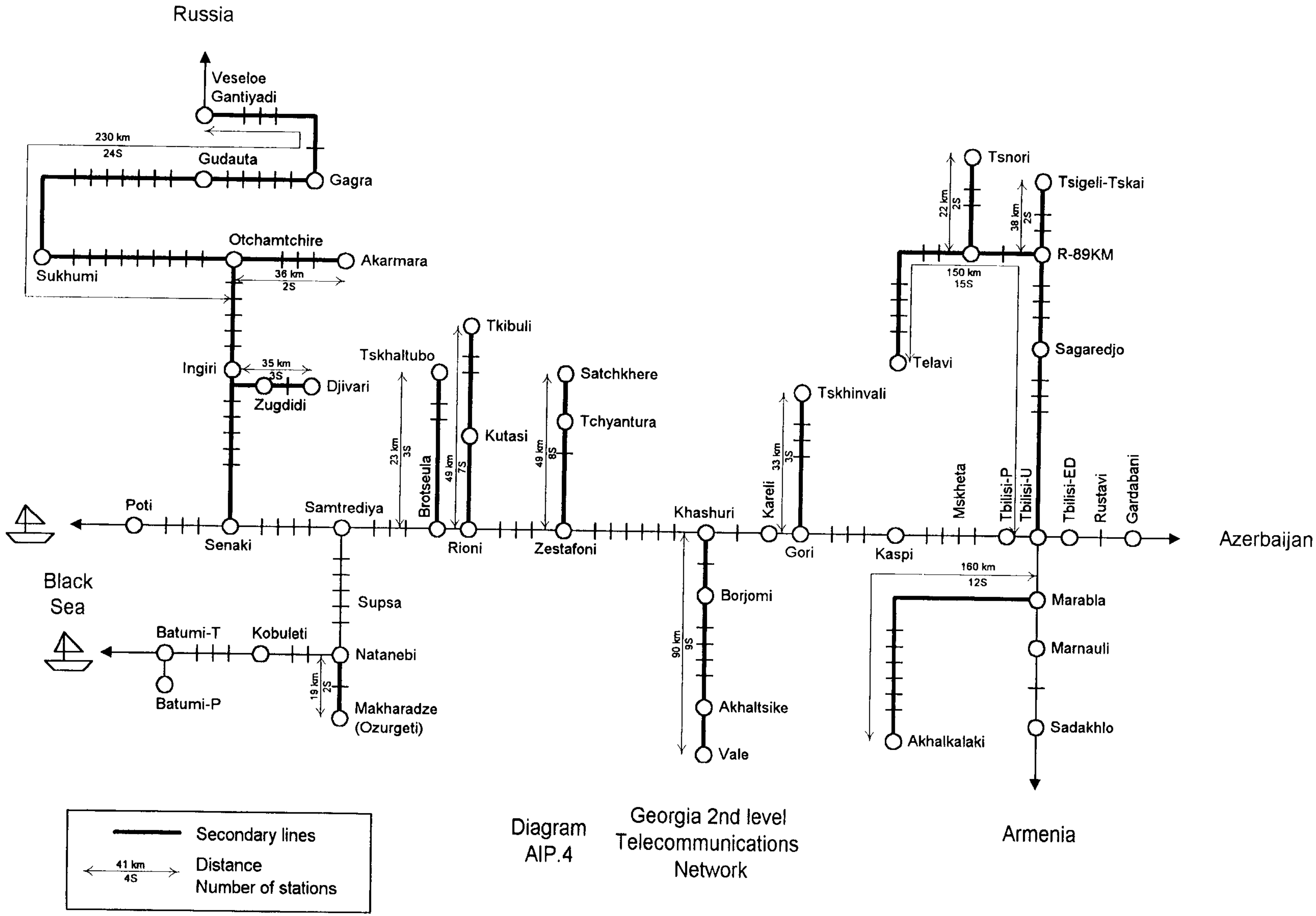


Diagram
AIP.4

Georgia 2nd level
Telecommunications
Network

Chapter 1

Caucasus - Recommendations and economic study Appendix 4 - Investment tables for the network of secondary railway lines

Investment in the secondary network, Caucasus -Summary - 18/02/99

	EU Investment (Millions of ECU)	Railway investment (Millions of ECU)
Armenia	2,55	0,46
Azerbaijan	7,80	1,54
Georgia	5,76	1,06
Total	**16,11**	**3,06**

Investment in the secondary network, ARMENIA
(V0.4 18/02/99)

Item No.	Item description	Comments	Length in km	Number of units	Unit price (in thousands of FRF)	Total (millions of FRF)	EU total (millions of ECU)	Total railway investment (adjusted to reflect local labour costs) (millions of ECU)
	cabling	supplies	409		17	6,95	1,05	
	cabling	supervision of staking-out work	409		2	0,82	0,12	
	cabling	installing links	409		4	1,64	0,25	
	cabling	staking out, civil engineering and laying (including labour)	409		75	30,68		0,46
1	**total expenditure on cabling**					40,08	**1,43**	**0,46**
	large and medium-sized stations	(Razdan, Masis, Gyumri)		3				
	smaller stations			23				
	total stations			26				
	number of links			8				
2.1	**ADM equipment**			31	64	1,98	0,30	
2.2	**hooking up ADM equipment**			31	8	0,25	0,04	
3	**ADM management**			1	100	0,10	0,02	
4.1	**low-capacity power supply**	(ADM, low-capacity station centre)		23	15	0,35	0,05	
5.1	**medium-capacity energy supply**	(STM1, medium-capacity station centre)		3	72	0,22	0,03	
6.1	**medium station equipment**	(30 lines)		3	217	0,65	0,10	
6.2	**hooking up**	(30 lines)		3	25	0,08	0,01	
7.1	**small station equipment**	(6 lines)		23	44	1,01	0,15	
7.2	**hooking up**	(6 lines)		23	4	0,09	0,01	
8	**spares**	(10% of items (2-7)				0,46	0,07	
		Total of items (1-8)				45,27	2,21	0,46
9	**provision for contingencies**	5% of aggregate investment (items 1-9)				2,26	0,34	
		AGGREGATE TOTAL of items 1-9				47,53	**2,55**	**0,46**

Investment in the secondary network, AZERBAIJAN
(V0.4 18/02/99)

Item No.	Item description	Comments	Length in km	Number of units	Unit price (in thousands of FRF)	Total (millions of FRF)	EU total (millions of ECU)	Total railway investment (adjusted to reflect local labour costs) (millions of ECU)
	cabling	supplies	1354		17	23,02	3,49	
	cabling	supervision of staking-out work	1354		2	2,71		
	cabling	installing links	1354		4	5,42		
	cabling	staking out, civil engineering and laying (including labour)	1354		75	101,55		1,54
1	**total expenditure on cabling**					132,69	**3,49**	**1,54**
	large and medium-sized stations	(Bakou-F., Baladjari, Alyati, Osmanli, Evlakh)		9				
	smaller stations			104				
	total stations			113				
	number of links			27				
2.1	**ADM equipment**			131	64	8,38	1,27	
2.2	**hooking up ADM equipment**			131	8	1,05	0,16	
3	**ADM management**			1	100	0,10	0,02	
4.1	**low-capacity power supply**	(ADM, low-capacity station centre)		104	15	1,56	0,24	
5.1	**medium-capacity energy supply**	(STM1, medium-capacity station centre)		9	72	0,65	0,10	
6.1	**medium station equipment**	(30 lines)		9	217	1,95	0,30	
6.2	**hooking up**	(30 lines)		9	25	0,23	0,03	
7.1	**small station equipment**	(6 lines)		104	44	4,58	0,69	
7.2	**hooking up**	(6 lines)		104	4	0,42	0,06	
8	**spares**	(10% of items (2-7)				1,85	0,28	
		Total of items (1-8)				153,45	6,63	1,54
9	**provision for contingencies**	5% of aggregate investment (items 1-9)				7,67	1,16	
		AGGREGATE TOTAL of items 1-9				161,12	**7,80**	**1,54**

Investment in the secondary network, GEORGIA
(V0.4 18/02/99)

Item No.	Item description	Comments	Length in km	Number of units	Unit price (in thousands of FRF)	Total (millions of FRF)	EU total (millions of ECU)	Total railway investment (adjusted to reflect local labour costs) (millions of ECU)
	cabling	supplies	934		17	15,88	2,41	
	cabling	supervision of staking-out work	934		2	1,87		
	cabling	installing links	934		4	3,74		
	cabling	staking out, civil engineering and laying (including labour)	934		75	70,05		1,06
1	**total expenditure on cabling**					91,53	**2,41**	**1,06**
	large and medium-sized stations	(Tbilissi, Marabla, Kashuri, Zestafoni, Rioni, Senaki)		6				
	smaller stations			86				
	total stations			92				
	number of links			23				
2.1	**ADM equipment**			109	64	6,98	1,06	
2.2	**hooking up ADM equipment**			109	8	0,87	0,13	
3	**ADM management**			1	100	0,10	0,02	
4.1	**low-capacity power supply**	(ADM, low-capacity station centre)		86	15	1,29	0,20	
5.1	**medium-capacity energy supply**	(STM1, medium-capacity station centre)		6	72	0,43	0,07	
6.1	**medium station equipment**	(30 lines)		6	217	1,30	0,20	
6.2	**hooking up**	(30 lines)		6	25	0,15	0,02	
7.1	**small station equipment**	(6 lines)		86	44	3,78	0,57	
7.2	**hooking up**	(6 lines)		86	4	0,34	0,05	
8	**spares**	(10% of items (2-7)				1,49	0,23	
		Total of items (1-8)				108,27	4,94	1,06
9	**provision for contingencies**	5% of aggregate investment (items 1-9)				5,41	0,82	
		AGGREGATE TOTAL of items 1-9				113,69	**5,76**	**1,06**

Chapter 1

Caucasus - Recommendations and economic study
Appendix 5 - Telecom switches

Pilot Project, PABX systems, Caucasus - Summary

	EU Investment (Millions of ECU)	Railway investment (Millions of ECU)	Total
Armenia	0,39	0,07	0,46
Azerbaijan	0,94	0,14	1,08
Georgia	1,08	0,16	1,25
Total	**2,41**	**0,38**	**2,79**

Pilot project, PABX systems, ARMENIA - V0.2 17/02/99 - EPK

	number of telephones	telephones to be fitted	unit price (FRF)	Total (FRF)	Total EU investment (ECU)	Total railway investment (ECU)
Yerevan						
PABX	2 000	1 500	1 000	1 500 000	227 273	
service to subscribers	2 000	1 500	150	225 000		34 091
AMS savings	1	1	-1 400 000	-1 400 000	-212 121	
Masis				0		
PABX	200	150	1 000	150 000	22 727	
service to subscribers	200	150	150	22 500		3 409
Gyumri				0		
PABX	1 500	1 125	1 000	1 125 000	170 455	
service to subscribers	1 500	1 125	150	168 750		25 568
technical facilities	1	1	500 000	500 000	75 758	
Sananin				0		
PABX	200	150	1 000	150 000	22 727	
service to subscribers	200	150	150	22 500		3 409
Ayrum				0		
PABX	100	75	1 500	112 500	17 045	
service to subscribers	100	75	225	16 875		2 557
Vanadzor				0		
PABX	200	150	1 000	150 000	22 727	
service to subscribers	200	150	150	22 500		3 409
Training					25 000	
Contingencies					18 580	3 622
Total					**390 170**	**72 443**

	number of telephones	telephones to be fitted	unit price (FRF)	Total (FRF)	Total EU investment (ECU)	Total railway investment (ECU)
Baku						
PABX	3 000	2 250	1 000	2 250 000	340 909	
service to subscribers	3 000	2 250	150	337 500		51 136
AMS savings	1	1	-1 400 000	-1 400 000	-212 121	
Alyat				0		
PABX	100	75	1 500	112 500	17 045	
service to subscribers	100	75	225	16 875		2 557
Kazi Magomed				0		
PABX	200	150	1 000	150 000	22 727	
service to subscribers	200	150	150	22 500		3 409
Kyurdamir				0		
PABX	200	150	1 000	150 000	22 727	
service to subscribers	200	150	150	22 500		3 409
Baladjari				0		
PABX	2 100	1 575	1 000	1 575 000	238 636	
service to subscribers	2 100	1 575	150	236 250		35 795
technical facilities	1	1	500 000	500 000	75 758	
Gyandja				0		
PABX	2 300	1 725	1 000	1 725 000	261 364	
service to subscribers	2 300	1 725	150	258 750		39 205
technical facilities	1	1	500 000	500 000	75 758	
Training					50 000	
Contingencies					44 640	6 776
Total					**937 443**	**142 287**

	number of telephones	telephones to be fitted	unit price (FRF)	Total (FRF)	Total EU investment (ECU)	Total railway investment (ECU)
Tbilissi						
PABX	4 300	3 225	1 000	3 225 000	488 636	
service to subscribers	4 300	3 225	150	483 750		73 295
AMS savings	1	1	-1 400 000	-1 400 000	-212 121	
Kashuri				0		
PABX	1 500	1 125	1 000	1 125 000	170 455	
service to subscribers	1 500	1 125	150	168 750		25 568
technical facilities	1	1	500 000	500 000	75 758	
Zestafoni				0		
PABX	380	285	1 000	285 000	43 182	
service to subscribers	380	285	150	42 750		6 477
Gori				0		
PABX	200	150	1 000	150 000	22 727	
service to subscribers	200	150	150	22 500		3 409
Samtredia				0		
PABX	2 000	1 500	1 000	1 500 000	227 273	
service to subscribers	2 000	1 500	150	225 000		34 091
technical facilities	1	1	500 000	500 000	75 758	
Senaki				0		
PABX	50	38	1 500	56 250	8 523	
service to subscribers	50	38	225	8 438		1 278
Poti				0		
PABX	200	150	1 000	150 000	22 727	
service to subscribers	200	150	150	22 500		3 409
Batumi				0		
PABX	500	375	1 000	375 000	56 818	
service to subscribers	500	375	150	56 250		8 523
Training					50 000	
Contingencies					51 487	7 803
Total					**1 081 222**	**163 854**

Investment in PABX systems, Caucasus - Summary

	EU Investment (Millions of ECU)	Railway investment (Millions of ECU)	Total
Armenia	0,56	0,10	0,66
Azerbaijan	1,25	0,19	1,44
Georgia	1,45	0,22	1,66
Total	**3,26**	**0,50**	**3,76**

	number of telephones	telephones to be fitted	unit price (FRF)	Total (FRF)	Total EU investment (ECU)	Total railway investment (ECU)
Yerevan						
PABX	2 000	2 000	1 000	2 000 000	303 030	
service to subscribers	2 000	2 000	150	300 000		45 455
AMS savings	1	1	-1 400 000	-1 400 000	-212 121	
Masis				0		
PABX	200	200	1 000	200 000	30 303	
service to subscribers	200	200	150	30 000		4 545
Gyumri				0		
PABX	1 500	1 500	1 000	1 500 000	227 273	
service to subscribers	1 500	1 500	150	225 000		34 091
technical facilities	1	1	500 000	500 000	75 758	
Sananin				0		
PABX	200	200	1 000	200 000	30 303	
service to subscribers	200	200	150	30 000		4 545
Ayrum				0		
PABX	100	100	1 500	150 000	22 727	
service to subscribers	100	100	225	22 500		3 409
Vanadzor				0		
PABX	200	200	1 000	200 000	30 303	
service to subscribers	200	200	150	30 000		4 545
Training					25 000	
Contingencies					26 629	4 830
Total					**559 205**	**96 591**

Telecom switches, AZERBAIJAN - V0.2 18/02/99 - EPK

	number of telephones	telephones to be fitted	unit price (FRF)	Total (FRF)	Total EU investment (ECU)	Total railway investment (ECU)
Baku						
PABX	3 000	3 000	1 000	3 000 000	454 545	
service to subscribers	3 000	3 000	150	450 000		68 182
AMS savings	1	1	-1 400 000	-1 400 000	-212 121	
Alyat				0		
PABX	100	100	1 500	150 000	22 727	
service to subscribers	100	100	225	22 500		3 409
Kazi Magomed				0		
PABX	200	200	1 000	200 000	30 303	
service to subscribers	200	200	150	30 000		4 545
Kyurdamir				0		
PABX	200	200	1 000	200 000	30 303	
service to subscribers	200	200	150	30 000		4 545
Baladjari				0		
PABX	2 100	2 100	1 000	2 100 000	318 182	
service to subscribers	2 100	2 100	150	315 000		47 727
technical facilities	1	1	500 000	500 000	75 758	
Gyandja				0		
PABX	2 300	2 300	1 000	2 300 000	348 485	
service to subscribers	2 300	2 300	150	345 000		52 273
technical facilities	1	1	500 000	500 000	75 758	
Training					50 000	
Contingencies					59 697	9 034
Total					**1 253 636**	**189 716**

Telecom switches, GEORGIA - V0.2 18/02/99 - EPK

	number of telephones	telephones to be fitted	unit price (FRF)	Total (FRF)	Total EU investment (ECU)	Total railway investment (ECU)
Tbilissi						
PABX	4 300	4 300	1 000	4 300 000	651 515	
service to subscribers	4 300	4 300	150	645 000		97 727
AMS savings	1	1	-1 400 000	-1 400 000	-212 121	
Kashuri				0		
PABX	1 500	1 500	1 000	1 500 000	227 273	
service to subscribers	1 500	1 500	150	225 000		34 091
technical facilities	1	1	500 000	500 000	75 758	
Zestafoni				0		
PABX	380	380	1 000	380 000	57 576	
service to subscribers	380	380	150	57 000		8 636
Gori				0		
PABX	200	200	1 000	200 000	30 303	
service to subscribers	200	200	150	30 000		4 545
Samtredia				0		
PABX	2 000	2 000	1 000	2 000 000	303 030	
service to subscribers	2 000	2 000	150	300 000		45 455
technical facilities	1	1	500 000	500 000	75 758	
Senaki				0		
PABX	50	50	1 500	75 000	11 364	
service to subscribers	50	50	225	11 250		1 705
Poti				0		
PABX	200	200	1 000	200 000	30 303	
service to subscribers	200	200	150	30 000		4 545
Batumi				0		
PABX	500	500	1 000	500 000	75 758	
service to subscribers	500	500	150	75 000		11 364
Training					50 000	
Contingencies					68 826	10 403
Total					**1 445 341**	**218 472**

Chapter 1

Caucasus - Recommendations and economic study
Appendix 6 - Economic tables

Hypothesis

	Armenia	Azerbaijan	Georgia	France
Length of cable laid (in km)	309	503	444	
PCM Cost in US$	0,014	0,014	0,014	0,057
Black Fibre Cost in US$	0,0005	0,001	0,001	0,0013 à 0,0033
km loco / year	100000	70000	100000	
Delays growth rate	1,05	1,02	1,03	

TRI

INV	Armenia	Azerbaijan	Georgia	Overall
+0%	19%	32%	16%	21%
+10%	17%	25%	15%	18%
-10%	23%	52%	18%	25%

TRI

REVENUES	Armenia	Azerbaijan	Georgia	Overall
+10%	20%	33%	17%	22%
-10%	18%	31%	15%	20%

	ARMENIA	AZERBAIJAN	GEORGIA
Line length (in km)	798	2117	1575
Length of cable laid (in km)	309	503	444
Telecomunications and Signalling staff	304	2086	1100
Telecomunications staff *	122	834	440

Expenditure in 1,000 US $

	ARMENIA	AZERBAIJAN	GEORGIA
salaries and social insurance	80	1250	508
materials	32	251	61
repairs and repair fund	27		396
other costs	4	914	36
Total	**144**	**2415**	**1002**
Total cost	56	574	282
Maintenance and Operating costs in 1000 US$	**22**	**230**	**113**
$ / year / employee (salary+social security contributions)	263	599	462
statistics (national sources)	252	348	564

Sources :

1. Tewet Studies — Armenia : '97 staff and '96 costs; Georgia : '96 costs

2. CIE Consult study on Azerbaijan, '96 staff and costs, source ADDY

Maintenance and operating costs	6
* equipment: 2 % of investment in equipment	0,02
* cable : 1 FRF/m	1,00

in Millions of US $	Armenia	Azerbaijan	Georgia
cable length (in km)	309	503	444
Total Inv	4,47	7,17	7,06
Inv for equipments	2,04	3,21	3,41
Operations	0,04	0,06	0,07
Cable maintenance	0,05	0,08	0,07
M+O Total	**0,092**	**0,148**	**0,142**

inv +10%

Maintenance and operating costs	6
* equipment: 2 % of investment in equipment	0,02
* cable : 1 FRF/m	1,00

in Millions of US $	Armenia	Azerbaijan	Georgia
cable length (in km)	309	503	444
Total Inv	4,91	7,89	7,77
Inv for equipments	2,24	3,53	3,75
Operations	0,04	0,07	0,08
Cable maintenance	0,05	0,08	0,07
M+O Total	**0,096**	**0,154**	**0,149**

inv -10%

Maintenance and operating costs	6
* equipment: 2 % of investment in equipment	0,02
* cable : 1 FRF/m	1,00

in Millions of US $	Armenia	Azerbaijan	Georgia
cable length (in km)	309	503	444
Total Inv	4,02	6,45	6,36
Inv for equipments	1,83	2,89	3,07
Operations	0,04	0,06	0,06
Cable maintenance	0,05	0,08	0,07
M+O Total	**0,088**	**0,142**	**0,135**

Unit price (in thousands of FRF)	TOTAL (in millions of FRF)	TOTAL (in millions of ECU)	TOTAL (in millions of US$)	Residual value per remaining year
Backbone	23,76	3,60	3,96	0,037
PABX	3,04	0,46	0,51	
Total	**26,80**	**4,06**	**4,47**	over 30 years
divided into: equipments	12,21	1,85	2,04	1,12
: optical cable	11,15	1,69	1,86	
+ 10 %				
Backbone	26,14	3,96	4,36	0,041
PABX	3,34	0,51	0,56	
Total	**29,48**	**4,47**	**4,91**	over 30 years
divided into: equipments	13,43	2,04	2,24	1,23
: optical cable	12,27	1,86	2,04	
- 10 %				
Backbone	21,38	3,24	3,56	0,033
PABX	2,73	0,41	0,46	
Total	**24,12**	**3,65**	**4,02**	over 30 years
divided into: equipments	10,99	1,67	1,83	1,00
: optical cable	10,04	1,52	1,67	

Unit price (in thousands of FRF)	**TOTAL (in millions of FRF)**	**TOTAL (in millions of ECU)**	**TOTAL (in millions of US$)**	**Residual value per remaining year**
Backbone	35,90	5,44	5,98	0,060
PABX	7,13	1,08	1,19	
Total	**43,03**	**6,52**	**7,17**	over 30 years
divided into: equipments	19,27	2,92	3,21	1,81
: optical cable	18,08	2,74	3,01	
+ 10 %				
Backbone	39,49	5,98	6,58	0,066
PABX	7,84	1,19	1,31	
Total	**47,34**	**7,17**	**7,89**	over 30 years
divided into: equipments	21,20	3,21	3,53	1,99
: optical cable	19,89	3,01	3,32	
- 10 %				
Backbone	32,31	4,90	5,39	0,054
PABX	6,42	0,97	1,07	
Total	**38,73**	**5,87**	**6,45**	over 30 years
divided into: equipments	17,34	2,63	2,89	1,63
: optical cable	16,28	2,47	2,71	

Unit price (in thousands of FRF)	TOTAL (in millions of FRF)	TOTAL (in millions of ECU)	TOTAL (in millions of US$)	Residual value per remaining year
Backbone	34,12	5,17	5,69	0,053
PABX	8,25	1,25	1,38	
Total	**42,37**	**6,42**	**7,06**	over 30 years
divided into: equipments	20,46	3,10	3,41	1,60
: optical cable	15,97	2,42	2,66	
+ 10 %				
Backbone	37,53	5,69	6,26	0,059
PABX	9,08	1,38	1,51	
Total	**46,61**	**7,06**	**7,77**	over 30 years
divided into: equipments	22,51	3,41	3,75	1,76
: optical cable	17,57	2,66	2,93	
- 10 %				
Backbone	30,71	4,65	5,12	0,048
PABX	7,43	1,13	1,24	
Total	**38,13**	**5,78**	**6,36**	over 30 years
divided into: equipments	18,41	2,79	3,07	1,44
: optical cable	14,37	2,18	2,40	

HYPOTHESIS (source : Study on Georgie) : 5 min stop time / 6,4 km section
5% growth/year for delays caused by old equipment

ARMENIA

		Delays growth rate
Length of cables laid (in km)	309	1,05
no /sections	48	

delays	2 000	2 001	2 002	2 003	2 004	2 005	2 006	2 007	2 008	2 009
min/day	241	253	266	279	293	308	324	340	357	375
hours/day	4	4	4	5	5	5	5	6	6	6
hours / year	1 469	1 542	1 619	1 700	1 785	1 874	1 968	2 066	2 170	2 278
day/year	61	64	67	71	74	78	82	86	90	95
Delays (hours/year)	1469	1542	1619	1700	1785	1874	1968	2066	2170	2278
number of locos	1	0	0	0	0	0	0	0	0	0
Cost	3	0	0	0	0	0	0	0	0	0
Residual Value	0,72	0	0	0	0	0	0	0	0	0
Total Residual Value	2,76									

delays	2 010	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019
min/day	393	413	434	455	478	502	527	553	581	610
hours/day	7	7	7	8	8	8	9	9	10	10
hours / year	2 392	2 512	2 637	2 769	2 908	3 053	3 206	3 366	3 534	3 711
day/year	100	105	110	115	121	127	134	140	147	155
Delays (hours/year)	2392	2512	2637	2769	2908	3053	3206	3366	3534	3711
number of locos	0	1	0	0	0	0	0	0	0	0
Cost	0	3	0	0	0	0	0	0	0	0
Residual Value	0	2,04	0	0	0	0	0	0	0	0
Total Residual Value										

Electric locomotive

Cost of one locomotive	3 M US $	
Lifespan (in years)	25	100 000 km/year
		8 333 km/month
		40 km/hrs
		208 hrs/month
		2500 hrs/year

HYPOTHESIS (source : Study on Georgie) 5 min stop time 6,4 km section
3% growth/year for delays caused by old equipment

GEORGIA

		Delays growth rate
Length of cables laid (in km)	444	1.03
no./sections	69	

delays	2 000	2 001	2 002	2 003	2 004	2 005	2 006	2 007	2 008	2 009	2 010	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019
mn/day	347	357	368	379	390	402	414	427	439	453	466	480	495	509	525	540	557	573	591	608
hours/day	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9	9	9	10	10	10
hours / year	2 110	2 173	2 239	2 306	2 375	2 446	2 520	2 595	2 673	2 753	2 836	2 921	3 009	3 099	3 192	3 288	3 386	3 488	3 592	3 700
day/year	88	91	93	96	99	102	105	108	111	115	118	122	125	129	133	137	141	145	150	154
Delays (hours/year)	2 110	2 173	2 239	2 306	2 375	2 446	2 520	2 595	2 673	2 753	2 836	2 921	3 009	3 099	3 192	3 288	3 386	3 488	3 592	3 700
number of locos	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,72	0,00	0,00	0,00	0,00	0,00	1,44	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total Residual Value	2,16																			

Electric locomotive

Cost of one locomotive	3 M US $	
Lifespan (in years)	25	100 000 km/year
		8 333 km/month
		40 km/hrs
		208 hrs/month
		2500 hrs/year

HYPOTHESIS (source : Study on Georgie) : 5 min stop time / 6,4 km section
2% growth/year for delays caused by old equipment

AZERBAIJAN

Length of cables laid (in km)	503	Delays growth rate	
no. sections	79	1,02	

delays	2 000	2 001	2 002	2 003	2 004	2 005	2 006	2 007	2 008	2 009	2 010	2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019
min/day	393	401	409	417	425	434	443	451	460	470	479	489	498	508	519	529	539	550	561	572
hours/day	7	7	7	7	7	7	7	8	8	8	8	8	8	8	9	9	9	9	9	10
hours / year	2 391	2 438	2 487	2 537	2 588	2 639	2 692	2 746	2 801	2 857	2 914	2 972	3 032	3 092	3 154	3 217	3 282	3 347	3 414	3 483
day/year	100	102	104	106	108	110	112	114	117	119	121	124	126	129	131	134	137	139	142	145
Delays (hours/year)	2 391	2 438	2 487	2 537	2 588	2 639	2 692	2 746	2 801	2 857	2 914	2 972	3 032	3 092	3 154	3 217	3 282	3 347	3 414	3 483
number of locos	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	1,44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Residual Value	1,44																			

Electric locomotive

Cost of one locomotive	3 M US $		
Lifespan (in years)	25	70 000	km/year
		5 833	km/month
		40	km/hrs
		146	hrs/month
		1750	hrs/year

(In millions of US $) ARMENIA AZERBAIJAN GEORGIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,365	0,372	0,3794	0,387	0,395	0,403	0,411	0,419	0,427	0,436	0,445	0,453	0,463	0,472	0,481	0,491	0,501	0,511	0,521	0,531
Inv Loco	12	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Cash flow	-12,365	-0,372	-0,379	-0,387	-0,395	-0,403	-3,411	-0,419	-0,427	-0,436	-0,445	-3,453	-0,463	-0,472	-0,481	-0,491	-0,501	-0,511	-0,521	5,829
Project case : S1																				
Investments	18,70																			
Maintenance cost	0,38	0,38	0,3825	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38
Residual Value	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,52
PCM revenues	0,00	0,00	0,00	0,05	0,10	0,21	0,31	0,42	0,53	0,63	0,74	0,85	0,95	1,01	1,06	1,06	1,06	1,06	1,06	1,06
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,10	1,10	2,20	2,20	3,30	3,30	4,41	4,41	5,51	5,51	6,61	6,61	6,61
Cash flow	-19,08	-0,38	-0,38	-0,33	-0,28	-0,18	-0,07	1,14	1,25	2,45	2,56	3,77	3,87	5,03	5,09	6,19	6,19	7,29	7,29	11,81
S1-S0	-6,72	-0,01	0,00	0,05	0,11	0,23	3,34	1,56	1,67	2,89	3,00	7,22	4,34	5,50	5,57	6,68	6,69	7,80	7,81	5,98

IRR **21%**

Locomotive cost	3		VR	
Maintenance cost increase		1,02	0	1
			1 PCM revenues	
REVENUE			1 Black fibres revenues	
revenues -10 %				
revenues +10 %				
Number of free 2Mb/s PCM channels		76		
Average 2Mb/s PCM cost		0,014		
Number of black fibres		36		0,02
Average black fibre cost				
Number of km		1256		

(In millions of US $) ARMENIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,022	0,023	0,023	0,024	0,024	0,025	0,025	0,026	0,026	0,027	0,027	0,028	0,028	0,029	0,029	0,030	0,031	0,031	0,032	0,032
Inv Loco	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,8
Cash flow	**-3,022**	**-0,023**	**-0,023**	**-0,024**	**-0,024**	**-0,025**	**-0,025**	**-0,026**	**-0,026**	**-0,027**	**-0,027**	**-3,028**	**-0,028**	**-0,029**	**-0,029**	**-0,030**	**-0,031**	**-0,031**	**-0,032**	**2,728**
Project case : S1																				
Investments	4,47																			
Maintenance cost	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09
Residual Value	0																			1,115
PCM revenues	0,00	0,00	0,00	0,05	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,15	0,15	0,31	0,31	0,46	0,46	0,62	0,62	0,77	0,77	0,93	0,93	0,93
Cash flow	-4,56	**-0,09**	**-0,09**	**-0,04**	**0,01**	**0,06**	**0,11**	**0,31**	**0,36**	**0,57**	**0,62**	**0,82**	**0,88**	**1,03**	**1,03**	**1,18**	**1,18**	**1,34**	**1,34**	**2,45**
S1-S0	-1,54	-0,07	**-0,07**	-0,02	**0,03**	**0,08**	**0,13**	**0,34**	**0,39**	**0,60**	**0,65**	**3,85**	**0,90**	**1,06**	**1,06**	**1,21**	**1,21**	**1,37**	**1,37**	-0,27

IRR **19%**

Locomotive cost	3		VR	
Maintenance cost increase		1,02	0	1
			1	PCM revenues
REVENUE			1	Black fibres revenues

Number of free 2Mb/s PCM channels	36
Average 2Mb/s PCM cost	0,014
Number of black fibres	12
Average black fibre cost	0,0005
Number of km	309

(In millions of US $) AZERBAIJAN

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,23	0,23	0,24	0,24	0,25	0,25	0,26	0,26	0,27	0,27	0,28	0,29	0,29	0,30	0,30	0,31	0,32	0,32	0,33	0,33
Inv Loco	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4
Cash flow	**-6,23**	**-0,234**	**-0,239**	**-0,244**	**-0,248**	**-0,253**	**-0,258**	**-0,264**	**-0,269**	**-0,274**	**-0,280**	**-0,285**	**-0,291**	**-0,297**	**-0,303**	**-0,309**	**-0,315**	**-0,321**	**-0,328**	**1,106**
Project case : S1																				
Investments	7,17																			
Maintenance cost	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
Residual Value	0,00																			1,808
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,12	0,15	0,18	0,22	0,25	0,28	0,31	0,31	0,31	0,31	0,31	0,31
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,50	0,50	1,01	1,01	1,51	1,51	2,01	2,01	2,52	2,52	3,02	3,02	3,02
Cash flow	**-7,32**	**-0,15**	**-0,15**	**-0,15**	**-0,15**	**-0,12**	**-0,09**	**0,45**	**0,48**	**1,01**	1,04	1,58	1,61	**2,14**	**2,17**	**2,67**	**2,67**	**3,18**	**3,18**	4,99
S1-S0	**-1,09**	**0,09**	**0,09**	0,10	0,10	0,14	0,17	0,71	0,75	1,29	1,32	1,86	1,90	2,44	2,47	2,98	2,99	3,50	3,51	3,88

IRR **32%**

Locomotive cost 3
Maintenance cost increase 1,02

VR
0 1
1 PCM revenues
1 Black fibres revenues

REVENUE

Number of free 2Mb/s PCM channels 22
Average 2Mb/s PCM cost 0,014
Number of black fibres 12
Average black fibre cost 0,001
number of km 503

(In millions of US $) **GEORGIA**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
cost	0,113	0,115	0,117	0,120	0,122	0,125	0,127	0,130	0,132	0,135	0,138	0,140	0,143	0,146	0,149	0,152	0,155	0,158	0,161	0,165
Inv Loco	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,2
Cash flow	**-3,11**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-3,13**	**-0,13**	**-0,13**	**-0,13**	**-0,14**	**-0,14**	**-0,14**	**-0,15**	**-0,15**	**-0,15**	**-0,16**	**-0,16**	**-0,16**	**2,00**
Project case : S1																				
Investments	7,06																			
cost	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14
Residual Value	0,00																			1,60
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,10	0,13	0,15	0,18	0,20	0,23	0,25	0,25	0,25	0,25	0,25	0,25
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,44	0,44	0,89	0,89	1,33	1,33	1,78	1,78	2,22	2,22	2,66	2,66	2,66
Cash flow	**-7,20**	**-0,14**	**-0,14**	**-0,14**	**-0,14**	**-0,12**	**-0,09**	**0,38**	**0,40**	**0,87**	**0,90**	**1,37**	**1,39**	**1,86**	**1,89**	**2,33**	**2,33**	**2,77**	**2,77**	**4,37**
S1-S0	**-4,09**	**-0,03**	**-0,02**	**-0,02**	**-0,02**	**0,01**	**3,04**	**0,51**	**0,53**	**1,01**	**1,03**	**1,51**	**1,53**	**2,01**	**2,03**	**2,48**	**2,48**	**2,93**	**2,94**	**2,38**

IRR **16%**

Locomotive cost 3
Maintenance cost increase 1,02

VR
0 1
1 PCM revenues
1 Black fibres revenues

REVENUE

Number of free 2Mb/s PCM channels	18
Average 2Mb/s PCM cost	0,014
Number of black fibres	12
Average black fibre cost	0,001
number of km	444

(In millions of US $) ARMENIA AZERBAIJAN GEORGIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,365	0,372	0,379	0,387	0,395	0,403	0,411	0,419	0,427	0,436	0,445	0,453	0,463	0,472	0,481	0,491	0,501	0,511	0,521	0,531
Inv Loco	12	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Cash flow	-12,365	-0,372	-0,379	-0,387	-0,395	-0,403	-3,411	-0,419	-0,427	-0,436	-0,445	-3,453	-0,463	-0,472	-0,481	-0,491	-0,501	-0,511	-0,521	5,829
Project case : S1																				
Investments	20,57																			
Maintenance cost	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40
Residual Value	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,97
PCM revenues	0,00	0,00	0,00	0,05	0,10	0,21	0,31	0,42	0,53	0,63	0,74	0,85	0,95	1,01	1,06	1,06	1,06	1,06	1,06	1,06
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,10	1,10	2,20	2,20	3,30	3,30	4,41	4,41	5,51	5,51	6,61	6,61	6,61
Cash flow	-20,97	-0,40	-0,40	-0,35	-0,30	-0,19	-0,09	1,12	1,23	2,44	2,54	3,75	3,86	5,01	5,07	6,17	6,17	7,27	7,27	12,25
S1-S0	-8,61	-0,03	-0,02	0,04	0,10	0,21	3,32	1,54	1,66	2,87	2,99	7,20	4,32	5,49	5,55	6,66	6,67	7,78	7,79	6,42

IRR **18%**

Locomotive cost 3

Maintenance cost increase 1,02

VR
0 1
1 PCM revenues
1 Black fibres revenues

Number of free 2Mb/s PCM channels 76
Average 2Mb/s PCM cost 0,014
Number of black fibres 36
Average black fibre cost
Number of km 1256

(In millions of US $) ARMENIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
cost	0,022	0,023	0,023	0,024	0,024	0,025	0,025	0,026	0,026	0,027	0,027	0,028	0,028	0,029	0,029	0,030	0,031	0,031	0,032	0,032
Inv Loco	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,8
Cash flow	**-3,022**	**-0,023**	**-0,023**	**-0,024**	**-0,024**	**-0,025**	**-0,025**	**-0,026**	**-0,026**	**-0,027**	**-0,027**	**-3,028**	**-0,028**	**-0,029**	**-0,029**	**-0,030**	**-0,031**	**-0,031**	**-0,032**	**2,728**
Project case : S1																				
Investments	4,91																			
Maintenance cost	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096	0,096
Residual Value	0,00																			1,23
PCM revenues	0,00	0,00	0,00	0,05	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,15	0,15	0,31	0,31	0,46	0,46	0,62	0,62	0,77	0,77	0,93	0,93	0,93
Cash flow	**-5,01**	**-0,10**	**-0,10**	**-0,05**	**0,00**	**0,05**	**0,11**	**0,31**	**0,36**	**0,57**	**0,62**	**0,82**	**0,87**	**1,03**	**1,03**	**1,18**	**1,18**	**1,33**	**1,33**	**2,56**
S1-S0	**-1,99**	**-0,07**	**-0,07**	**-0,02**	**0,03**	**0,08**	**0,13**	**0,34**	**0,39**	**0,59**	**0,64**	**3,85**	**0,90**	**1,05**	**1,06**	**1,21**	**1,21**	**1,37**	**1,37**	**-0,17**

IRR **17%**

Locomotive cost 3

Maintenance cost increase 1,02

VR

0 1

1 PCM revenues

1 Black fibres revenues

Number of free 2Mb/s PCM channels 36

Average 2Mb/s PCM cost 0,014

Number of black fibres 12

Average black fibre cost 0,0005

Number of km 309

(In millions of US $) AZERBAIJAN

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,23	0,23	0,24	0,24	0,25	0,25	0,26	0,26	0,27	0,27	0,28	0,29	0,29	0,30	0,30	0,31	0,32	0,32	0,33	0,33
Inv Loco	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4
Cash flow	**-6,23**	**-0,234**	**-0,239**	**-0,244**	**-0,248**	**-0,253**	**-0,258**	**-0,264**	**-0,269**	**-0,274**	**-0,280**	**-0,285**	**-0,291**	**-0,297**	**-0,303**	**-0,309**	**-0,315**	**-0,321**	**-0,328**	**1,106**
Project case : S1																				
Investments	7,89																			
Maintenance cost	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
Residual Value	0,00																			1,99
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,12	0,15	0,18	0,22	0,25	0,28	0,31	0,31	0,31	0,31	0,31	0,31
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,50	0,50	1,01	1,01	1,51	1,51	2,01	2,01	2,52	2,52	3,02	3,02	3,02
Cash flow	**-8,04**	**-0,15**	**-0,15**	**-0,15**	**-0,15**	**-0,12**	**-0,09**	**0,44**	**0,47**	**1,01**	**1,04**	**1,57**	**1,60**	**2,13**	**2,17**	**2,67**	**2,67**	**3,17**	**3,17**	**5,16**
S1-S0	**-1,81**	**0,08**	**0,08**	**0,09**	**0,09**	**0,13**	**0,17**	**0,70**	**0,74**	**1,28**	**1,32**	**1,86**	**1,89**	**2,43**	**2,47**	**2,98**	**2,98**	**3,49**	**3,50**	**4,06**

IRR **25%**

Locomotive cost 3

Maintenance cost increase 1,02

VR

0 1

1 PCM revenues

1 Black fibres revenues

Number of free 2Mb/s PCM channels 22

Average 2Mb/s PCM cost 0,014

Number of black fibres 12

Average black fibre cost 0,001

number of km 503

(In millions of US $) GEORGIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,113	0,115	0,117	0,120	0,122	0,125	0,127	0,130	0,132	0,135	0,138	0,140	0,143	0,146	0,149	0,152	0,155	0,158	0,161	0,165
Inv Loco	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,2
Cash flow	**-3,11**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-3,13**	**-0,13**	**-0,13**	**-0,13**	**-0,14**	**-0,14**	**-0,14**	**-0,15**	**-0,15**	**-0,15**	**-0,16**	**-0,16**	**-0,16**	**2,00**
Project case : S1																				
Investments	7,77																			
Maintenance and operating cost	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
Residual Value	0,00																			1,76
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,10	0,13	0,15	0,18	0,20	0,23	0,25	0,25	0,25	0,25	0,25	0,25
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,44	0,44	0,89	0,89	1,33	1,33	1,78	1,78	2,22	2,22	2,66	2,66	2,66
Cash flow	**-7,92**	**-0,15**	**-0,15**	**-0,15**	**-0,15**	**-0,12**	**-0,10**	**0,37**	**0,40**	**0,86**	**0,89**	**1,36**	**1,38**	**1,85**	**1,88**	**2,32**	**2,32**	**2,77**	**2,77**	**4,52**
S1-S0	**-4,80**	**-0,03**	**-0,03**	**-0,03**	**-0,03**	**0,00**	**3,03**	**0,50**	**0,53**	**1,00**	**1,03**	**1,50**	**1,53**	**2,00**	**2,03**	**2,47**	**2,48**	**2,93**	**2,93**	**2,53**

IRR **15%**

Locomotive cost 3
Maintenance cost increase 1,02

VR
0 1
1 PCM revenues
1 Black fibres revenues

Number of free 2Mb/s PCM channels 18
Average 2Mb/s PCM cost 0,014
Number of black fibres 12
Average black fibre cost 0,001 /km
number of km 444

(In millions of US $)	ARMENIA			AZERBAIJAN			GEORGIA													
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,365	0,372	0,379	0,387	0,395	0,403	0,411	0,419	0,427	0,436	0,445	0,453	0,463	0,472	0,481	0,491	0,501	0,511	0,521	0,531
Inv Loco	12	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Cash flow	**-12,365**	**-0,372**	**-0,379**	**-0,387**	**-0,395**	**-0,403**	**-3,411**	**-0,419**	**-0,427**	**-0,436**	**-0,445**	**-3,453**	**-0,463**	**-0,472**	**-0,481**	**-0,491**	**-0,501**	**-0,511**	**-0,521**	**5,829**
Project case : S1																				
Investments	16,83																			
Maintenance cost	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37
Residual Value	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,07
PCM revenues	0,00	0,00	0,00	0,05	0,10	0,21	0,31	0,42	0,53	0,63	0,74	0,85	0,95	1,01	1,06	1,06	1,06	1,06	1,06	1,06
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,10	1,10	2,20	2,20	3,30	3,30	4,41	4,41	5,51	5,51	6,61	6,61	6,61
Cash flow	**-17,20**	**-0,37**	**-0,37**	**-0,31**	**-0,26**	**-0,16**	**-0,05**	**1,16**	**1,26**	**2,47**	**2,58**	**3,78**	**3,89**	**5,05**	**5,10**	**6,21**	**6,21**	**7,31**	**7,31**	**11,38**
S1-S0	**-4,83**	**0,01**	**0,01**	**0,07**	**0,13**	**0,24**	**3,36**	**1,58**	**1,69**	**2,91**	**3,02**	**7,24**	**4,35**	**5,52**	**5,59**	**6,70**	**6,71**	**7,82**	**7,83**	**5,55**

IRR **25%**

Locomotive cost 3

Maintenance cost increase 1,02

VR

0 1

1 PCM revenues

1 Black fibres revenues

Number of free 2Mb/s PCM channels 76

Average 2Mb/s PCM cost 0,014

Number of black fibres 36

Average black fibre cost

Number of km 1256

(In millions of US $) ARMENIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,022	0,023	0,023	0,024	0,024	0,025	0,025	0,026	0,026	0,027	0,027	0,028	0,028	0,029	0,029	0,030	0,031	0,031	0,032	0,032
Inv Loco	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,8
Cash flow	**-3,022**	**-0,023**	**-0,023**	**-0,024**	**-0,024**	**-0,025**	**-0,025**	**-0,026**	**-0,026**	**-0,027**	**-0,027**	**-3,028**	**-0,028**	**-0,029**	**-0,029**	**-0,030**	**-0,031**	**-0,031**	**-0,032**	**2,728**
Project case : S1																				
Investments	4,02																			
Maintenance cost	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09
Residual Value	0,00																			1,00
PCM revenues	0,00	0,00	0,00	0,05	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,45	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,15	0,15	0,31	0,31	0,46	0,46	0,62	0,62	0,77	0,77	0,93	0,93	0,93
Cash flow	**-4,11**	**-0,09**	**-0,09**	**-0,04**	**0,01**	**0,06**	**0,11**	**0,32**	**0,37**	**0,57**	**0,62**	**0,83**	**0,88**	**1,03**	**1,03**	**1,19**	**1,19**	**1,34**	**1,34**	**2,35**
S1-S0	**-1,09**	**-0,07**	**-0,06**	**-0,01**	**0,04**	**0,09**	**0,14**	**0,34**	**0,39**	**0,60**	**0,65**	**3,86**	**0,91**	**1,06**	**1,06**	**1,22**	**1,22**	**1,37**	**1,37**	**-0,38**

IRR 23%

VR

Locomotive cost	3		0	1
Maintenance cost increase		1,02		

1 PCM revenues
1 Black fibres revenues

Number of free 2Mb/s PCM channels	36
Average 2Mb/s PCM cost	0,014
Number of black fibres	12
Average black fibre cost	0,0005
Number of km	309

(In millions of US $) AZERBAIJAN

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,23	0,23	0,24	0,24	0,25	0,25	0,26	0,26	0,27	0,27	0,28	0,29	0,29	0,30	0,30	0,31	0,32	0,32	0,33	0,33
Inv Loco	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4
Cash flow	**-6,23**	**-0,234**	**-0,239**	**-0,244**	**-0,248**	**-0,253**	**-0,258**	**-0,264**	**-0,269**	**-0,274**	**-0,280**	**-0,285**	**-0,291**	**-0,297**	**-0,303**	**-0,309**	**-0,315**	**-0,321**	**-0,328**	**1,106**
Project case : S1																				
Investments	6,45																			
Maintenance cost	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142	0,142
Residual Value	0,00																			1,63
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,12	0,15	0,18	0,22	0,25	0,28	0,31	0,31	0,31	0,31	0,31	0,31
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,50	0,50	1,01	1,01	1,51	1,51	2,01	2,01	2,52	2,52	3,02	3,02	3,02
Cash flow	**-6,60**	**-0,14**	**-0,14**	**-0,14**	**-0,14**	**-0,11**	**-0,08**	**0,45**	**0,48**	**1,02**	**1,05**	**1,58**	**1,61**	**2,15**	**2,18**	**2,68**	**2,68**	**3,18**	**3,18**	**4,81**
S1-S0	**-0,37**	**0,09**	**0,10**	**0,10**	**0,11**	**0,14**	**0,18**	**0,72**	**0,75**	**1,29**	**1,33**	**1,87**	**1,90**	**2,44**	**2,48**	**2,99**	**3,00**	**3,51**	**3,51**	**3,71**

IRR **52%**

Locomotive cost 3
Maintenance cost increase 1,02

VR
0 1

1 PCM revenues
1 Black fibres revenues

Number of free 2Mb/s PCM channels 22
Average 2Mb/s PCM cost 0,014
Number of black fibres 12
Average black fibre cost 0,001
number of km 503

(In millions of US $) GEORGIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,113	0,115	0,117	0,120	0,122	0,125	0,127	0,130	0,132	0,135	0,138	0,140	0,143	0,146	0,149	0,152	0,155	0,158	0,161	0,165
Inv Loco	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,2
Cash flow	**-3,11**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-3,13**	**-0,13**	**-0,13**	**-0,13**	**-0,14**	**-0,14**	**-0,14**	**-0,15**	**-0,15**	**-0,15**	**-0,16**	**-0,16**	**-0,16**	**2,00**
Project case : S1																				
Investments	6,36																			
Maintenance and operating cost	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135	0,135
Residual Value	0,00																			1,44
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,10	0,13	0,15	0,18	0,20	0,23	0,25	0,25	0,25	0,25	0,25	0,25
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,44	0,44	0,89	0,89	1,33	1,33	1,78	1,78	2,22	2,22	2,66	2,66	2,66
Cash flow	**-6,49**	**-0,14**	**-0,14**	**-0,14**	**-0,14**	**-0,11**	**-0,08**	**0,38**	**0,41**	**0,88**	**0,90**	**1,37**	**1,40**	**1,87**	**1,89**	**2,34**	**2,34**	**2,78**	**2,78**	**4,22**
S1-S0	**-3,38**	**-0,02**	**-0,02**	**-0,02**	**-0,01**	**0,01**	**3,04**	**0,51**	**0,54**	**1,01**	**1,04**	**1,51**	**1,54**	**2,01**	**2,04**	**2,49**	**2,49**	**2,94**	**2,94**	**2,22**

IRR **18%**

VR

0 1

Locomotive cost 3
Maintenance cost increase 1,02

1 PCM revenues
1 Black fibres revenues

Number of free 2Mb/s PCM channels 18
Average 2Mb/s PCM cost 0,014
Number of black fibres 12
Average black fibre cost 0,001 /km
number of km 444

(In millions of US $) ARMENIA AZERBAIJAN GEORGIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,365	0,372	0,3794	0,387	0,395	0,403	0,411	0,419	0,427	0,436	0,445	0,453	0,463	0,472	0,481	0,491	0,501	0,511	0,521	0,531
Inv Loco	12	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Cash flow	-12,365	-0,372	-0,379	-0,387	-0,395	-0,403	-3,411	-0,419	-0,427	-0,436	-0,445	-3,453	-0,463	-0,472	-0,481	-0,491	-0,501	-0,511	-0,521	5,829
Project case : S1																				
Investments	18,70																			
Maintenance cost	0,38	0,38	0,3825	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38
Residual Value	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,52
PCM revenues	0,00	0,00	0,00	0,06	0,11	0,23	0,34	0,46	0,58	0,70	0,81	0,93	1,05	1,11	1,17	1,17	1,17	1,17	1,17	1,17
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,21	1,21	2,42	2,42	3,63	3,63	4,85	4,85	6,06	6,06	7,27	7,27	7,27
Cash flow	-19,08	-0,38	-0,38	-0,33	-0,27	-0,15	-0,04	1,29	1,41	2,74	2,85	4,18	4,30	5,57	5,63	6,85	6,85	8,06	8,06	12,58
S1-S0	-6,72	-0,01	0,00	0,06	0,12	0,25	3,37	1,71	1,84	3,17	3,30	7,64	4,76	6,04	6,12	7,34	7,35	8,57	8,58	6,75

IRR 22%

Locomotive cost 3

Maintenance cost increase 1,02

VR

0 1

1 PCM revenues

1 Black fibres revenues

REVENUE +10%

revenues -10 %

revenues +10 %

Number of free 2Mb/s PCM channels 76

Average 2Mb/s PCM cost 0,0154

Number of black fibres 36

0,02

Average black fibre cost

Number of km 1256

(In millions of US $) ARMENIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,022	0,023	0,023	0,024	0,024	0,025	0,025	0,026	0,026	0,027	0,027	0,028	0,028	0,029	0,029	0,030	0,031	0,031	0,032	0,032
Inv Loco	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,8
Cash flow	**-3,022**	**-0,023**	**-0,023**	**-0,024**	**-0,024**	**-0,025**	**-0,025**	**-0,026**	**-0,026**	**-0,027**	**-0,027**	**-3,028**	**-0,028**	**-0,029**	**-0,029**	**-0,030**	**-0,031**	**-0,031**	**-0,032**	**2,728**
Project case : S1																				
Investments	4,47																			
Maintenance cost	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09
Residual Value	0																			1,115
PCM revenues	0,00	0,00	0,00	0,06	0,11	0,17	0,22	0,28	0,33	0,39	0,44	0,50	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,17	0,17	0,34	0,34	0,51	0,51	0,68	0,68	0,85	0,85	1,02	1,02	1,02
Cash flow	**-4,56**	**-0,09**	**-0,09**	**-0,04**	**0,02**	**0,07**	**0,13**	**0,35**	**0,41**	**0,64**	**0,69**	**0,92**	**0,97**	**1,14**	**1,14**	**1,31**	**1,31**	**1,48**	**1,48**	**2,60**
S1-S0	**-1,54**	**-0,07**	**-0,07**	**-0,01**	**0,04**	**0,10**	**0,15**	**0,38**	**0,44**	**0,66**	**0,72**	**3,94**	**1,00**	**1,17**	**1,17**	**1,34**	**1,34**	**1,51**	**1,51**	**-0,13**

IRR **20%**

Locomotive cost 3
Maintenance cost increase 1,02

VR
0 1
1 PCM revenues
1 Black fibres revenues

REVENUE +10%

Number of free 2Mb/s PCM channels	36
Average 2Mb/s PCM cost	0,0154
Number of black fibres	12
Average black fibre cost	0,00055
Number of km	309

(In millions of US $) AZERBAIJAN

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,23	0,23	0,24	0,24	0,25	0,25	0,26	0,26	0,27	0,27	0,28	0,29	0,29	0,30	0,30	0,31	0,32	0,32	0,33	0,33
Inv Loco	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4
Cash flow	**-6,23**	**-0,234**	**-0,239**	**-0,244**	**-0,248**	**-0,253**	**-0,258**	**-0,264**	**-0,269**	**-0,274**	**-0,280**	**-0,285**	**-0,291**	**-0,297**	**-0,303**	**-0,309**	**-0,315**	**-0,321**	**-0,328**	**1,106**
Project case : S1																				
Investments	7,17																			
Maintenance cost	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
Residual Value	0,00																			1,808
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,07	0,10	0,14	0,17	0,20	0,24	0,27	0,30	0,34	0,34	0,34	0,34	0,34	0,34
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,55	0,55	1,11	1,11	1,66	1,66	2,21	2,21	2,77	2,77	3,32	3,32	3,32
Cash flow	**-7,32**	**-0,15**	**-0,15**	**-0,15**	**-0,15**	**-0,11**	**-0,08**	**0,51**	**0,54**	**1,13**	**1,16**	**1,75**	**1,78**	**2,37**	**2,40**	**2,96**	**2,96**	**3,51**	**3,51**	**5,32**
S1-S0	**-1,09**	**0,09**	**0,09**	**0,10**	**0,10**	**0,14**	**0,18**	**0,77**	**0,81**	**1,40**	**1,44**	**2,03**	**2,07**	**2,67**	**2,71**	**3,27**	**3,27**	**3,83**	**3,84**	**4,21**

IRR **33%**

Locomotive cost	3		
Maintenance cost increase		1,02	
REVENUE +10%			
Number of free 2Mb/s PCM channels		22	
Average 2Mb/s PCM cost		0,0154	
Number of black fibres		12	
Average black fibre cost		0,0011	
number of km		503	

VR

0 1

1 PCM revenues

1 Black fibres revenues

(In millions of US $) **GEORGIA**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
cost	0,113	0,115	0,117	0,120	0,122	0,125	0,127	0,130	0,132	0,135	0,138	0,140	0,143	0,146	0,149	0,152	0,155	0,158	0,161	0,165
Inv Loco	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,2
Cash flow	**-3,11**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-3,13**	**-0,13**	**-0,13**	**-0,13**	**-0,14**	**-0,14**	**-0,14**	**-0,15**	**-0,15**	**-0,15**	**-0,16**	**-0,16**	**-0,16**	**2,00**
Project case : S1																				
Investments	7,06																			
cost	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14
Residual Value	0,00																			1,60
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,06	0,08	0,11	0,14	0,17	0,19	0,22	0,25	0,28	0,28	0,28	0,28	0,28	0,28
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,49	0,49	0,98	0,98	1,47	1,47	1,95	1,95	2,44	2,44	2,93	2,93	2,93
Cash flow	**-7,20**	**-0,14**	**-0,14**	**-0,14**	**-0,14**	**-0,11**	**-0,09**	**0,43**	**0,46**	**0,97**	**1,00**	**1,52**	**1,54**	**2,06**	**2,09**	**2,58**	**2,58**	**3,07**	**3,07**	**4,66**
S1-S0	**-4,09**	**-0,03**	**-0,02**	**-0,02**	**-0,02**	**0,01**	**3,04**	**0,56**	**0,59**	**1,11**	**1,14**	**1,66**	**1,69**	**2,21**	**2,24**	**2,73**	**2,73**	**3,22**	**3,23**	**2,67**

IRR **17%**

Locomotive cost	3		VR	
Maintenance cost increase		1,02	0	1
			1	PCM revenues
REVENUE +10%			1	Black fibres revenues

Number of free 2Mb/s PCM channels	18
Average 2Mb/s PCM cost	0,0154
Number of black fibres	12
Average black fibre cost	0,0011
number of km	444

(In millions of US $)

		ARMENIA		AZERBAIJAN			GEORGIA													
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Base case : SO																				
Maintenance and operating cost	0,365	0,372	0,3794	0,387	0,395	0,403	0,411	0,419	0,427	0,436	0,445	0,453	0,463	0,472	0,481	0,491	0,501	0,511	0,521	0,531
Inv Loco	12	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Cash flow	**-12,365**	**-0,372**	**-0,379**	**-0,387**	**-0,395**	**-0,403**	**-3,411**	**-0,419**	**-0,427**	**-0,436**	**-0,445**	**-3,453**	**-0,463**	**-0,472**	**-0,481**	**-0,491**	**-0,501**	**-0,511**	**-0,521**	**5,829**
Project case : S1																				
Investments	18,70																			
Maintenance cost	0,38	0,38	0,3825	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38	0,38
Residual Value	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,52
PCM revenues	0,00	0,00	0,00	0,05	0,09	0,19	0,28	0,38	0,47	0,57	0,67	0,76	0,86	0,91	0,96	0,96	0,96	0,96	0,96	0,96
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,99	0,99	1,98	1,98	2,97	2,97	3,97	3,97	4,96	4,96	5,95	5,95	5,95
Cash flow	**-19,08**	**-0,38**	**-0,38**	**-0,34**	**-0,29**	**-0,20**	**-0,10**	**0,99**	**1,08**	**2,17**	**2,27**	**3,35**	**3,45**	**4,49**	**4,54**	**5,53**	**5,53**	**6,52**	**6,52**	**11,04**
S1-S0	**-6,72**	**-0,01**	**0,00**	**0,05**	**0,10**	**0,21**	**3,31**	**1,41**	**1,51**	**2,61**	**2,71**	**6,81**	**3,91**	**4,96**	**5,02**	**6,02**	**6,03**	**7,03**	**7,04**	**5,22**

IRR **20%**

Locomotive cost 3

Maintenance cost increase 1,02

VR

0 I

1 PCM revenues

1 Black fibres revenues

REVENUE -10%

revenues -10 %

revenues +10 %

Number of free 2Mb/s PCM channels 76

Average 2Mb/s PCM cost 0,0126

Number of black fibres 36

Average black fibre cost 0,02

Number of km 1256

(In millions of US $) ARMENIA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,022	0,023	0,023	0,024	0,024	0,025	0,025	0,026	0,026	0,027	0,027	0,028	0,028	0,029	0,029	0,030	0,031	0,031	0,032	0,032
Inv Loco	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,8
Cash flow	**-3,022**	**-0,023**	**-0,023**	**-0,024**	**-0,024**	**-0,025**	**-0,025**	**-0,026**	**-0,026**	**-0,027**	**-0,027**	**-3,028**	**-0,028**	**-0,029**	**-0,029**	**-0,030**	**-0,031**	**-0,031**	**-0,032**	**2,728**
Project case : S1																				
Investments	4,47																			
Maintenance cost	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,09
Residual Value	0																			1,115
PCM revenues	0,00	0,00	0,00	0,05	0,09	0,14	0,18	0,23	0,27	0,32	0,36	0,41	0,45	0,45	0,45	0,45	0,45	0,45	0,45	0,45
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,14	0,14	0,28	0,28	0,42	0,42	0,56	0,56	0,70	0,70	0,83	0,83	0,83
Cash flow	**-4,56**	**-0,09**	**-0,09**	**-0,05**	**0,00**	**0,04**	**0,09**	**0,27**	**0,32**	**0,50**	**0,55**	**0,73**	**0,78**	**0,92**	**0,92**	**1,06**	**1,06**	**1,20**	**1,20**	**2,31**
S1-S0	**-1,54**	**-0,07**	**-0,07**	**-0,02**	**0,02**	**0,07**	**0,11**	**0,30**	**0,35**	**0,53**	**0,58**	**3,76**	**0,81**	**0,95**	**0,95**	**1,09**	**1,09**	**1,23**	**1,23**	**-0,42**

IRR **18%**

Locomotive cost 3
Maintenance cost increase 1,02

REVENUE -10%

VR
0 1
1 PCM revenues
1 Black fibres revenues

Number of free 2Mb/s PCM channels 36
Average 2Mb/s PCM cost 0,0126
Number of black fibres 12
Average black fibre cost 0,00045
Number of km 309

(In millions of US $) AZERBAIJAN

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
Maintenance and operating cost	0,23	0,23	0,24	0,24	0,25	0,25	0,26	0,26	0,27	0,27	0,28	0,29	0,29	0,30	0,30	0,31	0,32	0,32	0,33	0,33
Inv Loco	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4
Cash flow	-6,23	-0,234	-0,239	-0,244	-0,248	-0,253	-0,258	-0,264	-0,269	-0,274	-0,280	-0,285	-0,291	-0,297	-0,303	-0,309	-0,315	-0,321	-0,328	1,106
Project case : S1																				
Investments	7,17																			
Maintenance cost	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
Residual Value	0,00																			1,808
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,03	0,06	0,08	0,11	0,14	0,17	0,19	0,22	0,25	0,28	0,28	0,28	0,28	0,28	0,28
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,45	0,45	0,91	0,91	1,36	1,36	1,81	1,81	2,26	2,26	2,72	2,72	2,72
Cash flow	-7,32	-0,15	-0,15	-0,15	-0,15	-0,12	-0,09	0,39	0,42	0,90	0,92	1,40	1,43	1,91	1,94	2,39	2,39	2,85	2,85	4,65
S1-S0	-1,09	0,09	0,09	0,10	0,10	0,13	0,17	0,65	0,68	1,17	1,20	1,69	1,72	2,21	2,24	2,70	2,71	3,17	3,17	3,55

IRR 31%

Locomotive cost 3

Maintenance cost increase 1,02

VR

0 1

1 PCM revenues

1 Black fibres revenues

REVENUE -10%

Number of free 2Mb/s PCM channels	22
Average 2Mb/s PCM cost	0,0126
Number of black fibres	12
Average black fibre cost	0,0009
number of km	503

(In millions of US $) **GEORGIA**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Base case : SO																				
cost	0,113	0,115	0,117	0,120	0,122	0,125	0,127	0,130	0,132	0,135	0,138	0,140	0,143	0,146	0,149	0,152	0,155	0,158	0,161	0,165
Inv Loco	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Residual Value	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,2
Cash flow	**-3,11**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-0,12**	**-3,13**	**-0,13**	**-0,13**	**-0,13**	**-0,14**	**-0,14**	**-0,14**	**-0,15**	**-0,15**	**-0,15**	**-0,16**	**-0,16**	**-0,16**	**2,00**
Project case : S1																				
Investments	7,06																			
cost	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14
Residual Value	0,00																			1,60
PCM revenues	0,00	0,00	0,00	0,00	0,00	0,02	0,05	0,07	0,09	0,11	0,14	0,16	0,18	0,20	0,23	0,23	0,23	0,23	0,23	0,23
Black fibres revenues	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,40	0,40	0,80	0,80	1,20	1,20	1,60	1,60	2,00	2,00	2,40	2,40	2,40
Cash flow	**-7,20**	**-0,14**	**-0,14**	**-0,14**	**-0,14**	**-0,12**	**-0,10**	**0,33**	**0,35**	**0,77**	**0,79**	**1,22**	**1,24**	**1,66**	**1,68**	**2,08**	**2,08**	**2,48**	**2,48**	**4,08**
S1-S0	**-4,09**	**-0,03**	**-0,02**	**-0,02**	**-0,02**	**0,01**	**3,03**	**0,46**	**0,48**	**0,91**	**0,93**	**1,36**	**1,38**	**1,81**	**1,83**	**2,23**	**2,24**	**2,64**	**2,64**	**2,08**

IRR **15%**

Locomotive cost	3		VR	
Maintenance cost increase		1,02	0	1
			1	PCM revenues
REVENUE -10%			1	Black fibres revenues

Number of free 2Mb/s PCM channels	18
Average 2Mb/s PCM cost	0,0126
Number of black fibres	12
Average black fibre cost	0,0009
number of km	444

Chapter 2

General recommendations and methodology

General recommendations and methodology

Contents

General recommendations and methodology

General recommendations and methodology

1. Preliminary recommendations

The purpose of this chapter is to:

- specify the project context,
- outline the services to be provided,
- put forward a technical proposal, including a range of mandatory, recommendatory and informatory technical specifications,
- supply basic costs for products and systems.

1.1 Project context.

This project for linking the telecommunications systems in the TRACECA countries is part of the reconstruction of Central Asian railways. It constitutes Module E.

1.1.1 Project objectives

The aim of Module E is to examine the possibility of setting up an efficient telecommunications network within the TRACECA countries. It will also look at potential links with European railways.

Module E comprises:

- an analysis of existing telecommunications systems,
- a seminar to present the systems used in Europe,
- an action and investment plan,
- and perhaps, a training seminar on new telecommunications systems.

Chapter 1 contains a range of preliminary recommendations for the action and investment plan.

In particular, it specifies:

- the general context of the project,
- the telecommunications services to be provided, a framework of generic technical specifications (of general application, not targeted towards a specific project).

1.1.2 General context.

1.1.2.1 Investment concept model.

All investment plans stem from a logical sequence beginning with an expression of needs and culminating in implementation.

The concepting for this project is presented in Figure 1.

It shows that project implementation has to be the best possible trade-off between the needs of the railway operator, expressed in terms of traffic and the corresponding installations, and investment possibilities.

General recommendations and methodology

The concept complies with the need for a strict separation of the tasks of project developer and prime contractor:

- The project developer has a particularly important role. He:
  - voices the needs of the end user,
  - manages the financial resources,
  - fixes the schedule of work.
- The prime contractor implements the project within the framework set by the project developer.
- The choice of prime contractor is crucial to the success of the project.

This point is explained in greater detail in Sections 1.1.5. and 1.3.3.3.1. of this chapter.

1.1.2.2 Uncertainty over needs.

Current and predicted levels of traffic have been analysed extensively in the other modules. They are relatively well defined.

The funding available and investment potential are known to some extent.

However, the translation of needs into railway installations is not precise enough. For example, should installations be repaired or replaced by their exact equivalent or should they be rationalised and adjusted in accordance with predicted traffic levels?

While such uncertainty does not seriously affect the main choices to be made regarding the architecture of the telecommunications networks and technologies, it does have a major impact on the Action Plan.

At all events, it is essential to consult the railway operators in order to achieve consensus on the needs of the programme of operating requirements and the corresponding technical requirements.

1.1.3 Financial context.

One of the most important parameters of a project is its funding. Investors play a crucial role because their involvement is contingent upon an in-depth analysis of the sums to be invested, the return on investment and the financial guarantees needed for the project.

The architecture of a telecommunications network is clearly a compromise between the needs expressed and funding possibilities:

- The needs depend on the state of the network (available telecommunications services, quality of service, ease of maintenance and obsolescence),
- Funding possibilities depend on income from rail traffic and investment potential, which may involve loans that have to be guaranteed by the railways. So funding depends on their solvency.

Financing railway infrastructure is a fast changing arena in Europe today as a result of EU directives requiring a separation, at least in accounting terms, between infrastructure managers and railway operators for passenger and freight, etc.

Funding is no longer systematically channelled via the State, and new forms of finance have resulted from structural changes such as the creation of subsidiaries and privatisation.

Thus, the relationship between railways and telecommunications operators can take one of the following, very diverse forms:

- concession of right of way on railway territory,

- co-funding of cable laying,
- laying of separate cables in railway ducts,
- laying of cables by one party and use of part of the cable by the other party,
- provision of bearer and end-to-end telecommunications services by one party for the other party,
- allocation of entire sections of a network (cables, transmission equipment, switches) by one party to the other party.

1.1.4 National legal context.

Prior to any proposal to develop telecommunications networks, it is crucial to make a careful examination of national regulations governing telecommunications and, more importantly, those pertaining to railway telecommunications.

This is particularly important as regards the possibilities of setting up subsidiaries or privatising, as mentioned in Section 1.1.3 "Financial Context".

1.1.5 Legal context of the project.

- The project is to be put out to tender on the basis of administrative, financial and technical specifications.

This procedure exceeds the framework of Module E, as does the scope of the invitation to tender (which may be national or multinational).

- It is strongly hoped that the specifications will be based on a detailed statement of needs and technical specifications which are both:

- precise as regards:
  - the environment and
  - interfaces between telecommunications networks in order to ensure interoperability,
- and flexible as regards:
  - technical solutions,
  - the network architecture and
  - the potential to expand the network as telecommunications needs grow.

- Bibliographical reference [1] advocates a "turnkey" contract, with the contracting party being supervised by an experienced consulting firm which must be selected on the basis of an invitation to tender.

We agree with this recommendation: it has the advantage of awarding general project management to one single entity and prevents the project developer from being involved in decisions for which the prime contractor should be responsible.

The prime contractor should be given free range to specify how the project is to be organised, decide on any sub-contracts and choose his/her staff.

Notwithstanding, the contract should specify that the railways' telecommunications employees are to be trained so that they can later maintain the installations.

- It is essential to set up a project organisation including railways representatives of all levels of responsibility.

1.2 Services to be provided.

On the whole, railways make extensive use of telecommunications services in all areas.

There are generally considered to be three categories of telecommunications services:

General recommendations and methodology

- railway signalling (train headway and protection of train running - signalling telecommunications),
- railway operation (traffic control, energy, stations, depots, etc. - railway operating telecommunications),
- applications (traffic supervision, passenger, freight, invoicing, maintenance, etc. - applications telecommunications).

1.2.1 Signalling telecommunications

Signalling is not actually part of Module E.

Nonetheless, it directly affects the type and capacity of telecommunications systems used, cables in particular.

For this reason, signalling can not be disregarded.

We found the report listed in bibliographical reference [4] to be of particular interest.

1.2.1.1 Train detectors.

- They detect the presence of rail traffic on a given track section.
- The most commonly used detector is the track circuit (this appears to be the case in Transcaucasian and Central Asian countries)

The use of track circuits for detection is limited by transmission attenuation in the rail and by railway operating considerations.

The maximum distance is about 2,200 m for frequency track circuits and roughly 2,800 m for pulse coded track circuits.

- Rail traffic may also be detected using an axle counter, which counts and counter-checks the number of axles in a moving train.

There is no maximum physical distance for the use of axle counters.

- In and around stations, track circuits are a necessity.

On open track, axle counters and track circuits are in competition and the choice made will depend on required line throughput and costs.

1.2.1.2 Block systems.

- Train spacing involves a succession of zones commonly called block sections.

The block is the system comprising all the equipment which guarantees this spacing.

- There are many types of block, requiring varying amounts of equipment and procedures.
- The resulting throughput (i.e. the number of trains circulating on the track per unit of time) varies according to the block type used.
- The block system also determines the safety level.

1.2.1.3 Types of block

The ideas outlined in this section are based on material taken from bibliographical reference [3].

They therefore correspond to the signalling systems used by SNCF, although the same underlying principles are generally applied on other railways.

- The block type is usually directly related to the importance of the line (on all counts: resources obtained from traffic, public service function, strategic importance, etc.).

Block types can be classified as follows:

- Manual telephone blocks .

The two signal boxes at either end of the block section are linked by telephone (cf. below, dedicated safety line - 1.2.2.1 and 1.2.2.2).

The signalman at the entry point releases the entry signal (which may only be a simple manual stop signal), once the signalman at the exit point informs him/her that the entire train has left that block section. This type of block involves exclusively the application of written regulations via telephone communications.

It is reserved for lightly trafficked lines (maximum of a few trains per day).

- Manual blocks per equipment or interlocked blocks.

The two signal boxes at either end of the block section are electrically connected and have electromechanical devices which are manually controlled but do have some interlocks (the lever of the entry signal is locked electro-mechanically on closure, when the block section is occupied; the release signal is activated manually from the downline signal box but sent electrically and generally used in conjunction with a treadle or some other form of electrical override device monitoring train movements).

This type of block also has a telephone link so that measures can be taken in the event of unusual operating conditions or disruptions.

Manual blocks are only used on lightly trafficked lines.

- Automatic blocks, i.e. where block sections are controlled automatically.

It is current practice today to distinguish between two types of automatic block

- the short-section permissive automatic colour-light block (ACLB), which is installed when daily traffic approaches or exceeds 100 trains for both directions for a double track line or 40 trains on a single-track line.

  The maximum block section length is 2,800 m so that a driver does not forget the order given him at the entry to the block section.
- the long-section partly permissive automatic block (PPAB) for lower throughput lines. Block sections are long (minimum 6 km).

1.2.1.4 Role of telecommunications.

- It is crucial to remember that the transmission of safety information must be failsafe

- In and around stations, the role of telecommunications is to transmit signalling information (status of track circuits, position of switches, etc.) needed for the train spacing and protection functions of the signal boxes.

- On the open track, the role of telecommunications is:

- either to send signalling information (status of track circuits, etc.) back to the signal boxes in order to guarantee headway (in an absolute block where an entire line is covered by the signal boxes),
- or to send signalling information (status of track circuits, etc.) back to the lineside equipment centres and to exchange signalling information between these centres (in a permissive block where the entire line is not covered by the signal boxes).

- Extensive use is still made of fully dedicated signalling cables.

1.2.2 Railway operating telecommunications.

1.2.2.1 Types of Service.

- The term "Railway operating telecommunications" covers all telecommunications services directly involved in running trains.

- **It is essential to bear in mind that it is railway operating modes that have shaped railway operating telecommunications**. A change in the technology used may alter a service and thus the operating mode. Such a change requires prior consultation with the operators (who therefore act as project developers in this regard) on all aspects including costs.

- These services provide various links for the operations and energy functions, i.e.:

- operating and energy control,

- signals, switches, level crossings, significant points,
- station-to-station dedicated telephone lines for safety,
- dedicated telephone lines for track works crews,
- relay of alarms, track and OHL maintenance,
- ground-to-train radio,
- shunting radio,
- maintenance, incidents and track site radio,
- local radio,
- various lines,
- loud-speaker equipment at small stations,
- etc.

1.2.2.2 Types of communication.

- Most services are provided by telephone but data transmission is catching on for identification, vehicle location and emergency alarm purposes.

- Railway operations involve a wide range of voice communications services.

- They include:

- point to point,
- point to multi-point in a given geographical area (e.g. call from the traffic controller to all trains within a control block, a line section or the entire line),
- point to selective multi-point in a given geographical area (e.g. call from the traffic controller to all trains of a given type within a control block, a line section or the entire line.),
- broadcast (warning, loud-speaker equipment in small stations).

- Conventional switched telephone networks (STN) are essentially point-to-point systems, which means there is a certain amount of duality between railway operating telephone links and STN.

<u>NB:</u>

Some railways require services which involve the installation of lineside telephones or sockets at typical intervals of a few hundred metres (e.g. power alarm telephones on SNCF electrified lines, located every 500 m, or telephone sockets for the dedicated track works communication system on new SNCF lines).

At SNCF, these functional constraints are not due to traffic control as such.

Nowadays, for economic reasons, these services are based almost of necessity on the use of copper cables.

Other services required may have a similar impact on the technology used. It is therefore vital to consult with the railway operator (and other customers, such as the power supply division) in order to gain a precise idea of all services required.

<u>This is a crucial step since it has an impact on whether or not copper cables will be used</u>.

1.2.2.3 Performance criteria.

- An important characteristic of railway operating links is their performance levels and the high availability demanded by railway operators.

After safety, the operators' prime concern is to move their trains through at all costs.

- The access times required vary from a few hundred milliseconds to a maximum of a few seconds. This is because any wait or malfunction results in delays which directly affect customers and therefore undermines the operator's image.

- Very high availability is required on some links.

Consequently, the dedicated safety line is the last resort for moving a train from one station to another in the event of failure in the signalling system.

1.2.3 Applications telecommunications.

The past three decades have seen an explosive, sometimes uncontrolled development in computer applications for the transfer of data directly and indirectly linked to the railway business: traffic control, passenger and freight services, invoicing, maintenance, management information systems, etc.

In this, the rail mode is simply following a universal trend.

In the telecommunications area this has resulted in a move towards high transmission speeds and a proliferation of telecommunications installations.

At the same time, greater demands are being placed on transmission quality and network security.

To meet these demands, railways are applying a variety of solutions:

- use of the switched telephone network,
- X25 packet-transmission networks dedicated to railway data transmission applications,
- use of frame relay, or ATM (Asynchronous Transmission Mode),
- establishment of Local Area Networks (LAN) or Wide Area Networks (WAN),
- lease of circuits from the public operator,
- and perhaps in the future: Internet

The role of telecommunications is to make IT applications available and supply data transmission services with high throughputs and the requisite transmission quality.

1.3 Technical proposal.

1.3.1 Technological development.

1.3.1.1 A growth market.

- Generally speaking, telecommunications networks are developing at a rapid pace today, spurred by market demand for transmission of increasing volumes of information at ever faster speeds.
- This trend provides an incentive for technological development, one of the by-products of which is the rapid obsolescence of existing equipment.

1.3.1.2 Rapid renewal of equipment.

- It is now common for perfectly functional generations of equipment to be replaced by new, more sophisticated generations with lower life cycle costs (investment and use).
- Although such methods are the rule among telecommunications operators, they are somewhat of a culture shock for the railways who more are used to making their equipment last as long as possible.
- The railways must join the trend.
- This does not rule out the possibility of gradual migration or changes introduced on a stage-by-stage basis, with the discarded items being cascaded and used for spare parts, in particular in railway sectors less affected by the boom in requirements. A good case in point is railway operating telecommunications. Most railway companies today operate in this way if only out of financial motives.

General recommendations and methodology

1.3.1.3 Move towards digital technology.

- This has become an irreversible trend.

The productivity enhancements it allows and the resulting cost reductions, both for manufacturers and users, are such that it would be suicidal to envisage any solution other than digital technology.

1.3.1.4 Move towards optical fibre transmission media.

- Optical fibres are the only solution to meet demand for high transmission speeds.

- There are no problems with the use of optical fibres for :

- railway operating telecommunications,
- application telecommunications.

- By contrast, where signalling telecommunications are concerned, their use needs to be subjected to closer examination

This matter will be dealt with later on in this report;

1.3.2 Telecommunications network architecture.

1.3.2.1 Principles.

- The architecture of the telecommunications networks of railways in Georgia, Azerbaijan and Armenia has already been studied in depth.

- Bibliographical reference [1] is of particular interest.

This refers to a critical analysis of the paper shown under bibliographical reference [5] and includes a number of proposals (cf. summary in Chapter 3);

In summary, on the Baku - Tbilisi - Poti and Tbilisi - Yerevan routes (i.e. 1,225 km):

- The TEWET company suggests laying a 12 optical fibre cable hosting 30 channels (30-channel PCM) i.e., a bit rate of 2 Mbit/s.
- In bibliographical reference [1], F.W. Krämer proposes immediate adoption of SDH architecture (synchronous digital hierarchy) with a 155 Mbit/s bit rate (i.e., a STM1) and an active capacity of 120 telephone channels.

- An analysis of railway telecommunications networks currently being set up (for example on SNCF, PKP and ÖBB) shows that these railways are opting in favour of a two-tier structure:

- the first of SDH type with 155/622 Mbit/s.
- the second of PDH type with 2/8 Mbit/s.

cf., for example, bibliographical reference [2].

- The final say as regards architecture will be given to the telecommunications network operator.

It would nevertheless seem clear that the best starting approach would be one based on an SDH "backbone" network, initially on a very small scale, (155 Mbit/s STM1), as a support for a 2 Mbit/s drop-and-insert PCM PDH network (cf. Figure 2 for block diagram).

This solution is not only in tune with technological developments but also offers the necessary flexibility to provide a proper service in areas where railway installations are grouped heavily together (major centres) and to the smaller and medium-sized locations scattered along the various railway lines.

Bibliographical references [10] and [11] contain useful information about SDH technology.

General recommendations and methodology

1.3.2.2 Network back-up.

- Network back-up is a constant concern in the telecommunications sector.

It forms the leitmotiv of the TRACECA project with its telecommunications package (cf. references [1] and [4] for example).

- The need to ensure network back-up is largely dictated by quality of service considerations.

It is important to remember that quality of service standards is an indicator sine qua non for contracted telecommunications services.

This is increasingly true, even between entities that are part of the same company, and therefore all the more so between entities belonging to different companies (or when the contract involves a railway operator and a telecommunications operator).

- Availability is the most commonly applied quality-of-service indicator.

Availability refers to the probability of a given system operating in a given environment being available at a given moment in time.

It may take different forms.

For example:

- In the early 90s the Swedish railway administration (BV) required an availability rate of virtually 100 % and a maximum outage time of less than 3 hours in a given 3-year period (a severe constraint requiring ring-shaped network back-up).

- In relation to its subsidiary "Télécom Développement" the SNCF will undertake a commitment only with regard to the following MTTR:

=< 6 hours for transmission equipment,

=< 18 hours for cables (a reasonable objective for a 36-fibre cable, far more difficult to attain for 144-fibre cables).

- The SNCF is committed to the following availability levels for the radiocommunications operator, SFR:

99.95 % for redundant circuits,

99.0 % for non redundant circuits.

- The most common type of redundancy is a ring-shaped structure. This consists of linking both ends of a transmission medium (in the broadest sense of the term) which means that it is possible to have access to transmission equipment via two different transmission links.

Back-up of this nature is not without cost and may require duplication of all transmission media, namely duplication of cables. Because of the cost, it is often necessary to proceed in two stages, with the back-up only being provided if the availability targets are made more stringent (cf. for example [1]).

By way of illustration, the block diagram in Figure 2 shows:

- a loop between the end D of the 2 Mbit/s circuit and input B on the following SDH equipment forms a ring-shaped structure (apart from the common failure modes of the cable).

- the link between D and A of the 2 Mbit/s circuit by means of a pair of additional fibres offers partial protection for this circuit (for all failures in the transmission equipment as such, with the exception of the common failure modes of the cable).

In conclusion:

- Telecommunications network back-up has to be a compromise between quality of service and financial considerations.

- The possibility of using redundant techniques for part of the network and moving gradually from non redundant to redundant circuits should not be rejected out of hand.

1.3.2.3 Flexibility.

- Telecom networks should be capable of expansion.

. One important criteria therefore in judging network architecture is its flexibility, in other words its ability to evolve rapidly over time and at the lowest possible cost to adapt to demand.

It is necessary therefore:

- to be able to move gradually from a 30-channel drop-and-insert PCM-only architecture to an SDH architecture. This is in line with the recommendations of [1] and [6].

- for the internal structure of digital transmission equipment to be modular to cater to increases in transmission capacity by simply adding other basic modules and parameter adjustments.

1.3.3 Technical specifications.

These consist of:

- Mandatory specifications marked with (M) (Mandatory),
- Recommendatory specifications (R),
- Informatory specifications (I).

When it comes to telecommunications, it generally makes sense to follow the recommendations published by the telecommunications standardisation unit of the International Telecommunications Union (ITU-T) (M).

1.3.3.1. Signalling telecommunications.

1.3.3.1.1. The context is set out in § 1.2.1. **(I)**

1.3.3.1.2. One particular problem is that of theft of the copper used in signalling and telecommunications installations.

Should this be replaced by the same or should a new system be adopted perhaps even in a new railway operating context ?

One example:

- should track circuits and copper cables be replaced with the same ?
- or should a new block spacing system be used based on the use of optical fibre transmission, following rationalisation of railway installations - closure of a railway location: station, etc. ?

This is a technical and economic problem which goes far beyond the mere issue of technical specifications. A few examples may however be helpful:

1. For its new lines, the SNCF uses automatic block with short block sections but no wayside colour-light signals as a basis for TVM 300 and TVM 430-type ground-to-train transmission. This block system uses coded track circuits.

Two separate cables are employed:

- the first is a copper cable which serves to pass signalling data (status of track circuits, etc.) back to lineside equipment centres.

This solution is still the most economical today, in particular as regards its interfaces with signalling equipment and cable branches.

- The second cable is an optical fibre cable and is used to transmit:
  - signalling information between lineside signalling facilities, located every 12 km at the minimum).

- railway operation telecommunications circuits,
- telecommunications circuits used for applications,
- other available telecommunication circuits which may be leased or may belong to telecommunications operators.

2. The Swedish Rail Administration (BV)(Banverket) envisaged the possibility in as early as 1991 of transmitting block information using optical fibres. Cf. bibliographical reference [7] in which 2 fibres are dedicated to this function.

The technique is now used for double track automatic block. By contrast, for single track lines, the transmission medium used for signalling is still the copper cable.

BV considers that copper cables remain the most economical solution for transmitting small volumes of data over short distances (typically the case with signalling installations in station areas and with short block spacing systems) and that optical fibres are the most cost-effective answer for major data flows over longer distances.

3. The Danish Rail Administration (Banestyrelsen) uses a block system for train spacing based entirely on optical fibre transmissions (cf. bibliographical reference [12]).

A transmission system transmits data between the various sites using a dedicated pair of optical fibres. The bit rate is 2 Mbit/s. Interfaces are in compliance with ITU standard G 703/704.)

In addition to the headway function, the link acts as a host for 4 telephone channels available on each of the sites concerned. These telephone channels can be connected to a central PABX.

4. In a conversation with CIE-Consult concerning bibliographical reference [4], mention was made of the possibility of using a track circuit, not just to perform the standard function of detecting vehicle presence but also to ensure low speed transmission through the rails.

This is an interesting idea but it raises the problem of electrical separation joints and detection of broken rails. If this latter function is not required, track circuits may have greater scope, but:

- transmission power has to be increased (copper is needed for this),
- there is the risk of crosstalk between consecutive blocks (alternating A-B frequencies). An adequate buffer has to be provided and very carefully designed electrical joints.

N.B.: some countries do not require the broken rail detection function. In such cases, if the first break is not detected, a second break may result in a loss of transmission between the two breaks if track circuits are used. This constitutes a wrongside failure.

Another idea is to use pulse coded circuits rather than frequency circuits. These have a broader range but also have their limitations:

- because of their transmission power,
- because of the greater attenuation of the direct wave than of the backward wave, which places limitations on the discriminator.

The idea suggested by CIE-Consult will not subsequently be considered in that it falls outside the scope of the telecommunications study.

5. CIE-Consult also pointed out that from a cost angle, there would be a threshold at about 20 km, below which track circuits would be more advantageous and beyond which axle counters would have the edge. This threshold could be higher, however, for track circuits of Russian manufacture which are cheaper and less sophisticated.

In conclusion:

1.3.3.1.2.1. Transmission of signalling telecommunications must be fail-safe. **(M)**

The corresponding proof of safety shall apply to the whole of the signalling system: transmitter, transmission, receiver. **(M)**

1.3.3.1.2.2. For transmission of small volumes of signalling information over short distances, copper cables are the preferred solution **(R)**

1.3.3.1.2.3. Consideration should, however, be given to a block system based on optical fibre transmission which could prove an interesting alternative. **(R)**

1.3.3.1.2.4. For the transmission of large volumes of data over longer distances, the preferred transmission medium is optical fibre cables. **(R)**

1.3.3.1.2.5. The choice of transmission medium for signalling data depends on the cost of signalling and telecommunications equipment, equipment performance standards, their age, state of wear and tear and the risk of vandalism **(I)**

1.3.3.1.2.6. In cases where railway installations - and more particularly the block signalling system - are to be thoroughly overhauled, it is better to opt for interlocking signalling block sections (short-section automatic colour-light block system (ACLB), long-section partly permissive automatic block (PPAB), manual blocks per turnout or interlocked blocks).

Use of the manual telephone block should be the exception (lightly trafficked lines or downgraded operation of other types of block system). **(R)**

1.3.3.2. Railway operating telecommunications.

1.3.3.2.1 As explained in 1.2.2.1., some services used for railway operating telecommunications purposes may impose major constraints which require a solution based on the choice of copper transmission cables.

Discussions with operators are therefore essential to reach an "operating requirements - technical solution -cost" compromise. **(M)**

1.3.3.3. Transmission cables

This section deals exclusively with terrestrial cables. Underwater cables are discussed in another specific chapter.

1.3.3.3.1. Choice of prime contractor

1.3.3.3.1.1 The contractor selected must have excellent references for the manufacture, laying and connection of transmission cables in a railway environment. **(M)**

1.3.3.3.2 Type of cable.

1.3.3.3.2.1. Transmission using optical fibre cables is a speciality in itself. Detailed specifications for an optical fibre cable should contain a large number of parameters. It is worth consulting bibliographical reference [8] on this point. It is therefore a matter for professionals.

A minimum of requirements should however be set out. These are dealt with the following paragraphs. **(I)**

1.3.3.3.2.2. Leaving out the specific case of signalling telecommunications described in 1.3.3.1 and railway operating telecommunications described in 1.3.3.2, the obvious and imperative choice is optical fibre transmission cables. **(M)**

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1.3.3.3.2.3. Optical fibres shall be of the single-mode variety and be capable of being set for transmission frequencies of 1,300 nm and 1,550 nm these being the frequencies most commonly used by industry. **(M)**

Conformity shall be sought with the ITU-T recommendation G 652 "Characteristics of a single-mode fibre cable" **(M)**

It is advocated that a WDM cable be used in so far as is possible.

1.3.3.3.2.4 The **type of cable** chosen will depend on the following constraints:
- railway line characteristics (topography, geology),
- the type of electrification used on the line (d.c. or a.c.), if relevant.
- weather conditions if the cable is not buried in the ground (range of temperatures, rainfall and humidity, maximum wind speeds),
- particularly environmental conditions if the cable is not buried (salty atmosphere, chemical pollution),
- the volume of information to be transmitted,
- the telecommunications services needed,
- the cable-laying technique.

There is therefore no one single solution.
The prime contractor must be obliged to justify the type of cable he chooses in relation to the above-mentioned factors. **(M)**
- ability to withstand high crush loads in accordance with the IEC-794-E3 standard,
- ability to withstand load voltages in accordance with the IEC-794-E1 standard
- operating temperature range of -30 to +70°C (storage at -40 to +70°C, installation between - 10 et +50°C),
- sufficient strength for laying in an environment as harsh as that of an embankment,
- adequate strength to withstand vibrations,
- suitability for the requisite laying technique,
- if necessary, bearing a marking on the outside to identify it and distinguish it from the other cables,
- completely dielectric under a d.c. electrified line (case of many lines on the Transcaucasian and Central Asian networks electrified to 3,000 V=),
- longitudinal impermeability.

All these features carry a mandatory weighting. **(M)**

1.3.3.3.2.5. In general, it is recommended that manufacturers' standard cables be selected. **(R)**

1.3.3.3.2.6. Fibre attenuation measured by means of a calibrated light source (laser) and a meter for measuring the power between the fibre contacts, including losses at the connector, shall not exceed:
- for a wave length of 1,550 nm:
  - 0.25 dB/km over long distances,
  - 0.30 dB/km over short distances,
- for a wave length of 1,300 nm:
  - 0.45 dB/km over long distances,
  - 0.45 dB/km over short distances. **(M)**

1.3.3.3.3 Cable laying.

1.3.3.3.3.1 Cabling is not just a matter of purchasing a cable and laying it as such. It is an operation which must be viewed as a whole and shall include the following phases. **(M)** :
- staking out (showing exactly where the cable is to go),
- supplies (cable and accessories),
- civil engineering,
- cable laying as such,

- connection.

Price quotations shall cover all these items. **(M)**

In the rest of this text, the word "laying" is used in the broadest sense of the term and covers all the above-mentioned aspects.

1.3.3.3.3.2 Cables may be installed in 4 different ways.

1.3.3.3.3.2.1 Aerial cable under d.c. electrified line (for example 3,000 V =) (type A).
The cable shall be dielectric. **(M)**
It is advisable for the cable to be protected as far as possible, for example against gun shots. **(R)**
The cable may be laid without de-energising the overhead contact line. **(I)**
This type of cable is vulnerable to wind and ice. **(I)**

1.3.3.3.3.2.2. Aerial cable under a.c. electrified line (25,000 V, 50 Hz) (type B).
The cable may also have a steel wire for tensioning purposes. **(I)**
It is advisable for the cable to be protected as far as possible, for example against gun shots. **(R)**
To lay the cable, power to the overhead line shall be cut off. As a result, the cost of installing the cable varies considerably, depending for the most part on the duration of the power cut. **(M)**
This type of cable is without a doubt vulnerable to wind and ice. **(I)**

1.3.3.3.3.2.3. Cable laid in duct (type C).
The problem of rodents must be borne in mind. **(M)**

1.3.3.3.3.2.4. Buried cable (type D).

For a longer life span (some 50 years), cable shall be buried 50 - 60 cm underground in temperate climates. A depth of 70 - 100 cm may be necessary in Nordic countries. **(M)**
This guarantees stability of performance. **(I)**
It should be possible for the cable to be buried directly in the soil.
The problem of rodents shall be borne in mind. **(M)**
In addition, the new cable shall be laid at least 30 cm away from existing cables **(M)**
A better solution is to lay the cable in the soil in a tube (for example a 27/33 tube for a 16.5 mm cable). **(R)**
By using self-lubricating tubes combined with suction it is possible to achieve service ranges of 2 x 2,400 m or as much as 9,600 m in future. **(R)**

1.3.3.3.3.3. Choice of laying technique.
- Railways have always preferred underground to aerial cables. **(I)**

Better reliability is achieved in this way **(I)** :

- absence of potential problems due to wind, ice, gun shots,
- less risks from civil engineering works,
- none of the potential risks of falling trees.

Conversely, there is the problem of rodents that shall be borne in mind. **(M)**
Cables have a longer life span as a result. **(I)**
As one of the speakers at the TRACECA seminar in Warsaw said **(I)** :
"a happy fibre is a cold dry fibre,
an unhappy fibre is a hot damp fibre"
- Increasingly however railways and telecommunications operators are prepared to take the risk of laying aerial optical fibre cables. **(I)**

In conclusion:

- **It is recommended that cables be buried wherever this is cost-effective.** Cost-effectiveness should be judged on the basis of paragraph 1.3.3.3.3.1 . **(R)**

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- For crossing stations, it is better for cables to be buried or laid in ducts. **(R)**
- It is likely that the best solution may be a combination of the different laying techniques. Aerial cables would be best used in the open track and buried or ducted cables in station areas, on bridges, in tunnels, etc. **(I)**

1.3.3.3.3.4. Some 3 to 5 m of extra cable should be provided at all points to be served (now or later). These spare cable lengths should be left as a loop with a radius of at least 15 times the cable diameter (or other value to be specified by the manufacturer)

This shall also be done at specific points such as bridges, tunnels, transmission amplification points, maintenance points, etc. **(M)**

1.3.3.3.3.5. In general, cables are delivered on drums and are several km long.
Cable ends are then joined by splicing.
Splice attenuation must not exceed:

- 0.08 dB on average,
- 0.15 dB maximum. **(M)**

1.3.3.3.3.6. Price quotations shall cover the equipment needed to weld the fibres and the reflectometers to check the standard of the splice and pinpoint the source of any incident. **(M)**

1.3.3.3.4 Cable connections.

1.3.3.3.4.1. As far as possible, user needs should include details of all places where transmission equipment is to be connected up to the cable. It is strongly recommended that cables be provided with drop-and-inserts at the time of laying rather than having to provide expensive connections later.
This should, in particular, be done in all stations designated by operators, even if the actual connection is not immediately required. **(R)**

1.3.3.3.4.2. A block diagram of a drop-and-insert arrangement is shown in Figure F3. The following remarks apply:

- It is better to group together the cable as a whole at the end of the optical cable in the station so that welds may be made before the cable end (Figure 3A), rather than at the junction box (Figure 3B). **(R)**
- When the connection is not immediately required, an optical connector should be fitted in accordance with Figure 3C. **(R)**

- In general, at the junction point, all the fibres of the cable in the same tube should be cut and those not used should be welded to the junction point. Cable tubes not concerned are not to be cut. **(I)**

1.3.3.3.5. Cable capacity.

1.3.3.3.5.1. This point is of paramount importance for the project, given that:

- it has enormous impact on the financial cost of the project,
- it reflects the strategy of the railway company in relation to its telecommunications requirements,
- it reflects the position of the project in relation to public and/or private telecom operators.

1.3.3.3.5.2. Various cable capacity examples could be given **(I)**:

- Bibliographical reference [5] proposes a cable with 12 optical fibres (o.f.) for the TRACECA project.
- The BV network (bibliographical reference [7]) has 24 optical fibres per cable.
- The Polish railways' telecom network (PKP) uses cables with 12 to 18 optical fibres (bibliographical reference [9]).
- Developments as regards the number of optical fibres in the transmission cables used by SNCF on its new lines (LN) are particularly revealing:

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- ON LN3 (Paris - Lille - Channel Tunnel portal - Belgian border) 8 o.f. were used (including 4 for drop-and-insert PCMs in each railway location, 2 for the intermediate 8 Mbit/s PDH and 2 for the 140 Mbit/s PDH). If the LN3 transmission network were to be designed from scratch today, there would be no intermediate 8 Mbit/s PDH and the 140 Mbit/s PDH would be replaced by a 155 Mbit/s STM1 SDH, i.e. a total of 6 o.f..

- On LN5 currently under construction (Valence - Marseilles - Montpellier), two transmission cables are planned:
- The first, a buried 36 o.f. cable, in which:
  - 12 fibres are for SNCF i.e.:
    - 6 o.f. for basic needs (as for LN3 if the decision were made today, it would be an SDH backbone network) plus 6 fibres in reserve:
      - 2 for the radio frequency/optical fibre (RF/OF) interfaces needed for the ground-to-train radio,
      - 2 for the future UIC cellular, digital, multiservice interoperable radio (still referred to as the railway GSM or GSM-R),
      - 2 o.f. in reserve.
  - 24 fibres for the needs of the SNCF "Télécoms Développement" subsidiary and CEGETEL.
- The second cable is an aerial cable. It is in fact an Optical Aerial Protection Cable (CDPAO) and is used for earthing signalling, telecommunications and energy equipment. The cable has a steel core (electrification = 25,000 V - 50 Hz type). The "telecommunications capacity" of this cable is 72 o.f., all for use by the subsidiary, "Télécoms Développement".

From these various examples a number of conclusions and the following recommendations may be drawn :

- a minimum of 12 fibres are necessary for the telecommunications requirements of railway companies, **(R)**
- a minimum of 12 further fibres are desirable to allow for sale of transmission capacity and added value service or for associations with public or private telecom operators, i.e. a total of **24 fibres**. This may be considered the preferred solution. **(R)**
- In the event of prospects for very close cooperation - financial in particular - with one or more public or private telecom operators, an additional 12 or 24 fibres - if not more - may be requested by the operators, i.e. a total of 36 to 48 fibres. **(R)**

1.3.3.4. Telecommunications network.

1.3.3.4.1. Digital transmission equipment.

1.3.3.4.1.1. A deliberate choice shall be made to adopt digital technology. **(M)**

1.3.3.4.1.2. The new telecom network shall be able to be built up progressively.
As far as possible, old analog transmission circuits should be able to be connected up to the new digital transmission equipment. **(M)**
This may require the use of telephone signal adapters.

1.3.3.4.1.3. The architecture proposed in Figure 2 is recommended.
It consists of an SDH 155 Mbit/s (STM1) backbone network supporting a PDH 2 Mbit/s network. **(R)**

If necessary, manufacturers may install PDH networks with a capacity of more than 2 Mbit/s **(R)**

1.3.3.4.1.4. In general, the standards and recommendations of the ITU-T, CCITT and ETSI (European Telecommunications Standards Institute) shall be applied. **(M)**

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1.3.3.4.1.5. Some railway lines may be equipped with 2 Mbit/s PDH without immediately being connected up to the SDH equipment.
It shall be possible to migrate later from PDH to SDH, in accordance with the principle illustrated in Figure 4. **(M)**

1.3.3.4.1.6. One important factor is the range of digital equipment.
- At present, the maximum transmission distance without repeaters is approximately 200 km, which still needs a power booster. **(I)**
- In practice it is imperative to be able accurately to detect the position of a broken fibre by means of a reflectometer (N.B.: reflectometer accuracy diminishes with distance), whence the need for intermediary cutoff points. **(M)**
- A normal distance between consecutive PDH equipment is some 50 - 70 km, depending on the wave length used. **(R)**
- A normal distance between SDH equipment is some 70 - 100 km, depending on the wave length used. **(R)**
- The prime contractor shall indicate the attenuation (power budget) he guarantees (in accordance with recommendation G. 957 of ITU-T). **(M)**
By way of example, typical values are in the 25 to 30 dB range. **(I)**

1.3.3.4.2. Quality of service.

Quality of service shall be quantified on the basis of the ITU-T recommendation with the reference G.826:
"Error performance parameters and objectives for international constant bit rate digital paths at or above the primary rate" **(M)**

1.3.3.4.3. Network security.

1.3.3.4.3.1. Telecom network back-up is a compromise between quality of service objectives and financial constraints. **(I)**

1.3.3.4.3.2. It is recommended that telecom services and equipment be classified in relation to the required level of back-up, i.e.:

- no redundancy,
- partial redundancy,
- full redundancy. **(R)**

1.3.3.4.3.3. As far as possible, redundancy should be avoided or partial redundancy selected. **(R)**

1.3.3.4.3.4. When full circuit redundancy is required, rather than duplicating cables systematically, there should be no hesitation about using back-up circuits, or even replacement services provided by public or private operators. **(R)**

1.3.3.4.4. Network management.

1.3.3.4.4.1. Telecom networks need to be monitored from a central point. The telecom network provided by the prime contractor must have a Network Management System. **(M)**

1.3.3.4.4.2. The functions to be performed by the management system are set out in bibliographical reference [2].
They relate to:

- network management as such i.e.:
  - performance measurement:
    - traffic on the network,
    - quality of service indicators,
  - failure management:
    - network disruptions,

- network failures,
- errors in the network,
- network security (activation of redundancy back-ups),
- network configuration management:
  - for equipment and when in and out of service,
  - as regards the parameters set for the equipment,
- charging for services.

All these functions shall be provided. **(M)**

1.3.3.4.4.3. The management system is usually a proprietary system.

For the most part, telecom systems to date have developed independently and a variety of different networks co-exist, each with or without their own management systems.

This is better than having no management system at all but it does make finding failure harder especially when several networks are affected at the same time (common failure modes).

Moreover, there must be two different managers: one for the backbone network (STMi), the other for the local networks. **(M)**

It is therefore recommended that a measure of integration be sought, namely through the use of Q type standard interfaces. As an example a Q3-type operating interface is recommended in bibliographical reference [10]. **(R)**

The prime contractor shall supply a detailed description of the management interface used. **(M)**

It should be remembered that an interface depends entirely on:

- its mechanical connections,
- the electric signals exchanged,
- the telegrams interchanged,
- the protocols used. **(I)**

Operating system software is proprietary. In the long term, it is advisable to use a QX interface enabling networks from a variety of manufacturers to be managed from a central supervisory point. **(R)**

1.3.3.4.4.4. Where network management is concerned, the pitfall of over-centralisation should be avoided at all costs. What is important at national level is not exactly the same as what is important at regional level. For large railway networks, it is therefore recommended to have not just a national network management centre with all the above-mentioned functions but also to have several simpler regional centres. **(R)**

1.3.3.4.4.5. Bibliographical reference [10] contains an example of a network management centre. **(I)**

1.3.3.4.5. Network synchronisation.

1.3.3.4.5.1. PDH and SDH type synchronous transmission requires a timer synchronisation function. **(I)**

1.3.3.4.5.2 The prime contractor shall provide full details of the different synchronisation mechanisms used in his network (PDH and SDH levels): timer, GPS, etc. **(M)**

1.3.3.4.5.3. The prime contractor shall propose a solution for the synchronisation of his SDH and PDH network with a SDH and PDH network supplied by another contractor. **(M)**

1.3.3.5. Dedicated or integrated telecommunications networks?

1.3.3.5.1. **(I)** This chapter has been drawn up in relation to a particular typology of functions to be performed. A distinction has therefore been made between: signalling telecommunications, railway operating telecommunications and application telecommunications.

Other typologies are possible, for example the one set out in bibliographical reference [2], viz:

- long distance operational telephone installations,
- switched telephone network,
- data transmission network,
- radiocommunications,
- information and public address installations.

1.3.3.5.2. **(I)** Whatever the typology selected, developments over the years have led to dedicated systems each evolving along separate lines.

In the future, the trend is bound to be towards network and service integration but this can only be achieved gradually.

The TRACECA project is an ideal opportunity to branch out in this direction.

This is clearly the case for the physical transmission medium and the digital transmission equipment which may be the same throughout, except for part of the signalling telecommunications equipment which need further consideration.

It is less obvious in the case of services hosted using the transmission network. Services connected with train movements are not the same as voice and data application services which are very similar or even identical to the services offered on public or private telecom operator networks.

Bibliographical reference [2] lists the differences between railway networks and public networks, i.e.:

- public networks typically have a star-shaped or meshed structure, and have point-to-point links, no concentration/distribution function, no broadcast mode and small nodes,
- railways have typically linear, meshed ring-shaped structures, with multiple point-to-point links,. a concentration/distribution function, broadcast mode and small nodes

Under these conditions, is it better to group all the installations together (for example, using the same switch for the switched telephone network and station or control centre railway telephony)?

It is recommended that this aspect be left open in invitations to tender and to leave it to the manufacturers to prove that they can offer all the services needed. **(R)**

1.3.3.5.3. Whatever the answer given to the above question, it is necessary for the railway telecommunications operator console to incorporate all the requisite services shown in section 1.2.2.1. as well as access to data transmission services. **(M)**

Products of this type are available on the market, cf. bibliographical reference [13]. **(I)**

1.3.3.5.4. Mention has been made on several occasions of the need for a smooth transition from old to new systems.

If this is not possible, the manufacturer must indicate the extra costs of having to replace the old systems. **(M)**

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1.3.3.6. Power supply sources

1.3.3.6.1. Power supply is an integral part of the telecommunications network. **(I)**

1.3.3.6.2. The project developer shall indicate the primary source of energy provided for the prime contractor. **(M)**

1.3.3.6.3. The prime contractor must provide the secondary power supply to be used directly for the telecommunications network. **(M)**

1.3.3.6.4. The project developer shall specify the length of time for which the secondary supply is to be capable of running independently. **(M)**

1.3.3.6.5. The prime contractor must take all necessary steps to protect against power supply cuts and overvoltages in the primary power supply. **(M)**

1.3.3.6.6. It is accepted that elements of the telecommunications network may block in the event of overvoltages in the primary power supply or if capacity of the secondary supply is exceeded. **(M)**

1.3.3.6.7. Telecommunications installations shall restart automatically when the primary supply returns to its nominal level. **(M)**

1.3.3.6.8. Should the project developer fail to specify the primary power supply, the prime contractor must state the precise conditions under which the secondary power supply operates under nominal conditions, when blocked and for restart after blockage. He must also indicate the capacity of the secondary power supply system. **(M)**

1.3.3.6.9. A major factor is the loading on the power supply system. This factor is crucial to the reliability of the power supply system.
In this connection, it is recommended that the power supply operate to less than 50% of its nominal capacity (30 % is recommended for power components). **(R)**

1.3.3.7. Underwater cables

1.3.3.7.1. The TRACECA project contains sea sections: Black and Caspian Seas.
According to recent information, underwater cables should shortly be placed in service in the Black Sea between Poti and Varna (in 1998) and between Poti and Odessa (in 1999).
The link between Azerbaijan and Turkmenistan via the Caspian Sea, on the other hand, seems to have ground to a halt. **(I)**

1.3.3.7.2. Laying cables just for the TRACECA project cannot be justified. **(I)**

1.3.3.7.3. It is recommended, by contrast, that the use of underwater cables be given closer consideration for the following points:
- use of voice and data transmission for international railway applications (freight, wagon fleet management etc.),
- security of the transmission networks.

Underwater cables may in fact prove a financially viable option. **(R)**

1.3.3.8. Satellites

1.3.3.8.1. Obviously one or several satellites reserved for the TRACECA project alone could never be justified. **(I)**

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1.3.3.8.2. Conversely, it is recommended that more thorough consideration be given to use of satellites for the following:

- use of voice and data transmission for international railway applications connected with trains and wagons (wagon fleet management, customer information etc.),
- transmission network redundancy,
- train location, or wagon location using the GPS tracking system plus data transmission via, for example the NAVSTAR satellite. Such services could be of interest to railways and their freight customers. **(R)**

Bibliographical reference [14] provides an illustration of these points.

1.3.3.9. Radiocommunications

1.3.3.9.1. Radiocommunications are at present in extensive use on the railways (cf. telecom and IT inventories in this report: ground-to-train radio, shunting radio, voice and data transmission via the HF radiocommunications system known as Codan). **(I)**

1.3.3.9.2. Radiocommunications frequently offer an interesting alternative to wired solutions:

- they offer a wide range of voice and data transmission services,
- they offer an adequate quality of service although not as good as a wired network (bit error rate in the region of 10^{-5} or better in the case of carefully designed radio coverage, as against error rates in the region of 10^{-10} to 10^{-12} or better with wired networks),
- they spare or reduce the extent of the wired network,
- they are easy to apply,
- they are often highly competitive in terms of price (in any calculation, account should be taken not just of investment costs but also of all other costs for use, maintenance, licences, etc.).

By contrast, the use of radiocommunications is as a rule subject to regulation, both as regards frequency allocation in the radioelectric spectrum and the approval of radioelectric equipment. This regulations are national although use of the radioelectric spectrum and definition of radiocommunications systems are coordinated and standardised at supranational level (Europe and world).**(I)**

1.3.3.9.3. Radiocommunications are an alternative that should be considered as a rapid solution to short and very short-term problems where only low data transmission rates are required. **(R)**

1.3.3.9.4. In the past the UIC standardised the ground-to-train radio system for voice communications between stations, control centres, drivers and track maintenance personnel. The system is an analog system operating in the 450-460 Mhz band. It may also to some extent be used for data transmission. The corresponding leaflet still applies (cf. bibliographical reference [15]).
Whilst waiting for the emergence of GSM-R (see below), this solution is still interesting. In particular it is more efficient than the present HF ground-to-train radio system in use in TRACECA countries. **(I)**

1.3.3.9.5. The UIC is currently working on standards for a digital, cellular, multiservice radiocommunications system - theoretically grouping together all the radiocommunications services at present in use in Europe on the railways. This future system is the GSM-Railways, called by this name because it is based on the GSM standard (extended to include additional services currently being standardised). It operates in the 900 Mhz band and should be available in the next 2 to 3 years.
It will then become mandatory for the European Union for reasons connected with interoperability.
It is therefore recommended that extra optical fibres already be set aside for the ground network of this system (cf. § 1.3.3.3.5. "Cable capacity"). **(R)**

1.3.3.9.6. Radiocommunications are a booming sector, in particular in the wake of efforts to obtain better use of the spectrum.
This explains why some people support other types of radiocommunication system such as:

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- trunked radio networks (3RP) and the future TETRA standard which is to be derived from these (cf. bibliographical reference [2]). These networks are particularly well suited to station areas and direct mode (direct link between a radioelectric transmitter and receiver without onward relay),
- spread spectrum radio networks (CDMA) are particularly suitable for radioelectric propagation in difficult environments (for example remote control of leading and trailing locomotives in heavy-haul trains).

In theory all this should converge on a single universal standard called UMTS (Universal Mobile Telecommunication System) in the first decade of the next millennium. **(I)**

1.3.3.9.7. HF radiocommunication is not used by the railway enterprises of the European Union.
By contrast it is widely used in TRACECA countries for train radios.

It is also used occasionally by the railways with the CODAN system, donated by the "World Food Program" to railway companies in Caucasian countries.
Propagation with this system is harder to control than with the VHF and especially UHF bands which are the preferred choice of railways in the European Union at the moment. Conversely, the range of this system is extensive, which may make it of interest in the case of seas or in very scarcely populated areas (with very few railway installations by definition).
In such cases, HF radio should not be summarily dismissed and more thorough studies should be carried out into the various possible technical solutions, in relation to actual needs and cost criteria. **(I)**

1.3.3.9.8. More specifically where the Codan HF radiocommunications system mentioned in the IT inventory part of this report is concerned, this could rapidly be used for exchanging data on trains worked across borders, thus compensating for the poor quality of the present cable networks. This should be considered as a very short-term solution. **(R)**

1.3.3.10 Environment

1.3.3.10.1 **(I)**
There are two approaches to dealing with environmental considerations:
- The environment is defined by its most extreme climatic, mechanical, electromechanical, electrostatic and physico-chemical constraints, which telecommunications network equipment must then withstand.
- The telecommunications network is composed of standard manufacturer's models, with no alterations whatsoever.

In this case, if external environmental constraints are tougher than those met by the manufacturer, the corresponding products must be isolated from the external environment and placed in:
- air-conditioned room
- ventilated, heated cabinets
- protective and earthing equipment
- etc.

Transmission and connecting cables fall into the former category, while as a rule, digital transmission devices, switching installations (telecom switches and railway operating telephone equipment) and power-supply sources come under the latter category.

1.3.3.10.2 **(I)**
The environmental constraints to be borne in mind are:
- climatic:
  -- temperature,
  -- rainfall,
  -- wind,
  -- ice, etc.
- mechanical:
  -- vibrations,

-- impacts,
- electromagnetic:
  -- electromagnetic compatibility (EMC)
  -- high altitude nuclear electromagnetic pulses (HEMP),
- electrostatic,
- physico-chemical:
  -- corrosion,
  -- contact potentials, etc.

1.3.3.10.3 **(M)**
Transmission cables must comply with the environmental constraints listed in paragraph 1.3.3.3.2.4, Chapter 2.

1.3.3.10.4 (M)
Equipment (transmission cables and installations) must be properly protected and earthed.

1.3.3.10.5 (M)
Staff must be properly protected against:
- temperature extremes,
- electromagnetic radiation,
- electric discharges,
- laser-generated light rays.

1.3.3.11 Maintenance

1.3.3.11.1 Network maintenance shall be organised in accordance with the recommendations of series M of the ITU-T. **(M)**

1.4 Cost factors

1.4.1 General.

1.4.1.1. The cost factors referred to below are examples only.

1.4.1.2. The utmost caution should be exercised in relation to prices. In general prices can vary greatly for many reasons :
- assessment of customer requirements,
- technological progress,
- product/system study and manufacture costs,
- product and system installation costs,
- transport costs,
- labour costs,
- risk evaluation,
- corporate strategy.

Ultimately, prices can only be gauged well by calling for tenders (and carrying out the related negotiations).
Nonetheless, the approximate prices involved in a project do need to be correctly estimated, despite the difficulties involved in such an exercise.
Hence this section has been compiled.

1.4.2 Optical fibre cable.

1.4.2.0. Although copper cables are not considered in this study, it is helpful to have a reference price for that cable type.

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2. Method and general technical options selected

The purpose of this section is to provide details of the method used to define the future network and assess the corresponding investment.

- The principles selected for telecom network architecture are set out in the following chapter on "block diagrams"

- The method adopted is based on the following concepts:

  - In the telecom architecture proposed considerable importance is attached to specific railway telecom services, in particular for railway operating purposes and ensuring the safety of rail vehicle movements.
  This requires a system of collection and distribution between the Control Centre, which is in charge of the regulation of traffic over one or several railway lines and the stations dotted along this (or these) line(s).
  It is therefore somewhat different to conventional telecom networks.

  - The approach adopted is exclusive to the railways.
  Network architecture may vary if the private operator of a telecom network, other than the railway, is involved.
  The proposal would then need to be adapted to take account of the strategy of this private operator.

  - The proposed modernisation of the telecom network is based on the use of optical fibre cables and digital transmission equipment.
  It is not recommended that additional copper cables be used, although this would be possible on an occasional basis for purposes of network harmony and maintenance.
  For the same reasons, it is not being suggested that new analog transmission equipment be added.
  N.B.:
    - It is important that a detailed check be made of the condition of existing copper cables and analog transmission equipment.
    - From an investment angle, it is highly desirable to keep those installations that are still in good working order.

  - In the study account is not taken of dedicated signalling cables, which are treated as local cables.
  2 optical fibres have however been set aside in the optical fibre cable for any necessary signalling applications.

  - Similarly the study does not take account of local telecommunications cables..

  - The proposed telecom network architecture conforms to ITU standard T G-803:
  "Architecture of transport networks based on synchronous digital hierarchy". (cf. section 3).

  - The study strategy finally selected is in two parts, i.e.:

    -- Establishment of a "backbone" network taking account of the points from which lines branch out and all the stations on this backbone,

    -- Completion of the whole network including the secondary lines.

  - The method may be broken down into the following successive stages:
    -- Installation of the SDH network,

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The differential is approximately 50 % per additional group of 12 fibres, in other words a 10 to 15% differential for a complete cable-laying operation.

1.4.2.8. In light of the above, the rest of the study is based on the following preferential hypotheses:

- The capacity of the fibre optic cable (f.o.) has been determined as follows:
  -- 2 f.o. for the SDH,
  -- 2 f.o. for the distribution networks,
  -- 2 f.o. for border crossing and to handle other special cases,
  -- 2 f.o. partial network back-up,
  -- 2 f.o. reserved for the signalling applications,
  -- 2 f.o. reserved for ground to train radio applications,

Thus a total of 12 f.o. for railway requirements.

It is advantageous in economic terms to make provision for "dark" fibres for one or more telecommunications operators. Rentals of between 1.2 and 3 Ecus / m / year can be levied for those fibres.

The economics study already carried out takes account of that option.

It is proposed that 12 "dark" f.o. be reserved for telecommunications operators.

In other words a cable with an aggregate capacity of 24 optical fibres is proposed.

- Solution D: cable buried or laid in a duct at an average price of: **18636 Ecus / km**

In the following sections (4 and 5) the cost will be broken down into two parts:

- Costs covered by the European Union or by an EBRD loan:
  - Cable and supplies used in laying
  - Supervision of staking out
  - Cable connections
  - Transmission equipment
  - Energy supply
  - Spares
  - Training
- Costs covered by the railways
  - Staking out
  - Civil engineering
  - Laying

The sum involved has been estimated at ten times lower than the cost of the job in western Europe owing to the difference in labour costs.

1.4.3 Digital transmission equipment.

1.4.3.1. The average price of PCM 30-channel digital terminal equipment (DTE) is in the region of **11000 Ecu.**

1.4.3.2. The average price of SDH STM1 end multiplexers, standard version, is some **29333 Ecu.**

The prices vary from 22000 to 41250 Ecu for the basic (no back-up) and higher-level versions.

1.4.3.3. The mean price of SDH STM1 add-drop multiplexers, standard version, is in the region of **22000 Ecu.**

1.4.4 Network management.

- The SDH network management system costs **106060 Ecu**.

- The average cost of the distribution network management system is **15150 Ecu.**
(N.B.: a simplified version costs 7333 Ecu).

- Bibliographical reference [4] contains a price of **183333 Ecu.**

1.4.5 Switching equipment.

1.4.5.1. This covers switches in the conventional telephone switched network (STN) and telephone equipment for railway operations (see section 1.3.3.5. "Dedicated or integrated telecommunications networks?").

1.4.5.2. In the case of automatic telephone switches, as a rule of thumb a conventional subscriber's link (point to point only) is priced at **147 Ecu**, on the basis of 100 subscriber links minimum.

Below that figure, the fixed charge rises. Thus, for 50 subscriber links, the cost of the switch is in the region of 11733 Ecu.

In the case of the proposed PABX (see paragraph 2), it should be noted that the cost is **303 Kecus**, which breaks down as follows:

- Cost of the telecom switch itself, equipped for 1200 subscribers: **212.1 KEcus**
- Cost of the control room (complete environment, power supply and management system included):
90.9 KEcus.

1.4.5.3. The telephone equipment used for railway operations generally has less capacity. However it provides the various services described in section 1.2.2 "Telecommunications and Railway Operations".

A degree of variability is given by the number of station operators (signalman, traffic manager, etc.) and control offices (traffic controllers, etc.) linked up to the installation.
The following figures may serve as a guide:

- low capacity equipment (for example dedicated to new lines) (1 operator, up to 8 lines) :
7333 Ecu i.e. **917 Ecu/line**
- modest capacity equipment (1 to 2 operators, up to 30 lines) :
36850 Ecu i.e. **1228 Ecu/line**
- medium capacity equipment (1 to 4 operators, up to 60 lines) :
56100 Ecu i.e. **935 Ecu/line**
- high capacity equipment (4 to 12 operators, over 100 lines) :
125400 Ecu i.e. **1256 Ecu/line**

It is interesting to note that bibliography reference [4] gives a price of **45833 Ecu** per station (without specifying what is understood by the term station).

In this instance too, it is important to be very cautious in drawing comparisons (for example to establish whether digital transmission equipment - SDH or PDH - is included in the figures stated or not).

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1.4.6 Power supply sources.

Three types of power supply are considered:
1.4.6.1 Power supply to a complete control room - in the case of a large centre including, for instance, the PABX, an STM1 and the control office installations. The make-up of such a control room is defined in the Methods part. The corresponding figure is: **90.9 KEcus** (see 1.4.5.2).

1.4.6.2 Medium capacity power supply - in the case of an STM1 grouping plus ADM plus medium capacity station control centre or indeed an ADM group providing control centre back-up. The figure for this is **10.9 KEcus.**

1.4.6.3 Modest capacity power supply - in the case of an ADM plus small station. The figure here is **2.3 KEcus**.

1.4.7 Satellites.

1.4.7.1. Various cost figures were quoted at the TRACECA seminar in Warsaw (bibliography reference [14]), i.e.:

- cost of a fixed station: **45833 Ecu to 91667 Ecu,**
- cost of a mobile unit: **3677 Ecu** to **4583 Ecu,**
- cost of one minute of voice, fax and data transmission: **0.92 Ecu**
- cost of hiring a permanent 64 kbit/s duplex channel: **1833 Ecu / month**.

1.4.7.2. One of the speakers at the TRACECA seminar in Warsaw stated that a minute of communication with INMARSAT cost **3.7 to 5.5 Ecu.**

This also demonstrates a degree of variation in costs which needs to be investigated. It is definitely due in part to differences in subscription and pricing formulae in the sector.

1.4.8 Spares

1.4.8.1 Provision is made for spares equivalent to **10 %** of the investment in equipment.

1.4.9 Training

1.4.9.1 Training as described in the "Method" section requires an investment budget of **94.6 KEcu**.

1.4.10 Provision for contingencies

1.4.10.1 This sum is traditionally included in a preliminary project study as a contingency fund. It is calculated on the basis of the aggregate investment.

1.4.10.2 Currently the chosen percentage is **5 %** at SNCF (some years ago it was 10 %).
That value is also advocated by F.W. Krämer, in his report " TRACECA - Communication Network for the Caucasian Railways. Feasibility Study. (1/10/1997)" (bibliography reference 1 in the Progress Report).

1.4.11 Maintenance

- In western Europe, annual maintenance of installations is estimated at **4 %** of the total investment.

This cost includes all basic costs: personnel, measuring equipment, logistics, etc.

- Annual maintenance of the cable and the line (ducts, etc...) is estimated at **0.15 Ecu/m**.

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  - The approach adopted is exclusive to the railways.
  Network architecture may vary if the private operator of a telecom network, other than the railway, is involved.
  The proposal would then need to be adapted to take account of the strategy of this private operator.

  - The proposed modernisation of the telecom network is based on the use of optical fibre cables and digital transmission equipment.
  It is not recommended that additional copper cables be used, although this would be possible on an occasional basis for purposes of network harmony and maintenance.
  For the same reasons, it is not being suggested that new analog transmission equipment be added.
  N.B.:
    - It is important that a detailed check be made of the condition of existing copper cables and analog transmission equipment.
    - From an investment angle, it is highly desirable to keep those installations that are still in good working order.

  - In the study account is not taken of dedicated signalling cables, which are treated as local cables.
  2 optical fibres have however been set aside in the optical fibre cable for any necessary signalling applications.

  - Similarly the study does not take account of local telecommunications cables..

  - The proposed telecom network architecture conforms to ITU standard T G-803:
  "Architecture of transport networks based on synchronous digital hierarchy". (cf. section 3).

  - The study strategy finally selected is in two parts, i.e.:

    -- Establishment of a "backbone" network taking account of the points from which lines branch out and all the stations on this backbone,

    -- Completion of the whole network including the secondary lines.

  - The method may be broken down into the following successive stages:
    -- Installation of the SDH network,

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-- Installation of the distribution network,
-- Installation of the PABX,
-- Installation of telephone equipment at the control centre (PC) and in the stations,
-- Installation of the SDH network management system,
-- Installation of the management systems of the distribution networks,
-- Network synchronisation,
-- Network back-up,
-- Decision on spares requirements,
-- Calculation of training requirements.

- An **investment table** has been drawn up for each of the Caucasus countries on this basis (Georgia, Azerbaijan and Armenia) and for the following options:
  -- Network without back-up,
  -- Network with partial back-up.

In the following details are given of the method for each of the stages shown above.

2.1 Installation of the SDH network

- Here account is taken of:
  -- the size of urban centres,
  -- the size of railway junctions,
  -- the position and size of existing switches,
  -- the number of transmission channels per link,
  -- the distance between SDH nodes,
  -- the number of stations between SDH nodes.

- All SDH nodes and the physical links between them go to make up the "SDH backbone" or, by extension, the "backbone".

- Railway branch lines connecting to the main lines have been analysed separately. Depending on the circumstances, it is possible either to:
  -- set up an additional SDH node at the point where the branch joins the main line,
  -- lay extra o.f. cable to serve a station close to the backbone and connect it to the nearest SDH node.

- SDH nodes are equipped with 155 Mbit/s throughput STM1.

2.2 Installation of distribution networks.

- These are essentially for links between the Control Centres and the railway locations directly involved in ensuring the safety of rail vehicle movements (stations, signal boxes, sub-stations, etc.).

- Links between SDH nodes are achieved by means of a drop-and-insert type PCM network.
- A distribution link should not serve more than 5 points to avoid immediate saturation (some 30% spare capacity should be kept free on commissioning).
- The number of links between SDH nodes will equal the number of stations served divided by 5 and rounded up to the nearest whole integer.

- Distribution nodes will have 2 Mbit/s add/drop multiplexers (ADM) on 2 or 8 Mbit/s transmission medium.

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- If there is more than 1 link, use will be made of 2 Mbit/s ADM over a 8 Mbit/s transmission medium.
If there is one link only, 2 Mbit/s ADM will suffice.

N.B.: given the flexibility of existing ADM equipment- easy transfer from a 2 Mbit/s ADM to a 2 Mbit/s ADM over a 8 Mbit/s transmission medium- and the minimal cost differentials between these types, it could be advisable to go for the same option throughout for maintenance reasons.

- As the SDH backbone stops at the national borders, services up to and across these borders are covered by a separate study.

- Since circuits start at the Control Centre (PC) controlling the stations, this centre needs to have as many ADM as there are links served.

2.3 Installation of PABX

- These switches are the crux of the Switched Telephone Network. They handle all communications **other** than those of the traffic control centres and railway establishments directly involved in ensuring the safety of rail vehicle movements.

N.B.: A distinction may be made between 3 types of switches:
- those only handling transit traffic with, on average some 4 or 5 bundles,
- those handling transit traffic and providing some limited local services,
- those handling transit traffic, limited local services and with possibilities for extension.

- It is proposed that a PABX be installed in each of the capital cities of the republics in the Caucasus and Central Asia.
The role of this switch will be:
  - to handle communications between the republics in the Caucasus and Central Asia,
  - to handle communications with Europe.
The switch will be a transit switch, also handling limited local traffic and with possibilities for extension.
This means that an extra hierarchical level is added to each of the national interconnected automatic networks.

Depending on requirements and the age of existing telecom switches, a master plan should be drafted outlining the deployment of new switches.

- A PABX software module should be developed to adapt the signalling protocols and enable connection of the existing switches.

General recommendations and methodology

2.4 Installation of telephone equipment at the control centre (PC) and in stations

- As already stated in § 1.2 "Installation of distribution networks", links between control centre and stations rely on a drop-and-insert PCM distribution network which houses the dedicated services required for railway operations.
In this respect, the distribution and concentration functions of the drop-and-insert PCM are used to a very large extent (cf. block diagrams).

- The distinctive feature of this equipment is its different levels of capacity for connecting telephone calls (high capacity for the control centre, medium for major stations, low for other stations).

2.5 Installation of the SDH network management system

- One SDH management system is to be installed per country.

2.6 Installation of the management systems of the distribution networks

- One or several management systems are to be installed for the distribution networks (with add/drop multiplexer equipment) per country (normally as many as there are local telecom control centres).

- The distribution network management system (ADM) is to be separate from the SDH network management system.

- At a later stage, the possibility of having a supervisor to combine management of the SDH network with that of the distribution networks may be envisaged.

2.7 Network synchronisation

- A network is to be set up to synchronise the SDH network to set the timer for the SDH nodes from a single atomic clock at network and SSU synchronisation unit level.
It is proposed that a GPS-type system be used as back-up for the network synchronisation system.

2.8 Network back-up

- Full active back-up (two separate sets of cables and digital transmission equipment) has been ruled out because of the cost of the corresponding investment.

- Back- up using a flattened transmission loop is recommended both for the backbone SDH network and for the drop-and-insert PCM distribution networks, since this provides partial redundancy against all other failures than a complete break in the cable whilst only requiring two of the optical fibres in the optical fibre cable.

- Where the safety of train movements more particularly is concerned (dedicated links between control centre and stations), the idea of partial back-up has been considered, in which case the control centre transmission equipment would be duplicated.

This duplicated equipment would be installed on the backbone network, geographically as far as possible from the control centre and accessible to an outside network used to provide a bridge between the duplicated equipment and the control centre.

- Naturally back-up comes in many different forms (public telecom network, satellite links, underwater cables, microwave links, etc.).
Back-up arrangements will, therefore, need to be studied in closer detail by the designer of the future network, in relation to the quality objectives set out in the list of requirements and in relation to local circumstances (existence of an outside network, local geography).

2.9 Environment (Power supply)

- This is an important item which includes:
  -- power supply,
  -- protection against overvoltage, lightning,
  -- earthing,
  -- technical facility equipment,
  -- air-conditioning in technical facilities,
  -- distribution frames, etc.

- The following approach was adopted in this study:
  -- **The environmental item as a whole** was considered separately for the PABX advocated for international connections, and for the control centre equipment.
  -- For the digital transmission equipment for lines and stations, power supply sources were treated separately.
  The rest of this item was considered to be included in the cost of the equipment.

- On the subject of **power supply** as such, the following approach was adopted:
  -- Power supply to the PABX and control centre equipment (1 STM and as many ADM as links) is incorporated in the technical facilities.
  -- Medium capacity power supply is used for major stations (1 STM, 1 ADM, 1 medium capacity telephone equipment for railway operations).
  -- Low capacity is used for small stations (1 ADM, 1 low capacity telephone equipment for railway operations).
  -- Medium capacity power supply is used for partial redundancy for the control centre function (as many extra ADM as extra links).

N.B.:

Power supply systems need to have a permanent management interface to allow remote monitoring from a management centre.
The power supply systems deliver contact loops that can be incorporated in the ADM equipment.
Spare bits in the time slots serve to report the status of these contacts to the control centre where they are transferred to a dedicated manager.
In addition, in view of the choice of partial network back-up, it is essential to have a system for supervising power supply.
The extra cost is trivial by comparison with the total cost of the project. It has, at all events, been included in the investment tables shown elsewhere.

2.10 Training

- This item is fundamental to the working of the network.

- It is recommended that the manufacturer selected should train **instructors** who will then train the telecom staff of the railways concerned.

- Training should include the following:

-- Training in transmission equipment maintenance:
--- Basic training in digital transmission: 2 weeks
--- Practical training: 1 week

-- Training in operating the management control centre: 1 week

-- Training in the maintenance control centre:
--- Basic training: 2 weeks
--- Specific training for drop-and-insert PCM: 1 week
--- Specific training for SDH: 3 weeks.

-- Cable maintenance training:
--- Basic training: 1 week
--- Practical training: 1 week

-- Special training in station telephone equipment: 1 week

-- Training in electric power supply systems and miscellaneous equipment: 1 week

N.B.: Training for the PABX is included in the price of the switch (equipment and management)

i.e. total training: 14 weeks.

- A training programme internal to the railways should then be drawn up in relation to the maintenance scheduling principles of each of the countries concerned.

2.11 Spares.

Spares are provided as part of investment

3 Block diagrams

3.1 Introduction

- The purpose of this explanation is to set out the principles selected for the structure of the telecom networks of the three Caucasian countries: Georgia, Azerbaijan and Armenia.

- By definition the <u>block diagrams</u> are generic in nature.
They have a general value and are not specifically related to the particular cases under study.

3.2 **Architectural concept** (Block diagram SP1)

- Telecom network architecture is based on ITU-T G 803 recommendation:
  "Architecture of Transport Networks based on the Synchronous Digital Hierarchy"

- This includes three network layers:
  - layer 1: "Optical fibre or microwave transmission support layer",
  - layer 2: "SDH channel layer network with VC12 or VC3" containers,
  - layer 3: "Circuit switching, packet switching networks with dedicated links

- For the purposes of this study, the "drop-and-insert PCM distribution network" has been added in layer 3, this having the particular feature of being supported by both layer 1 and layer 2.

- The main advantages expected of recommendation G 803 are:
  -- Simple design and operation of separate layers,
  -- Each layer has its own operating and maintenance capacities,
  -- Changes or additions to a layer have no effect on the other layers from an architectural point of view.

3.3 **Basic components** (Block diagram SP2)

- This diagram shows the basic components used in the other block diagrams as well as the symbols used in them (STM1, ADM2, ADM2/8, DTE).

General recommendations and methodology

- It also shows the different types of audio-frequency interface and data available for the 64 Kbits channels. Examples of terminal equipment are given by way of illustration.

3.4 Backbone and distribution networks (Block diagram SP3)

3.4.1 Backbone network

- The backbone is the central core of the telecommunications network.

SDH technology has been selected for the backbone network.

-Given the present transmission load in terms of the number of channels revealed by the progress report study of existing networks, the nodes of the backbone network are to have a minimum configuration, hence STM1.

- The reasons for the choice of STM1 are the following:
  - Transmission capacity of an STM1 is 155 Mbit/s.
  - 63 x 2 Mbit/s channels are available to users.
  - In the case of the Caucasian countries, the maximum load is in their respective capitals.
    It is one channel maximum for the PABX and 17 channels for the distribution networks (Georgia). This gives a total of 18 channels.
    If spare capacity is provided with a view to a 30 % increase, the number of channels would be 20 in use or in spare capacity.
    43 channels are therefore available for potential negotiations with public or private telecom operators (i.e. about 2/3 of capacity in terms of channels used).

- The STM1 are located in major areas: capitals and major railway establishments (stations and marshalling yards).
Siting depends essentially on two factors:
  - the number of existing switches with at least about one hundred subscribers (cf. interim report),
  - a maximum distance in the 70 - 100 Km bracket between consecutive STM1.

3.4.2 Distribution network

- The distribution network makes use of drop-and-insert pulse coded modulation (PCM).
Transmission equipment is of the Add Drop Multiplexer (ADM) type.

- The distribution network serves basically to ensure the safety of railway traffic. It involves a Control Centre connected in linear fashion to the different stations.
The Control Centre must be connected to an STM1.

- The distribution network carries the 2 Mbit/s links between the control centre and the stations along the line.

- Each station has an ADM.

- For operating reasons the number of these ADM per link is, in principles, limited to 5.

- As a result, a simple rule can apply for estimating the number of links between consecutive STM1:
  -- the number of links is equal to the quotient of the number of stations divided by 5, if necessary rounded up to the next integer.

- Given that in almost 50 % of cases it will be necessary to have more than one link between 2 STM1, the distribution nodes have been equipped with 2 Mbit/s Add/Drop Multiplexers (ADM) on an 8 Mbit/s transmission support (shown as ADM8 in the block diagrams).

The corresponding ends at control centre level are, by contrast, equipped with 2 Mbit/s ADM on a 2 Mbit/s transport support (shown as ADM2 in the block diagrams).
Block diagram SP2 shows the details of ADM2 and ADM8.

3.5 Partial back-up of the backbone and distribution networks

(1) Principle of the flattened loop (Block diagram SP4)

- Full back-up for the telecom network solely for railway purposes seems unrealistic in view of the cost factor.

- It is however possible to provide partial back-up for the system as follows:

  -- The backbone network can be provided with back-up by establishing a loop between the most remote STM1 and the originating STM1 (e.g. in the control centre) by means of 2 additional optical fibres in the same optical fibre cable.
  This forms a flattened loop.
  In fact, the intermediate nodes are spread over the loop to avoid too great a distance between the originating STM1 and the STM1 the furthest away.

  -- The end of the distribution network is connected to the next STM1. This creates a ring at distribution network level.

- This type of back-up using a flattened loop is effective against all potential network failure modes with the exception of a failure common to all the optical fibres concerned in the optical fibre cable (e.g. if the cable is completely severed by earthworks machinery).

3.6 Partial back-up for the backbone and distribution networks

(1) Simultaneous transmission of time slots (Block diagram SP5)

- This diagram shows network operation with flattened loop back-up:

  -- For a transmission channel requiring back-up, use is made of two time slots (TS) which are transmitted simultaneously eastwards and westwards.

  -- The "eastern" TS arrives directly at the ADM (add/drop multiplexer) to which it is addressed.

  -- Should this ADM detect a break in the eastern link, a reflex switch cuts in to transfer the ADM to the western link.

  -- The ADM addressed will then be able to receive the western TS which transits via and the ADM from which the connection originated.

3.7 Interconnection of networks at the border (Block diagram SP6)

- The problem of interconnections at borders may be illustrated by taking the example of the border between Georgia and Azerbaijan.

- Since the telecom networks are national, the backbone networks are not connected directly from one STM1 to another and the distribution networks come to a halt at Gardabani and Beyuk-Kasik respectively.

General recommendations and methodology

- Interconnection is via an extra pair of dedicated optical fibre between the STM1 at Tbilissi and at Akstafa. The following are installed:
Either a:

  - 2 Mbit/s OLTE (Optical Link DTE) at the output from the G703 interface in the STM1 multiplexer
  This means that a 2 Mbit/s channel is provided between the two capitals: Tbilissi and Baku.
  - STM1 tributaries cards in the STM1 multiplexers
  This means that 63 2 Mbit/s channels are provided between the capitals of the two countries, Tbilisi and Bakou. This solution is preferable so that this capacity can be leased to other parties.

- It is possible to have local links between Gardabani and Beyuk-Kasik for reasons of convenience if necessary, using an additional pair of dedicated optical fibres and the Digital Terminal Equipment (DTE) for the purpose.

3.8 Management of distribution networks (Block diagram SP7)

- This is achieved through a central manager and his operator consol in the control centre.

- The dedicated control centre interfaces for managing the ADM are connected to the central manager via a management bus.

- The control centre ADM are the "master" and are connected to the remote ADM via an operating and maintenance channel using the spare bits of the PCM frame.

3.9 Management of the backbone network (Block diagram SP8)

- This is achieved through a central manager and one or several operator consoles (PEX) in the control centre.

- QB3, the dedicated management interface of the control centre STM1 is connected with the central manager via the local IT network.

- The backbone operating channel, managed by the control centre STM1, operates in one direction only (because of management constraints in the routing tables in the STM1).
In the event of a break in the optical fibres, the operating channel will be out of service for part of the network.
To overcome this difficulty, the central manager needs two points of access to the backbone network.
To this end, the dedicated management interface, QB3, of the STM1 located at the furthest distance from the control centre is connected to the control centre central manager by means of an X25 link and routers connected to the corresponding local IT networks.

- Transit over an X25 network independent of the railway network is recommended for the back-up function.

- If the public operator or private operators cannot provide an X25 service, there are two solutions:
  -- not to provide back-up for the operating channel, which would make repairs to the network more difficult in the event of failure.
  -- to use a dedicated 64 Kbit/s link between routers.

General recommendations and methodology

3.10 Network synchronisation (Block diagram SP9)

- When using the SDH, it is essential to ensure synchronisation between the various networks.

- This is done via the control centre.

- A reference 10^{-11} stability clock (CPR) controls a 10^{-9} stability clock Synchronization Supply Unit (SSU).
The stability of the CPR and SSU must conform to the recommendations of ITU-T G 811 and G 812 respectively.
The SSU sets off a timer which then enables the 2 Mbits/s clock signals to be distributed to the control centre equipment (STM1, PABX, ADM2).
The timer signals are then transmitted on to the other STM1 in the backbone network using the transport frames; this sets the timing at equipment level.

- Back-up should be provided for the synchronisation system at the end of the backbone network. This should be based, for example, on the GPS and one SSU.

- Timing is synchronised on the basis of a synchronisation plan, including back-up by GPS.

- The network used for synchronisation requires central control in conjunction with the management of the SDH.

3.11 Connection of the PABX (Block diagram SP10)

- The PABX located in the capitals are responsible for handling traffic between the various TRACECA countries and Europe.

- International links with railways in Europe can be established via a bundle of dedicated links scaled to take account of the volume of traffic to be handled.

- A software module needs to be developed for connecting the existing switches (adaptation of the signalling protocols).

- It is recommended that use be made of the QSIG signalling protocol between the PABX, rather than CCITT n° 7, for the following reasons:
    -- QSIG is a standard developed by ECMA (European Computer Manufacturers Association) and ETSI (European Telecom Standards Institute),
    -- QSIG developments are harmonised between ECMA and ETSI,
    --QSIG has been chosen by UIC for connecting the automatic trunk networks of railways in western Europe,
    -- QSIG gives access to a variety of suppliers.

- A new numbering scheme and a new routing scheme need to be established to take account of the possibility of international access via the PABX.

3.12 Connection with existing switches (Block diagram SP11)

- The diagram shows how switches are connected in the following circumstances:

-- connection between remote user and his automatic switch over the same 2 Mbit/s channel of the same distribution network,

-- connection between two existing switches via different 2 Mbit/s channels on the same distribution network,

-- connection between two existing switches depending on two different STM1 (one connected at control centre level, the other at distribution network level).

3.13 Connection of IT applications (Block diagram SP12)

- The diagram shows how IT applications are connected in the following cases:

-- connections between two computers on different 2 Mit/s channels on the same distribution network via the backbone and the originating control centre.

-- connection of two local computer networks via routers, each depending on a different STM1.

3.14 Connection of IT applications to a computer centre (Block diagram SP13)

- The diagram shows how a stand-alone computer can be connected to the local IT network and to the computer centre in Tbilissi. The principles of diagram SP12 also apply.

3.15 Control Centre operation (Block diagram SP14)

- The diagram shows the voice communications between the control centre and the stations for a traffic control type circuit.

- Using broadcasting and collection amplifiers, the control centre can communicate with one or several or all of the stations on the network as a whole;
The control centre has as many such amplifiers as there are distribution networks.
The microphones and receivers needed for voice communications are connected to the ADM by means of audio cards.

- the call signal (not shown in the diagram) is transmitted in voice frequency over the control centre transmission pair.

3.16 Time Slot (TS) allocation on a distribution network (Block diagram SP15)

- This diagram shows one example of how time slots may be allocated between the control centre and stations (or other railway locations)

- The TS1 (traffic control), TS2 (energy control) and TS15 (ground-to-train radio) are of the broadcasting/collection type, in view of the fact that the control centre must be able to call one, several or all stations on the distribution network.

- TS3 is reserved for the safety bus. Since this only involves links between adjacent stations, the same TS is used throughout the distribution network..

- TS4 to 8 are allocated to the other automatic telephone links. These links are of the point-to-point type.

- TS9 to 13 are allocated to IT applications. These are also of the point-to-point type.

- TS14 (maintenance conferencing) is used for dialogue between all link users.

- It will be noted that in the example given, only half of the TS (15) have been allocated of a possible total of 30.
This spare capacity is sufficient for a large number of stations and other locations.

3.17 Control centre back-up (Block diagram SP16)

- Assuming the principles for partial back-up of the backbone and distribution networks to have been agreed (cf. Sections **5** and **6**) block diagram SP16 shows how voice communications links between control centre and stations are provided with back-up.
It is important to realise that if communications break down completely between the control centre and the stations, this will disrupt operating of the railway network and lead to delays, cancelled trains, etc.

- Under these circumstances, it is advisable to provide greater back-up for the main links (for example, traffic control, energy supply).

- The steps taken are similar to those in section **6.** i.e.:

  -- ADM and redundant broadcasting/collection amplifiers which are a mirror image of the control centre, are connected to the STM1 the furthest away from that of the control centre.

  -- a reflex redundant system is installed in stations. Should the easterly link fail, the system automatically switches over to the western link.
  The redundant broadcasting/collection amplifiers are connected to those of the control centre via an external network using a dedicated telephone link (300 - 3400 Hz).

3.18 Network of secondary railway lines (Block diagram SP17)

- Where the telecom networks of secondary railway lines are concerned, SDH technology is not used but only PCM drop and insert.

- An originating ADM manages the link. Additional ADM are initially added to demultiplex the 2 Mbit/s channels not demultiplexed by the original ADM.

- In the block diagram proposed, the ADM are of the ADM8 type.

General recommendations and methodology

The originating ADM8 demultiplexes one of the 4 channels directly (for example, Channel A).
If necessary, the other channels (B, C and D) are demultiplexed by the additional ADM2 situated at the originating end.

- In the case of small secondary railway lines with only one link, it is possible to use only ADM2.

3.19 Administrative telephone network (Block diagram SP18)

- Replacement of existing switches with PABX based on digital technology.

- Small PABX (50 and 500 users) are configured as remote units of the master PABX in the major stations. Master PABX have a manager to control remote units.

- Signals between master PABX are QSIG, as they are between the PABX in the national capitals.

- Signalling between PABX and the remote units is not necessarily by QSIG

- Each remote unit will be connected by a 2Mbits/s channel.

- Links between PABX are estimated at one 2Mbits/s channel (i.e. 20 erlangs as an annual average) for each group of 500 users.

3.20 Computer links between the two SDH networks (Block diagram SP19)

If the rail network topology is such that not one but several SDH transmission networks are advocated, it may be that the computer centre is not located at the intersection of these networks.
To allow stations situated along SDH networks other than that serving the computer centre to communicate with said centre, data multiplexers should be installed to interconnect the SDH networks for data transmission.

Chapter 2

General recommendations and methodology
Appendix 1 - Bibliography and diagrams

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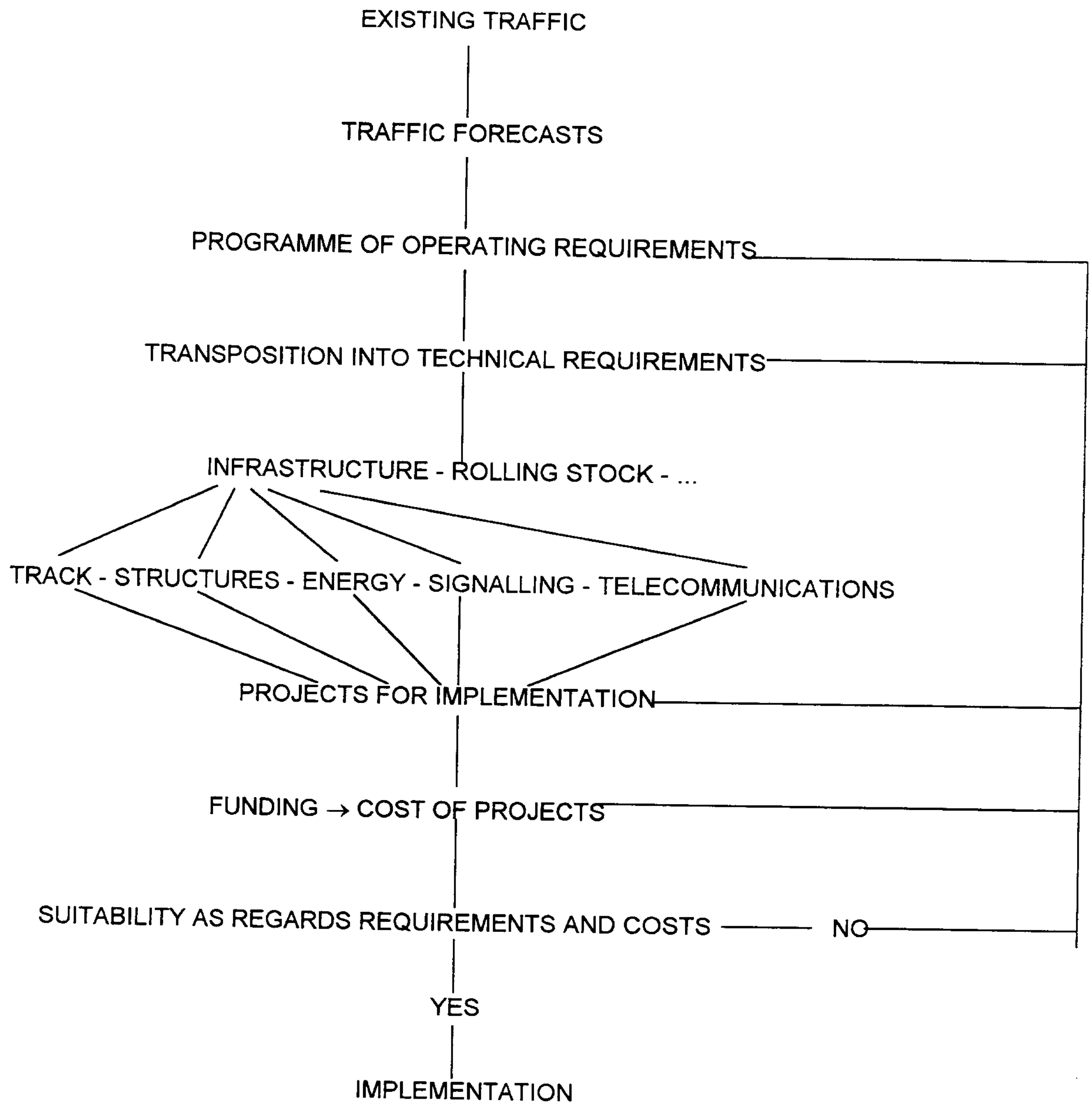
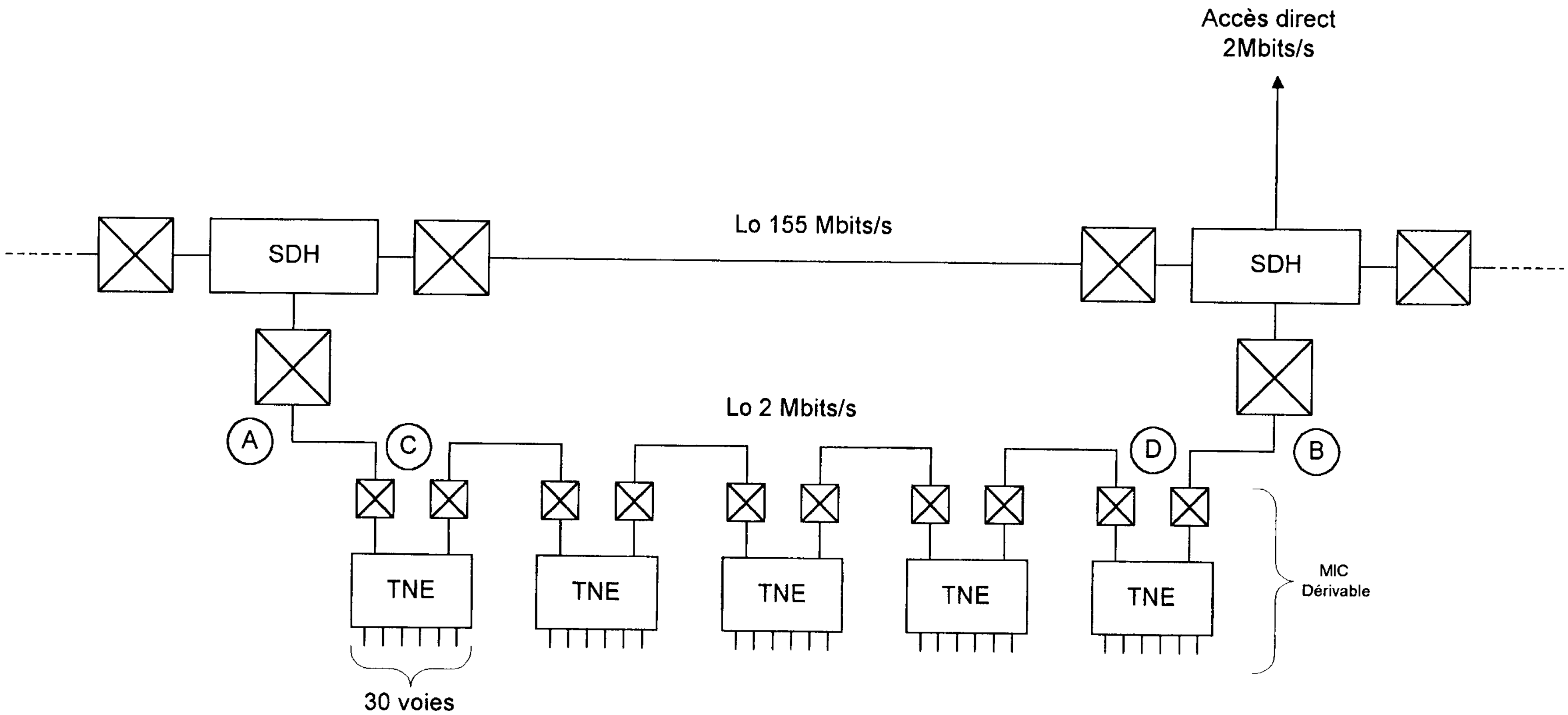
INVESTMENT CONCEPT MODEL

Diagram 1



Architecture du réseau de Télécommunications
Schéma de principe

Figure 2



Légende

SDH Synchronous Digital Hierarchy
☒ Terminal Numérique de Ligne Optique
TNE Terminal Numérique d'Extrémité

Diagram 3A

Connection of optical fibre cable
Recommended solution

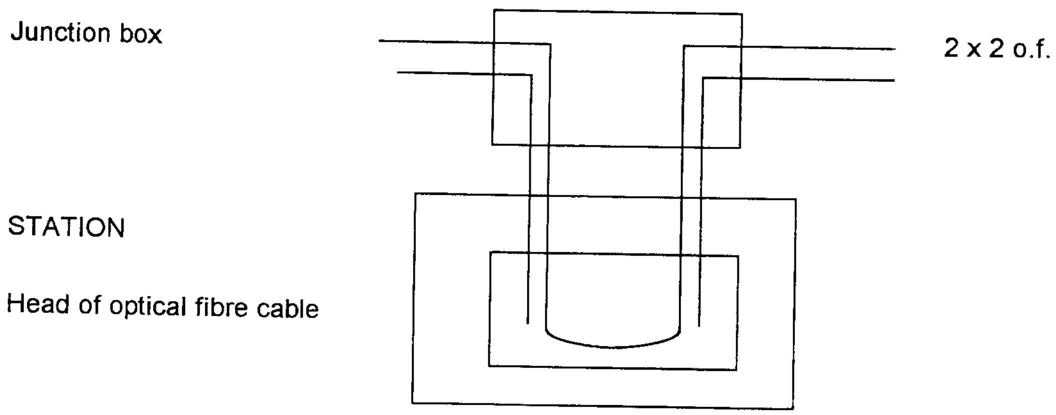


Diagram 3B

Connection of optical fibre cable
Solution not recommended

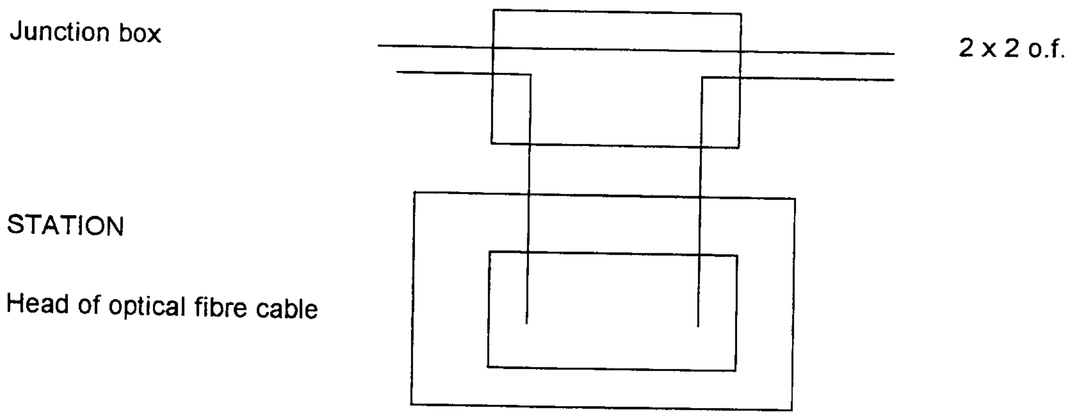


Diagram 3C

Connection of optical fibre cable
Holding solution (optical connector)

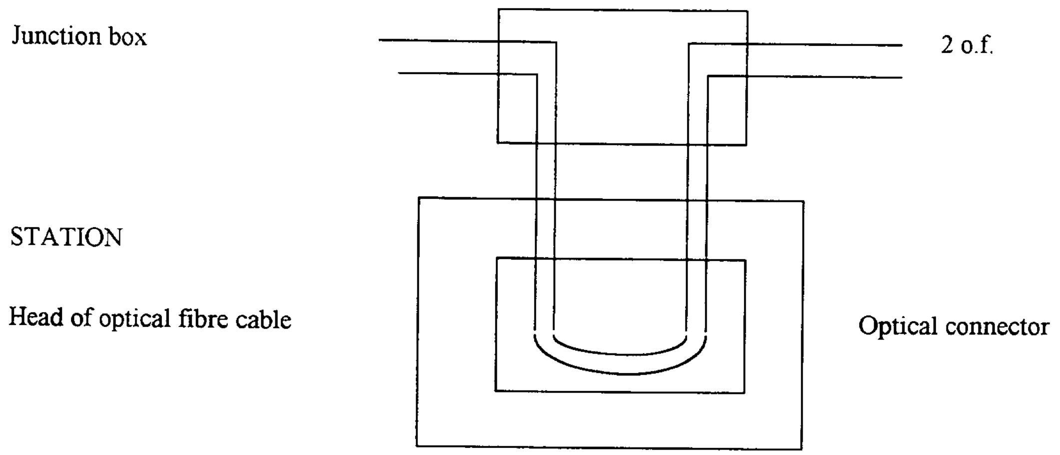
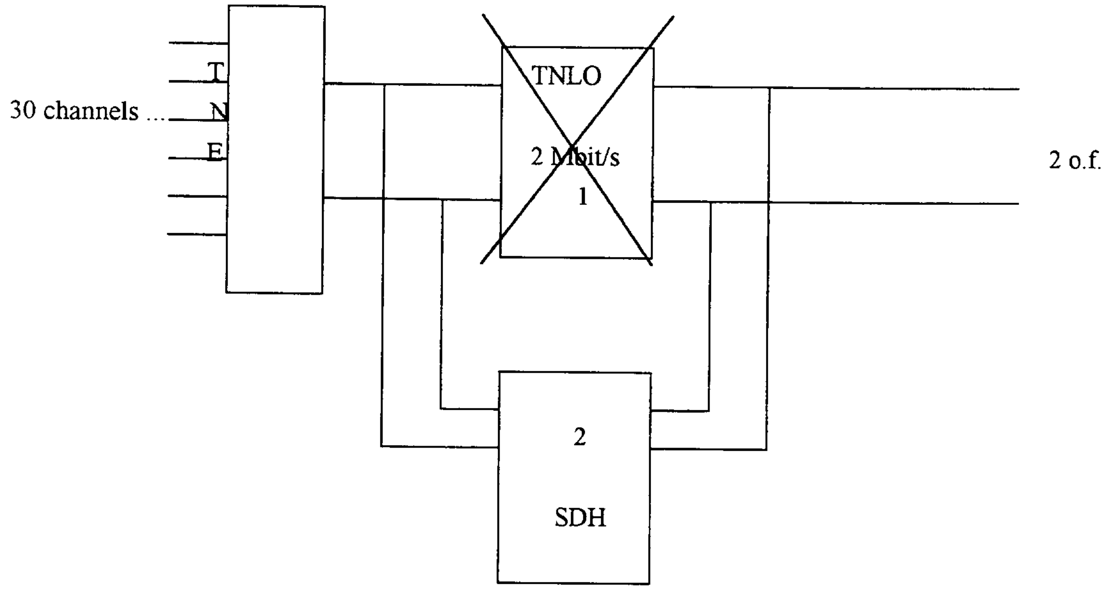


Diagram 4

Migration from PDH to SDH



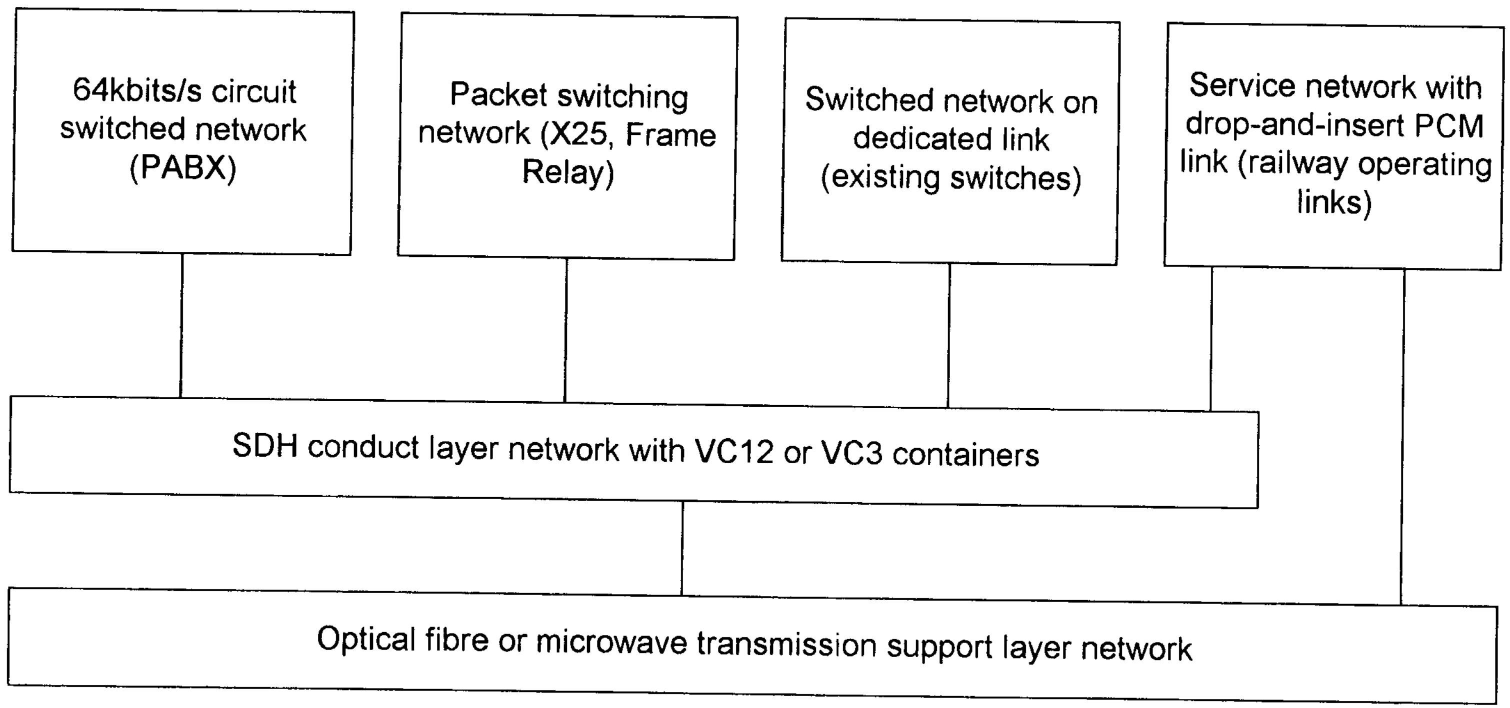
SDH : Synchronous Digital Hierarchy
TNE : End Digital Terminal
TNLO : Optical Line Digital Terminal

Chapter 2

General recommendations and methodology
Appendix 2 - Bloc diagrams

Appendix 2 - Bloc diagrams

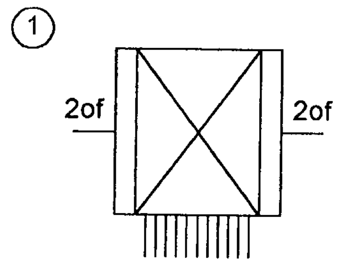
- This architechture is based on ITU recommendation G-803 "Architecture of transport networks with synchronous digital hierarchy (SDH), with the "circuit layer" extended to the PCM drop-and-insert distribution network



Architechtural concept selected

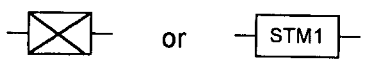
Diagram SP-1

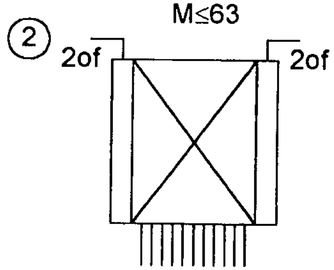
Appendix 2 - Bloc diagrams



STM1 Multiplexer by extension STM1 (equivalent to ADM 155 Mbits/s)

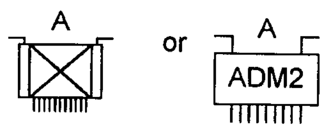
Symbol selected:



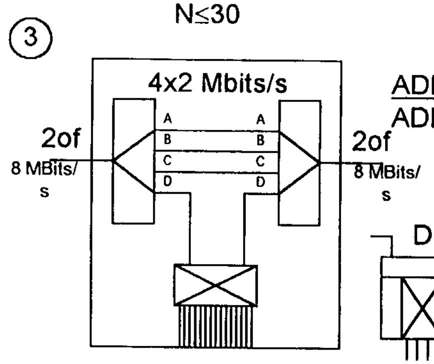


ADM 2 Mbits/s by extension ADM2

Symbol selected:

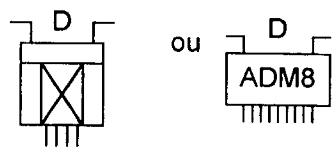


A: 2 Mbits/s channel drop-and-insert



ADM 2 / link 8 Mbits/s by extension ADM8

Symbol selected:

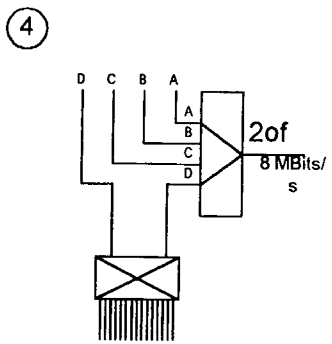


D: 2 Mbits/s channel drop-and-insert

Logical representation ADM2/8 A B C D (D being the 2 Mbits/s drop-and-insert)

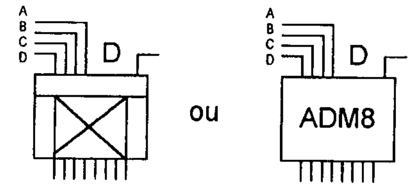
Basic components

Diagram SP-2 1/2

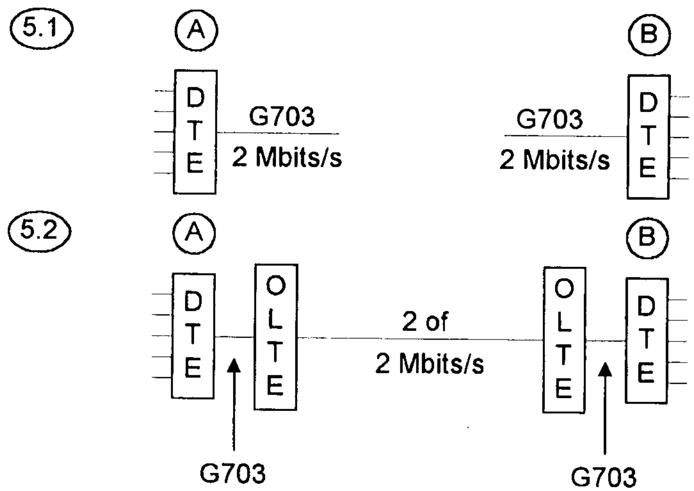


ADM 2 / 8 used at the end

Symbol selected:



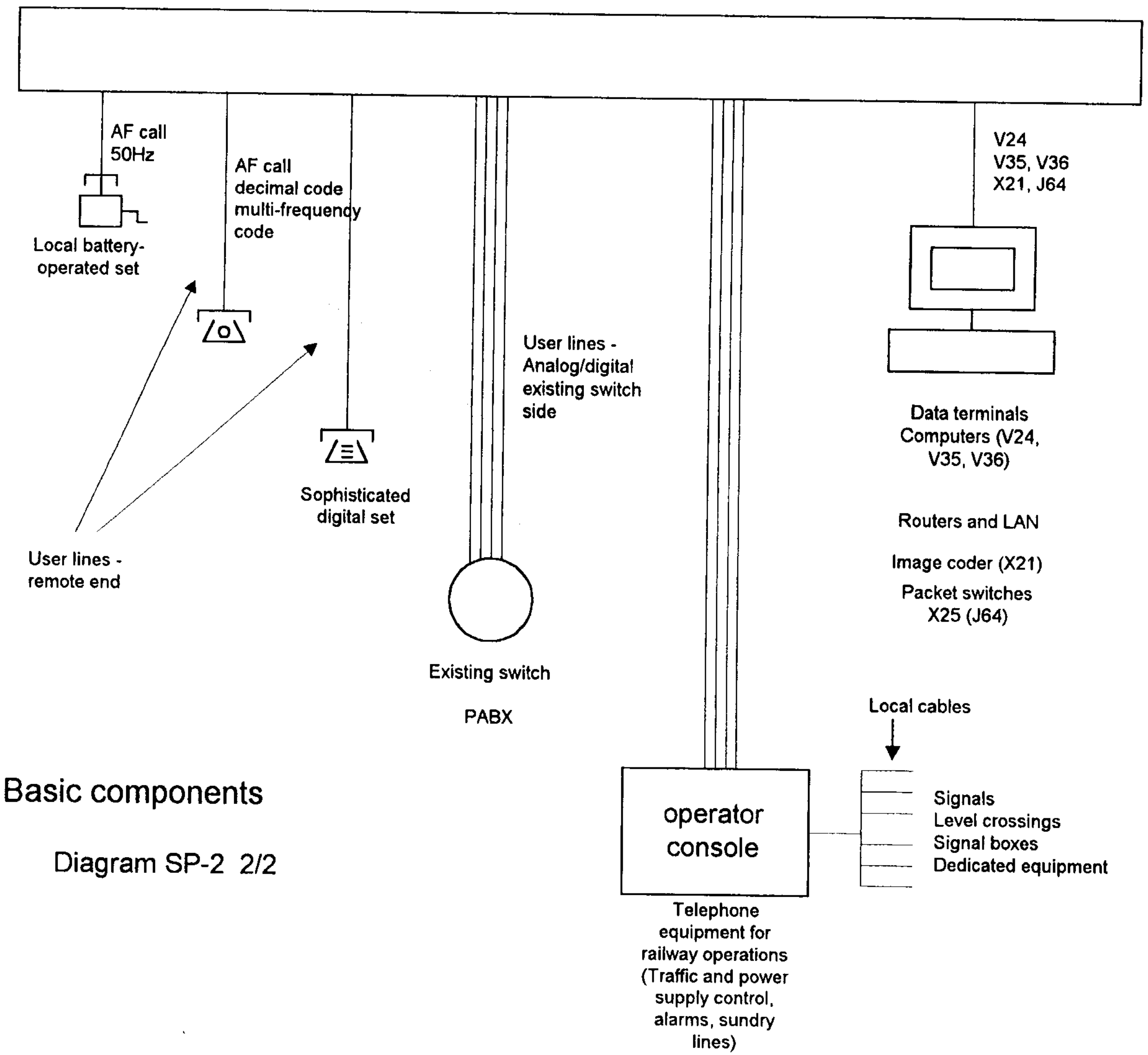
5 Digital Terminal Equipment (DTE)



One DTE provides a 2Mbits/s point-to-point link between two points A and B in accordance with diagrams 5.1 and 5.2. The link may be electrical (conforming with G703) or optical. In the latter case, Optical Line Terminal Equipment (OLTE) shall be used for the fibre interface)

Appendix 2 - Bloc diagrams

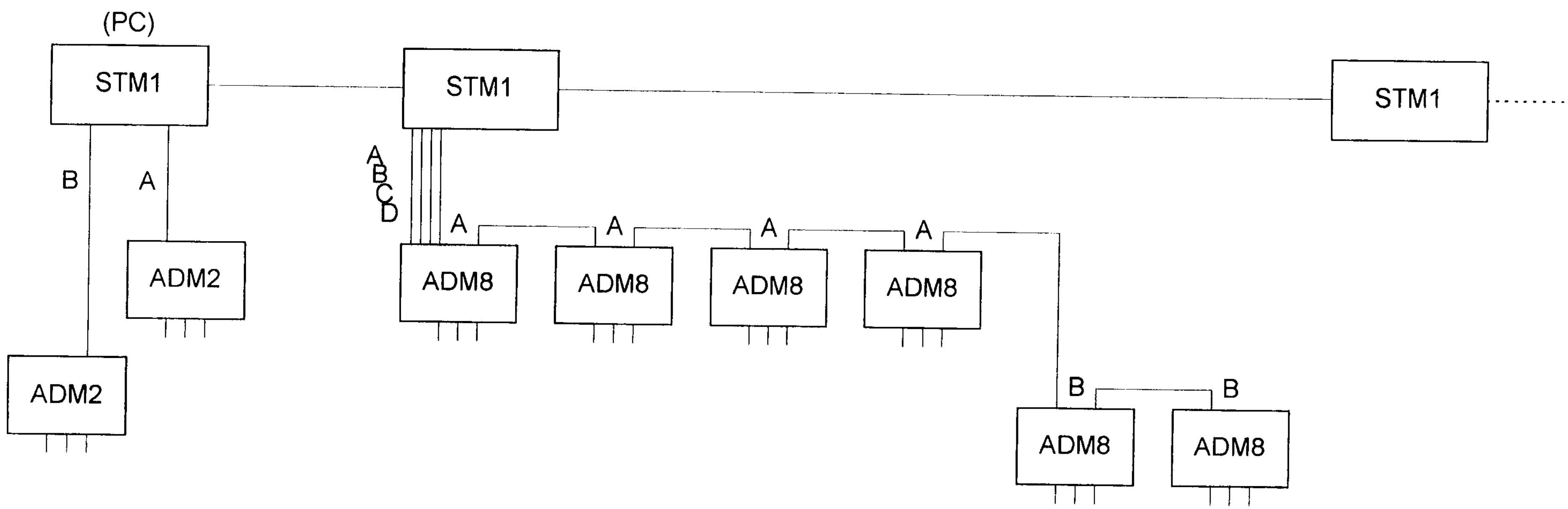
(6) Interfaces available: audio frequency (analog) and data for 64kbits/s channels



Basic components

Diagram SP-2 2/2

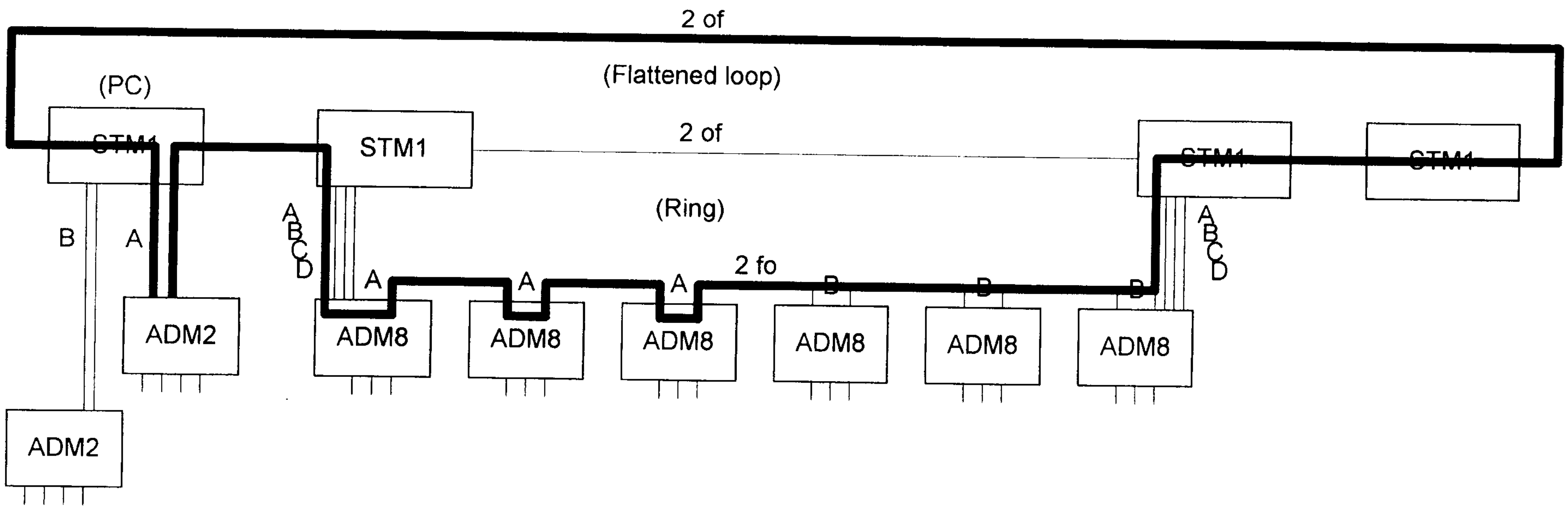
Appendix 2 - Bloc diagrams



Backbone and distribution network

Diagram SP-3

Appendix 2 - Bloc diagrams



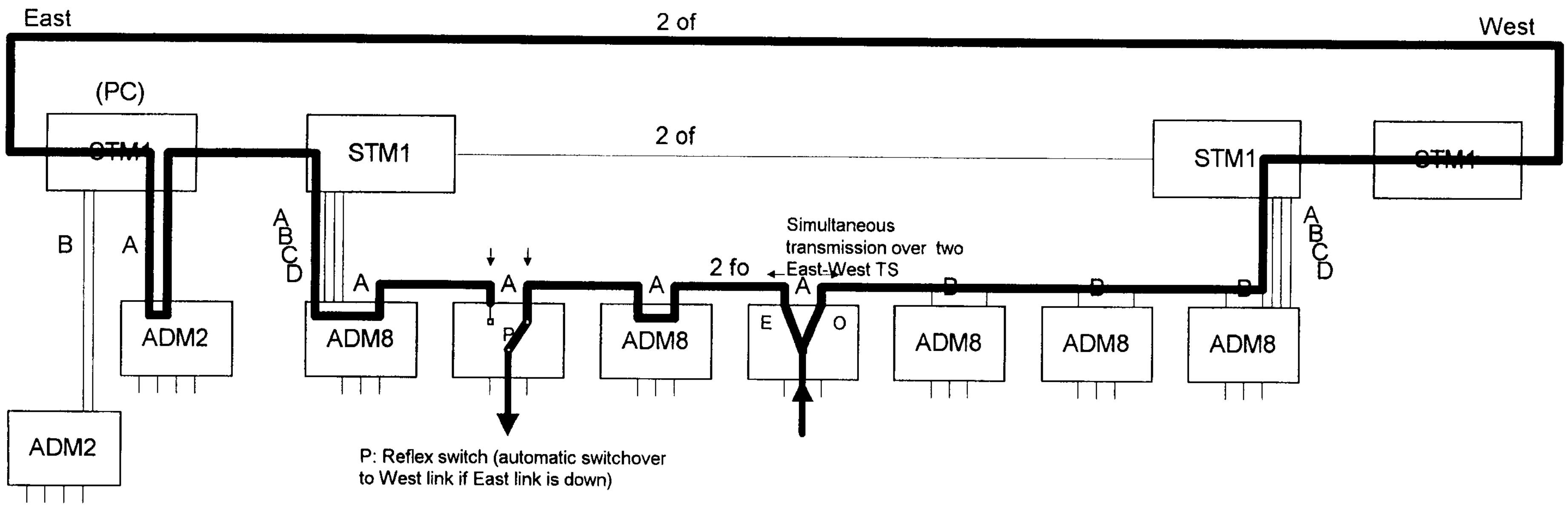
NB:

- The part highlighted in yellow is the 2Mbits/s "A" loop with back-up.
- The distribution network may be equated with a ring on a flattened loop.
- The 3x2 of are in the same optical fibre cable.

Partial redundancy for backbone and distribution networks
(flattened loop)

Diagram SP-4

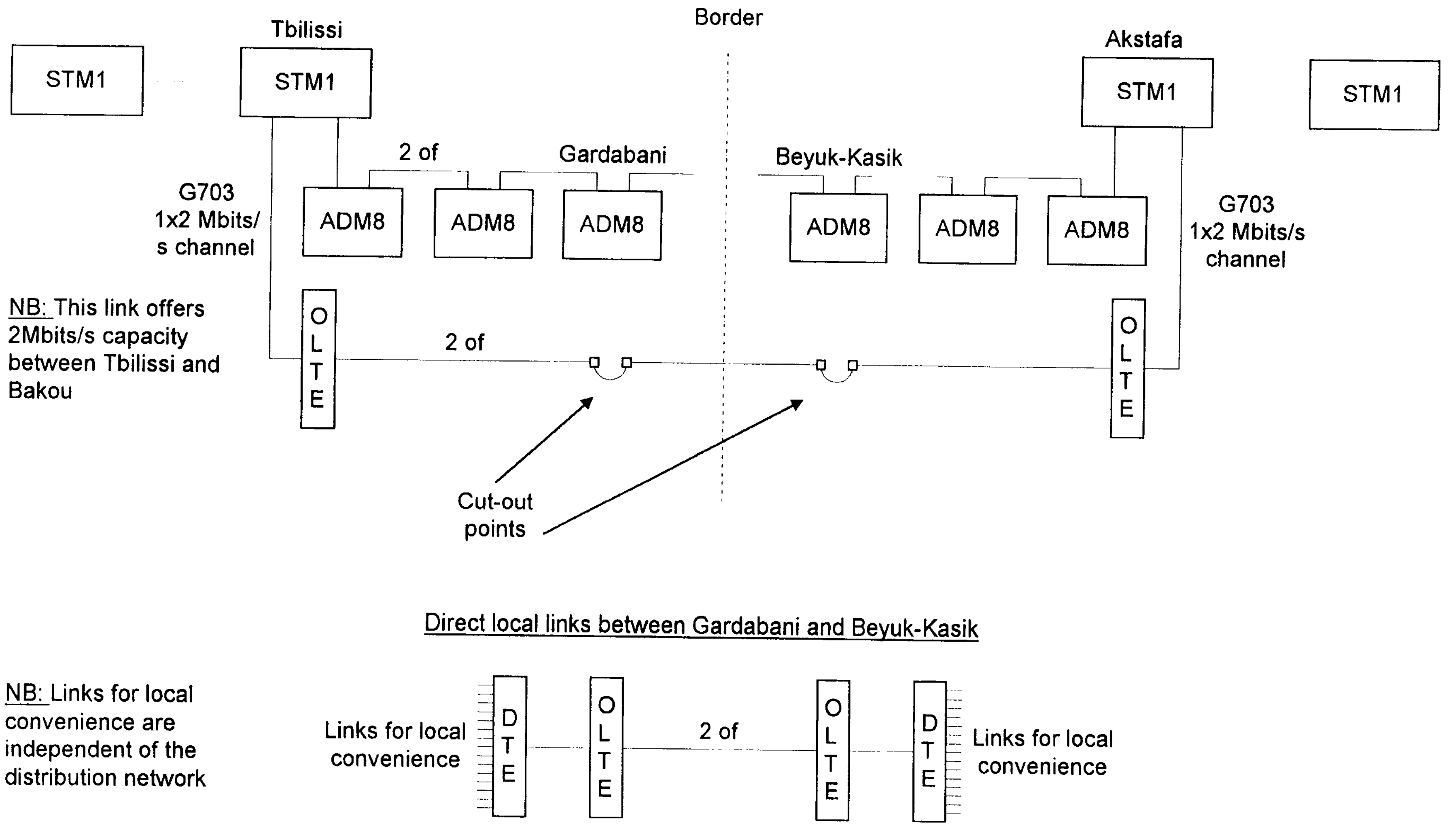
Appendix 2 - Bloc diagrams



Partial redundancy for backbone and distribution networks (2)
(Simultaneous transmission over two Time Slots (TS))

Diagram SP-5

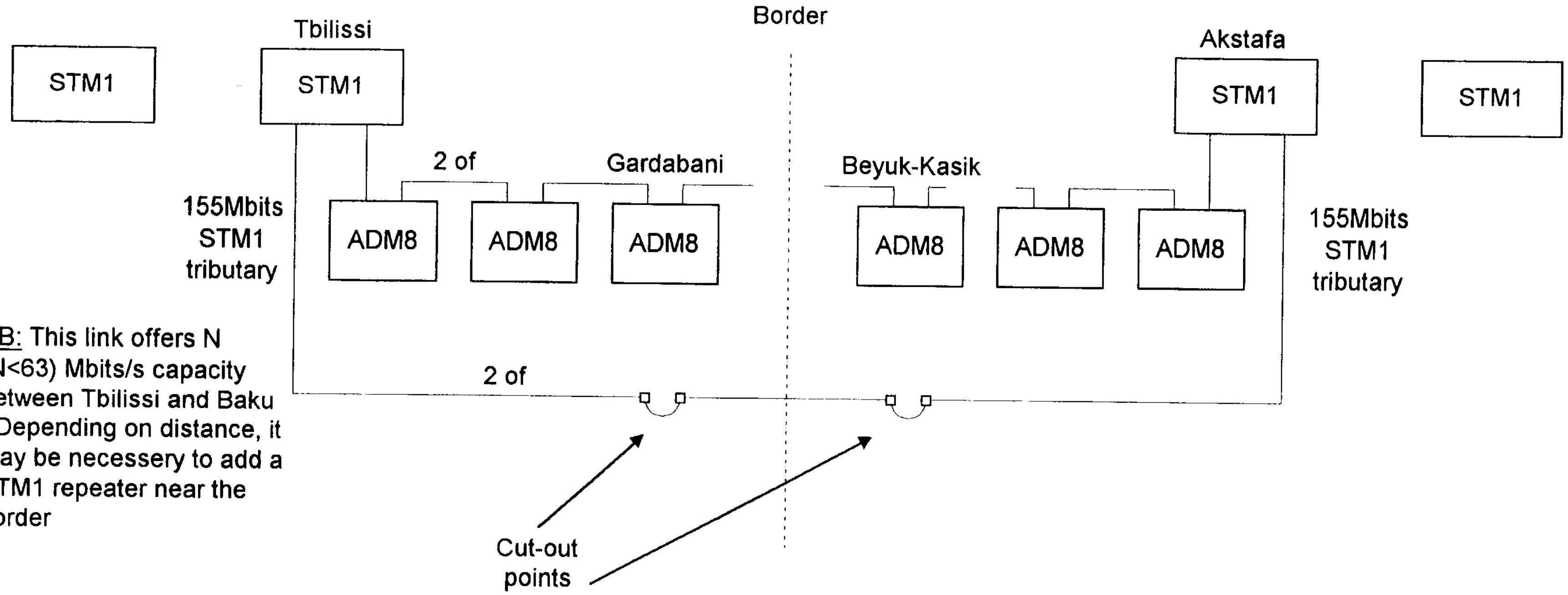
Appendix 2 - Bloc diagrams



Interconnexion of networks at the borders

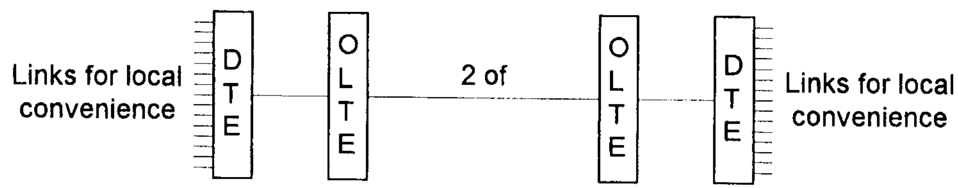
Diagram SP-6 1/2

Appendix 2 - Bloc diagrams



<u>NB:</u> This link offers N (N<63) Mbits/s capacity between Tbilissi and Baku - Depending on distance, it may be necessery to add a STM1 repeater near the border

<u>Direct local links between Gardabani and Beyuk-Kasik</u>

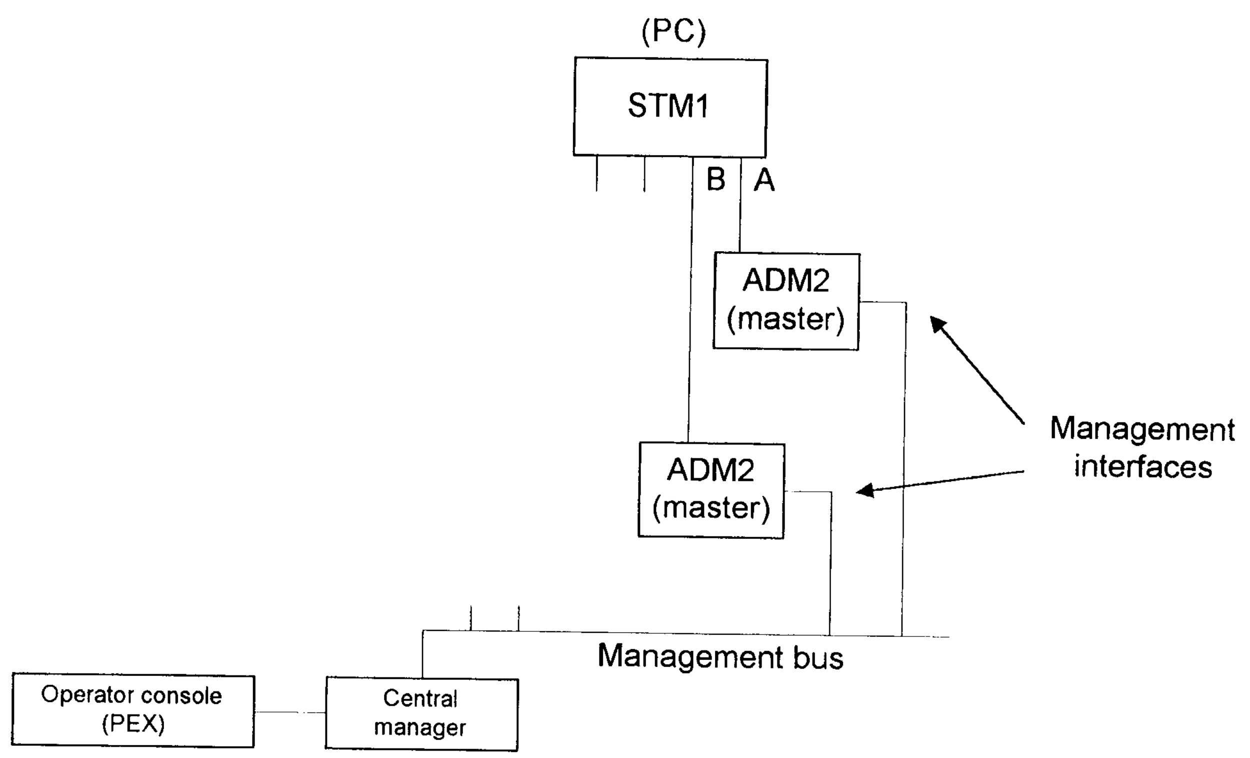


<u>NB: Links for local convenience are independent of the distribution network</u>

Interconnexion at 155Mbits/s of networks at the borders

Diagram SP-6 2/2

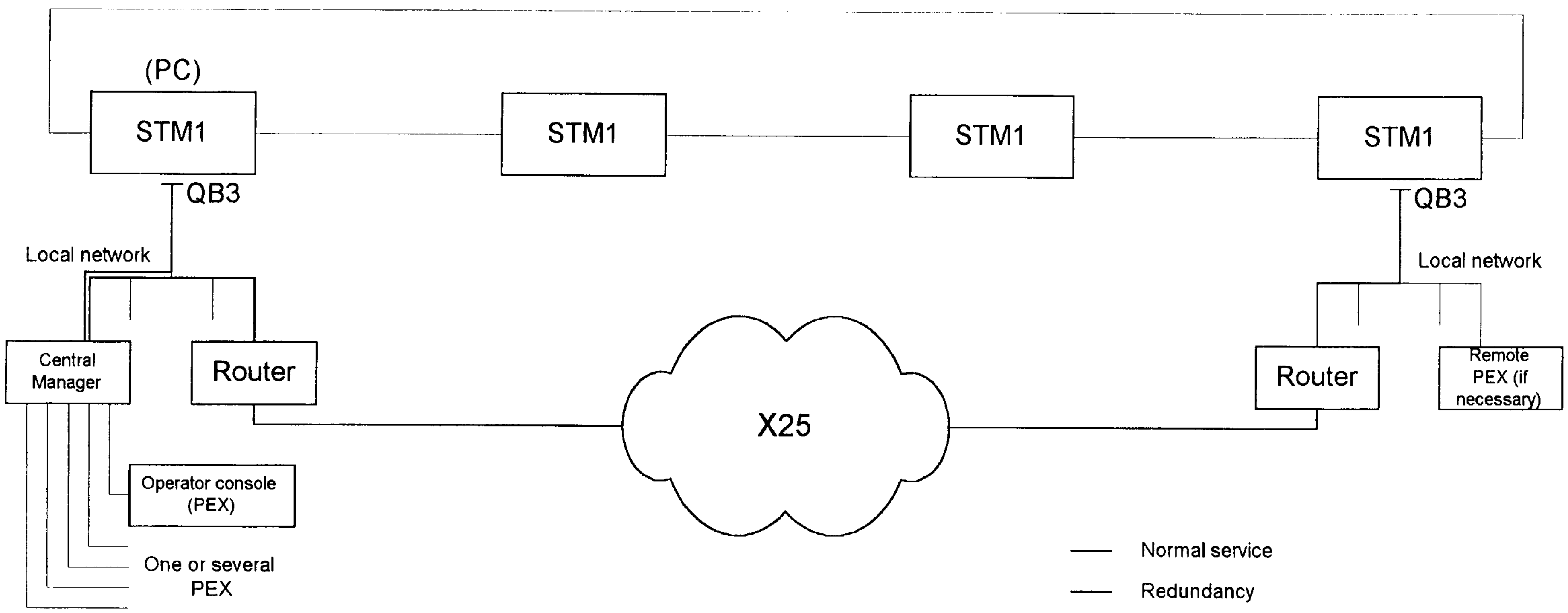
Appendix 2 - Bloc diagrams



Distribution network managed from control centre

Diagram SP-7

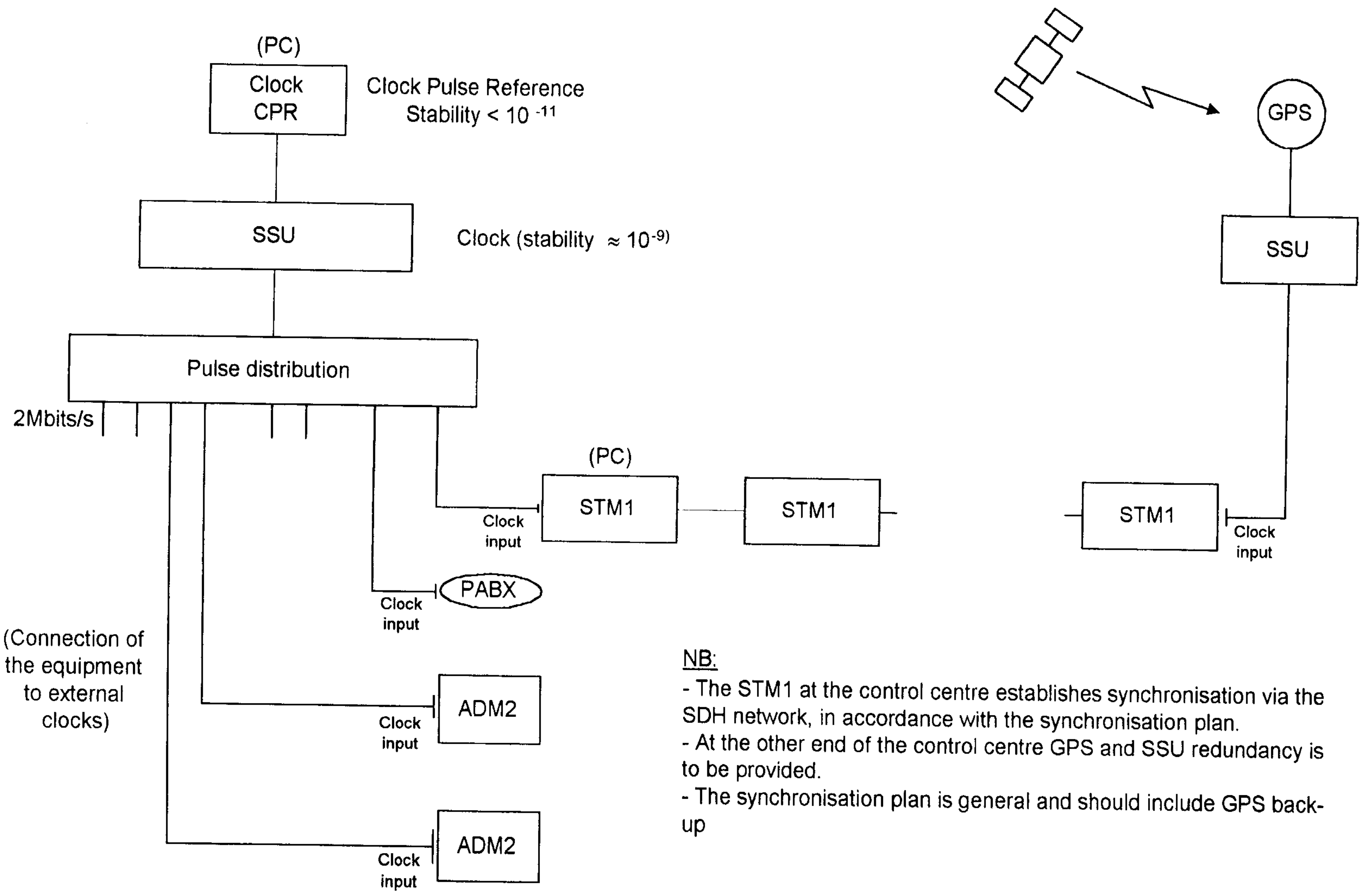
Appendix 2 - Bloc diagrams



Network Management

Diagram SP-8

Appendix 2 - Bloc diagrams

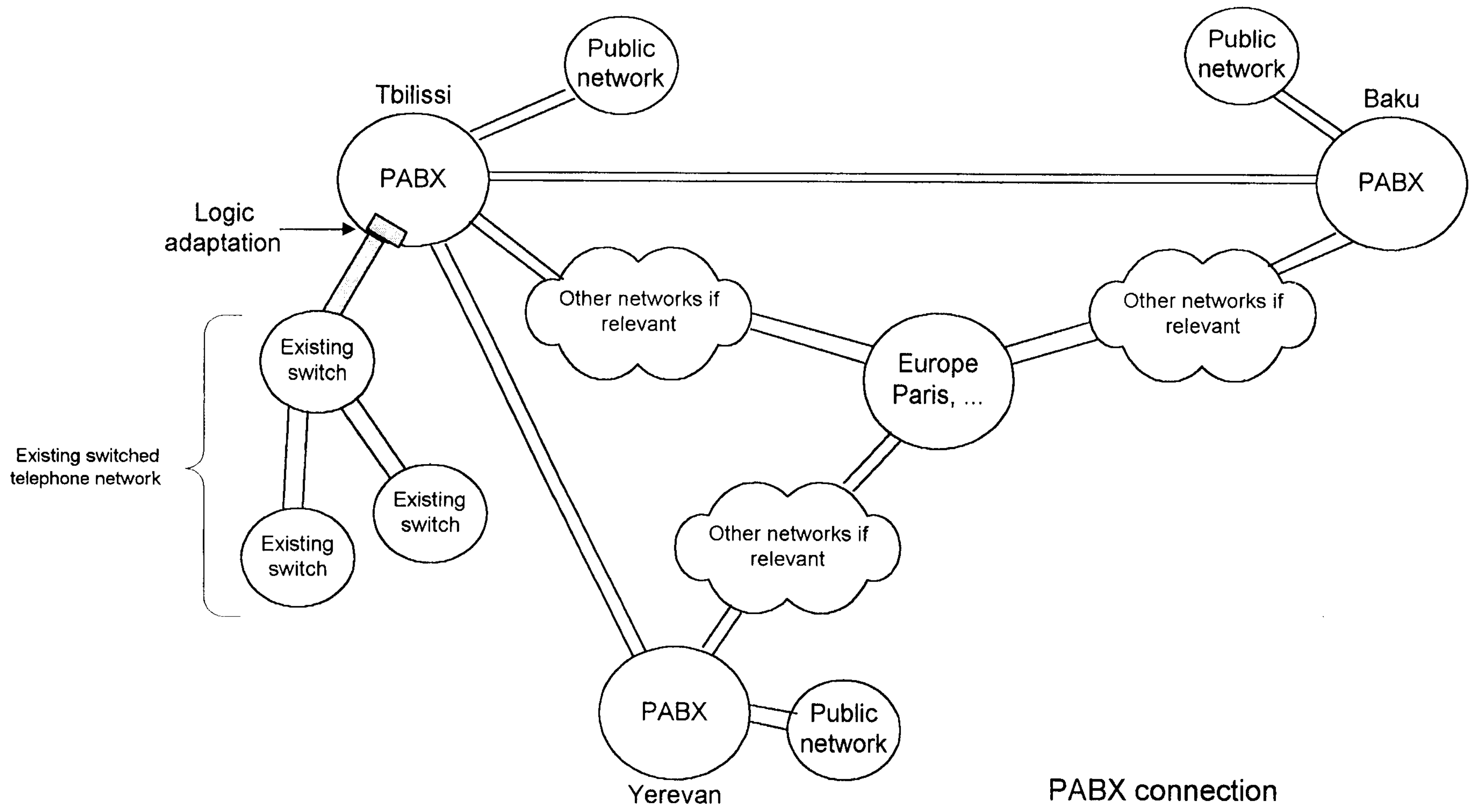


NB:
- The STM1 at the control centre establishes synchronisation via the SDH network, in accordance with the synchronisation plan.
- At the other end of the control centre GPS and SSU redundancy is to be provided.
- The synchronisation plan is general and should include GPS back-up

Network synchronisation

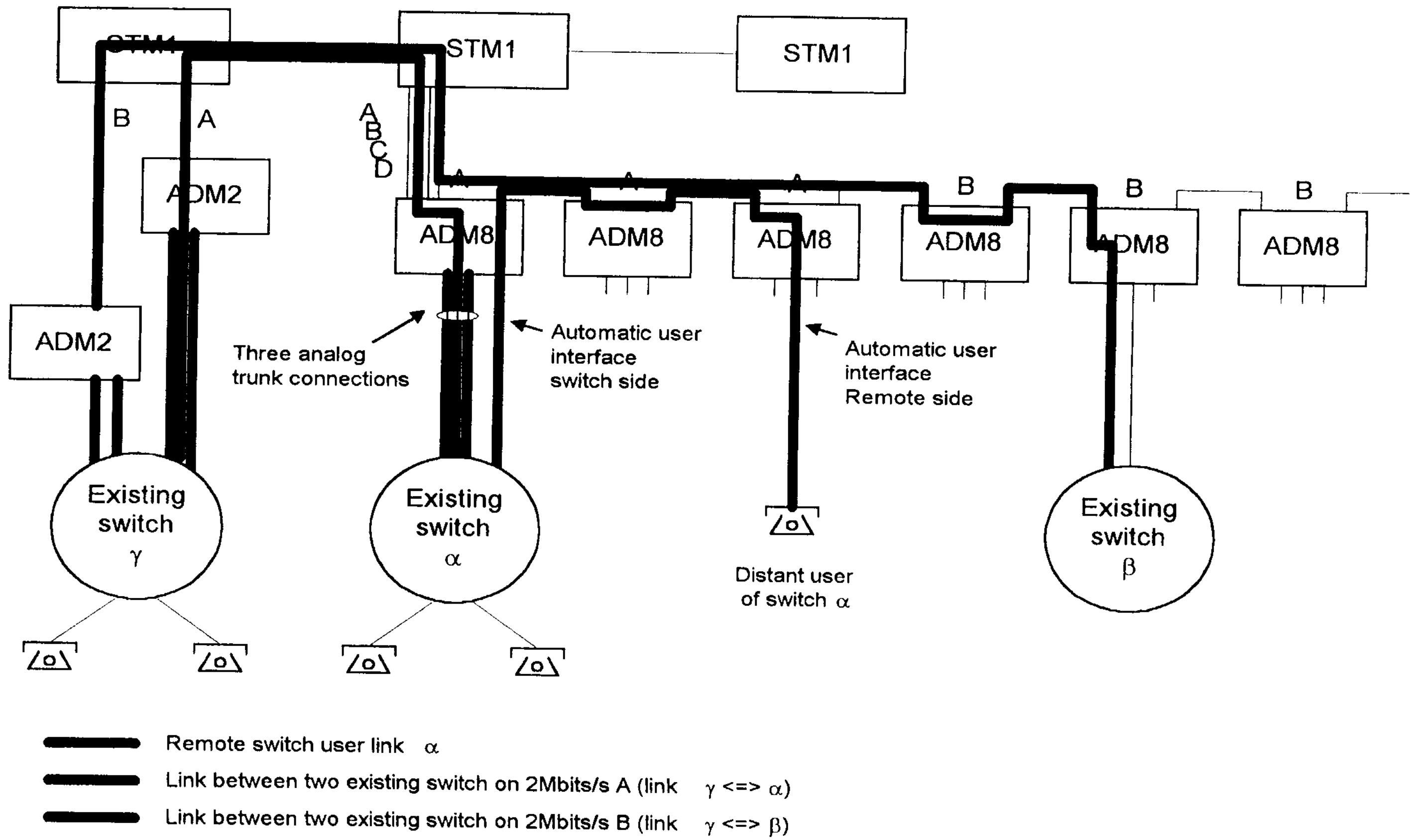
Diagram SP-9

Appendix 2 - Bloc diagrams



PABX connection
Diagram SP-10

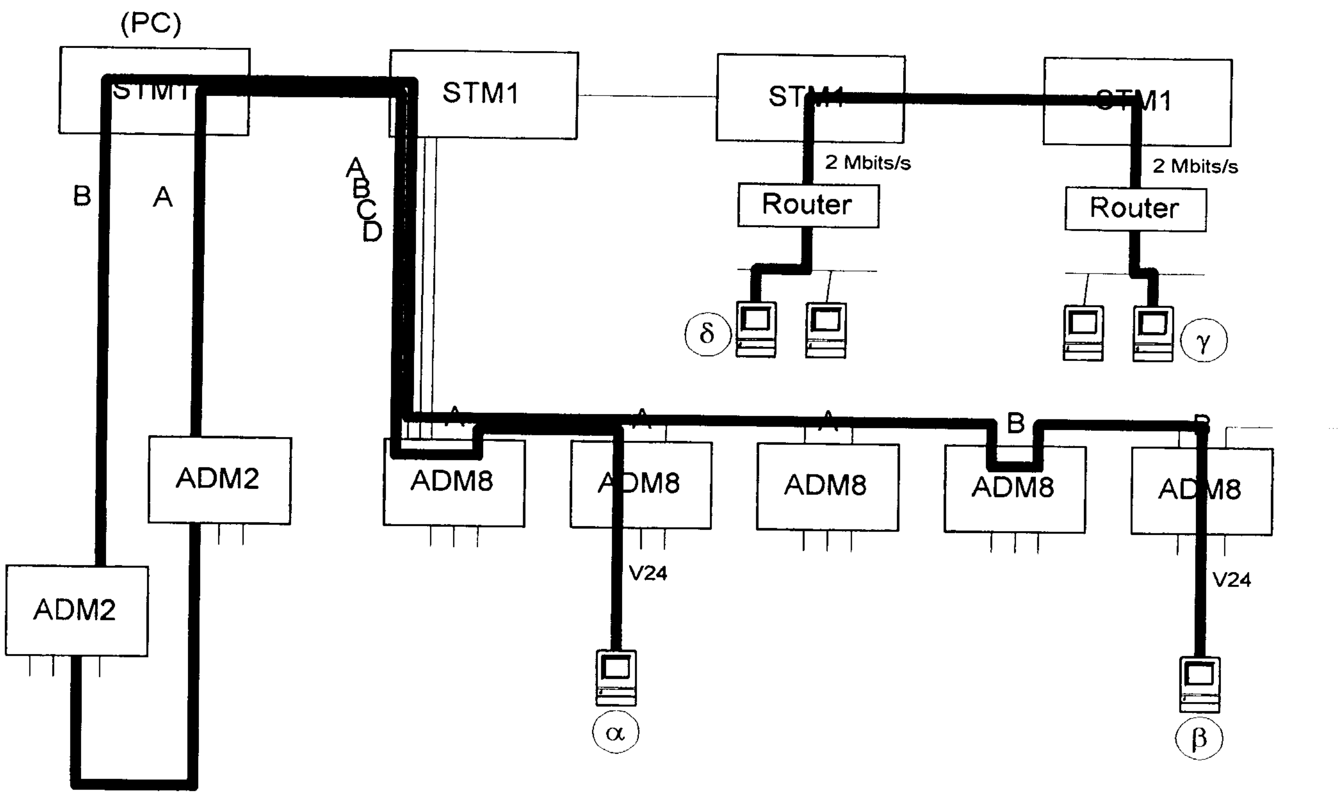
Appendix 2 - Bloc diagrams



Existing switch connection

Diagram SP-11

Appendix 2 - Bloc diagrams



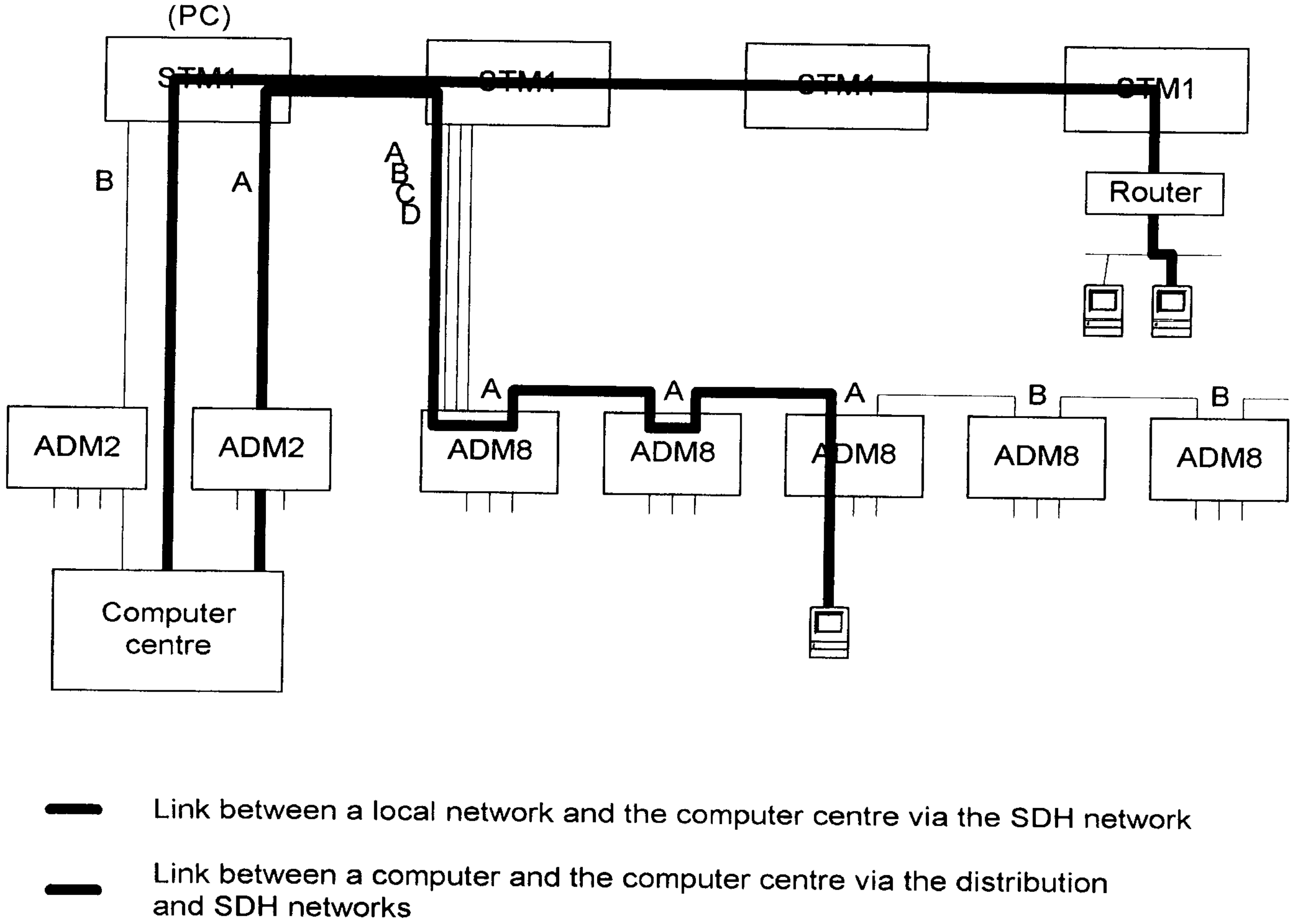
Connection between two computers α et β via the distribution and SDH networks

Connection between two local networks γ et δ via the SDH network

Connection of IT applications

Diagram SP-12

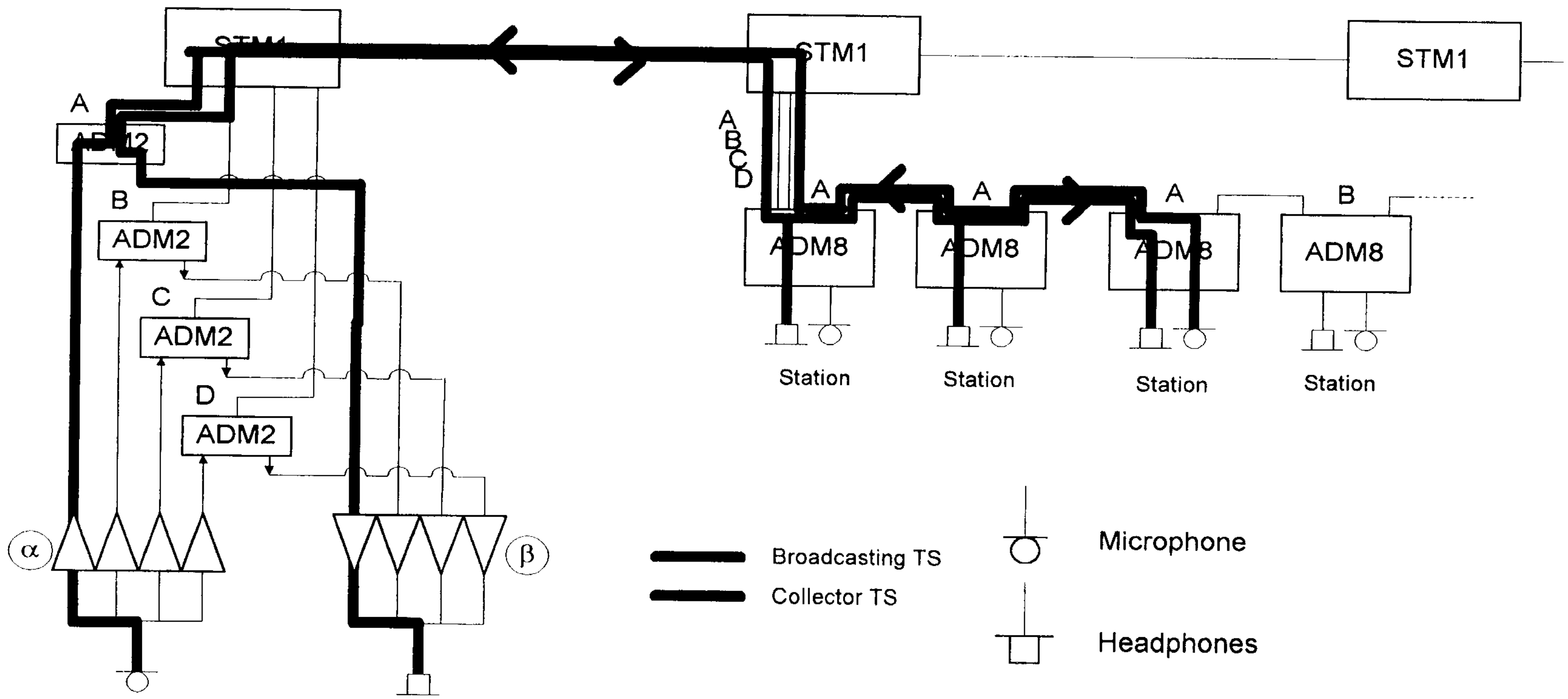
Appendix 2 - Bloc diagrams



Connection of an IT computer centre

Diagram SP-13

Appendix 2 - Bloc diagrams



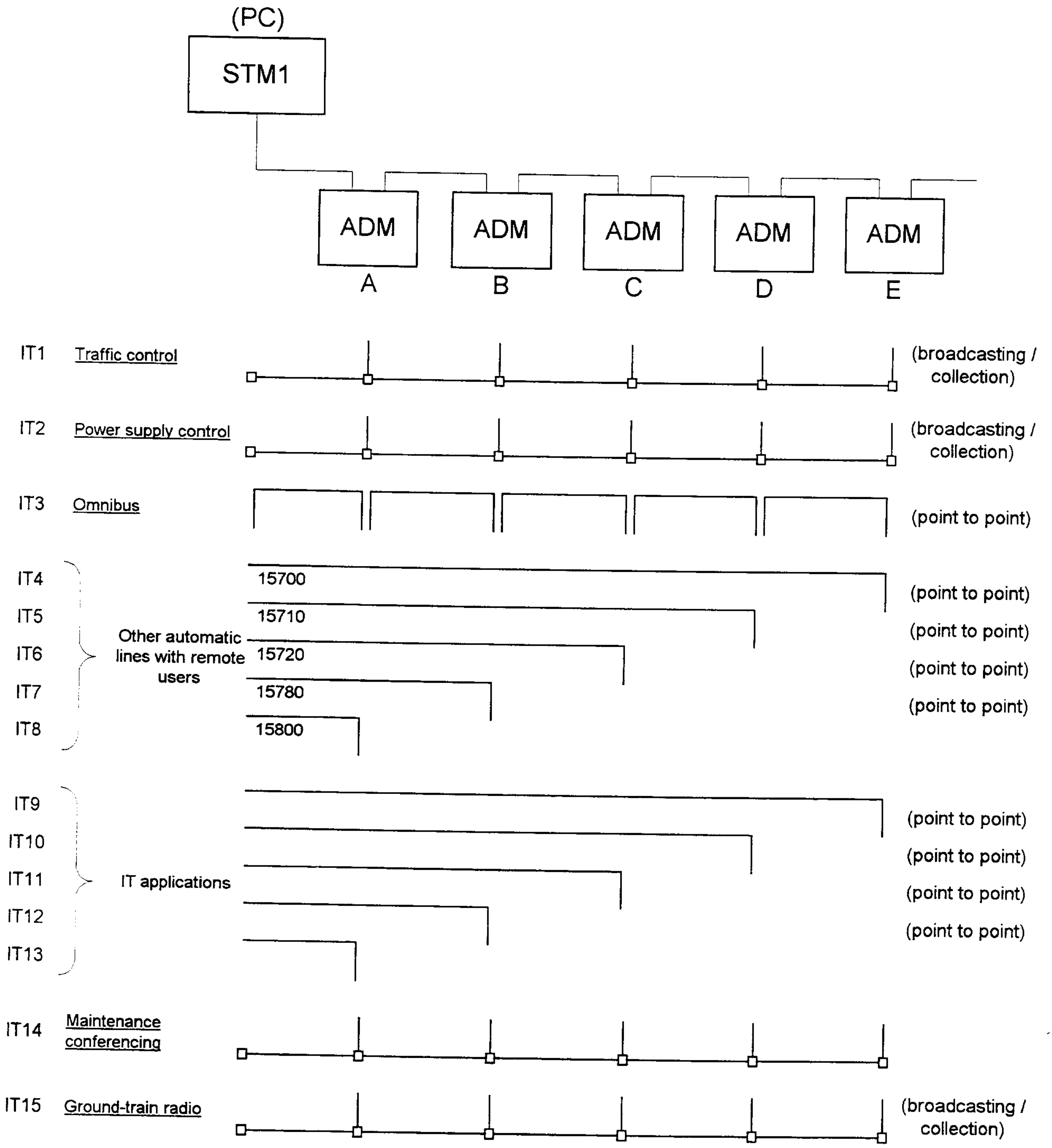
NB:

- Use of broadcasting amplifiers α et collector amplifiers β (as many as there are drop-and-inserts)
- Call receivers are not shown but the paths followed are identical
- Input/outputs in the ADM is by audiocard

Control centre operation

Diagram SP-14

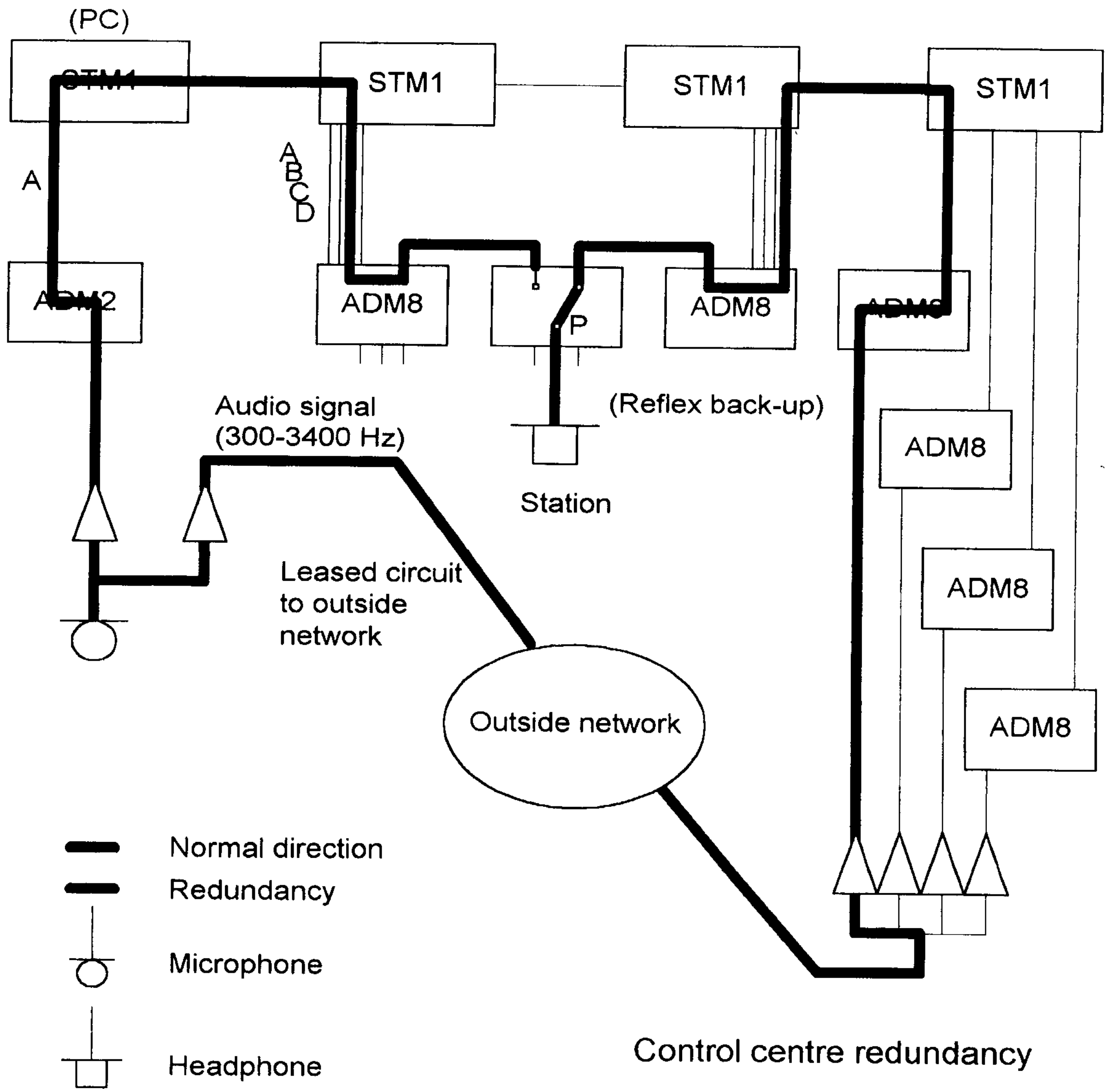
Appendix 2 - Bloc diagrams



Allocation of Time Slots (TS) PCM on control centre to stations distribution network (example)

Diagram SP-15

Appendix 2 - Bloc diagrams

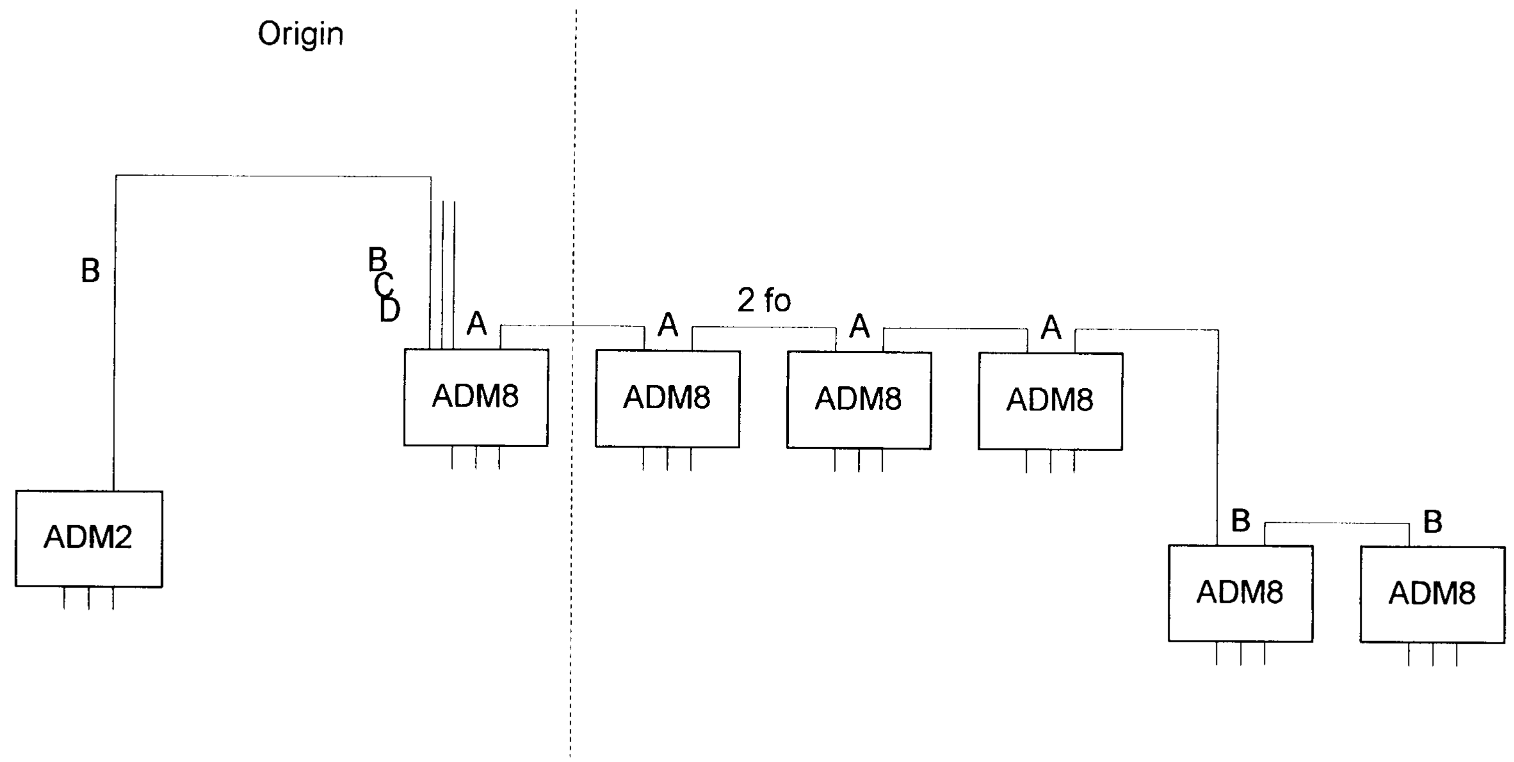


NB:
Redundancy shown over a single link in one direction only (control centre -> station)

Control centre redundancy

Diagram SP-16

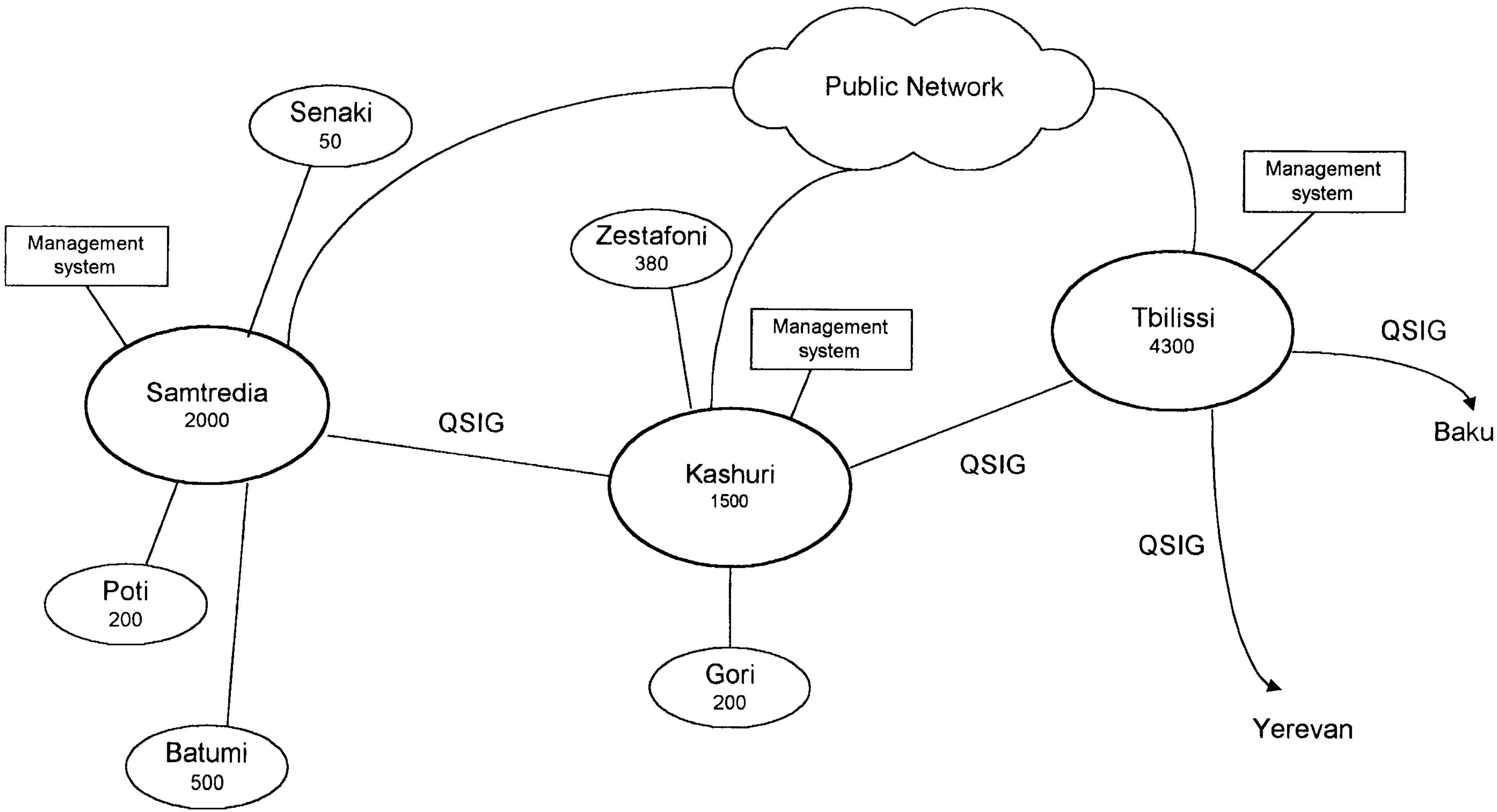
Appendix 2 - Bloc diagrams



Network of secondary railway lines

Diagram SP-17

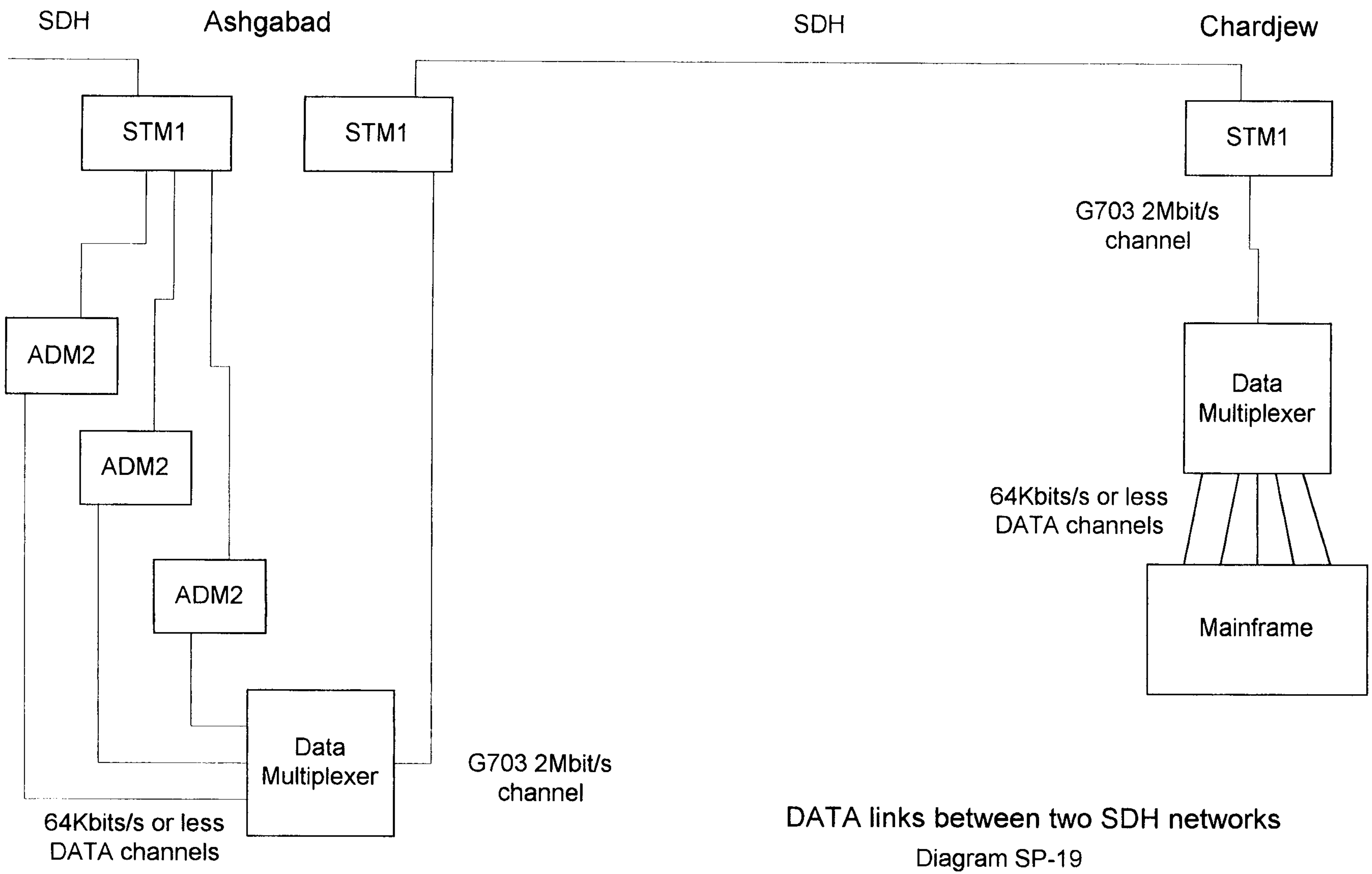
Appendix 2 - Bloc diagrams



Administrative telephone network

Diagram SP-18

Appendix 2 - Bloc diagrams



DATA links between two SDH networks

Diagram SP-19

Chapter 3

Caucasian countries - Inventory

Caucasian Countries - Inventory

Contents

Caucasian Countries - Inventory

Caucasian Countries - Inventory

1. General information on the railway networks

1.1 Armenia

Railway abbreviation	**ARM**	
Total country surface area:		
Population:		
Total line length :	798 km	
Length of lines electrified		
Railway employees :		
Passenger traffic figures:	*1995:*	*1996:*
- number of passengers:	2,969 $x10^3$	1,859 $x10^3$
- number of passenger/km:	166 $x10^6$	84 $x10^6$
Freight traffic figures	*1989:*	*1996:*
- hauled tonnage:	33,900 $x10^3$	1,200 $x10^3$
- number of tonne/km:	5,121 $x10^6$	351 $x10^6$
Length of Traceca corridor:		
Length of corridor electrified		
Type of electric current	3.3 kV D.C.	
Number of trains per day:	*(capacity)* 35	*(at the present time)* 4
- forecast	12	

outline map of railway network:

Caucasian Countries - Inventory

1.2 Azerbaijan

Railway abbreviation	**AZ**			
Total country surface area:	86,600 km^2			
Population:	7,500 000			
Total line length :	2,117 km			
Length of lines electrified	1,278 km			
Length of double-track line	791 km			
Length of single-track line	487 km			
Railway employees :	42,800			
Passenger traffic figures:	*1995:*		*1996:*	
- number of passengers:		8,955 x10^3	x10^3	
- number of passenger/km:	791 x10^6		558 x10^6	
Freight traffic figures	*1995:*		*1996:*	
- hauled tonnage:	9,073 x10^3		x10^3	
- number of tonne/km:	2,409 x10^6			2,778 x10^6
Length of Traceca corridor:	503 km			
Length of corridor electrified	503 km			
Type of electric current	3.3 kV D.C.			
Number of stations on corridor	47, *distance :*		mean =12km, max =15km	
Number of trains per day:	*(capacity)*	2x 45	*(at the present time)* 2x 8	
- forecast *(opt., pes.)*	2x 30		2x 15	

outline map of railway network:

1.3 Georgia

Railway abbreviation	**GR**		
Total country surface area:	69,700 km^2		
Population:	5,400 000		
Total line length :	1,575 km		
Railway employees :	10,800		
Passenger traffic figures:	*1995:*		*1996:*
- number of passengers:	3,674 x10^3		x10^3
- number of passenger/km:	371 x10^6		380 x10^6
Freight traffic figures	*1995:*		*1996:*
- hauled tonnage:	4,656 x10^3		x10^3
- number of tonne/km:	1,246 x10^6		1141 x10^6
Length of Traceca corridor:			
Length of corridor electrified			
Type of electric current	3.3 kV D.C.		
Number of trains per day:	*(capacity)*	2x 45	*(at the present time)* 2x 7
- forecast *(opt., pes.)*	2x 25		2x 15

outline map of railway network:

2. Telecommunications

2.1 Inventory

2.1.1 Armenia

2.1.1.1 Introduction

Armenian Railways use analog systems only and are equipped with electromechanical telecom switches. Local calls (between subscribers connected to the same telecom switch) are processed automatically; outside calls (requiring a link between two different telecom switches) go through an operator. The transmission links are HF (frequency modulation) electronic transmission facilities. The media used are copper cables and aerial lines.

Figure 2.1.1.A depicts the Armenian railway network, with the Traceca corridor marked out in bold.

2.1.1.2 General characteristics

The telecommunications installations are standardised (GOST) and comply with OSJD leaflets as regards railway applications. Parts originate from the former Soviet Union or eastern Europe and are no longer in production. Neither are they compatible with today's technology.

Installations are primarily fed from the public grid. A secondary power supply (transformation, rectification, back-up) is provided by the railway. Back-up energy is generated by a battery with an few hours' capacity (depending on the condition of the battery). Major centres have the additional safeguard of diesel generators which are activated, automatically or manually, in the event of a public grid power cut.

2.1.1.3 Switching

Switching nodes are located at the following stations: Yerevan, Masis, Gyurmi, Vanadzor, Sanain and Ayrum. To make a local call, the subscriber dials the desired number and is put through automatically.

To make an outside call, the subscriber must dial the operator and state the name and number of the connection sought. The operator calls back once end-to-end communication has been established (a process which may involve several operators) This manual procedure is limited by the operator's switchboard capacity and the number of transmission channels. The switchboards used are type MPU-80, MPU-20 or MPU-60. Call connection times no longer meet modern-day requirements.

Caucasian Countries - Inventory

Figure 2.1.1.B shows the location of telecom switches on the railway network. The following table lists the capacity (number of subscribers) per node. Telecom switches are currently saturated.

Location	*Kilometre point*	*Number of subscribers*	Model
Yerevan	2877/0	2000	KR
Masis	2863/598	500	ATS
Gyurmi	2723	2000	ATS
Vanadzor	2654	500	ATS
Sanain	2613	400	ATS
Ayrum	2582	100	ATS

The telecom switches employ either rotary or crossbar technology. The oldest dates from 1949 (Gyurmi) and is still operational. It is powered by a central 48 or 60 V battery.

2.1.1.4 Services

To complement the switched telephone network (cf. § 2.1.1.3), a certain number of voice services are also provided on dedicated lines. These links consist of a primary railway telephone transmitter/receiver and terminal installations (subscribers) linked in parallel on the transmission line. The operator (controller) is in permanent receiver mode. Subscribers are selected manually by pressing a button on the operator's switchboard. The primary transmitter/receiver emits the dial tone frequency, which is received by the subscriber selector (APC-1). These connections date from the 70s-90s. Nothing further has been introduced since then, although some circuits are planned.

The services involved are:

- Traffic control (2 wire link)

The traffic control centre is located in the same building as the railway headquarters (Yerevan). It manages 4 line sections, but a proposed upgrading programme would reduce this number to two, which would mean replacing the telecommunications installations and re-organising the circuits.

- Energy control (2 wire link)

This line runs between the energy control centre and energy controllers in the OHL power supply sub-stations. The energy and traffic control centres are situated side by side and cover identical geographical zones.

- Dedicated station-to-station telephone lines (2 wire link between the manual KPS-2/3 and UKSS-8 telecom switches). Call frequency is 25 or 50 Hz.
- Distribution of reserved tickets.

The ticket reservation/distribution centre is connected to some main-line passenger stations.

- Teleconferencing

A 4-wire link connects a supervisor's installation to those of his/her team.

- Railway police
- Operator management of outside calls to and from line stations connected in parallel to a dedicated circuit.
  (2 wire link).
- Signalling and telecommunications maintenance
- Track maintenance
- Lineside alarm (2 wire link).

- Traffic controller - depot link.
- Traffic controller - passenger train formation yard link.

The local circuits at stations are arranged in the same fashion and energised by local 50 or 80 V batteries.

- Telegraphy

Armenian Railways also has telegraph links: The network dates from the latter half of the 60s, with a few changes in terminal equipment (upgrade in models), and remains in service today. The models currently in use are T-63, STA 67 and F-1100. Several dozen of these terminal installations still function today.

Transmission rates correspond to those achieved by older European systems, i.e. 50 baud (24-channel transmission system), 100 baud (12-channel transmission system) or 200 baud (6-channel transmission system). Connection is automatic and P-327-3 or P-327-12 transmission equipment is used.

The telegraph office is located at the railway undertaking's headquarters. Terminal installations are connected to the switch and can be linked to other installations in the former SZD telegraph network (the central switch of the RZD network is situated in Moscow). Today, the telegraph links are used to send written instructions concerning traffic control and commercial aspects.

2.1.1.5 Transmission media

The transmission media are copper cables and aerial lines. Most of the cables are buried. Transmission links are generally served by HF (frequency modulation) electronic transmission installations, although use is also made of direct audiofrequency transmission over copper cables and aerial lines. Adaptation is carried out by a translator.

The cables are type 7x4x1.2+5x2x0.7+1x0.7 (7 star-shaped quads, 1.2 mm diameter wire; 5 pairs and 1 wire of diameter 0.7 mm) MKPAB (paper insulation, aluminium armouring and PVC outer sheath). The wire pairs also carry signalling information.

The following table indicates the inauguration year and overall transmission quality for the main cable sections.

Section	*Length*	*Year introduced*	*Quality*	
Yerevan - Masis	14.5 km	1966	poor condition, not in use	
Masis - Ararat	39 km	1986	poor condition, not in use	
Ararat - Eraskh	12 km	1986	8 km missing	
Masis - Araks	46 km	1987	in use	
Yerevan - Kanaker	17 km	1975	poor condition	
R-51km - Razdan	36 km	1985	in use	
Razdan - Indjevan	83 km	1985	poor condition; 2.5km missing	
Sevan - Shorja	45 km	1978	poor condition	
Masis - R-51km	51 km	1981	poor condition	
Araks - Gyumri	95 km			
Gyumri - Vanadzor	69 km			
Gyumri - Arevik				
R-51km - Kanaker		1997	adequate; insufficient capacity : 4 quads, 1.2 mm wire diameter	*Note:*

Caucasian Countries - Inventory

Poor transmission quality is primarily due to cable insulation lying outside the minimum tolerance limits. This is more often than not caused by moisture penetrating through to the cables at the junction boxes. Penetration increases over time in relation to the different materials used for the junction boxes and the cable armouring.

In some cases, it was necessary to replace a faulty junction box with two new boxes linked by a strip of intermediate cable. Such measures trigger signal reflections and interfere with capacitance regulation. This interference is not easily eliminated from cables that have already been laid. All these problems also arise when cable sections are stolen.

The situation is worsened by the poor condition of earthing cable protective material (theft, inadequate maintenance), leading to an increase in stray currents and, hence, greater cable sheath permeability via electrolysis.

Some sections of the aerial line between Vanadzor and Ayrum (72 km) are fitted out with cables :

Location	*Length*
Vanadzor	570 m
Pambak	28+45 m
Site N°517	920 m
Shagali	30 m
Tumyan	30 m
Kober	60 m
Sanain	2x130 m
km 2609	150 m
Alaberdy	92+52 m
Akhnat	57 m
Akhmala	400 m
km 2589	40 m
Ayrum	54+137+20 m

The cables used are 7x4x1.2 (TZB). The alternation between cables and aerial lines generates signal reflections, thus exacerbating transmission quality. The aerial line wires are made of bronze or steel, with diameters of 4 mm (main line, 6 HF wires) or 5 mm (main line, 10 LF wires).

Figure 2.1.1.C shows the layout of cables and aerial lines.

Most of the transmission installations are HF (frequency modulation), with 3 (frequency range of 4 kHz to 31 kHz) or 12 (frequency range of 36 kHz to 143 kHz) channels.

The frequency influences the cable attenuation coefficient. The following signal attenuation values apply to 1km of cable:
0.41 dB / km for 0.8 kHz,
1.78 dB / km for 110 kHz,
3.04 dB / km for 250 kHz.

Caucasian Countries - Inventory

The distance between two consecutive amplification points is inversely proportional to the selected frequency range. Along the Vanadzor-Arask line (length 164 km ; district telecommunications headquarters at Gyurmi), amplifiers are positioned at the following stations /KP : Arask / 2818, Karakert / 2803, Aragats / 2786, Anyi/ 2767, Aguin / 2748, Bayandur / 2735, Gyurmi / 2723, Maisyan / 2712, Kaltakhin / 2692, Spitak / 2673, Vanadzor / 2654. Furthermore, signals are amplified at emitting stations and at the channel endpoints listed in the table below. Amplification takes place in telecommunications facilities (as opposed to lineside cabins).

Transmission channel capacity between centres is as follows:

Station	*Station*	*Number of channels*
Yerevan	Gyumri	(2x)24 channels
Gyumri	Vanadzor	24 channels
Vanadzor	Sanain	12 channels
Vanadzor	Sanain	3 channels
Sanain	Ayrum	12 channels
Yerevan via Kanaker	Razdan	12 channels
Yerevan via Egvard	Razdan	12 channels
Yerevan	Abovyan	3 channels
Yerevan	Egvarg	3 channels
Razdan	Sevan	12 channels
Sevan	Shorja	3 channels
Razdan	Dilijan	12 channels
Dilijan	Idjevan	12 channels
Shorja	Zod	

An international 3-channel link between Sanain and Tbilisi (Georgia) is fed by V-3-3 installations.

Figure 2.1.2.D illustrates the railway's transmission capacity.

48 channels are currently required between Yerevan and Gyurmi, however, only 24 are in working order as a result of one transmission installation being dismantled and recycled for spare parts.
Transmission between Yerevan and Razdan via Egvard is down due to the critical state of the cable between Masis and the R-51 km split.
Transmission between Razdan and Indjevan via Dilijan is down and no longer operational following a break in the cable (2.5 km) between Dilijan and Kuybyshevo.

2.1.1.6 Radiocommunications

The railway employs radiocommunications for railway operations. In general, all locomotives are fitted with 2Mhz/VHF radio sets, with the exception of shunting and freight locomotives, which have only VHF radio. Rolling stock comprises electric and diesel locomotives. A breakdown of electric locomotives reveals 47 VL-8 series, 44 VL-10 series and 11 EP-2 EMUs (Electric Multiple Units), 4 of which are in active service.

Two radio systems are used conventionally:

- Train radio

The train radio system enables drivers and controllers/stations to communicate. It is similar to the ground-to-train radio system (standardised in UIC Leaflet 751.3) in all but the following points:

The selected frequency is unique (2.130 MHz) and the operating mode is simplex. All transmitters are positioned in stations. Aerials are situated at a distance of 20 to 50 m from the corresponding radio base. Transmission power is 10 W. Radio bases are not synchronised.

As a result, radio coverage does not extend beyond the station itself and the line sections on either side. However, it should be noted that coverage is not continuous (this would require several distinct frequencies).

Furthermore, from a traffic control point of view, a control circuit is divided up into radio blocks, each comprising several stations and therefore several radio transmitters/receivers.

The locomotives are in permanent receiver mode. Communication is limited to one train per radio block, at the instigation of the controller, the station or the locomotive.

Most of the radio equipment used is 15 to 20 years old.

- Shunting radio

This system provides for communication between the head station traffic controller and shunting team members, including the driver of the shunting locomotive. A similar system is used by maintenance teams (intervention in the event of an accident, etc.).

The shunting radio is a stand-alone system mainly covering station or railway location sites. It is based on the use of simplex frequencies in the 150 - 156 MHz VHF range.

The radio system is similar to those still sometimes used in Europe to transmit over distances of several dozen kilometres. This point was not examined any further within the framework of the present project.

- Transcaucasian radio

This radiocommunications system is shared by all Caucasian railways and was donated by the United Nations "World Food Program". It serves mainly to manage empty wagons and trace trains loaded at ports.

Codan 8528 SSB Transceiver radio sets are used. If connected to a Codan 9001 HF Fax & Data Interface, these sets can also transmit and receive data and faxes. At present, voice communication is most prevalent (only a few sets have a 9001 interface).

See Figure 2.1.1.E

The following Armenian stations are connected: Ayrum, Sanain, Vanadzor, Gyumri, Vardenis, Razdan and Yerevan (traffic control). The transmission channels used are type P01 (3695 kHz), P03 (4560kHz), P05 (5845 kHz), P06 (6995 kHz), P09 (7645 kHz) and P10 (7740 kHz).

Caucasian Countries - Inventory

2.1.2 Azerbaijan

2.1.2.1 Introduction

Azerbaijan Railways use analog systems only and are equipped with electromechanical telecom switches. Local calls (between subscribers connected to the same telecom switch) are processed automatically; outside calls (requiring a link between two different telecom switches) go through an operator. The transmission links are HF (frequency modulation) electronic transmission installations. The physical media used are copper cables and aerial lines.

Figure 2.1.2.A depicts the Azerbaijani railway network, with the Traceca corridor marked in bold. A ferryboat service ensures rail transport between the ports of Bakou and Krasnovodsk (Turkmenbashi). The service to Aktau port (Mangyshlak station) is not yet running.

Caucasian Countries - Inventory

2.1.2.2 General characteristics

The telecommunications installations are standardised (GOST) and comply with OSJD leaflets as regards railway applications. Parts originate from the former Soviet Union or eastern Europe and are no longer in production. Neither are they compatible with today's technology.

Installations are primarily fed from the public grid. A secondary power supply (transformation, rectification, back-up) is provided by the railway. Back-up energy is generated by a battery with a few hours' capacity (depending on the condition of the battery). Major centres have the additional safeguard of diesel generators which are activated, automatically or manually, in the event of a public grid power cut.

2.1.2.3 Switching

Switching nodes are located at the following stations: Bakou, Alyati, Kazi-Magomed, Gyandja, Akstafa, Beyuk-Kyasik, Evlakh, Udzari, Baladjari, Eybat, Sangatchali, Duvanyiy, Karadag, Kyurdamir, Dolyar. To make a local call, the subscriber dials the desired number and is put through automatically.

To make an outside call, the subscriber must dial the operator and state the name and number of the connection sought. The operator calls back once end-to-end communication has been established (a process which may involve several operators). This manual procedure is limited by the operator's switchboard capacity and the number of transmission channels. The switchboards used are type MPU-80, MPU-20 or MPU-60. Call connection times no longer meet modern-day requirements.

The following table lists the number of subscribers per node. Capacity is currently at saturation point.

Station	*KP*	*Number of subscribers*	*Model*	*Level*
Bakou	2661	3000	ATS-54	LAZ
Baladjari	2648	2100	UATS-49	Trans
Alyati-gl.	461	100	KRJ	Trans
Alyati-pr.	5	100	KRJ	LAZ
Kazi-Magomed	417	300	ATS-49	LAZ
Kyurdamir	342	200	ATSK-50	Trans
Udzari	295	200	UATS-49	Trans
Evlakh	250	200	ATSK-50	Trans
Gyandja	183	2300	ATSK-100	LAZ
Dolyar	149	100	KRJ	Trans
Akstafa	88	400	ATSK	LAZ
Beyuk-Kiasik	45	50	ATSK	LAZ

Telecom switches employ either rotary or crossbar technology. They were put into service in the 80s and remain operational today. They are powered by 48 or 60 V central batteries.

The position of the telecom switches is shown in Figure 2.1.2.B

2.1.2.4 Services

To complement the switched telephone network (cf. Section 2.1.2.3), a certain number of voice services are also provided on dedicated lines. These connections consist of a primary railway telephone transmitter/receiver and terminal installations (subscribers) linked in parallel on the transmission line. The operator (controller) is in permanent receiver mode. Subscribers are selected manually by pressing a button on the operator's switchboard. The primary transmitter/receiver emits the dial tone frequency, which is received by the subscriber selector (APC-1). These connections date from the 70s-90s. Nothing further has been introduced since then, although some circuits are planned.
The services involved are:

- Traffic control (2 wire link).

The traffic control centre is housed in the same building as the railway headquarters (Bakou) and manages several line sections totalling 479 km. Rationalisation has triggered an overhaul of traffic regulation, resulting in circuits being reorganised and telecommunications equipment replaced.

- Energy control (2 wire link).

This line runs between the energy control centre and energy controllers in the OHL power supply sub-stations. The energy and traffic control centres are situated side by side and cover identical geographical zones.

- Dedicated station-to-station telephone lines (2 wire link between manual KPS-2/3 and UKSS-8 telecom switches). Call frequency is 25 or 50 Hz.
- Distribution of reserved tickets.

The ticket reservation/distribution centre is connected to some main-line passenger stations.

- Teleconferencing

A 4-wire link connects a supervisor's installation to those of his/her team.

- Railway police
- Operator management of outside calls to and from line stations connected in parallel on a dedicated circuit.
  (2 wire link).
- Signalling and telecommunications maintenance
- Track maintenance
- Lineside alarm (2 wire line).
- Traffic controller - depot link.
- Traffic controller - passenger train formation yard link.

Station circuits are arranged in the same fashion and energised by local 50 or 80 V batteries.

- Telegraphy

Azerbaijan Railways also has telegraphic links. The network dates from the latter half of the 60s, with a few changes in terminal equipment (upgrade in models), and is still in service today. The models currently in use are T-63, STA 67 and F-1100. 155 terminal installations still function today.

Transmission rates correspond to those achieved by older European systems, i.e. 50 baud (24-channel transmission system), 100 baud (12-channel transmission system) or 200 baud (6-channel transmission system). Connection is automatic and P-327-3 or P-327-12 transmission equipment is used.

The telegraph office is located at the railway undertaking's headquarters. Terminal installations are hooked up to the switch and can be connected to other installations in the former SZD telegraph network (the central switch of the RZD network is situated in Moscow). Today, the telegraph links are used to send written instructions concerning traffic control and commercial aspects.

2.1.2.5 Transmission media

The transmission media are copper cables and aerial lines. Most of the cables are buried. Transmission links are generally served by HF (frequency modulation) electronic transmission installations, although use is also made of direct audiofrequency transmission over copper cables and aerial lines. Adaptation is generally carried out by a translator.

The cables are type 7x4x1.2+5x2x0.7+1x0.7 (7 star-shaped quads, 1.2 mm diameter wire; 5 pairs and 1 wire of diameter 0.7 mm) MKPAB (paper insulation, aluminium armouring and PVC outer sheath). The wire pairs also carry signalling information.

The following tables indicates the inauguration year and overall transmission quality for the main cable sections.

Section			*Length*	*Number*	*Year introduced*	*Quality*
Bakou	-	Alyati	89 km	2 cables	1980	7 quads; 4 meet standards
Baladjari	-	Shirvan	40 km	1 cable		
Divetchi	-	Yalama	65 km	1 cable		

On the whole, maintenance has ensured relatively adequate transmission quality. Deterioration is primarily due to cable insulation lying outside the minimum tolerance limits, more often than not as a result of moisture penetrating through to the cables at the junction boxes. Penetration increases over time depending on the different materials used for the junction boxes and the cable armouring.

In some cases, it was necessary to replace a faulty junction box with new boxes linked by a strip of the intermediate cable. Such measures trigger signal reflections and interfere with capacitance regulation. This interference is not easily eliminated from laid cables. All these problems also apply when cables sections are stolen.

The situation is worsened by the poor condition of earthing cable protective material (theft, inadequate maintenance), leading to an increase in stray currents and, hence, greater cable sheath permeability by electrolysis.

Aerial lines total 414 km. The Alyati/Beyuk-Kyasik line section is fitted with 32 bronze (4 mm diameter) and steel (5 mm diameter) wires. This aerial line is sited along the 3.3 kV DC electric railway line, and the operation of electric locomotive engines produces electromagnetic disturbances which undermine transmission quality.

Some sections of the aerial line are fitted with TZB or TEB 7x4x1.2 cables. Alternation between the cables and aerial lines generates signal reflections which exacerbate transmission quality.

The cables and aerial lines are mapped out in Figure 2.1.2.C

Transmission installations are generally HF (frequency modulation) models. 60-channel equipment is type
K-60 (frequency range 12-252 kHz) and 12-channel installations (frequency range 36-143 kHz) are V-12-3, PV-12-3 and P-305 series.

The frequency influences the cable attenuation coefficient. The following signal attenuation values apply to 1km of cable:
0.41 dB / km for 0.8 kHz,
1.78 dB / km for 110 kHz,
3.04 dB / km for 250 kHz.

The distance between two consecutive amplification points is inversely proportional to the selected frequency range. Amplifiers are positioned at the following stations : Dolyar, Evlakh, Udziari, Kyurdamir, Alyati, Dubanyi, Sangatchali, Karadag, Eubat et Baladjari. Furthermore, channels are amplified at emitting stations and at the endpoints listed in the table below. Amplification takes place in telecommunications facilities (as opposed to lineside cabins).

Transmission channel capacity between centres is as follows:

Station	*Station*	*Number of channels*
Bakou	Kazi-Magomed	12 channels
Kazi-Magomed	Gyandja	12 channels
Akstafa	Beyuk-Kyasik	12 channels
Bakou	Alyati	2x60 channels
Alyati	Beyuk-Kyasik	12 channels
Shirvan	Devitchi	12 channels

An international transmission line (1 channel) links Bakou and Tbilisi (Georgia).
The section between Alyati and Beyuk-Kyasik was built in 1943.

Figure 2.1.2.D: Diagram of Azerbaijan Railway's transmission capacity.

Transmission quality corresponds to that obtained from analog systems with proper maintenance but a lack of spare parts. This level of quality no longer meets modern-day requirements.

2.1.2.6 Radiocommunications

The railway employs radiocommunications for railway operations. In general, all locomotives are fitted with 2Mhz/VHF radio sets, with the exception of shunting and freight train locomotives, which have only VHF radio. Rolling stock comprises electric and diesel locomotives. The breakdown of electric motive power units is: 252 VL-8 and V-11 series and 76 EP-2 EMUs (Electric Multiple Units). Diesel engines total 280 with 4 models : TEM-2, TE-3, 2-TE10M, 2M62 and 4ME3.

Two radio systems are used conventionally:

- Train radio

The train radio system enables drivers and controllers/stations to communicate. It is similar to the ground-to-train radio system (standardised in UIC Leaflet 751.3) in all but the following points:

The selected frequency is unique (2.130 MHz) and the operating mode is simplex. All transmitters are positioned in stations. Aerials are situated at a distance of 20 to 50 m from the corresponding radio base. Transmission power is 10 W. Radio bases are not synchronised.

As a result, radio coverage does not extend beyond the station itself and the line sections on either side. However, it should be noted that coverage is not continuous (this would require several distinct frequencies).

Further, from a traffic control point of view, a control circuit is divided up into radio blocks, each comprising several stations and therefore several radio transmitters/receivers.

The locomotives are in permanent receiver mode. Communication is limited to one train per radio block, at the instigation of the controller, the station or the locomotive.

Most of the radio equipment used in 15 to 20 years old.

- Shunting radio

This system provides for communication between the head station traffic controller and the shunting team members, including the driver of the shunting locomotive. A similar system is used by maintenance teams (intervention in the event of an accident, etc.).

The shunting radio is a stand-alone system mainly covering the station or railway sites. It uses simplex frequencies in the 150 - 156 MHz VHF range.

The radio system is similar to those still sometimes used in Europe to transmit over distances of several dozen kilometres. This point was not examined any further within the framework of the present project.

- Transcaucasian radio

This radiocommunications system is shared by all Caucasian railways and was donated by the United Nations "World Food Program". It serves primarily to manage empty wagons and trace trains loaded at ports.

Codan 8528 SSB Transceiver radio sets are used . If connected to a Codan 9001 HF Fax & Data Interface, these sets can also transmit and receive data and faxes. At present, voice communication is most prevalent (only a few sets have the 9001 interface).

See Figure 2.1.2.E

The following Azerbaijani stations (including the traffic control centre) are connected: Bakou, Beyuk-Kyasik, Astara, Mindjevan, Nakhichevan, Yalama, Gyandja, Evlakh, Salyani, Imishli, Kazi-Magomed, Ali-Bayramli, Udzari, Divetchi. The selected transmission channels are P02 (4020 kHz), P04 (5810 kHz), P07 (7095 kHz) and P08 (7605 kHz).

2.1.3 Georgia

2.1.3.1 Introduction

Georgian Railways use both analog and digital systems with electromechanical telecom switches. Local calls (between subscribers connected to the same telecom switch) are processed automatically. Outside calls (requiring a link between two different telecom switches) generally go through an operator, although connection between some telecom switches is obtained automatically (by dialling an area code). The transmission links are HF (frequency modulation) electronic transmission facilities and digital equipment for part of the network. The physical media used are copper cables, aerial links and optical fibre cables.

Figure 2.1.3.A describes the Georgian railway network, with the Traceca corridor marked in bold. At the ports of Poti and Batumi, freight is transferred to boats. There are plans for a ferry to transport broad-gauge wagons to Odessa.

2.1.3.2 General characteristics

The telecommunications installations are standardised (GOST) and comply with OSJD leaflets as regards railway applications. Parts originate from the former Soviet Union or eastern Europe and are no longer in production. Neither are they compatible with today's technology. The digital equipment used for optical fibre transmission was specially commissioned from the technical university at Tbilisi.

The primary power supply for installations is from the public grid. A secondary power supply (transformation, rectification, back-up) is provided by the railway. Back-up energy is generated by a battery with a few hours' capacity (depending on the condition of the battery). Major centres have the additional safeguard of diesel generators which are activated, automatically or manually, in the event of a public power cut. These diesel generators are located at Tbilisi, Khashuri, Samtredia and Supsa.

2.1.3.3 Switching

Switching nodes are located at the following stations: Gardabani, Rustavi-Gruzovaya, Tbilisi-Uzlovaya, Tbilisi-Passagirskaya, Tbilisi- Elektricheskoe depo, Mskheta, Gori, Khashuri, Zestafoni, Samtredia, Supsa, Batumi, Senaki and Poti. To make a local call, the subscriber dials the desired number and is put through automatically.

To make an outside call, the subscriber must dial the operator and state the name and number of the connection sought. The operator calls back once end-to-end communication has been established (a process which may involve several operators). This manual procedure is limited by the operator's switchboard capacity and the number of transmission channels. The switchboards used are type MPU-80, MPU-20 or MPU-60. Call connection times no longer meet modern-day requirements.

Calls are put through automatically between the telecom switch at Tbilisi - Passagirskaya and those positioned at the following stations: Tbilisi - Elektricheskoe depo, Tbilisi - Uzlovaya, Zestafoni, Samtredia, Khashuri, Batumi and Sukhumi. The line to Moscow could be obtained automatically (using the dialling code 6), but is not currently operational. Diagram 2.1.3.B illustrates the dialling code scheme.

Caucasian Countries - Inventory

The following table lists capacity (number of subscribers) per node. The telecom switches are currently at saturation point.

Station	*KP*	*No. of subscribers*	*Model*	*Note*
Gardabani	33			
Rustavi (Gruz.)	25	50	ATS	
Tbilisi (Uzlov.)	0/2510	600	ATS	
Tbilisi (Pass.)	2503/2304	4500+300	Kor+ATS	1990
Tbilisi (El.depo)		900	ATS	
Mskheta	2482			
Gori	2428	100	ATS	
Khashuri	2384	1000	Kor	1980
Zestafoni	2321	200	ATS	
Samtredia	2260/106	1300	ATS	
Batumi	0	500	ATS	
Poti	41	200	ATS	

The telecom switches use rotary or crossbar technology. They were installed between 1947 and 1956 and are still in working order. The inauguration years for the telecom switches at Tbilisi - Passagirskaya and Khashuri are given in the column headed "Note". Power is supplied by 48 or 60 V central batteries.

The position of the telecom switches is shown in Figure 2.1.3.C.

2.1.3.4 Services

To complement the switched telephone network (cf. Section 2.1.1.3), a certain number of voice services are also provided on dedicated links. These links consist of a primary railway telephone transmitter/receiver and terminal installations (subscribers) linked in parallel on the transmission line. The operator (controller) is in permanent receiver mode. Subscribers are selected manually by pressing a button on the operator's switchboard. The transmmitter/receiver emits the dial tone frequency, which is picked up by the subscriber selector (APC-1). These connections date from the 70s-90s. Nothing further has been introduced since then, although some circuits are in the pipeline.

The services involved are:

- Traffic control (2 wire link)

Traffic control centres are located at the railway headquarters in Tbilisi and in the Samtredia region. Together they manage 7 line sections. The following table lists the sections managed and corresponding lengths. A proposed upgrading programme would see all control sets transferred to Tbilisi and the number of line sections cut. This, in turn, would involve replacing telecommunications equipment and rearranging existing circuits

Control centre	*Line section*	*Length*
Samtredia	Batumi - Samtredia	106 km
Samtredia	Poti - Samtredia	70 km
Samtredia	Samtredia - Zestafoni	61 km
Tbilisi	Zestafoni - Khashuri	63 km
Tbilisi	Khashuri - Tbilisi	120 km
Tbilisi	Tbilisi - Beyuk-Kyasik	45 km (Gardabani) + 12 = 67 km
Tbilisi	Tbilisi - Ayrum	70 km (Sadakhlo) + 13 = 83 km

- Energy control (2 wire link)

This line runs between the energy control centre and regulation points in the OHL power supply sub-stations. The energy and traffic control centres are situated side by side and generally cover identical geographical zones.

- Dedicated station-to-station telephone lines (2 wire link between the manual KPS-2/3 and UKSS-8 telecom switches). Call frequency is 25 or 50 Hz.
- Distribution of reserved tickets.

The ticket reservation/distribution centre is connected to some main-line passenger stations.

- Teleconferencing

A 4-wire link connects a supervisor's installation to those of his/her team.

- Railway police
- Operator management of outside calls to and from line stations connected in parallel on a dedicated circuit.
  (2 wire link).
- Signalling and telecommunications maintenance
- Track maintenance
- Lineside alarm (2 wire line).
- Traffic controller - depot link.
- Traffic controller - passenger train formation site link.

The local circuits at stations are arranged in the same fashion and energised by local 50 or 80 V batteries.

- Telegraphy

Georgian Railways also has a telegraph network. It dates from the latter half of the 60s, with a few changes in terminal equipment (upgrade in models), and is still in service today. The model currently used is the G-2000 model (for communication in the Russian or Georgian language) Over a hundred terminal installations still function today.

Transmission rates correspond to those achieved by older European systems, i.e. 50 baud (24-channel transmission system), 100 baud (12-channel transmission system) or 200 baud (6-channel transmission system). Connection is automatic and P-327-3 or P-327-12 transmission equipment is used.

The telegraph office is located at the railway undertaking's headquarters. AT-PS-PD equipment is used. Terminal installations are connected to the switch and can be connected to other installations in the former SZD telegraph network (the central switch of the RZD network is located in Moscow). The following stations are linked to the central office: Batumi, Poti, Samtredia, Zestafoni, Khashuri, Gori, Tbilisi-Pass and Tbilisi-Uzi. Today, the telegraph network is used to send written instructions concerning traffic control and commercial aspects.

2.1.3.5 Transmission media

The transmission media used are copper cables, aerial lines and optical fibre cables. Most of the cables are buried. Transmission lines are generally served by HF (frequency modulation) electronic transmission installations. Part of the network is served by IKM (8-channel input/output unit) and IKM-30 (30-channel input/output unit) digital equipment constructed locally at Tbilisi Technical University. Use is also made of direct audiofrequency transmission over copper cables and aerial lines. Adaptation is generally carried out by a translator.

Caucasian Countries - Inventory

Cables are type 14 or 7x4x1.05+5x2x0.7+1x0.7 (14 or 7 star-shaped quads, 1.05 mm diameter wire; 5 pairs and 1 wire of diameter 0.7 mm) MKPAB (paper insulation, aluminium armouring and PVC outer sheath), MKBAB, MKPAP, MKPAP and MKVM-K replaced by 4-fibre OKP-10-01-04-4 single-mode VOK (optical fibre cables). The copper wire has an electrical resistance to direct current of 55Ω/km for a diameter of 0.7 mm, and 21.2Ω/km for a diameter of 1.05 mm.

The following table gives the section lengths and the number and type of cables for the major cables sections. The Khashuri - Zestafoni section was inaugurated in 1979 with the Samtrediya extension following a year later. The Khashuri - Tbilisi cable began transmission in 1982 and the Gardabani extension (Azerbaijani border) was added two years later. The optical fibre cables were launched in 1995.

Station / KP	*Station / KP*	*Length*	*Number of cables*	*Type*
Rustavi / 25	Tbilisi / 2510	25,5 km	2	MKPAP 7x4+5x2
Sadakhlo / 2563	Tbilisi / 2510	53 km	2	MKBAB 7x4+5x2
Tbilisi / 2510	Garajani / 116	116 km	1	MKBAB 7x4+5x2
Tbilisi / 2510	Khashuri / 2384	126 km	2	MKPAB 7x4+5x2
Khashuri / 2384	Zestafoni / 2321	63 km	2	MKBAB 7x4+5x2
Zestafoni / 2321	Senaki / 2232	89 km	1	MKBAB 7x4+5x2
Zestafoni / 2321	Senaki / 2232	89 km	1	MKBAB 14x4+5x2
Batumi / 0	Samtrediya / 2260	106 km	1	VOK (4 wire)
Samtrediya /2260	Poti / 39	67 km	1	VOK (4 wire)

The low transmission quality is primarily due to cable insulation lying outside the minimum tolerance limits. This is more often than not caused by moisture penetrating through to the cables at the junction boxes. Penetration increases over time in relation to the different materials used for the junction boxes and the cable armouring.

In some cases, it was necessary to replace a faulty junction box with two new boxes linked by a strip of the intermediate cable. Such measures trigger signal reflections and interfere with capacitance regulation. This interference is not easily eliminated from cables that have already been laid. All these problems also apply when cables sections are stolen.

The situation is worsened by the poor condition of earthing cable protective material (theft, inadequate maintenance), leading to an increase in stray currents and, hence, greater cable sheath permeability by electrolysis.

The aerial lines have a diameter of 4 mm (main line, 6 HF wires) or 5 mm (main line; 10 LF wires). Some sections of the aerial lines are fitted with cables, generally type TEB or TZB 7x4x1.2. Alternation between cables and aerial lines generates signal reflections which exacerbate transmission quality.

Caucasian Countries - Inventory

The cables, aerial lines and optical fibre cables are mapped out in Figure 2.1.3.D

HF (frequency modulation) transmission equipment is used for the copper cables and aerial lines:

OV-3-3 (3 channels) 4-31 kHz frequency range,
OV-12-3 (12 channels) 36-143 kHz frequency range,
P-305 (12 channels) 36-143 kHz frequency range,
K-12+12 (24 channels) 8-150 kHz frequency range,
K-60-P (60 channels) 1-252 kHz frequency range, i.e.:

- group I (12 channels) 208-252 kHz frequency range,
- group II (12 channels) 160-204 kHz frequency range,
- group III (12 channels) 112-156 kHz frequency range,
- group IV (12 channels) 64-108 kHz frequency range,
- group V (12 channels) 12-57 kHz frequency range.

These installations are fed 24 V direct current taken from the 220 V alternating current public grid.

The frequency affects the cables attenuation coefficient. The following values are for signal attenuation over 1km of cable :
0.41 dB / km for 0.8 kHz,
1.78 dB / km for 110 kHz,
3.04 dB / km for 250 kHz.

The distance between two consecutive amplification points is inversely proportional to the selected frequency bandwidth. Amplifiers are positioned at the following stations: Sadakhlo, Marnauli, Rustavi, Tbilisi-Uzlovaya, Sagaredjo, Katchreti, Mskheta, Gori, Khashuri, Zestafona and Rioni. In addition, channels are amplified at the emitting station and the endpoints indicated in Diagram 2.1.3.E. Amplification takes place in telecommunications facilities (as opposed to lineside cabins).

Transmission channel capacity between centres and the types of installation used are listed below:

Station	*Station*	*Number of channels*	*Type of installation*
Tbilisi	Khashuri	60 channels	K-60-P
Tbilisi	Samtrediya	120 channels	2 x K-60-P
Tbilisi	Garajani	24 channels	K-12+12
Tbilisi	Rustavi	12 channels	V-12-3
Tbilisi	Gardabani	12 channels	P-305
Tbilisi	Marnauli	12 channels	P-305
Tbilisi	Sadkhlo	3 channels	V-3-3
Khashuri	Gory	12 channels	P-305
Khashuri	Borjomi	12 channels	P-305
Khashuri	Vale	3 channels	V-3-3
Khashuri	Zestafoni	3 channels	V-3-3
Zestafoni	Tchyatura	(12+3) channels	P-305 + V-3-3
Zestafoni	Kutaisi	3 channels	V-3-3
Kutaisi	Samtrediya	3 channels	V-3-3
Samtrediya	Poti	30 channels	IKM-30
Samtrediya	Batumi	30 channels	IKM-30
Samtrediya	Kolobani	8 channels	IKM
Samtrediya	Sadjavakho	8 channels	IKM

Caucasian Countries - Inventory

An international 3-channel line serviced by V-3-3 equipment links Tbilisi and Sanain (Armenia).

Figure 2.1.3.D below illustrates the railway's transmission capacity.

Transmission is down between Zestafoni and Tchyatura due to missing cable in the line section. Installations are operational thanks to recycling of other transmission facilities to obtain spare parts. Transmission quality is often poor as a result of the inferior cable technology.

2.1.3.6 Radiocommunications

The railway employs radiocommunications for railway operations. In general, all locomotives are fitted with 2Mhz/VHF radio sets, with the exception of shunting and freight train locomotives, which have only VHF radio. Rolling stock comprises electric and diesel locomotives and electric multiple units (EMU). A further breakdown reveals 235 VL-8, VL-10 and VL-11 series electric locomotive, 92 EP-2 EMUs and 185 TE and M series diesel locomotives (range of models).

Two radio systems are used conventionally:

- Train radio

The train radio system enables drivers and controllers/stations to communicate. It is similar to the ground-to-train radio system (standardised in UIC Leaflet 751.3) in all but the following points:

The selected frequency is unique (2.130 MHz) and the operating mode is simplex. All transmitters are positioned in stations. Aerials are situated at a distance of 20 to 50 m from the corresponding radio base. Transmission power is 10 W. Radio bases are not synchronised.

As a result, radio coverage does not extend beyond the station itself and the line sections on either side. However, it should be noted that coverage is not continuous (this would require several distinct frequencies).

Furthermore, from a traffic control point of view, a control circuit is divided up into radio blocks, each comprising several stations and therefore several radio transmitters/receivers.

The locomotives are in permanent receiver mode. Communication is limited to one train per radio block, at the instigation of the controller, the station or the locomotive.

Most of the radio equipment used in 15 to 20 years old.

- Shunting radio

This system provides for communication between the head station traffic controller and the shunting team members, including the driver of the shunting locomotive. A similar system is used by maintenance teams (intervention in the event of an accident, etc.).

The shunting radio is an stand-alone system mainly covering the station or railway sites. It uses simplex frequencies in the 150 - 156 MHz VHF range.

The radio system is similar to those still sometimes used in Europe to transmit over distances of several dozen kilometres. This point was not examined any further within the framework of the present project.

Caucasian Countries - Inventory

- Transcaucasian radio

This radiocommunications system is shared by all Caucasian railways and was donated by the United Nations "World Food Program". It serves mainly to manage empty wagons and trace trains loaded at ports.

Codan 8528 SSB Transceiver radio sets are used . If connected to a Codan 9001 HF Fax & Data Interface, these sets can also transmit and receive data and faxes. At present, voice communication is most prevalent (only a few sets have the 9001 interface).

See Figure 2.1.3.F

The following Georgian stations and control centres are hooked up: Batumi (station + port), Poti (station + port), Gardabani, Sadakhlo, Tbilisi, Samtredia, Zestafoni, Gory, Rioni, Telavi, Gurjaani, Tsalka, Kazreti and Dedoplitskaro.

2.2 Survey of existing studies

2.2.1 Infrastructure Maintenance 1 - Railways pre-investment study and Baku - Tbilisi - Batumi/Poti pilot train - Module A - Draft Final Report - May 1997. (Tewet / DE-Consult)

2.2.1.1 Azerbaijan

2.2.1.1.1 Summary

Although it is old, the signalling system is in satisfactory condition. Nonetheless the technology is old and the condition of the system is deteriorating. Renovation is advocated in the short and medium term. The requisite budget is estimated at US$ 138.6 million. Priority investment over the first four years will be US$ 16.5 million.

The telecommunications system cannot ensure reliable communications. The insulating outer sheath dates back to 1983 and has become porous. The poor quality of transmission has a direct impact on rail traffic.
Renovation in the short term is necessary. The budget is US$ 43.1 million, 13.2 of which would go on priority investment.

The current condition of both signalling and telecommunications makes it impossible to manage more traffic.

2.2.1.1.2 Technical solutions

The signalling system can largely be maintained. It is proposed above all to replace faulty components. It is proposed that the replacement parts be Russian and of the same type. The equipment in question is robust and the staff familiar with it can install it with ease.

It is advocated that the equipment in the following stations be completely replaced over the next 5-10 years :

Kasi-Magomed
Mugan
Gadshievo
Kyrdamir
Yevlakh
Geran
Kyurok-Tshai
Beyuk-Kyassik

Caucasian Countries - Inventory

Owing to the increase in traffic on the Baku to Beyuk-Kyassik line, it is advocated that the following manual signal boxes be replaced :

Kyrdamir
Alabashli
Shamkir
Dallyar
Dsegam
Kovlyar

The telecommunications system needs to be totally replaced. A system of optical fibres is recommended for the Baku - Beyuk-Kyassik line.
An architecture based on two 147-fibre (!) cables, using SDH/STM-1 technologies is recommended. A 155Mbits/s STM-1 can carry 1920 channels per optical fibre. By installing a second cable, a ring is created and thus a very high rate of system availability achieved.

The following stations are to be equipped :

Beyuk-kyassik
Akstafa
Alabashli
Gyandsha
Yevlakh
Padar
Kasi-Magomed
Alyat
Baku
Baladshary

Baku will have a CCM (cross connect multiplexer) to allow connection with other telecommunications networks and other stations will be equipped with ADM (add/drop multiplexer).
This capacity will be sufficient to meet both railway and non-railway needs.
By installing spare capacity, system saturation and subsequent works can be avoided.

Switching equipment should gradually be replaced with digital equivalents.

It is advocated that a ground-to-train radio system be installed : "train radio 2002", which complies with current European standards.

2.2.1.2 Georgia

2.2.1.2.1 Summary

The signalling system as a whole is in satisfactory condition. However, the Samtredia - Poti and Samtredia - Batumi sections are down. The main problem seems to be electricity supply to these installations.
The budget for signalling renewal and maintenance for the next ten years is estimated at US$ 124 million, 12.65 of which for priority work to be carried out by 2000.

The telecommunications system is in critical condition. Renewal of the system is a top priority. The impact of the current situation on train running is substantial.
The budget for signalling renewal and maintenance for the next ten years is estimated at US$ 34.4 million, 5.3 of which to be invested before 2000.

2.2.1.2.2 Technical solutions

Basically the signalling system can be retained. Equipment is to be replaced by Russian components of the same type. The Russian equipment is robust and easy for the staff to install, as they are already familiar with it. Some of the equipment will be manufactured locally. Re-establishment of the automatic block system is necessary to increase rail traffic.
The Samtredia - Poti and Samtredia - Batumi sections will be re-equipped with semi-automatic blocks. Transmission of information from these two sections will be via the optical fibre already fitted on the above-mentioned sections.

The telecommunications system is to be totally changed. An optical fibre system is recommended.
An architecture based on two 147-fibre (!) cables, using SDH/STM-1 technologies is advocated. The 155Mbits/s STM-1 can carry 1920 channels per optical fibre. By installing a second cable, a ring is created and thus a very high rate of system availability achieved.

The following stations are to be equipped :

Gardabani	
Tbilisi	
Gori	
Khashuri	
Rioni	
Samtredia	
Senaki	Natanebi
Poti	Batumi

Tbilisi and Samtredia will have a CCM (cross connect multiplexer) to allow connection with other telecommunications networks and other stations will be equipped with an ADM (add/drop multiplexer).

NB : there is already a cable between Samtredia and Poti, Samtredia - Batumi.

This capacity would meet both railway and non-railway needs.
By installing spare capacity, system saturation and subsequent works can be avoided.

Switching equipment should be gradually replaced with its digital equivalent.

It is advocated that a ground-train radio system be installed : "train radio 2002", which complies with current European standards.

UIC comments :

- It is unrealistic to recommend that the signalling system be repaired to Soviet-era standards, both in light of current and expected traffic and of available budgets.
- Regarding telecommunications, 147 fibres seems excessive, perhaps there has been a typing error and in fact only 14 fibres are proposed.

Caucasian Countries - Inventory

2.2.2 Project Identification Report for Georgian Railways - EBRD (CIE Consult)

2.2.2.1 Context

This report was commissioned by the EBRD in order to define the priority investments for Georgian railways within a maximum budget of USD 30 million.

Apart from the Tbilisi/Kaspi section where the automatic block has been restored, signalling installations have been almost totally destroyed in the western region.
The sections around Samtredia have a centralised traffic control system which is fairly sophisticated.

During the civil war, buried cables were dug up for their copper, as were track circuits for their metal components. Signalling equipment lights and lenses, points motors (...) were stolen.

Thanks to the optical fibre cable supplied by the European Union for the Samtredia/Batumi & Poti section, the telephone system is back in operation allowing minimum "telephone block" traffic management.

2.2.2.2 Technical proposal

2.2.2.2.1 Signalling

By contrast to the Tewet reports, only emergency measures are recommended owing to the low levels of finance available.

Between Tbilisi and Senaki, the average block length is 6.4km which is a lot less than necessary.
The proposal is to close at least 50% of stations in order to double or triple of the size of the sections.
The resulting network should be reconstructed with a reduced automatic block only.

Freight operations are to be concentrated in the main stations.

The equipment recommended is the type used in existing installations, i.e. Soviet.

The investment is estimated at USD 6.5 million.

2.2.2.2.2 Telecommunications

The current system based on a 4-optical fibre cable between Poti, Batumi and Samtredia is unsatisfactory in that it is regularly damaged owing to a lack of armouring.
It is proposed to replace the system and to install a general SDH system based on optical fibres. It will first be used in STM-1 with 155Mbits/s, i.e. 1890 audio channels. Throughputs could be improved in the future.

The system should form a ring with two 12-fibre cables. The ring ensures redundancy should one of the cables be damaged.
This system offers sufficient capacity for current and future railway needs. Furthermore, it supplies excess capacity which could be marketed.

The two cables should be armoured, not made of metal and strung between the catenary masts on each side of the track. An additional mast will have to be erected on the other side of the track on single track sections.

To maintain the benefits of the ring configuration, it is proposed to extend it with a micro-wave link between Poti and Batumi (additional investment : USD 0.5 million).

The investment would consist of the following :

- 2x500km of 12-fibre cable @ USD 3,500/km, i.e. USD 3.5 million.
- 35 sets of station installations @ USD 50,000 each, i.e. USD 1.75 million.
- 2 supervision centres, i.e. USD 0.40 million
- USD 1 million for installation
- USD 0.35 million for training and spare parts.

Thus a total of USD 7 million.

UIC comments :

- Station installations : the section concerned includes 55 stations, thus only 2/3 of the stations will be equipped.
- Installation : USD 7,000/km is more in line with the European prices. The enormous difference in salaries between Europe and Georgia can go some way towards explaining such a differential. The cost of erecting additional masts on the single-track sections and on certain curves (the pitch between catenary masts is substantially greater than the usual in Europe) does not seem to have been calculated.

2.2.2.3 Financing and calls for tender

2.2.2.3.1 Signalling

The bulk of the USD 6.5 million budget is earmarked for Soviet spare parts.

A call for tender (ICB - International Competitive Bidding) in line with EBRD rules (EBRD will provide the finance) is recommended.

The railways' signalling and telecommunications departments will carry out installation work.

Date of call for tender : 09/98
Date contract is awarded : 02/99
Date contract expires : 12/99

2.2.2.3.2 Telecommunications

The budget will be provided by the European Union. The calls for tender will thus be open in accordance with European Union rules.

The cable will be installed by the railways' signalling and telecommunications department.
Note from UIC : the total budget is USD 7 million. Only USD 6 million will be provided by the European Union. The railways will provide USD 1 million, which is equivalent to the budget set aside for installation.

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The first call for tender is for the optical fibre cable, the second for the supervision system and station installations. Installation and training will be carried out by the contract holder.

Detailed technical specifications will be part of the technical assistance for the call for tender and for installation.

Cable :
Date of call for tender : 09/98
Date contract is awarded : 12/98
Date contract expires : 12/99

Station installations and supervision :
Date of call for tender : 01/99
Date contract is awarded : 07/99
Date contract expires : 05/00

1.3.2.4 Commercial openings

Cursory consideration is given to the commercial potential of the optical fibre system in an appendix to this document.
The conclusions drawn are that the main potential markets are for communications between Europe and Asia. Installation of an optical fibre system is thus highly recommended for the railways of Central Asia. However, connections across the Black Sea and the Caspian Sea are not considered.

A study proposal on the matter is requested. It should include :
- An analysis of potential telecom traffic on an optical fibre running through Traceca as a whole.
- Financial analysis of the sales potential offered by a higher-capacity cable.
- Technical restrictions
- Institutional aspects and intentions in the various countries
- An action and investment plan

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2.2.3 Joint venture(s) for the Caucasian railways - Draft Final Report - October 1997. (Tewet / DE-Consult / Gtz)

2.2.3.1 Summary

This project follows on from "Infrastructure Maintenance 1"(cf 2.2.1). Armenia has been added to the project.

The technical condition and interoperability of the equipment no longer ensures safe train running. Train running relies heavily on radio and operational procedures.
Signalling equipment has not been replaced as it should have been in recent years.

The disastrous state of the railway telecommunications system has become a priority.
A common telecommunication system via which information can be exchanged between railways is imperative.

It is proposed to install a system of optical fibres along the tracks. In the first instance the following sections would be fitted out :

Baku - Tbilisi - Poti
Tbilisi - Gyumri - Yerevan

Total investment breaks down as follows :

Description	Cost of investment in millions of USD			
	ARM	AGZD	GRZD	total
Signalling	42.5	148.0	135.0	325.5
Telecom	25.0	38.5	31.4	94.9
Total	67.5	186.5	166.4	420.4

2.2.3.2 Technical proposal

Three-phase implementation is proposed.

1st phase :
Installation of an optical fibre system, based on a 12-fibre cable strung between the catenary masts, and PCM equipment (32 digital channels) on main lines, and fitting out all stations :
- Yerevan - Ayrum
- Baku - Beyuk-Kyassik
- Gardabani - Tbilisi - Samtredia - Poti & Batumi.

(24 fibres between Baku and Baladshary).

2nd phase :
Installation of an optical fibre system, based on a 12-fibre cable strung between catenary masts, and PCM equipment (32 digital channels) on other lines, and fitting out all stations.

3rd phase :
Installation on all lines of a second six-fibre cable, connected with interchange stations and installation of higher-capacity equipment of the SDH/STM-1 type (1920 digital channels). A ring is thus formed.
This cable will be strung between catenary masts on double-track sections, and buried on other sections.

2.2.3.3 Financing

It is proposed that the railways set up a joint venture for the telecommunications part of phases 1 and 2. A foreign partner could be involved in the third phase.

Phase 1 is covered by a European Union grant for USD 15 million.

The expected revenue from selling the excess capacity created during the 3rd phase (for example to the national telecom operator) will not cover all the other investments immediately. A sum of USD 13.7 million is needed to cover the period before the cash flow becomes positive in 2002. This sum should come from either the foreign partner, the European Union, or the EBRD.

It should be noted that the legal situation regarding telecommunications in these countries does not yet allow for this type of joint venture.

Caucasian Countries - Inventory

2.2.4 Summary of the TRACECA report - Communication Network for the Caucasian Railway Feasibility Study 1/10/1997 (F.W.Krämer 19/10/1997)

1. Any new investment in railway telecommunications must be in line with the EV-TACIS/TRACECA/EBRD recommendations and the EBRD's financing prospects.

2. The contribution of telecom investments to improving railway system operation.

3. Inventory of telecom installations.
- mostly analog, old, with limited functionality, low level of automation, limited performance.

Inventory of IT equipment.
- old, a proportion of applications centralised in Moscow and Rostov.

4. Difficulties in identifying railway telecom requirements (in particular requirements for typical activities such as management, operations and administration).

5. TEWET study proposal (pilot project) consists of the following items:
- Installation of an overhead 12-optical fibre cable along the Bakou-Tbilisi-Poti and Tbilisi-Yerevan lines (i.e. 1225 km):
  - with capacity for 30 telephone channels (PCM type, 2 Mbit/s),
  - 70 % of which would be used by the railways.
- Connection of all stations.
- It is supposed that the signalling and communications equipment and the computers are used without additional technical equipment.
- Network supervision centre in Tbilisi.

6. In addition to the pilot project, TEWET proposes 2 additional phases:
- Second, parallel, optical fibre cable, separate from the first, allowing safety to be ensured by means of a ring. Introduction of the SDH.
- Rehabilitation of the switches in all stations.

7. Opinion and proposal of the expert:
- There is no need for a second cable parallel to the first. Complete redundancy and an SDH ring structure are not justifiable in economic terms.
- The cables must be buried.
- The SDH (155 Mbit/s) and 120-channel telephone capacity, in 6 main stations (Bakou, Tbilisi, Poti, Yerevan and 2 border stations) is needed at once. Connection of all stations is recognised as difficult.
- The various analog switching systems must be replaced by a single standard digital system.
- The main railway stations must be connected with digital equipment replacing analog equipment (depending on available funds or at a later stage).
- Installation of a single supervision system in each country.

8. Problems regarding implementation
- Use a "turnkey" project structure
- The "turnkey" contractor must guarantee all the performance levels and functionalities for the whole project during at least one year.
- An experienced consultant, for instance, should be entrusted with supervising the "turnkey" contractor.
- The "turnkey" contractor must be selected following a call for tenders.

Caucasian Countries - Inventory

9. Project budget (in Ecus):

9.1
- Module A (Georgia) 4.45 Mecu
- Module B (Azerbaijan) 5.125 Mecu
- Module C (Armenia) 3.42 MEcu Total: 15.01 Mecu
- Supervision of "turnkey" contractor 1.3 Mecu
- Contingency fund 0.715 MEcu

9.2 A firm commitment from the 3 countries concerned is essential.

10. Project feasibility
- The 3 governments concerned must guarantee joint funding of the cost of installing the optical fibre network locally, including for transmission equipment.
- Furthermore, the railways must release staff to supervise installation.
- It will be difficult for the project to survive without substantial subsidies if telecom service suppliers cannot be attracted.
- The project cannot be expected to be viable, given the current insufficient level of rail traffic.
- Thus the project cannot attract private or commercial funding. The European Union is planning to provide a grant. The EBRD will consider the latter as a complement to the loans which it is planned to grant to the Georgian and Azeri railways.
- If the economy, and thus the railways, enjoy a revival, the second phase of the project will be necessary and all the stations will have to be connected to the network.

11. The project will not be complete until competition is allowed by law and new services can be offered by privatised telecom companies.

12. In short, the project is worth pursuing.
The European Union grant will serve as a catalyst to the project.
The impact may run to complete de-regulation of the railway and telecom sectors.

2.2.5 The equipment and cables used in the Optical Fibre Network at Banverket, Sweden (Ericsson)

Topic: Analysis of the document.
"The equipment and cables used in the Optical Fibre Network at Banverket, Sweden"
(K.N. Skalman, E. Siönäs, S. Edman and G. Danielsson) (1991).

The article describes the installation of a 2500 km optical fibre network by Banverket at the beginning of the 90s.

It provides detailed information on the techniques used to lay the optical cable and quantified indications of the level of performance obtained.

The following key pieces of information may be retained:

- Banverket has set an availability objective of almost 100 %, with less than three hours downtime over a 3 year period. To this end, the network redundancy is ensured by means of a ring structure.
- The article includes a description (fig. 2) of a 40-60 km repeater section with a pair of dedicated signalling fibres branching off every 2.5-4.5 km.
- Cable-laying procedures are described in detail:
    - civil engineering resources: plough, mini-excavator, tractor on the track able to clear the track rapidly (the main objective being not to interrupt traffic),
    - detailed planning of cable-laying work - to contain downtime losses at less than 1%, instead of 7% for fixed-length cable sections,
    - splices at about every 3 km,
    - cable buried 0.65 m below surface and at least 0.3 m from existing cables,
    - 3-5 m of reserve cable at special points: bridges, maintenance sites, etc.
    - loss of less than 0.1 dB at points where welded splices are made.
- The cable contains 24 optical fibres (monomodal) ?. Transmission is in the ranges 1285-1330 nm and 1530-1570 nm. The cable has the following principle features:
    - ability to bear high crushing loads (>6000 N),
    - operating temperature range of -30 to +70°C (storage -40 to +70°C, installation between -10 and +50°C),
    - sufficient rigidity for laying in an environment as awkward as an embankment,
    - sufficiently resistant to vibrations,
    - can be ploughed into the ground,
    - to carry external markings to identify and distinguish it from other cables,
    - be completely dielectric,
    - block water longitudinally.

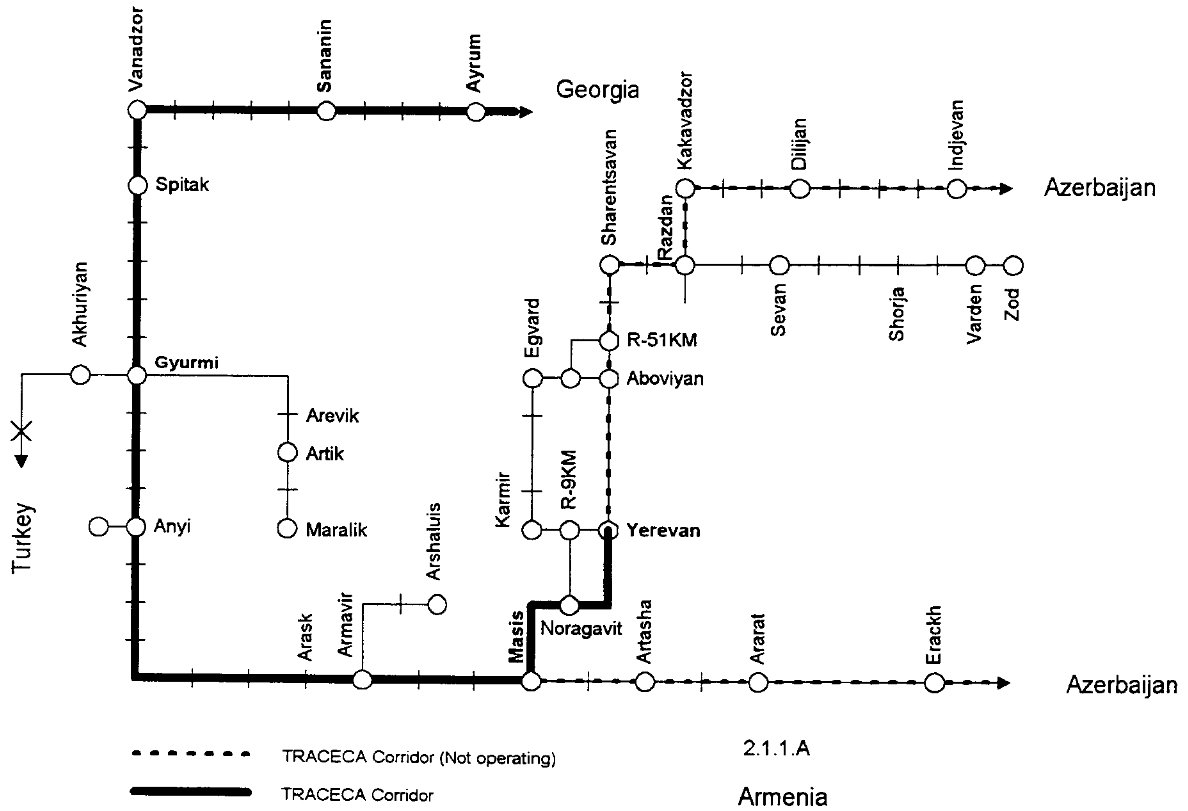
The following results were obtained:
- Laying the 2770 km cable took 17 months,
- The rate was 1.5 km/day/12-man team with tractor on track,
- 1220 cable splices, at a rate of 4 splices/week/team,
- 48 sets of 565 Mbit/s equipment and 175 sets of 34 Mbit/s equipment were installed.

The article gives the cost of various types of laying (on the catenary mast side, on the side opposite the catenary mast, outside the catenary masts, in a duct) (figure 15).

Chapter 3

Caucasian countries - Inventory
Appendix 1 - Telecommunications

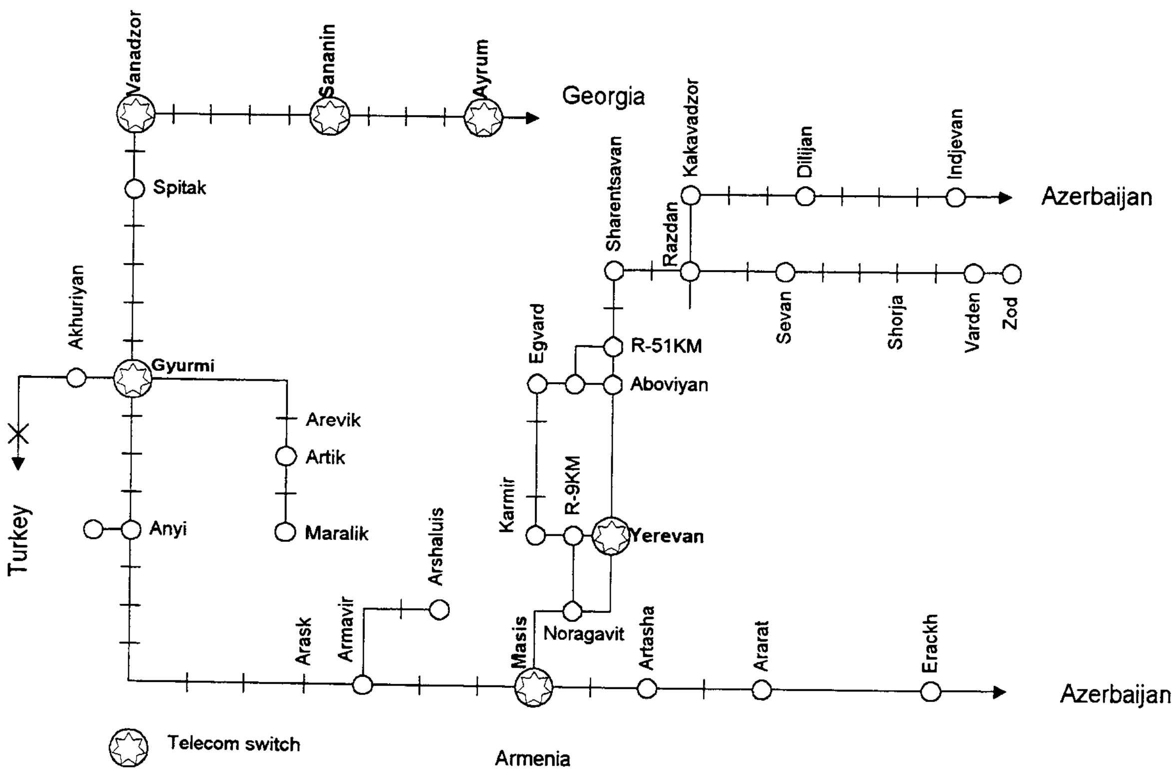
Appendix 1 - Telecommunications



2.1.1.A

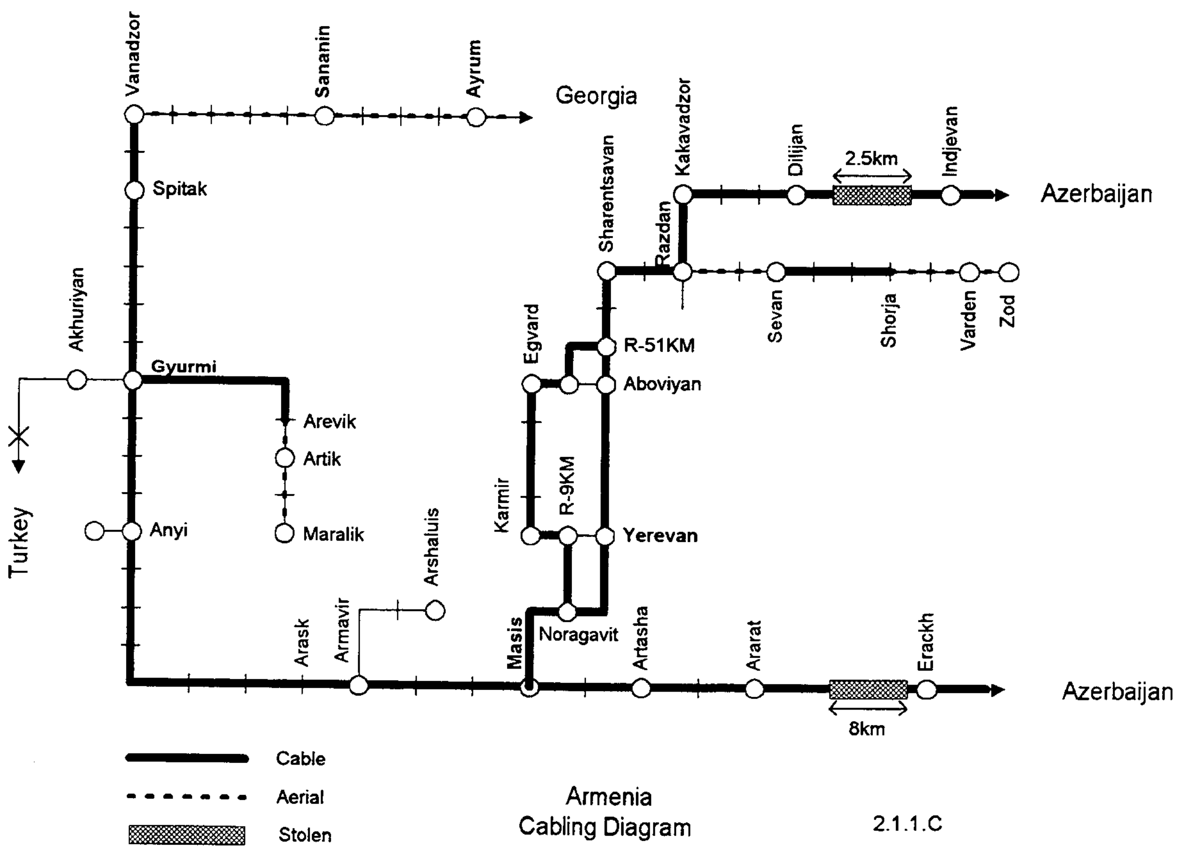
Armenia
Railways Diagram

Appendix 1 - Telecommunications



Armenia
Position of telecom switches
2.1.1.B

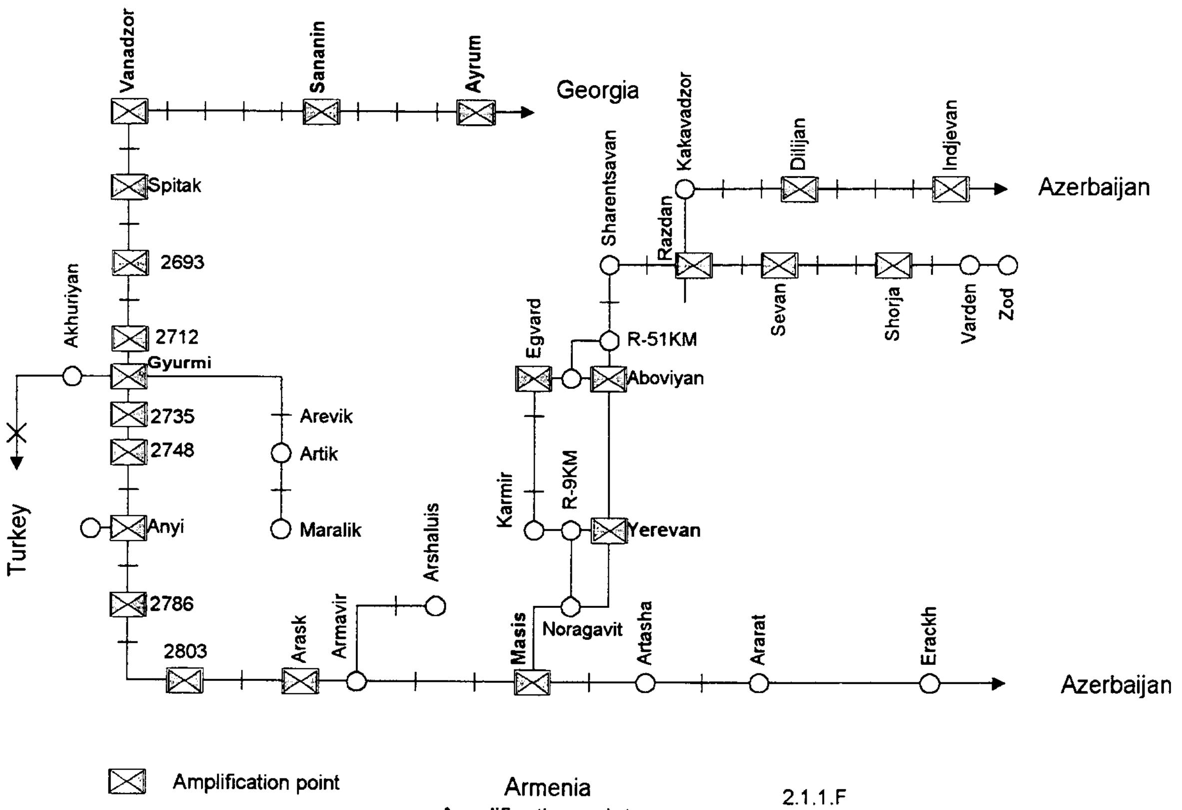
Appendix 1 - Telecommunications



Armenia
Cabling Diagram

2.1.1.C

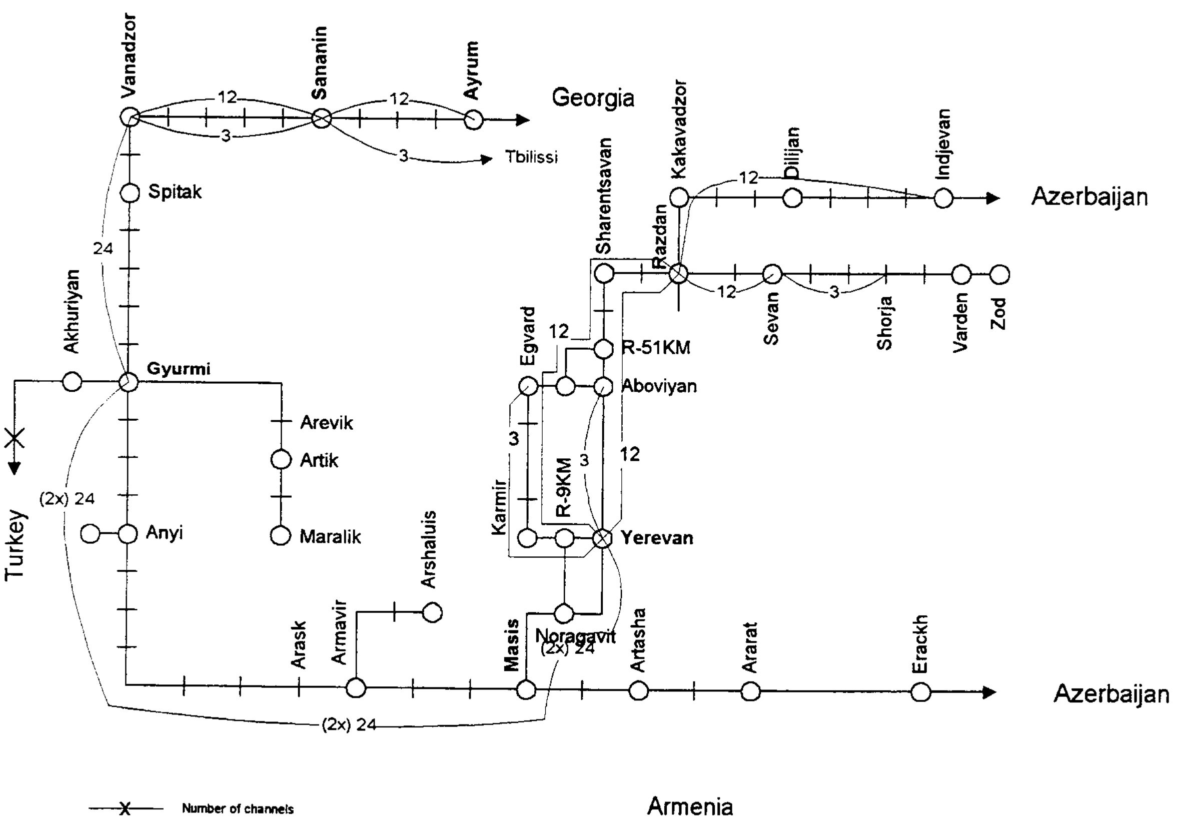
Appendix 1 - Telecommunications



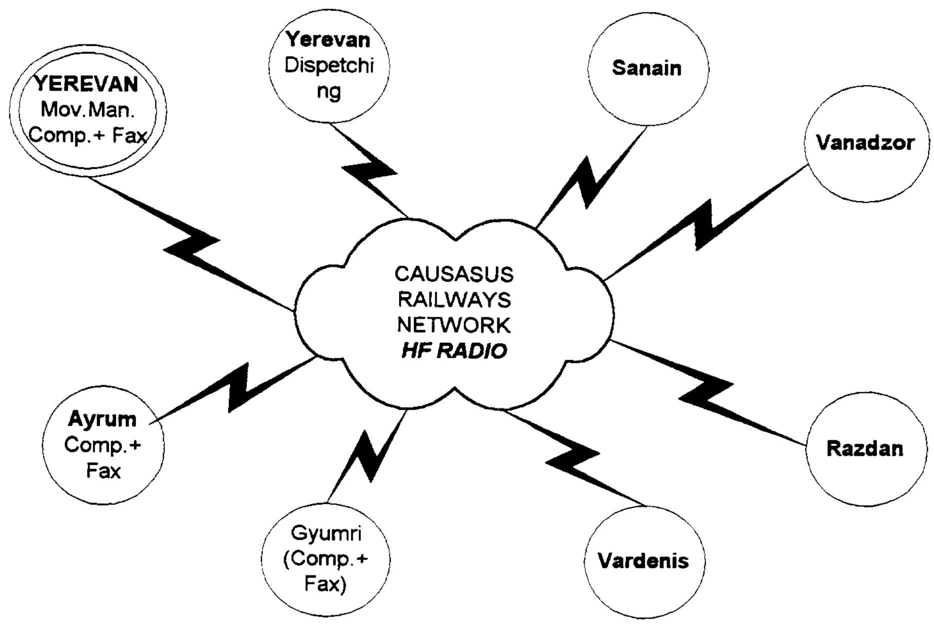
Armenia
Amplification points

2.1.1.F

Appendix 1 - Telecommunications



Armenia
Transmission capacity 2.1.1.D



Armenie 2.1.1.E

Appendix 1 - Telecommunications

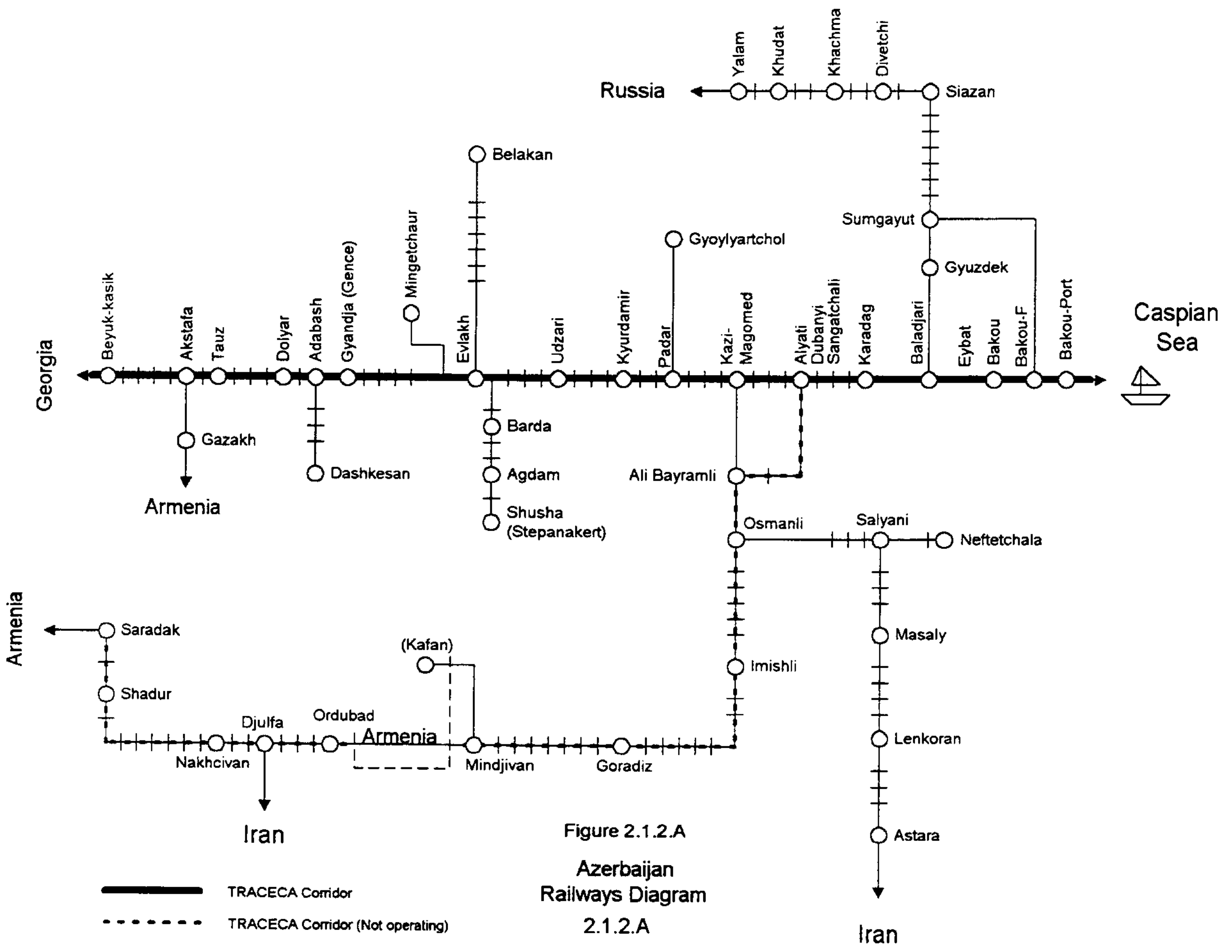
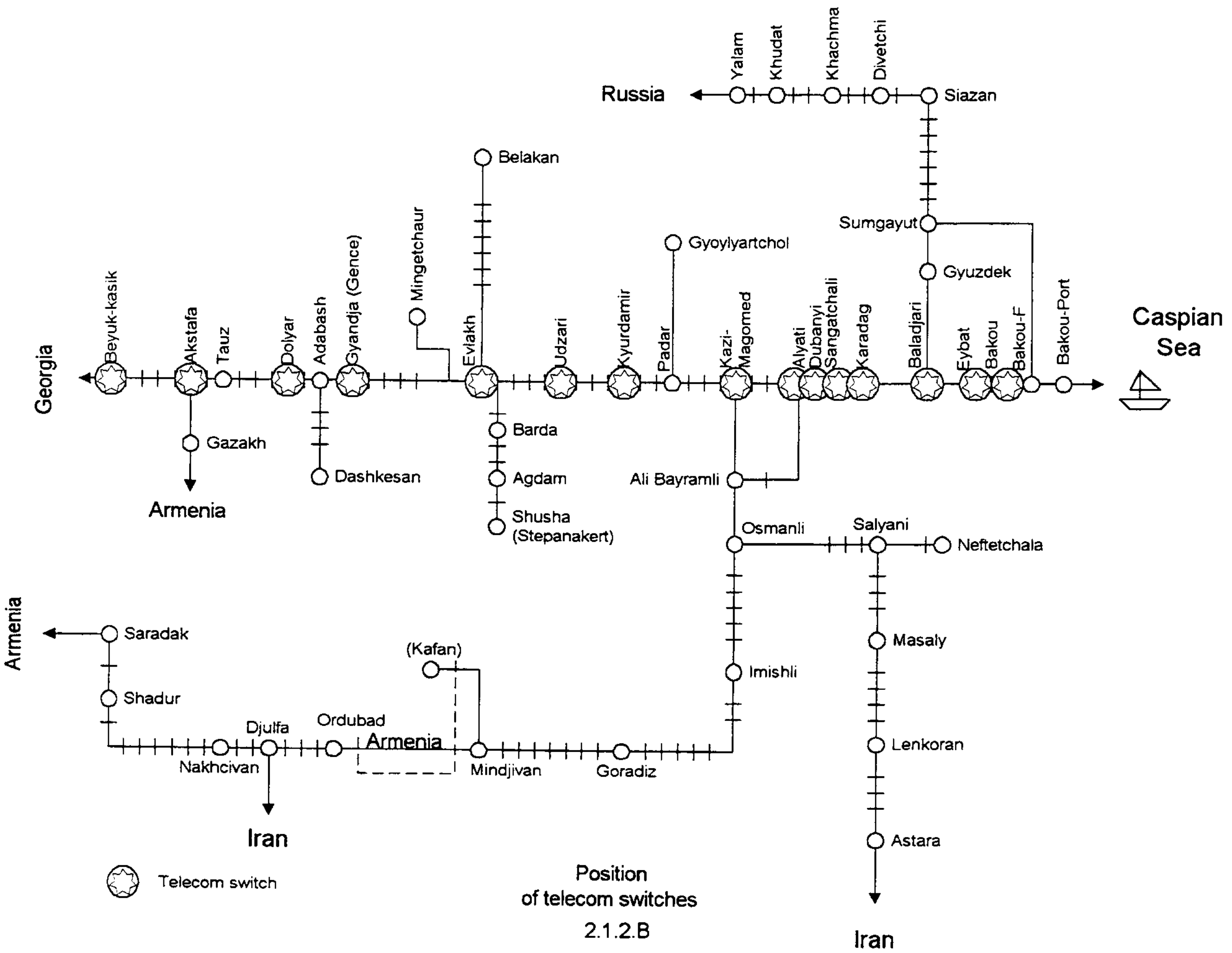


Figure 2.1.2.A

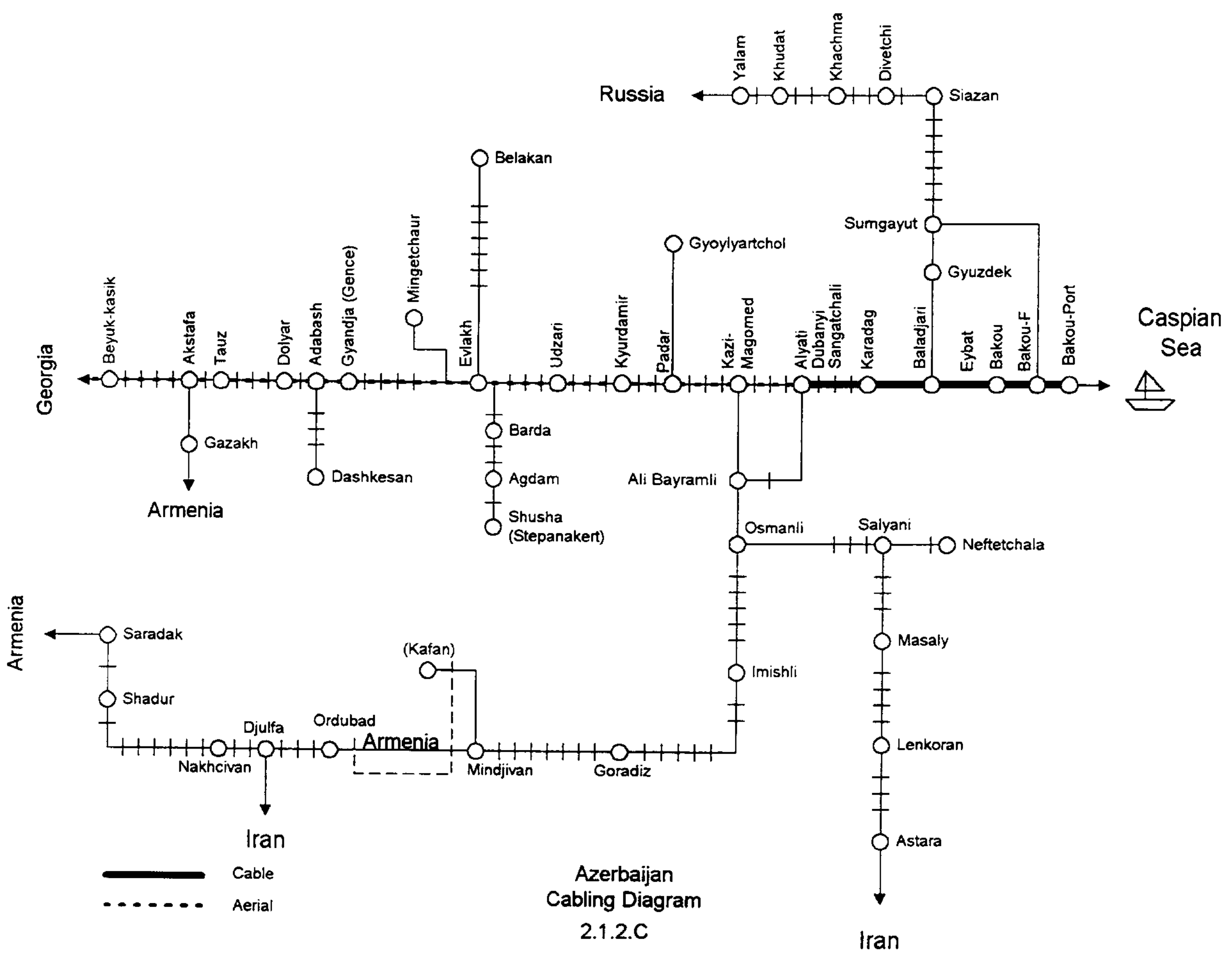
Azerbaijan Railways Diagram
2.1.2.A

Appendix 1 - Telecommunications

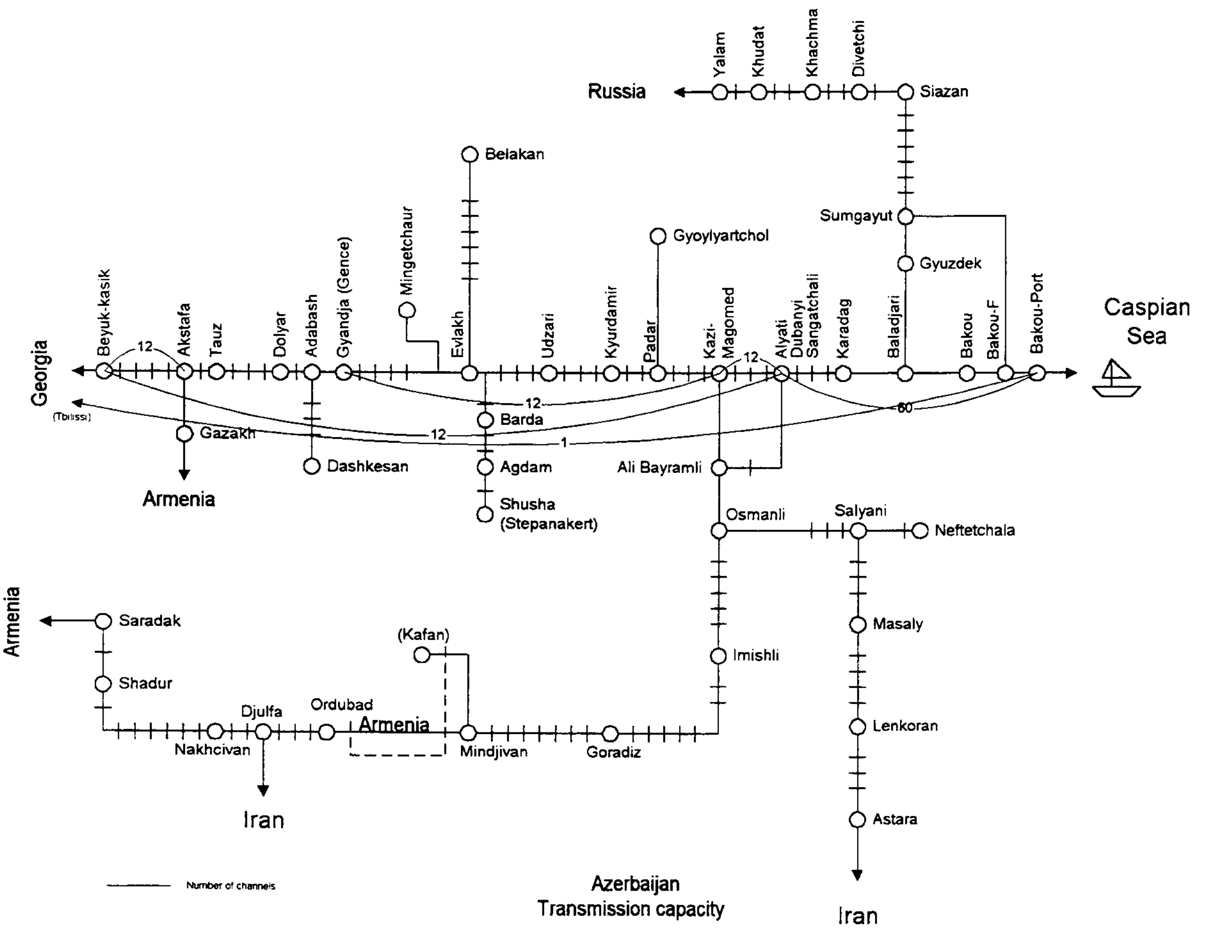


Position
of telecom switches
2.1.2.B

Appendix 1 - Telecommunications

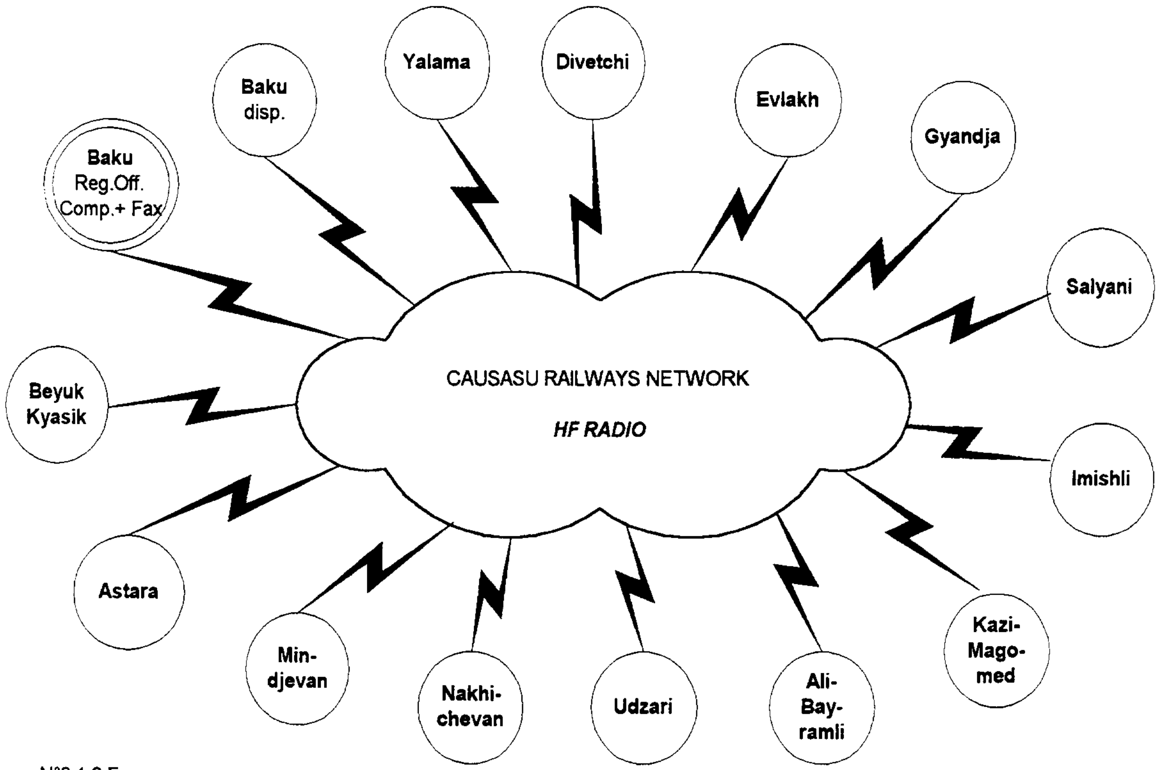


Appendix 1 - Telecommunications



Azerbaijan
Transmission capacity
2.1.2.D

Appendix 1 - Telecommunications



N°2.1.2.E

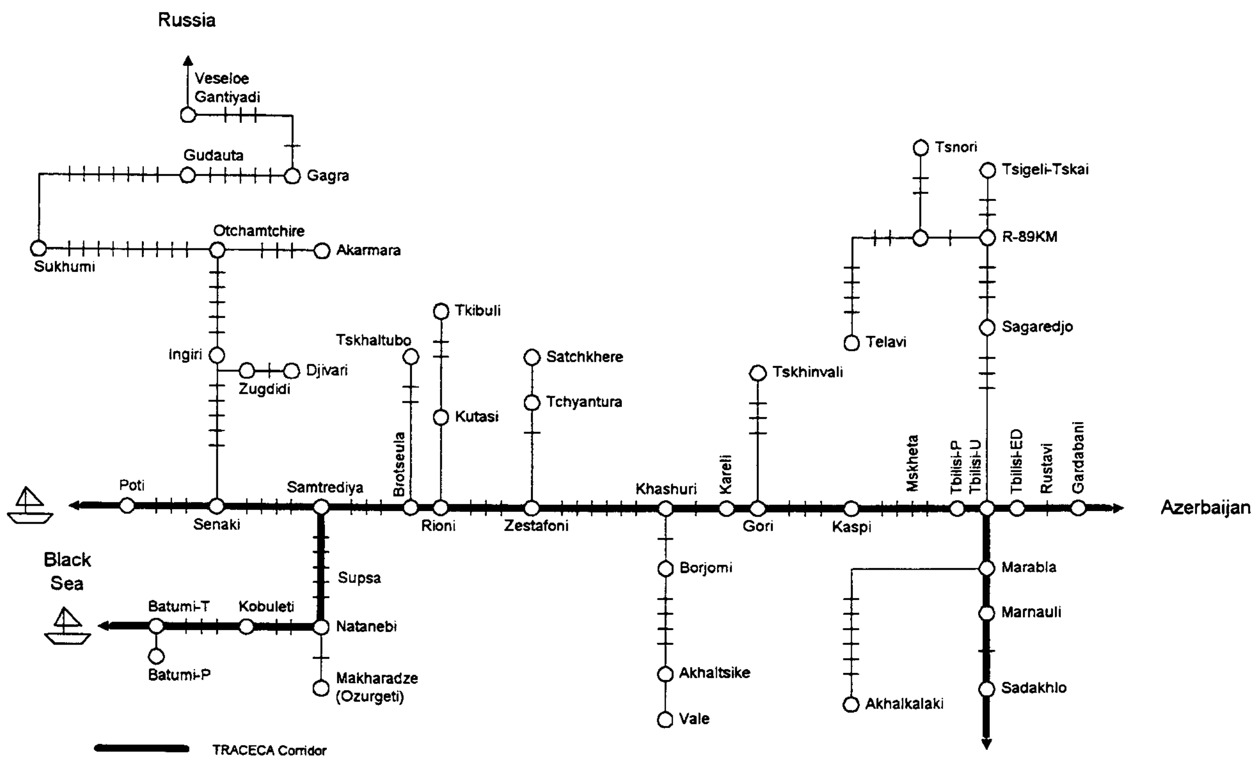
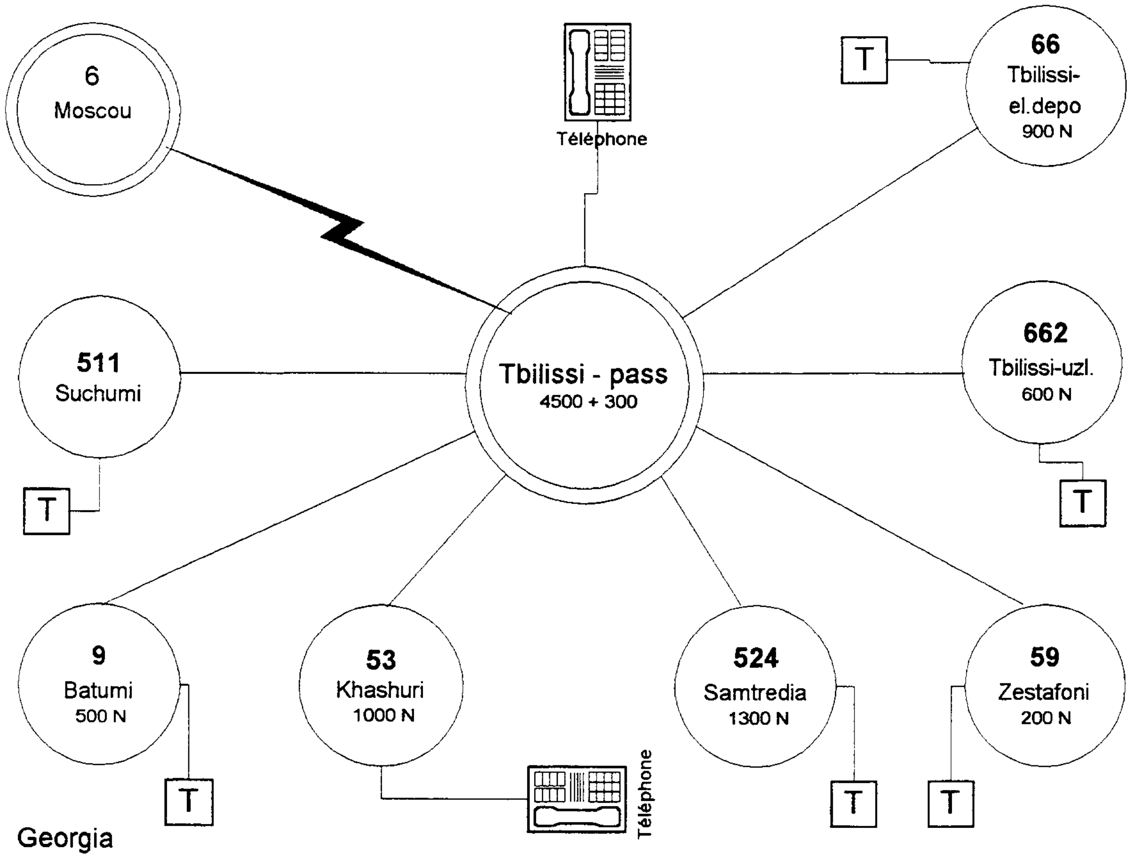


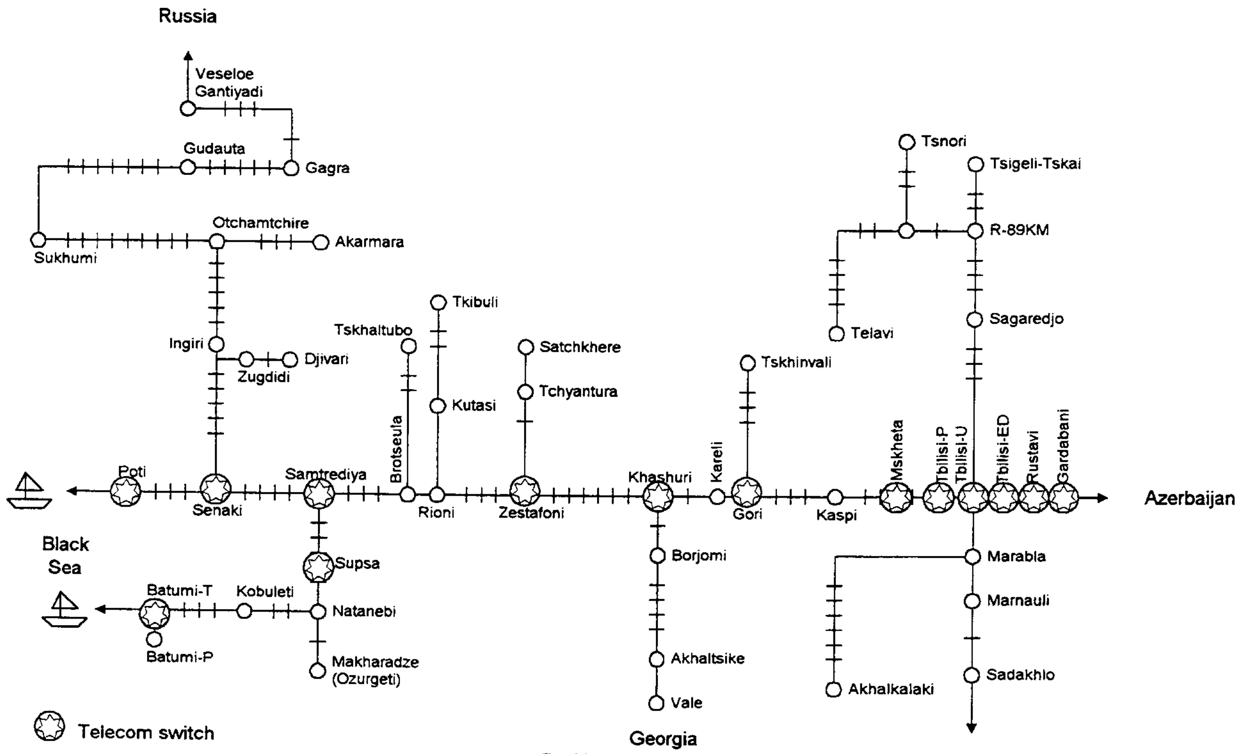
Figure 2.1.3.A
Georgia Railways Diagram

Appendix 1 - Telecommunications



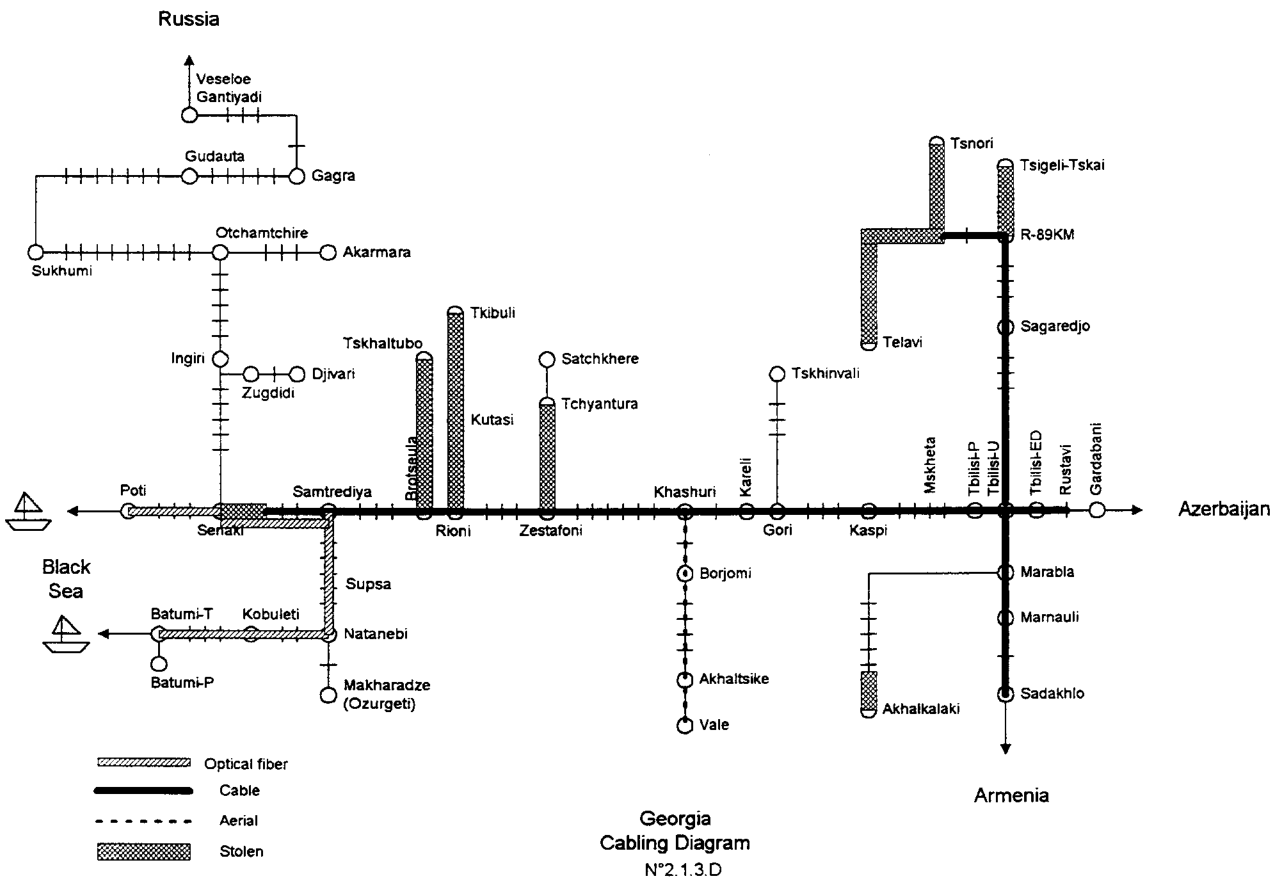
Georgia
N°2.1.3.B

Appendix 1 - Telecommunications



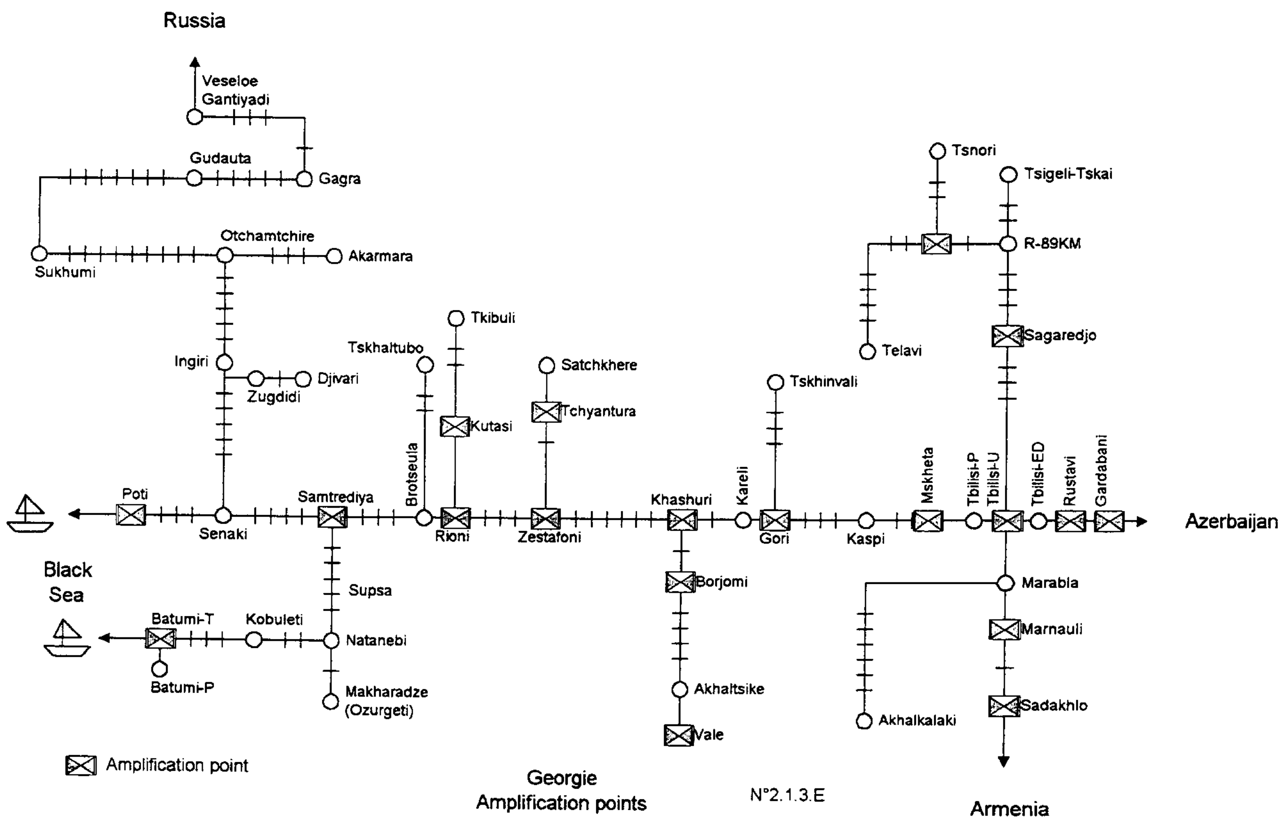
Georgia
Position of telecom switches
N°2.1.3.C

Appendix 1 - Telecommunications

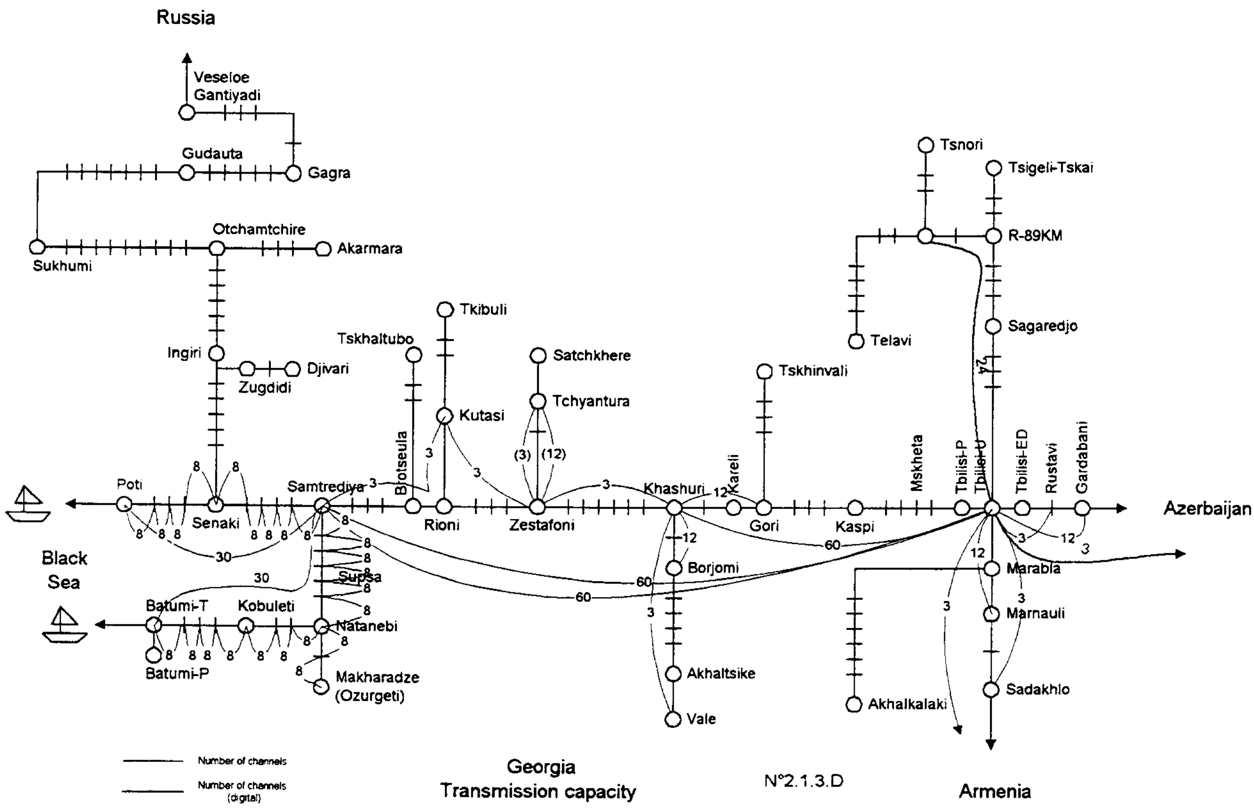


Georgia
Cabling Diagram
N°2.1.3.D

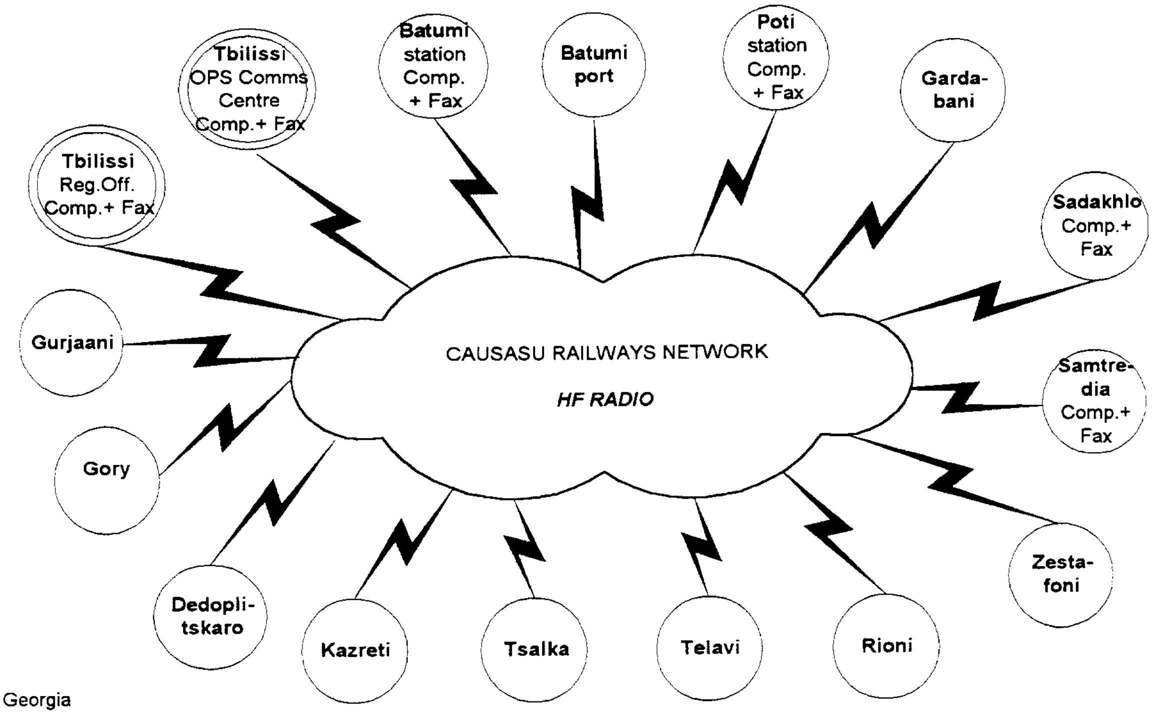
Appendix 1 - Telecommunications



Appendix 1 - Telecommunications



Appendix 1 - Telecommunications



Georgia
N°2.1.3.F

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