FP6 IST

SEEFIRE

South-East Europe Fibre Infrastructure for Research and Education

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Deliverable D3.2

Economic Model for the Acquisition and Operation of Dark Fibre Networks in SE Europe

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Abstract: This deliverable contains an analysis and evaluation of the different economic models for dark fibre acquisition at international and national level comparing the costs of alternative approaches and produces simple models showing the cross-over points for the different approaches.

The SEEFIRE Project

The SEEFIRE Project is a special support action co-funded by the FP6 IST programme of the European Commission. SEEFIRE builds on the success of previous activities and projects, including SEEREN, to support research and education networks in southeast Europe and will provide input for preparing the next-generation networks for research and education in the region. The 12-month, project started on 1 March 2005, will:

- establish a benchmark of existing and potentially available optical fibre for NRENs in the region;
- make an analysis of the technical options available for the deployment of dark fibre and the management of optical transmission by NRENs in the region;
- report on economic aspects and regulations;
- disseminate information and increase awareness about dark-fibre deployment both at technical and policy-making levels.

The recent progress in technology for optical transmission at high speed has made the deployment of owned or leased fibre networks a reality for NRENs. SEEFIRE will make a first step in the direction of a cost-effective gigabit network in southeast Europe, connecting researchers and universities in the region with other research users in Europe and worldwide. In doing so, the project will contribute to reducing the digital divide that affects several countries in southeast Europe, due in part to past political and economic circumstances.

The SEEFIRE Consortium consists of:

TERENA (co-ordinating contractor)	The Netherlands
GRNET	Greece
CESNET	Czech Republic
NIIF/HUNGARNET	Hungary
AMREJ	Serbia and Montenegro
DANTE	United Kingdom
RoEduNet	Romania
ISTF	Bulgaria
MARNet	FYROM
ASA	Albania
BIHARNET	Bosnia and Herzegovina

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1. Executive Summary

This document considers the contractual parameters associated with the acquisition of dark fibre, both from a technical and financial point of view, based on the experience of procuring dark fibre as part of the GÉANT2 project. To assist in the development of budgetary estimates two cost modelling tools are described. The first model provides a simple budgetary, tool based on route length, to calculate an approximate cost of lighting any dark fibre route. The second model, derived from work carried out in the GÉANT2 procurement enables more detailed comparisons of different routes to be made. A number of national scenarios using the simple model are attached to give an indication of the likely budgetary costs associated with lighting fibre in the region.

1. Introduction

The key requirement in terms of investing in dark fibre is to build a business case which shows the savings involved in acquiring and lighting dark fibre when compared with leasing wavelength capacity. A number of parameters are required to build such a model. The key parameters are:

a) knowledge of the fibre route

b) the type of contract that is offered in respect of fibre

c) the document analysis in terms of wavelengths over the period of investment

d) the capacity and operational costs in terms of equipment associated with lighting the appropriate route.

This deliverable examines the main issues that need to be addressed from an economic perspective. It looks at the issues surrounding the acquisition of dark fibre from a contractual perspective. It constructs the main technical issues associated with the acquisition of equipment and the ongoing operation and maintenance of such equipment.

Two models are presented. The first model is a simple model that gives an approximate cost based purely on route length. The second model introduces the demand matrix so that the total cost of implementation can be seen based over a certain period.

Finally, cost estimates are provided for a number of beneficiary countries in SEE based on the standard parameters defined in the first model.

2. Parameters Affecting the Contracting for Dark Fibre and DWDM Equipment

2.1. Dark Fibre

2.1.1. Duration of Fibre Contract

The length of time for which a commitment can be made is a key factor; in general, the longer the commitment the better the terms that can be achieved. In practice, assuming a standard discounting rate of 10 %, the benefits of a longer term commitment are limited after 10 years. This is without taking into account the cost of hardware upgrades which will in any case be necessary over a period of time, and ignores issues such as fibre lifetime and fibre obsolescence. An important factor is also the obligations that may be part of a longer term commitment eg maintenance obligations such as a share of the cost of repairing fibre cuts, which may be associated with a fibre lease. These should be avoided if a "continuous future intention to use" is not expected.

2.1.2. Structure of Fibre Contract

It should be possible to structure the payments in such a way that cash flow obligations etc can be met. In principle the balance between up front payments and periodic payments is negotiable. It might be possible to negotiate to pay only for maintenance in later years.

2.1.3. Nature of the Route

A precise description of what is being provided should include summary information, including route length, and detailed information including fibre type, fibre characteristics, span characteristics, and straight line diagram of the routing involved. An important parameter is the location where in-line amplifier housing is available. This will be defined by the route. It can have significant effects on the actual hardware configuration of the route as well as the options where it may be possible to break-out.

2.1.4. In-Line Amplifier Housing

The location and spacing is required as part of 3) above. Some suppliers will seek to charge separately for housing in-line amplifier sites (huts) and possibly also for power in such sites. In general, this can be factored in as part of the overall costs. There may be some small savings if individual ILAs are not needed. In general however, it is probably better to try and avoid dark fibre providers who seek to apply such additional charges.

2.1.5. Service Level Agreement (SLA)

Defines the willingness of the dark fibre supplier to guarantee operational and support parameters over the duration of the contract.

2.2. DWDM Equipment

2.2.1. The Structure and Technical Performance of the Equipment

In general all DWDM equipment has a similar set of cost elements. These include the terminal equipment at the ends of the route and the in-line amplifiers that are located at intermediate points on the route to amplify the analog signal. The detailed design basis of the equipment varies quite considerably between suppliers and between different systems from the same supplier. This is apparent in relation to two specific parameters: route length and system tolerance.

There is a very fundamental parameter relating to DWDM equipment, namely the route length that it can support before regeneration becomes necessary. Subject to the points raised above the amplifiers employed on a route will be capable of handling all the wavelengths implemented in the system. There will, however, be a route length beyond which it is not be possible to simply amplify a signal. For lengths greater than this limit regeneration is necessary. Unlike amplification, regeneration is a per wavelength cost. For routes which require regeneration, the implementation of an additional wavelength will, in general, be double the cost of those where regeneration is unnecessary. Thus, the range of a system, ie the route length that it can support without regeneration may be a very significant parameter in respect of system choice, particularly in the case of longer routes. Another aspect which needs to be considered is system tolerance. The range will be defined on the basis of various fibre parameters. In real life these parameters are guaranteed within some tolerance. It is also important to consider very carefully the issue of tolerance in relations to system range. This can potentially have a significant effect on the overall cost of implementation.

2.2.2. The Likely Demand Profile over the Lifetime of the Commitment

The business case associated with the investment in dark fibre is dependant on the number of wavelengths that will be implemented over the lifetime of the system. Lighting dark fibre, using DWDM equipment, is characterised by a very high initial cost and very low marginal costs for implementing additional wavelength capacity. In a competitive telecommunications market it is highly unlikely that a business case can be made for lighting a route on the basis of a demand for a single wavelength. Where the telecommunications markets are not competitive, which is often the case in SEE countries, the competitiveness of the dark fibre market may be better or worse than that of that for leased capacity. In general wavelength providers are very unwilling to share their own economies of scale. As a result the business case for lighting fibre improves significantly as the number of wavelengths required increases. There will be a route specific break-even point. Knowing the likely demand profile, on a per route basis, enables a convincing breakeven analysis to be proved.

2.2.3. The Footprint Requirements of the Equipment in Terms of Space at the Terminal Sites

There is often a significant advantage involved in locating DWDM equipment in carrier neutral locations. There are two reasons for this. Firstly, carrier neutral locations generally attract multiple fibre providers and therefore offer greater and more competitive choice. Secondly, to avoid the need to acquire potentially expensive and relatively unreliable local loops for all the trunk circuits coming into a particular location. There is, however, a downside associated with this in as much as space in carrier neutral locations (so-called carrier hotels) may be a significant cost element. Whilst, in terms of total costs it will not be huge, in terms of choosing between competing DWDM vendors, the cost of additional footprint needed may more than offset differences in the offered price of hardware.

2.2.4. The Power Requirements of the Terminal Equipment

Just as space costs may be a differentiator between competing DWDM systems, the same issue applies to power requirements, particularly in carrier hotels where power costs are non trivial. A calculation for the lifetime costs of power is necessary, similar to that for the lifetime costs of space, may be necessary to establish an overall cost of ownership. This may not be significant in terms of total system costs but can be decisive in respect of the choice of hardware vendor, particularly in terms of decisions made as a result of public procurement.

2.2.5. Maintenance Costs

Maintenance is generally expressed as a percentage of equipment purchase price. A key factor in maintenance costs is the level of service required. The other important factor is the length of warrant period offered, as maintenance during warrantee should be cheaper than out of warrantee. This parameter is not likely to be decisive in relation to a decision to "light or not to light" but can be significant in the comparison of total lifetime costs when choosing between competing systems.

2.2.6. Network Management Costs

The element costs relating to network management and the associated centralised systems costs for NOC functions etc need to be carefully calculated, as do potential vendor specific training costs.

3. Economic Models

Two economic models have been developed as part of the SEEFIRE work. They are described in the following chapters of this section.

3.1. Model 1

Model 1, which is attached as Annex I, is designed to give a "ball-park" estimation of the cost of lighting a fibre route. It is primarily driven by route length. For a given route length, it calculates a set of costs namely, fibre lease and maintenance costs, hardware acquisition and maintenance costs and co-location costs. These costs are calculated over a pre-defined period, set at 1, 5 or 15 years. In the context of a hardware investment, 5 years is the realistic amortization period. In general, a longer lease, with appropriate lease terms, will represent better value for money than that for a shorter period. In practice funding and budgetary considerations will typically be the deciding factor in terms of the period that can be afforded. The calculations are carried out using a basic set of cost assumptions defined by a simple set of parameters. The model does not give incremental costs for increasing levels of capacity. Using this model it is possible to obtain budgetary estimates of the likely cost of lighting dark fibre.

In the SEEFIRE model 1 co-location is seen as a separate cost, but it is worth recognising that it could well be bundled: co-location costs are often, in practice, bundled as part of lease costs when dark fibre leases are concerned. In the one GÉANT2 contract where there was a clear separate charge, the charge represented 14% of the total lease costs. When they are charged separately co-location costs may vary greatly depending on the provider.

The parameters used in Model 1 are expressed in the table below.

Fiber Acquisition Cost		
Type of contract	Value	Unit
1 year lease	1	€/m
5 year lease	3	€/m
15 years IRU	5	€/m
Fiber Maintenance Cost		
Type of contract	Value	Unit
1 year lease	0	€
5 year lease	0	€
15 years IRU	3.5	% of IRU cost per year
Equipment Acquisition Cost		
Equipment cost components	Value	Unit
Terminal Equipment Cost (Type A)	100000	€
Intermediate Equipment Cost (Type B)	50000	€ per 100km
Equipment Maintenance Cost		
	Value	Unit
1 year lease	10	% of the equipment cost
Equipment Co-location Cost		
	Value	Unit
1 year lease	12000	€ per 100km per year

Table 1 - Parameters used in cost model 1

3.2. Model 2

Model 2, which is attached as Annex II, is designed to allow more precise comparisons to be made between the differing offers for dark fibre on a per-route basis. It has two primary sets of data inputs

i A set of route offers. These are assembled in a database of offers. The offers can be described according to a variety of commercial and technical parameters. The model normalises this to the cost of a four year period.

ii A per-route demand scenario. This looks at the demand for capacity, in terms of wavelengths, over a period of years. The demand data is combined with the offer data to determine total and incremental costs on a per route basis. This information can then be compared with leased wavelength data to determine the cost effectiveness of an investment in dark fibre. Future demand data is obviously crucial in calculating per route costs but forecasting is necessarily subject to tolerances. The model therefore provides for low, medium and high demand scenarios to enable the sensitivity of investment decisions to be assessed.

In order to illustrate its functionality, in the absence of specific tendered offers in respect of SEEFIRE routes, the model is currently populated with data based on the GN2 procurement. This consists of an anonymised set of route offers. They are derived from information in the responses to the GN2 invitation to tender and have been made suitably anonymous, so that, although the general principles of the analysis are feasible, it is not possible to identify individual routes. This is combined with the per route demand forecasts assembled as part of the GÉANT2 procurement to give data for a break-even analysis.

This spreadsheet consists of seven worksheets, each of which is described briefly as follows.

3.2.1. Routes And Calculations

This spreadsheet currently contains specimen data on 100 fibre routes from 12 different suppliers. Each route has a unique route identifier (RR'X') which is used to address the associated route in subsequent analysis and processing. The basic parameters of the offer are contained in columns "E-I." The offers are a mixture of annual leases and IRU offers. The typical data provided is contained in columns "J-T." It should be noted that the offers specified on the spreadsheet vary considerably in terms of the commercial parameters that were proposed. The spreadsheet normalises the offers to give a four year price for fibre connectivity. In practice, it is a very good idea to ask for a more consistent presentation of offers in terms of commercial parameters required but some suppliers will insist on their own terms and conditions and issues, such as maintenance costs, housing costs, minimum durations etc vary quite considerably. Columns "U-AF" contain the financial analysis, which normalises the data so that a consistent comparison can be done over the amortisation period. On the basis of the fibre data the worksheet calculates equipment cost to equip the router specified. This base equipment cost does not include any lambdas. Finally, in columns "AG-AP," the total equipment cost is averaged over the number of lambdas implemented up to a maximum of ten. Using this data it is easy to carry out a breakeven analysis against leased wavelengths.

The period of demand is controlled by the variable amortisation period. It is currently set at 4 years in this example No attempt is made to introduce the "time value" of money into the analysis"

3.2.2. Capacity

In order to analyse the investment case for dark fibre it is necessary to have a forecast of the way demand for wavelengths will develop over time. The fixed investments in transmission equipment to light dark fibre are very large compared with the incremental investments to light additional wavelengths. As a result the demand forecasts are an important factor in determining the validty of an investment. In order to provide a degree of sensitivity analysis, low medium and high demand scenarios are defined. The model is populated with the low, medium and high scenarios from GEANT 2. These were defined for all the potential routes in GEANT 2. In practice not all routes were lit and so only the demand data for the lit routes is relevant for the further analysis.

3.2.3. General Input

A set of assumptions regarding commercial factors is contained in the general inputs worksheet. The basic cost elements are the list prices for the different component parts of a transmission system. Maintenace and installation costs are typically quoted as a percentage of the list price of the equipment. These approximates numbers are based on general experience of the commercial market. In practice, although list prices are used as the basis for costings, it is universally the case that equipment is offered at a discount to list price. Two discount factors are, therefore, introduced recognising that some items are more heavily discountable than others.

3.2.4. Annualised Capacity

The annualised capacity on a per route basis for the low, medium and high scenario has been extracted and moved to a separate worksheet to overcome the indexing limitations of excel.

3.2.5. Costed Model

For the routes that have been lit the costed model, based on the data in this workbook, is presented. This costed model is selectable on the basis of low, medium and high scenarios. A comparison is made between this data and a specimen quote contained in workbook.

3.2.6. Specimen Quote

This worksheet contains a reasonably accurate quote for a set of routes. It is not however attributable to any individual supplier.

3.2.7. Variables Used

The definition and the position of the variables used in the spreadsheet.

4. SEE DF Cost Estimates

This chapter presents individual country's cost estimates in SEE: Albania, Bosnia and Herzegovina, Bulgaria, FYR of Macedonia, Romania, Serbia and Montenegro.

4.1. ASA - Cost Estimation Albania

Dark fibre is still not available on Albanian telecommunication market. The only optical backbone network in the country is owned by ALBTELECOM, till now state owned, but the privatisation procedures are in progress. In fact, ALBTELECOM was acquired by CALIK ENERJI, a Turkish company, but the new government had asked for an international audition of the privatisation procedures. So the privatisation hasn't taken place and there are some uncertainties about the company ownership.

ALBTELECOM also owns some international submarine optical fibre lines connecting Durres with Dubrovnik (Croatia), Bari (Itali) and Corfu (Greece). Another optical fibre owner is the AFB (Albanian Fibre Backbone), a private company, which owns some optical fibre lines mainly in Tirana.

No.	PoP1	PoP2	Approx. Distance [km]
1	Tirana	Shkodra	120
2	Shkodra	Border to Montenegro	20
3	Tirana	Durres	42
4	Durres	Rrogozhine	40
5	Rrogozhine	Elbasan	44
6	Rrogozhine	Vlore	95
7	Elbasan	Pogradec	90
8	Pogradec	Border to FYROM	8
9	Pogradec	Korce	52
10	Korce	Greek border	22

Table 2 - Planned national optical links between PoPs in Albanian NREN backbone network (including cross-border optical links)

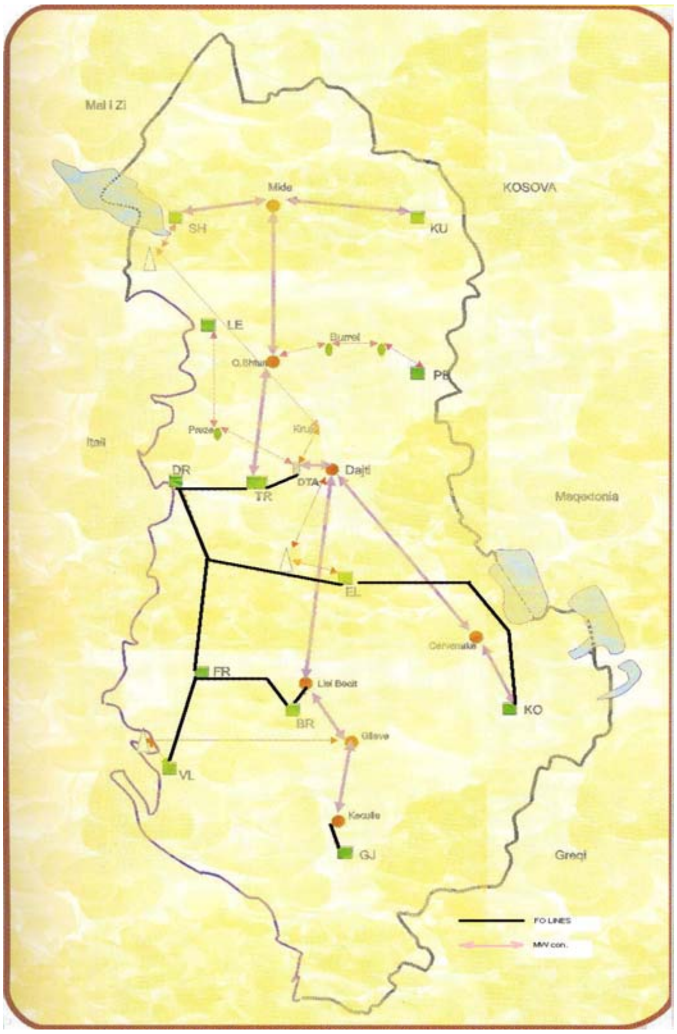

Figure 1 - Map of Albanian existing fibre optic infrastructure

4.1.1. National optical connectivity

Having no real figures for DF leasing costs, the cost estimate presented below is based on the agreed (default) parameters.

Using the Cost Estimation Tool given in annex I, the costs were calculated for three scenarios: 1 year lease, 5 year lease of dark fibre and 15 years IRU. Only the 5 years scenario is presented in this document. There are two new optical fibre lines: Korce-Kapshtica (Greek border) 22 km, finished but not operative yet, and Tirana-Shkodra, 120 km, under construction (almost 75% finished). These two lines are included in the 5 year lease scenario given below. Other costs (personnel, travel, consumables) were excluded from the analysis. No co-location costs are included. The results from calculations are summarized in the following tables.

PoP A Location	PoP B Location	Dist. in km	Fibre Cost	Fibre Maint. Cost	Equipment Acquisition	Equip. Maint. Cost	Total
Tirana	Durres	42	126,000 €	0 €	121,000 €	60,500 €	**307,500 €**
Durres	Rrogozhine	40	120,000 €	0 €	120,000 €	60,000 €	**300,000 €**
Rrogozhine	Elbasan	44	132,000 €	0 €	122,000 €	61,000 €	**315,000 €**
Elbasan	Pogradec	90	270,000 €	0 €	145,000 €	72,500 €	**487,500 €**
Pogradec	Korce	52	156,000 €	0 €	126,000 €	63,000 €	**345,000 €**

Pogradec	FYROM Brd.	8	24,000 €	0 €	104,000 €	52,000 €	**180,000 €**
Rrogozhine	Vlore	95	285,000 €	0 €	147,500 €	73,750 €	**506,250 €**
Shkoder	Monteneg. Brd.	20	60,000 €	0 €	110,000 €	55,000 €	**225,000 €**
Korce	Greek border	22	66,000 €	0 €	111,000 €	55,500 €	**232,500 €**
Tirana	Shkoder	120	360,000 €	0 €	160,000 €	80,000 €	**600,000 €**
		533	1,599,000 €	0 €	1,266,500 €	633,250 €	**3,498,750 €**

Table 3 – Cost estimate for national optical links

Annual cost structures are given in the graph below.

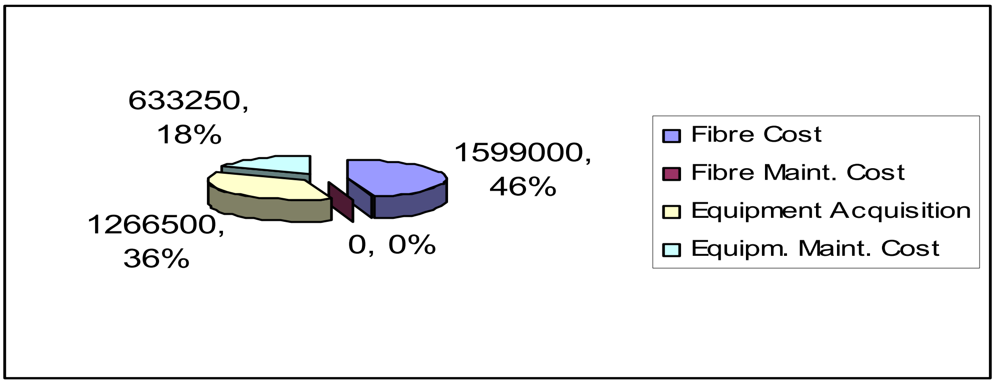

Figure 2 – Annual costs structure for national links (in € and %)

The figure below compares the cost evolution in the three scenarios. Here the actualised (per year) costs are reported i.e. the 5 and 15 year costs are simply divided by 5 and 15 respectively in order to report them to a one year cost.

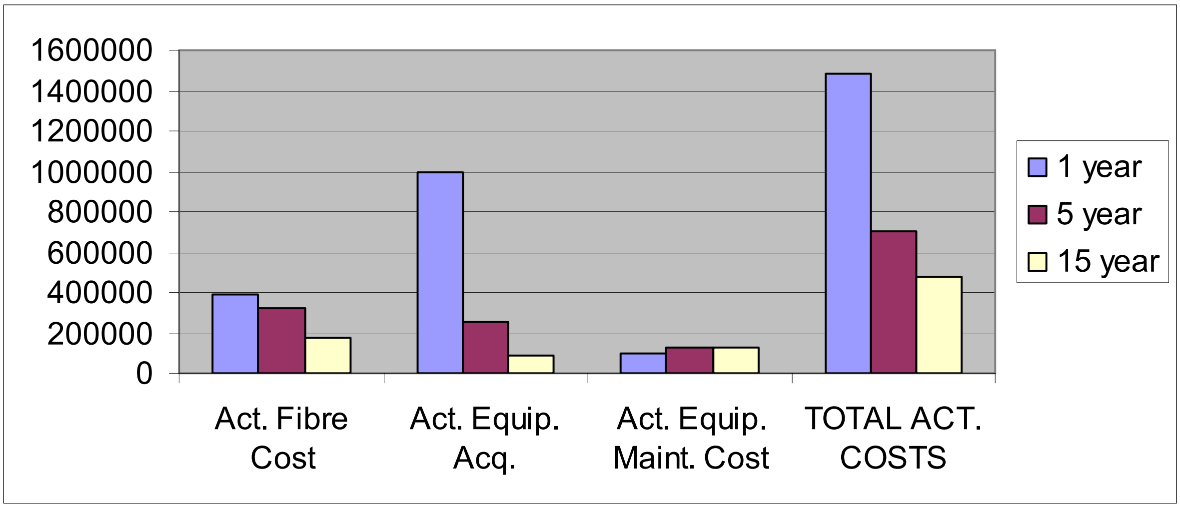

Figure 3 – Annual actualised costs structure (in €)

4.2. Bosnia and Herzegovina – Cost Estimation

SEEFIRE aims to support the establishment of national and local level optical infrastructure to fulfill the needs of academic and research communities in Bosnia and Herzegovina. This infrastructure should be based on leased dark fiber connections between all the universities in the country as well as international links to neighboring countries.

Planned national PoP’s and distances between them are presented in the following table:

PoP 1	PoP 2	Distance [km]
Banja Luka	Bihac	155
Brcko	Banja Luka	250
Brcko	Tuzla	60
Brcko	Bijeljina	40
East Sarajevo	Zvornik	159
East Sarajevo	Sarajevo	6
Sarajevo	Mostar	136
Sarajevo	Zenica	78
Zvornik	Bijeljina	55

Table 4 - National PoP’s

This would connect universities (or faculties) in: Banja Luka, Bihac, East Sarajevo, Mostar, Sarajevo, Tuzla and Zenica.

As some of the universities have dislocated faculties, they were included in the table as if dark fibre was already going through that city (Bijeljina, Brcko, Zvornik).

The University of East Sarajevo has two additional locations to connect: Foca and Trebinje. The University of Banja Luka has dispersed faculties in the city as well as Mining Faculty in Prijedor. Details about distances can be found in the following tables:

PoP A Location	PoP B Location	Distance in km
East Sarajevo FEE	Foca	180
Trebinje	Foca	150

Table 5 - University of East Sarajevo PoP’s

PoP A Location	PoP B Location	Distance in km
Banja Luka FEE	Banja Luka URC	2.5
Banja Luka New Campus	Banja Luka URC	2.5
Banja Luka PMF	Banja Luka FEE	2.5
Banja Luka	Prijedor (Mining Faculty)	60

Table 6 - University of Banja Luka PoP’s

There are several routes for international connectivity. They connect to AMREJ (Serbia), AMREJ (Montenegro) or CARNET (Croatia). They are presented in following table:

PoP A Location	PoP B Location	Distance in km
Zvornik	Border (SCG)	1
Mostar	Border (Montenegro)	108
Mostar	Border (Croatia)	52
Banja Luka	Border (Croatia)	50

Table 7 - Potential international links

This map represents planned optical fibre links on the international, national (between universities) and local (university level).

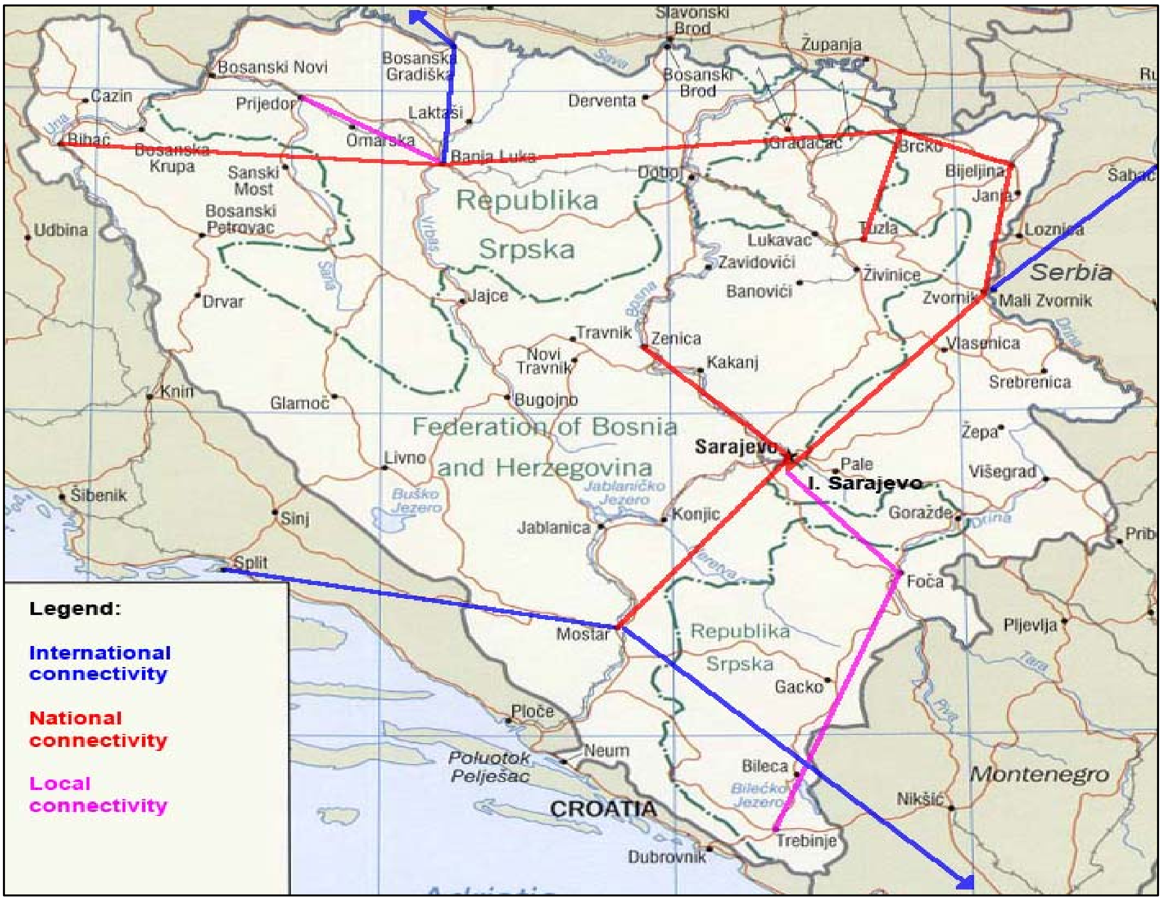

Figure 3 - Map of planned international, national and local DF connections

4.2.1. Local optical connectivity

Universities in Bosnia and Herzegovina can be divided into two categories based on whether all the faculties are located together or the university is of "dispersed" type. The latter applies to the University of East Sarajevo as the faculties are distributed throughout the country. Another example is the Mining Faculty (UoBL) that is stationed in Prijedor. Faculties in Bijeljina and Brcko can be easily connected as the DF is going through those cities and it would be an ideal place for regeneration point as well.

Here is the detailed table for connectivity:

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation on equipment cost	Total
Banja Luka FEE	Banja Luka URC	2.5	7,500.00 €	101,250.00 €	50,625.00 €	0.00 €	**159,375.00 €**
Banja Luka New Campus	Banja Luka URC	2.5	7,500.00 €	101,250.00 €	50,625.00 €	0.00 €	**159,375.00 €**
Banja Luka PMF	Banja Luka FEE	2.5	7,500.00 €	101,250.00 €	50,625.00 €	0.00 €	**159,375.00 €**
Banja Luka	Prijedor (Mining Faculty)	60	180,000.00 €	130,000.00 €	65,000.00 €	0.00 €	**375,000.00 €**
							853,125.00 €

Table 8 - University of Banja Luka local network

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
East Sarajevo FEE	Foca	180	540,000.00 €	190,000.00 €	95,000.00 €	108,000.00 €	**933,000.00 €**
Trebinje	Foca	150	450,000.00 €	175,000.00 €	87,500.00 €	90,000.00 €	**802,500.00 €**
							1,735,500.00 €

Table 9 - University of East Sarajevo local network

4.2.2. National connectivity

National level network will be made of fibers obtained from different providers as there is no single provider that can connect all the universities.

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
East Sarajevo	Zvornik	159	477,000.00 €	179,500.00 €	89,750.00 €	95,400.00 €	**841,650.00 €**
East Sarajevo	Sarajevo	6	18,000.00 €	103,000.00 €	51,500.00 €	3,600.00 €	**176,100.00 €**
Sarajevo	Mostar	136	408,000.00 €	168,000.00 €	84,000.00 €	0.00 €	**660,000.00 €**
Sarajevo	Zenica	78	234,000.00 €	139,000.00 €	69,500.00 €	0.00 €	**442,500.00 €**
Brcko	Banja Luka	250	750,000.00 €	225,000.00 €	112,500.00 €	150,000.00 €	**1,237,500.00 €**
Brcko	Tuzla	60	180,000.00 €	130,000.00 €	65,000.00 €	36,000.00 €	**411,000.00 €**
Banja Luka	Bihac	155	465,000.00 €	177,500.00 €	88,750.00 €	0.00 €	**731,250.00 €**
Brcko	Bijeljina	40	120,000.00 €	120,000.00 €	60,000.00 €	24,000.00 €	**324,000.00 €**
Zvornik	Bijeljina	55	165,000.00 €	127,500.00 €	63,750.00 €	33,000.00 €	**389,250.00 €**
							5,213,250.00 €

Table 10 - National connectivity

4.2.3. International connectivity

There are several possible international links with neighboring countries. Maybe the most appealing thing is the fact that if there were at least two links to different NREN's (AMREJ and CARNET) the country would be able to benefit from backup links for both of them as they have completely different international connections.

PoP A Location	PoP B Location	Dist. in km	Fibre Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Zvornik	Border (SCG)	1	3,000.00 €	100,500.00 €	50,250.00 €	0.00 €	**153,750.00 €**
Mostar	Border (Montenegro)	108	324,000.00 €	154,000.00 €	77,000.00 €	0.00 €	**555,000.00 €**
Mostar	Border (Croatia)	52	156,000.00 €	126,000.00 €	63,000.00 €	0.00 €	**345,000.00 €**
Banja Luka	Border (Croatia)	50	150,000.00 €	125,000.00 €	62,500.00 €	0.00 €	**337,500.00 €**
							1,391,250.00 €

Table 11 - International connectivity

It is worth noting that one should take into account that if we have a PoP that connects to a number of other PoP's then the price of the equipment for that PoP does not increase linearly with the number of connecting PoP's.

4.3. ISTF - Cost Estimation Bulgaria

ISTF's vision is to establish a local optical infrastructure, a nationwide optical backbone infrastructure based on leased dark fibres, connecting all the university cities in the country (PoPs), and international optical connections to neighbouring countries.

No.	PoP1	PoP2	Approx. Distance [km]
1	Sofia	Plovdiv	178
2	Plovdiv	Stara Zagora	111
3	Sofia	Veliko Tarnovo	267
4	Veliko Tarnovo	Pleven	151
5	Veliko Tarnovo	Svishtov	108
6	Veliko Tarnovo	Rousse	126
7	Sofia	Blagoevgrad	118
8	Sofia	Pravetz	72
9	Veliko Tarnovo	Gabrovo	55
10	Rousse	Shumen	136
11	Shumen	Varna	110
12	Varna	Burgas	153
13	Veliko Tarnovo	Varna	274
14	Sofia	Serbian Border	72
15	Blagoevgrad	Greek Border	98
16	Rousse	Romanian Border	15

Table 12 - Planned national optical links between PoPs in ISTF's backbone network (including cross-border optical links)

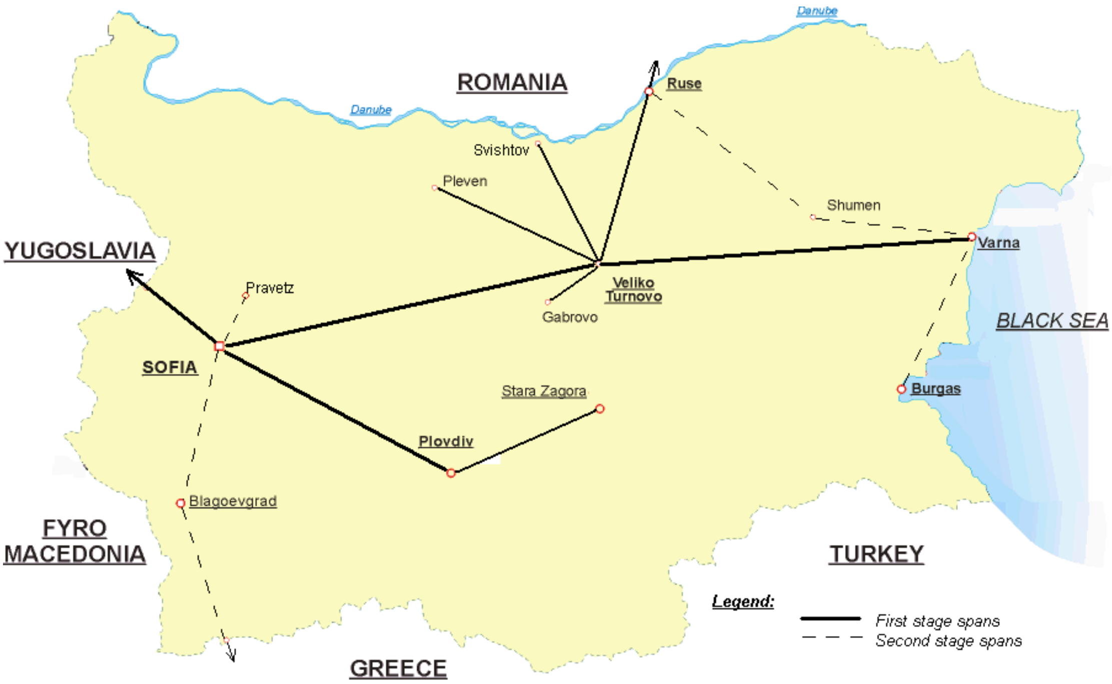

Figure 4 - Backbone network topology including cross-border optical links

4.3.1. Local optical connectivity

Most of the university cities in the country have a need for a metro optical networking infrastructure. Specifically, the one with the most urgent need is the city of Plovdiv, because there are several universities on different locations in the city.

Using the Cost Estimation Tool based on the default parameters, the costs were calculated for a 5 year lease scenario for dark fibre. Other costs (personnel, travel, consumables) were excluded from the analysis. The results from calculations are summarized in the tables below.

Figure 5 - Metro optical networking topology in city of Plovdiv

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Tecnical University of Sofia, in Plovdiv	Agricultural Univesity	3,36	10 080,00 €	0,00 €	101 680,00 €	50 840,00 €	2 016,00 €	**164 616,00 €**
Tecnical University of Sofia, in Plovdiv	Medical Univesity	3,36	10 080,00 €	0,00 €	101 680,00 €	50 840,00 €	2 016,00 €	**164 616,00 €**
Tecnical University of Sofia, in Plovdiv	Univesity of Food Technologies	3,72	11 160,00 €	0,00 €	101 860,00 €	50 930,00 €	2 232,00 €	**166 182,00 €**
Tecnical University of Sofia, in Plovdiv	Univesity of Plovdiv - Paisii Hilendarski	0,76	2 280,00 €	0,00 €	100 380,00 €	50 190,00 €	456,00 €	**153 306,00 €**
								648 720,00 €

Table 13 - Cost estimate for local optical links in Plovdiv

4.3.2. National optical connectivity

Optical connectivity on a national level includes links among thirteen university cities in the country. The cost estimate presented below is based on the default parameters. Using the Cost Estimation Tool, the costs were calculated for a 5 year lease of dark fibre scenario. Other costs (personnel, travel, consumables) were excluded from the analysis. The results from calculations are summarized in the following table.

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Sofia	Plovdiv	178	534 000,00 €	0,00 €	189 000,00 €	94 500,00 €	106 800,00 €	**924 300,00 €**
Plovdiv	Stara Zagora	111	333 000,00 €	0,00 €	155 500,00 €	77 750,00 €	66 600,00 €	**632 850,00 €**
Sofia	Veliko Tarnovo	276	828 000,00 €	0,00 €	238 000,00 €	119 000,00 €	165 600,00 €	**1 350 600,00 €**
Veliko Tarnovo	Pleven	151	453 000,00 €	0,00 €	175 500,00 €	87 750,00 €	90 600,00 €	**806 850,00 €**
Veliko Tarnovo	Svishtov	108	324 000,00 €	0,00 €	154 000,00 €	77 000,00 €	64 800,00 €	**619 800,00 €**
Veliko Tarnovo	Rousse	126	378 000,00 €	0,00 €	163 000,00 €	81 500,00 €	75 600,00 €	**698 100,00 €**
Sofia	Blagoevgrad	118	354 000,00 €	0,00 €	159 000,00 €	79 500,00 €	70 800,00 €	**663 300,00 €**
Sofia	Pravetz	72	216 000,00 €	0,00 €	136 000,00 €	68 000,00 €	43 200,00 €	**463 200,00 €**
Veliko Tarnovo	Gabrovo	55	165 000,00 €	0,00 €	127 500,00 €	63 750,00 €	33 000,00 €	**389 250,00 €**
Rousse	Shumen	136	408 000,00 €	0,00 €	168 000,00 €	84 000,00 €	81 600,00 €	**741 600,00 €**
Shumen	Varna	110	330 000,00 €	0,00 €	155 000,00 €	77 500,00 €	66 000,00 €	**628 500,00 €**
Varna	Burgas	153	459 000,00 €	0,00 €	176 500,00 €	88 250,00 €	91 800,00 €	**815 550,00 €**
Veliko Tarnovo	Varna	229	687 000,00 €	0,00 €	214 500,00 €	107 250,00 €	137 400,00 €	**1 146 150,00 €**
								9 880 050,00 €

Table 14 - Cost estimate for national optical links

4.3.3. International optical connectivity

Optical connectivity on international level includes links 14-16 listed in Table 12. The cost estimate presented below is based on the default parameters, with only one difference: terminal equipment cost = 50 000 € (instead of 100 000 €)[1].

Using the Cost Estimation Tool, the costs were calculated for a 5 year lease of dark fibre. Other costs (personnel, travel, consumables) were excluded from the analysis. The results from calculations are summarized in the following table.

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Sofia	Serbian Border	72	216 000,00 €	0,00 €	68 000,00 €	68 000,00 €	43 200,00 €	**463 200,00 €**
Blagoevgrad	Greeк Border	98	294 000,00 €	0,00 €	74 500,00 €	74 500,00 €	58 800,00 €	**576 300,00 €**
Rousse	Romanian Border	15	45 000,00 €	0,00 €	53 750,00 €	53 750,00 €	9 000,00 €	**215 250,00 €**
								1 254 750,00 €

Table 15 - Cost estimate for international optical links

4.4. MARNet - Cost estimation FYR of Macedonia

Dark fibre is still not available on Macedonian telecommunication market. AD Makedonski telekomunikacii has the biggest optical backbone network in the country, but they only offer digital leased lines. MEPSO, an electric power transmission company, and Macedonian Railways own dark fibres nationwide, but dark fibres are still not offered on the market.

MARNet’s vision is to build a local optical infrastructure (where needed), a nationwide optical backbone infrastructure based on leased dark fibres, connecting all the university cities in the country (PoPs), and international optical connections to neighbouring countries.

No.	PoP1	PoP2	Approx. Distance [km]
1	Skopje	Prilep	100
2	Prilep	Bitola	45
3	Bitola	Ohrid	90
4	Prilep	Stip	120

[1] This is based on the assumption that international optical links should be treated as half circuits (equipment only at end A within the country under consideration), unlike the national optical links, which are treated as full circuits (equipment in both ends A and B). The same assumption has been made by all countries involved in this study.

5	Skopje	Tetovo	60
6	Stip	Border to Bulgaria	100
7	Skopje	Border to Serbia and Montenegro	80
8	Skopje	Border to Greece	200
9	Bitola	Border to Greece	40
10	Ohrid	Border to Albania	50

Table 16 - Planned national optical links between PoPs in MARNet's backbone network (including cross-border optical links)

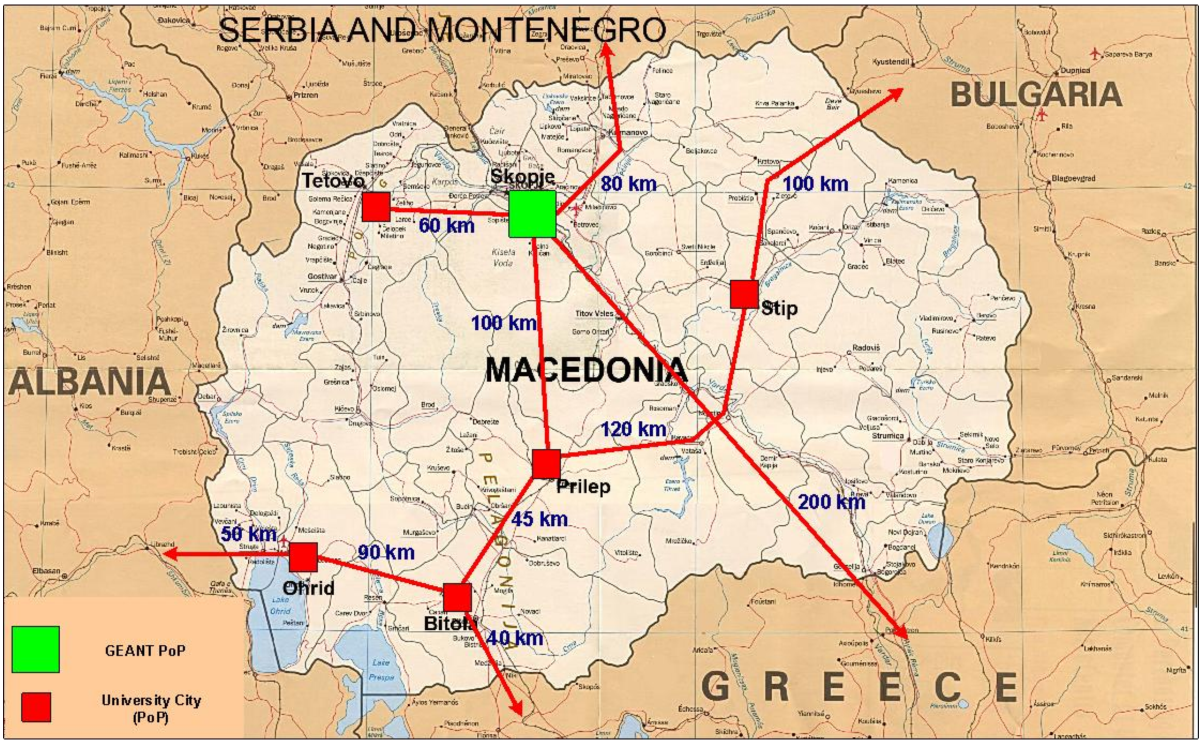

Figure 6 - Map of FYR of Macedonia PoPs

4.4.1. Local Optical Connectivity

Besides Skopje, most of the other university cities in the country do not have a need for a metro optical networking infrastructure. This is due to the fact that there is only one faculty (or institute) building in such cities or, there are two buildings very close to each other, so the optical connectivity, if needed, is part of the their LAN infrastructure.

Bitola is the only university city with a real need for metro optical networking infrastructure, since there are several faculty buildings on different locations in the city. MARNet already has experience in building metro optical network in Skopje that can be used in the case of Bitola.

The Gigabit Metro Optical Network (GMON) in Skopje, fully owned by University "Sts. Kiril and Metodij" (MARNet), was built in 2 year period (2003-2005). Total cost for acquisition and installation of 17 km optical cables (with 24 fibres) was approximately 170 000 € (realised as turn-key project with the implementer). The agreed unit price was 10 €/m. Besides the costs for the fibre, there were additional costs (approximately 200 000 €) for transmission and networking equipment. According to this experience, it could be expected that the Bitola GMON (less than 10 km) would cost less than 200 000 € (including both fibre and equipment).

4.4.2. National optical connectivity

Using Model 1, the costs of national optical connectivity were calculated for two scenarios: 5 year lease of dark fibre and 15 years IRU. Other costs (personnel, travel, consumables) were excluded from the analysis. The results from calculations are summarized in the following tables.

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Skopje	Prilep	100	300,000 €	0 €	150,000 €	75,000 €	60,000 €	**585,000 €**
Prilep	Bitola	45	135,000 €	0 €	122,500 €	61,250 €	27,000 €	**345,750 €**
Bitola	Ohrid	90	270,000 €	0 €	145,000 €	72,500 €	54,000 €	**541,500 €**
Prilep	Stip	120	360,000 €	0 €	160,000 €	80,000 €	72,000 €	**672,000 €**
Skopje	Tetovo	60	180,000 €	0 €	130,000 €	65,000 €	36,000 €	**411,000 €**
			1,245,000 €		**707,500 €**	**353,750 €**	**249,000 €**	**2,555,250 €**

Table 17 - Cost estimate for national optical links

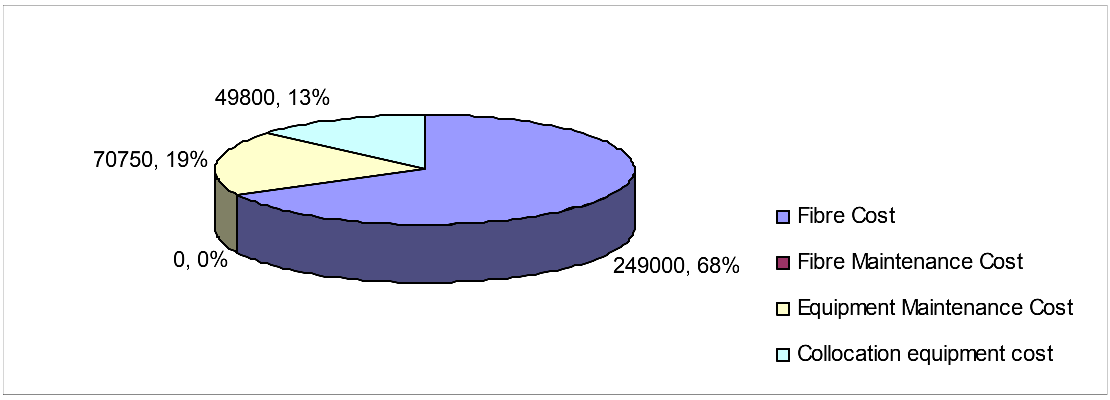

Figure 7 – Annual costs structure (excluding equipment acquisition cost) for national links (in € and %)

Additional cost savings may be considered if collocation equipment costs are reduced. This can be achieved if NREN's local optical infrastructure in each university city can reach the DF provider premises. In the best-case scenario (no collocation costs in all cities), MARNet could save significant 49 800 € per year.

4.4.3. International optical connectivity

Optical connectivity on international level includes links 6-10 listed in Table 16. The cost estimate presented below is based on the standard parameters except for the terminal equipment cost (50 000 € instead of 100 000 €).

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Stip	Bulgaria border	100	300,000€	0€	150,000€	75,000€	60,000€	**585,000€**
Skopje	Serbia border	80	240,000€	0€	140,000€	70,000€	48,000€	**498,000€**
Skopje	Greece border	200	600,000€	0€	200,000€	100,000€	120,000€	**1,020,000€**

Bitola	Greece border	40	120,000€	0€	120,000€	60,000€	24,000€	**324,000€**
Ohrid	Albania border	50	150,000€	0€	125,000€	62,500€	30,000€	**367,500€**
			1,410,000€	**0€**	**735,000€**	**367,500€**	**282,000€**	**2,794,500€**

Table 18 - Cost estimate for international optical links

Additional cost savings may be considered if collocation equipment costs are reduced. This can be achieved if NREN's local optical infrastructure in each university city can reach the DF provider premises. In the best-case scenario (no collocation costs in all cities), MARNet could save significant 56 400 € per year (846 000 € in 15 years).

4.5. RoEduNet - Cost Estimation Romania

According to the results of the SEEFIRE drak fibre survey, there are some potential DF providers in Romania. There are two state owned companies able to provide this type of infrastructure: S.C. Telecomunicatii CFR SA and S.C. Teletrans SA. Also, there are at least three private companies willing to provide DF to the Romanian NREN (RoEduNet).

None of them, except Romtelecom, is able to provide a full countrywide solution using own fibre infrastructure. RoEduNet has already signed a collaboration agreement with SC Telecomunicatii CFR to offer lambda services and DF services for the education and research. In fact, the solution could be much more complicated because the Ministry of Education and Research plans to connect to RoEduNet directly not only the institutions in the cities where the POPs of RoEduNet are located but also 2,300 other locations. To solve this problem the collaboration with Telecomunicatii CFR (or any other carrier) could be more complex than leasing dark fibre.

4.5.1. National Optical Connectivity For The Main POPs (NOCs)

RoEduNet use a hierarchical structure because not all of the POP's need the same type of service. There are 6 main POPs (NOCs – Network Operation Centers) in the country and the main NOC in Bucharest. Each NOC provides services to a number of 3 to 9 POP in their area of responsibility. This structure allows RoEduNet to use different technologies for the connections between NOCs and between NOCs and POPs. There are plans to use DWDM between NOCs and CWDM between NOCs and POPS. This vision has been presented in D2.2. The estimated cost for the equipments for this solution has been also included in D2.2 and the total amount of investment is about 9 million Euros.

The proposed dark fiber topology, based on the agreement with Telecomunicatii CFR, is presented in the picture below.

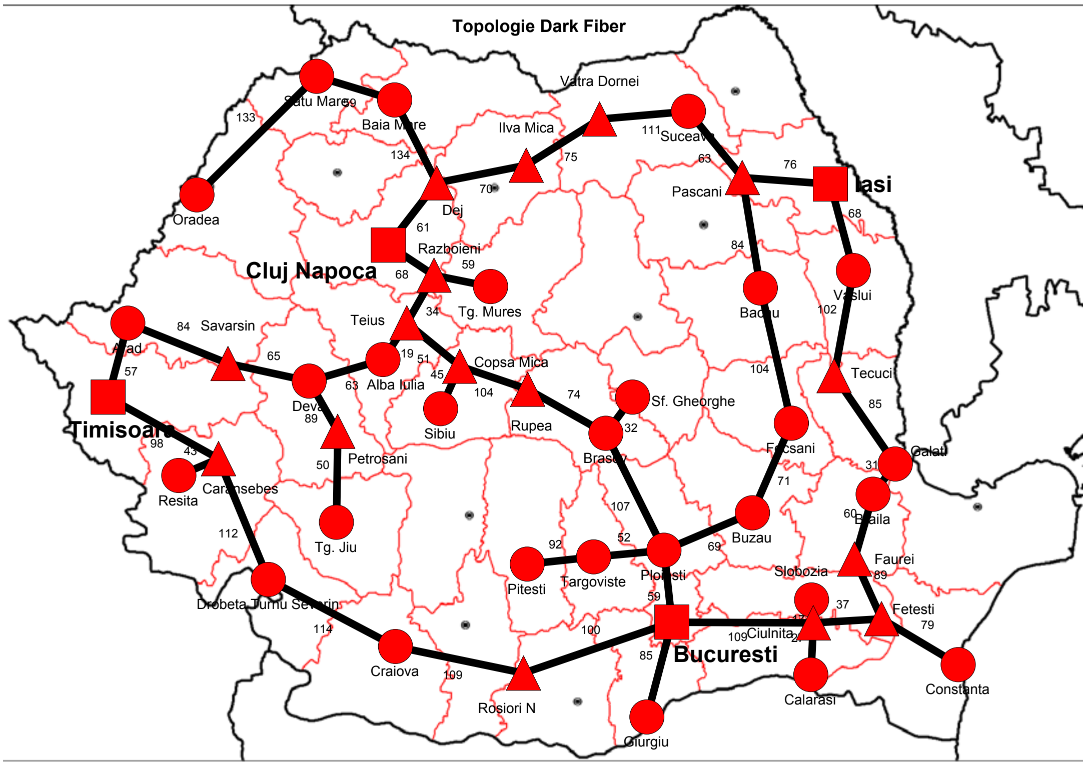

Figure 8 - Proposed DF topology for RoEduNet.

The estimated costs calculated using Model 1, to connect the NOCs using DWDM, and based on a 5 year scenario are presented in the table below:

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Bucharest	Iasi	581	1,743,000.00 €	0.00 €	390,500.00 €	195,250.00 €	348,600.00 €	**2,677,350.00 €**
Bucharest	Cluj	497	1,491,000.00 €	0.00 €	348,500.00 €	174,250.00 €	298,200.00 €	**2,311,950.00 €**
Bucharest	Timisoara	533	1,599,000.00 €	0.00 €	366,500.00 €	183,250.00 €	319,800.00 €	**4,989,300.00 €**
Iasi	Cluj	456	1,368,000.00 €	0.00 €	328,000.00 €	164,000.00 €	273,600.00 €	**2,133,600.00 €**
Cluj	Timisoara	390	1,170,000.00 €	0.00 €	295,000.00 €	147,500.00 €	234,000.00 €	**1,846,500.00 €**
		2457	**7,371,000.00 €**		**1,728,500.00 €**	**864,250.00 €**	**1,474,200.00 €**	**13,958,700.00 €**

Table 19 - Costs to interconnect RoEduNet NOCs using DWDM (5 year lease)

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4.5.2. National optical connectivity for all POPs

If we consider the optical DWDM countrywide infrastructure the costs will be much more important: there are many fiber cross points and many POPs to be equipped with DWDM capable equipments.

The estimated costs to connect the POPs using DWDM are presented in the tables below:

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Bucharest	Ciulnita	109 km	327,000.00 €	0.00 €	154,500.00 €	77,250.00 €	65,400.00 €	**624,150.00 €**
Ciulnita	Slobozia	17 km	51,000.00 €	0.00 €	108,500.00 €	54,250.00 €	10,200.00 €	**223,950.00 €**
Ciulnita	Calarasi	27 km	81,000.00 €	0.00 €	113,500.00 €	56,750.00 €	16,200.00 €	**267,450.00 €**
Ciulnita	Fetesti	37 km	111,000.00 €	0.00 €	118,500.00 €	59,250.00 €	22,200.00 €	**310,950.00 €**

Fetesti	Constanta	79 km	237,000.00 €	0.00 €	139,500.00 €	69,750.00 €	47,400.00 €	**493,650.00 €**
Fetesti	Braila	149 km	447,000.00 €	0.00 €	174,500.00 €	87,250.00 €	89,400.00 €	**798,150.00 €**
Braila	Galati	31 km	93,000.00 €	0.00 €	115,500.00 €	57,750.00 €	18,600.00 €	**284,850.00 €**
Galati	Vaslui	187 km	561,000.00 €	0.00 €	193,500.00 €	96,750.00 €	112,200.00 €	**963,450.00 €**
Iasi	Vaslui	68 km	204,000.00 €	0.00 €	134,000.00 €	67,000.00 €	40,800.00 €	**445,800.00 €**
Iasi	Pascani	76 km	228,000.00 €	0.00 €	138,000.00 €	69,000.00 €	45,600.00 €	**480,600.00 €**
Pascani	Bacau	84 km	252,000.00 €	0.00 €	142,000.00 €	71,000.00 €	50,400.00 €	**515,400.00 €**
Bacau	Focsani	104 km	312,000.00 €	0.00 €	152,000.00 €	76,000.00 €	62,400.00 €	**602,400.00 €**
Focsani	Buzau	71 km	213,000.00 €	0.00 €	135,500.00 €	67,750.00 €	42,600.00 €	**458,850.00 €**
Buzau	Ploiesti	69 km	207,000.00 €	0.00 €	134,500.00 €	67,250.00 €	41,400.00 €	**450,150.00 €**
Ploiesti	Bucharest	59 km	177,000.00 €	0.00 €	129,500.00 €	64,750.00 €	35,400.00 €	**406,650.00 €**
Giurgiu	Bucharest	85 km	255,000.00 €	0.00 €	142,500.00 €	71,250.00 €	51,000.00 €	**519,750.00 €**
Ploiesti	Targoviste	52 km	156,000.00 €	0.00 €	126,000.00 €	63,000.00 €	31,200.00 €	**376,200.00 €**
Pitesti	Targoviste	92 km	276,000.00 €	0.00 €	146,000.00 €	73,000.00 €	55,200.00 €	**550,200.00 €**
Ploiesti	Brasov	107 km	321,000.00 €	0.00 €	153,500.00 €	76,750.00 €	64,200.00 €	**615,450.00 €**
Brasov	Sf. Gheorghe	32 km	96,000.00 €	0.00 €	116,000.00 €	58,000.00 €	19,200.00 €	**289,200.00 €**
Brasov	Copsa Mica	178 km	534,000.00 €	0.00 €	189,000.00 €	94,500.00 €	106,800.00 €	**924,300.00 €**
Copsa Mica	Sibiu	45 km	135,000.00 €	0.00 €	122,500.00 €	61,250.00 €	27,000.00 €	**345,750.00 €**
Copsa Mica	Teius	51 km	153,000.00 €	0.00 €	125,500.00 €	62,750.00 €	30,600.00 €	**371,850.00 €**
Teius	Razboieni	34 km	102,000.00 €	0.00 €	117,000.00 €	58,500.00 €	20,400.00 €	**297,900.00 €**
Razboieni	Tg. Mures	59 km	177,000.00 €	0.00 €	129,500.00 €	64,750.00 €	35,400.00 €	**406,650.00 €**
Razboieni	Cluj Napoca	68 km	204,000.00 €	0.00 €	134,000.00 €	67,000.00 €	40,800.00 €	**445,800.00 €**
Cluj Napoca	Dej	61 km	183,000.00 €	0.00 €	130,500.00 €	65,250.00 €	36,600.00 €	**415,350.00 €**
Dej	Suceava	256 km	768,000.00 €	0.00 €	228,000.00 €	114,000.00 €	153,600.00 €	**1,263,600.00 €**
Suceava	Pascani	63 km	189,000.00 €	0.00 €	131,500.00 €	65,750.00 €	37,800.00 €	**424,050.00 €**
Dej	Baia Mare	134 km	402,000.00 €	0.00 €	167,000.00 €	83,500.00 €	80,400.00 €	**732,900.00 €**
Baia Mare	Satu Mare	59 km	177,000.00 €	0.00 €	129,500.00 €	64,750.00 €	35,400.00 €	**406,650.00 €**
Satu Mare	Oradea	133 km	399,000.00 €	0.00 €	166,500.00 €	83,250.00 €	79,800.00 €	**728,550.00 €**
Teius	Alba Iulia	19 km	57,000.00 €	0.00 €	109,500.00 €	54,750.00 €	11,400.00 €	**232,650.00 €**
Alba Iulia	Deva	63 km	189,000.00 €	0.00 €	131,500.00 €	65,750.00 €	37,800.00 €	**424,050.00 €**
Deva	Tg. Jiu	139 km	417,000.00 €	0.00 €	169,500.00 €	84,750.00 €	83,400.00 €	**754,650.00 €**
Deva	Arad	149 km	447,000.00 €	0.00 €	174,500.00 €	87,250.00 €	89,400.00 €	**798,150.00 €**
Arad	Timisoara	57 km	171,000.00 €	0.00 €	128,500.00 €	64,250.00 €	34,200.00 €	**397,950.00 €**
Timisoara	Caransebes	98 km	294,000.00 €	0.00 €	149,000.00 €	74,500.00 €	58,800.00 €	**576,300.00 €**
Caransebes	Resita	43 km	129,000.00 €	0.00 €	121,500.00 €	60,750.00 €	25,800.00 €	**337,050.00 €**
Caransebes	Drobeta Turnu Severin	112 km	336,000.00 €	0.00 €	156,000.00 €	78,000.00 €	67,200.00 €	**637,200.00 €**
Craiova	Drobeta Turnu Severin	114 km	342,000.00 €	0.00 €	157,000.00 €	78,500.00 €	68,400.00 €	**645,900.00 €**
Craiova	Bucharest	209 km	627,000.00 €	0.00 €	204,500.00 €	102,250.00 €	125,400.00 €	**1,059,150.00 €**
		3679 km	**11,037,000.00 €**		**6,039,500.00 €**	**3,019,750.00 €**	**2,207,400.00 €**	**22,303,650.00 €**

Table 20 - Costs of nationwide DWDM infrastructure (5 year lease)

4.5.3. International optical connectivity

RoEduNet is a member of the GN2 consortium and have a 1.2 Mbps total bandwidth using 2 STM-4 circuits between Bucharest and Budapest. Also, RoEduNet signed the application for SEELight project that aims to build a fibre backbone for education and research in South East Europe and will provide dark fiber connections to Budapest and Sofia. The total cost for Romania in this project is about 6 million Euros. The Romanian government is committed to support this programme but there are also some backup plans.

Using the SEEFIRE Dark Fiber Cost Model 1 the cost of the connections is as follows:

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Total
Bucharest	Sofia	398	1,194,000.00 €	0.00 €	299,000.00 €	149,500.00 €	238,800.00 €	**1,881,300.00 €**
Bucharest	Budapest	866	2,598,000.00 €	0.00 €	533,000.00 €	266,500.00 €	519,600.00 €	**3,917,100.00 €**
TOTAL			***3,792,000.00 €***		***832,000.00 €***	***416,000.00 €***	***758,400.00 €***	***5,798,400.00 €***

Table 21 - International connectivity cost calculation

In the total cost calculated for the international connectivity the Romanian path is about 665 km, about half of the total length of the fiber.

It is interesting to see the annual price for the international connectivity and to compare with the actual price for traditional connectivity used at this time. RoEduNet did not include the initial cost of the equipments: the same for all examples: 299KEuros for Bucharest to Sofia and 533KEuros for Bucharest to Budapest. The results are presented in the table below.

PoP A Location	PoP B Location	Distance in km	Equipment Acquisition	Cost/Year
Bucharest	Sofia	398	299,000.00 €	**316,460.00 €**
Bucharest	Budapest	866	533,000.00 €	**676,820.00 €**
TOTAL			**832,000.00 €**	**993,280.00 €**

Table 22 - Equipment costs and yearly costs for international connectivity

The conclusion of this table is that the cost for Bucharest to Budapest connection is about 600,000Euros, the cost of the actual connections but it should be noted that this cost does not includes the GÉANT core contribution of RoEduNet.

4.5.4. Discussions and conclusions

A full countrywide DWDM solution seems to be unaffordable for RoEduNet because the costs are too high. Therefore RoEduNet proposed a slightly different solution that fits their organization well. RoEduNet intend to use DWDM for the connections between NOCs presented in the section 4.5.1 and CWDM to minimize the initial costs for the connectivity between NOCs and POPs.

4.6. AMREJ - Cost Estimation Serbia & Montenegro

AMREJ, the Serbian NREN started to build its dark fibre backbone in 2002. At the moment only a part of the network is connected to the dark fibre backbone, while the rest is still expected to be implemented, according to the contract with Telekom Srbija which is the only company that has fibre infrastructure countrywide.

The main AMREJ PoPs are listed in Table 23. Possible routes between them and the estimation of the length of different spans are given in Table 24, according to data gathered in WP1 of the SEEFIRE Project.

No.	PoP1	PoP2	Fibre type	Approx. Distance [km]
1	Beograd	Novi Sad	G.652	100
2	Novi Sad	Subotica	G.652	110
3	Novi Sad	Sombor	G.652	90
4	Subotica	Szeged	G.652	55
5	Novi Sad	Zrenjanin	G.652	80
6	Beograd	Pančevo	G.652	25
7	Beograd	Šabac	G.652	95
8	Šabac	Bosnian border	G.652	85
9	Beograd	Valjevo	G.652	100
10	Valjevo	Užice	G.652	70
11	Užice	Čačak	G.652	60
12	Čačak	Kraljevo	G.652	50
13	Kraljevo	Kruševac	G.652	70
14	Kraljevo	Novi Pazar	G.652	100
15	Kruševac	Niš	G.652	115
16	Beograd	Kragujevac	G.652	155
17	Beograd	Niš	G.652	270
18	Niš	Bor	G.652	135
19	Niš	Pirot	G.652	75
20	Pirot	Bulgarian border	G.652	35
21	Niš	Leskovac	G.652	55
22	Leskovac	Vranje	G.652	80
23	Vranje	FYROM border	G.652	45

Table 23 - Main intercity routes in Serbian NREN

Other routes and different topologies will be possible with the development of the dark fibre market in Serbia. Figure 9 below shows desired physical topology of the backbone of the Serbian NREN.

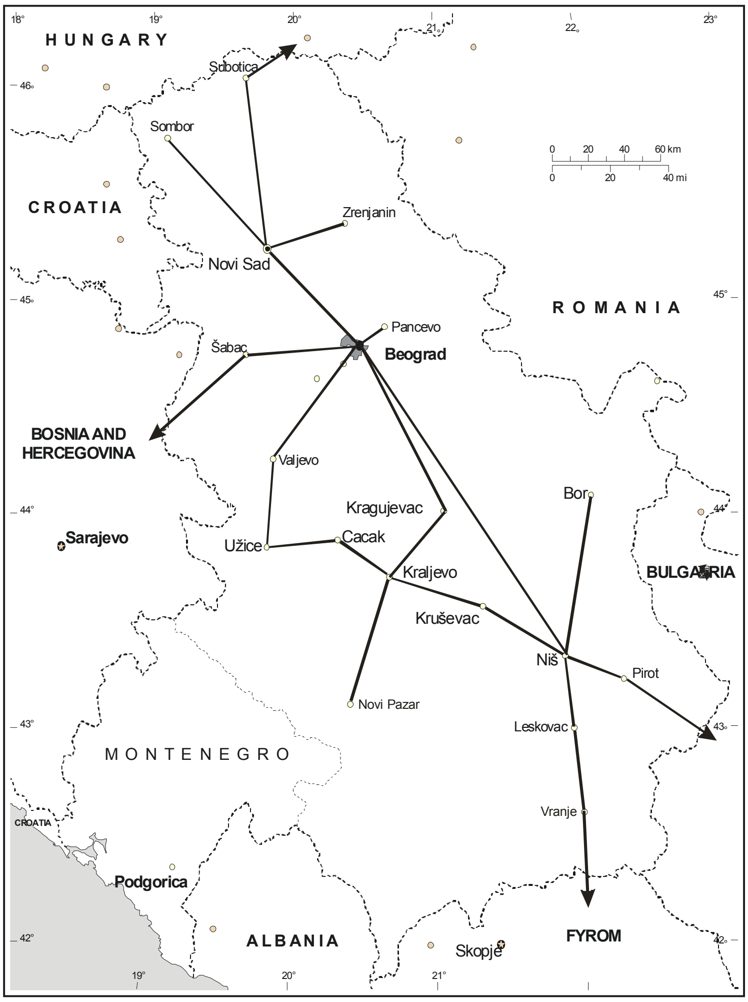

Figure 9 - AMREJ dark fibre topology

4.6.1. Local Optical Connectivity

AMREJ has significant parts of MANs in Belgrade, Novi Sad, Kragujevac and Niš already based on dark fibre, and is going to increase the number of institutions connected to the dark fibre backbone. All the existing dark fibre MAN lines are provided by Telekom Srbija, and there is also at least the same number of lines that will be established under the existing contract. The costs of establishment of the dark fibre based MANs are lower compared to the costs for the establishment of intercity dark fibre connections, because terminal equipment is much cheaper (usually only 1Gbps GBIC or SFP interfaces are used) and fibre lengths are by one or two orders of magnitude smaller than those at national or international level. Therefore the Cost Estimation Model 1 developed under SEEFIRE project is only used for the estimation of the costs of national and international optical lines.

4.6.2. National and international optical connectivity

One of the strategic goals in Serbian NREN is to have all the equipment in institutions which are members of the NREN, and to avoid collocation of the equipment in provider's premises wherever possible. Distances between PoPs are such that allow this strategy, except in few long routes where collocation is necessary.

Costs for personnel are calculated on a basis of 15 engineers paid for the activities on the project of Serbian NREN during the whole 5 years. Cost for personnel can't be calculated per dark fibre line, as required by Cost Model 1 and this is therefore calculated in total, and divided equally among all dark fibre lines in Serbian NREN.

Travelling costs are calculated according to the assumption that there will be in average two travels for two engineers per PoP per year, and according to the law which regulates domestic business travels.

The price for consumables consists of:

- Price of two patch cords for one side of the line and two spare patch cords per PoP
- Price of basic fibre cleaning equipment (isopropyl alcohol and cotton swabs), one kit per PoP

Using the Cost Model 1, the costs were calculated for a 5 year lease of dark fibre.

The results from calculations are summarized in the following table.

PoP A Location	PoP B Location	Distance in km	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Other Costs	Total
Beograd	Novi Sad	100	300,000	0	150,000	75,000	0	80,300	605,300
Novi Sad	Subotica	110	330,000	0	155,000	77,500	0	80,300	642,800
Novi Sad	Sombor	90	270,000	0	145,000	72,500	0	80,300	567,800
Subotica	Szeged	55	165,000	0	127,500	63,750	0	83,300	439,550
Novi Sad	Zrenjanin	80	240,000	0	140,000	70,000	0	80,300	530,300
Beograd	Pančevo	25	75,000	0	112,500	56,250	0	78,300	322,050
Beograd	Šabac	95	285,000	0	147,500	73,750	0	80,300	586,550
Šabac	Bosnian border	85	255,000	0	142,500	71,250	0	80,300	549,050
Beograd	Valjevo	100	300,000	0	150,000	75,000	0	80,300	605,300
Valjevo	Užice	70	210,000	0	135,000	67,500	0	80,300	492,800
Užice	Čačak	60	180,000	0	130,000	65,000	0	80,300	455,300
Čačak	Kraljevo	50	150,000	0	125,000	62,500	0	80,300	417,800
Kraljevo	Novi Pazar	100	300,000	0	150,000	75,000	0	80,300	605,300
Kraljevo	Kruševac	70	210,000	0	135,000	67,500	0	80,300	492,800
Kruševac	Niš	115	345,000	0	157,500	78,750	0	80,300	661,550
Beograd	Kragujevac	155	465,000	0	177,500	88,750	93,000	80,300	904,550
Beograd	Niš	270	810,000	0	235,000	117,500	162,000	80,300	1,404,800
Bor	Niš	135	405,000	0	167,500	83,750	81,000	80,300	817,550
Pirot	Niš	75	225,000	0	137,500	68,750	0	80,300	511,550
Bulgarian border	Pirot	35	105,000	0	117,500	58,750	0	80,300	361,550
Niš	Leskovac	55	165,000	0	127,500	63,750	0	80,300	436,550
Leskovac	Vranje	80	240,000	0	140,000	70,000	0	80,300	530,300
Vranje	FYROM border	45	135,000	0	122,500	61,250	0	80,300	399,050
TOTAL		**2,055**	**6,165,000**	**0**	**3,327,500**	**1,663,750**	**336,000**	**1,847,900**	**13,340,150**

Table 24 - 5-year lease cost model

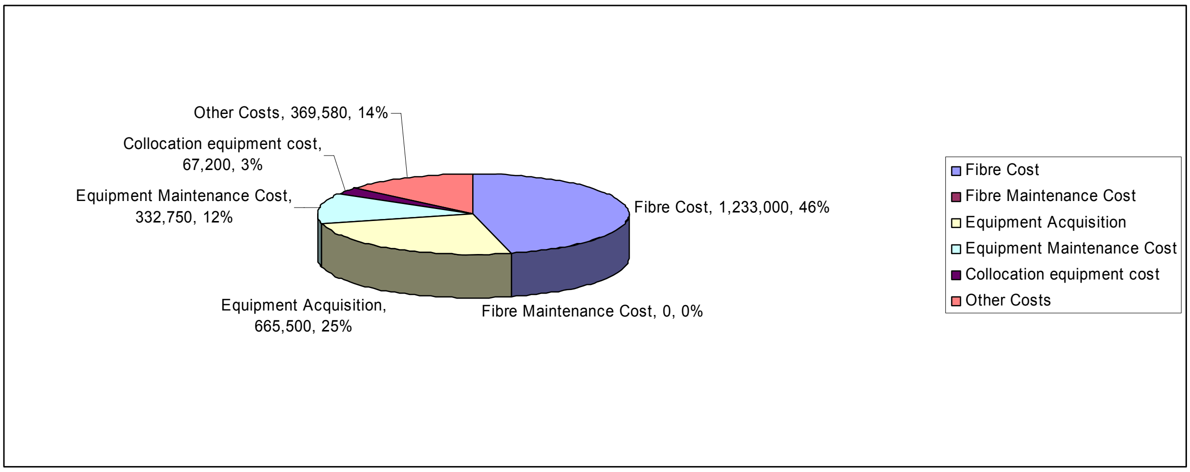

Figure 10 - Annual expenses for 5 year lease model

4.6.3. Analysis and discussion

The Chart shows that Fibre Costs with Fibre Maintenance Costs make the majority of the annual expenses. Our opinion is that in stable telecommunication markets with competition, shorter term contracts present better solution then longer IRUs, because of several factors like: the possibility to better react to changes in the price of dark fibre lease, less issues with fibre obsolescence and lifetime and less risk in case of providers bankruptcy.

Annex I

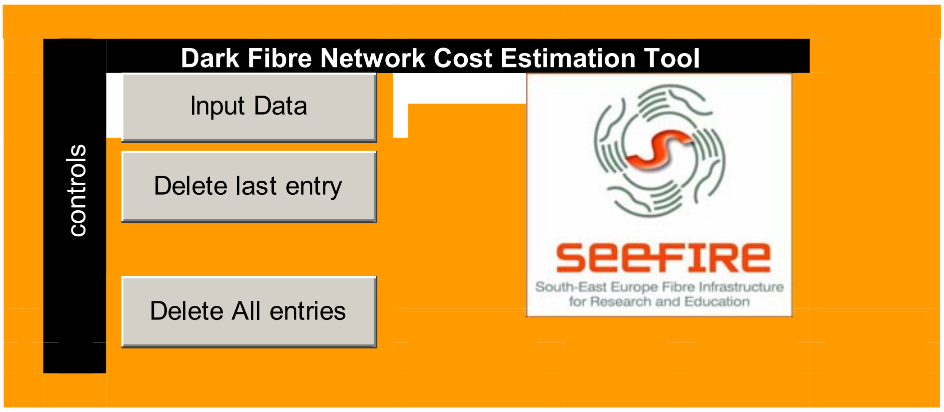

Table 25 - Controls

input parameters	Dark Fibre Network Cost Estimation Tool			
	Fiber Acquisition Cost			
	Type of contract	Value	Unit	Source of value
	1 year lease	1	€/m	
	5 year lease	3	€/m	
	15 years IRU	5	€/m	2005 Contracts in SEE
	Fiber Maintenance Cost			
	Type of contract	Value	Unit	Source of value
	1 year lease	0	€	
	5 year lease	0	€	
	15 years IRU	3.5	% of IRU cost per year	2005 Contracts in SEE
	Equipment Acquisition Cost			
	Equipment cost components	Value	Unit	Source of value
	Terminal Equipment Cost (Type A)	100000	€	
	Intermediate Equipment Cost (Type B)	50000	€ per 100km	
	Equipment Maintenance Cost			
		Value	Unit	Source of value
		10	% of the equipment cost	
	Equipment Collocation Cost			
		Value	Unit	Source of value
		12000	€ per 100km per year	

Table 26 - Parameters

PoP A Location	PoP B Location	Distance in km	Type of service	Fibre Cost	Fibre Maintenance Cost	Equipment Acquisition	Equipment Maintenance Cost	Collocation equipment cost	Other Costs	Total
Thessaloniki	Sofia	278,4	*15 years IRU*	1,392,000.00 €	730,800.00 €	239,200.00 €	358,800.00 €	501,120.00 €		**3,221,920.00 €**
Sofia	Bucharest	398,4	*15 years IRU*	1,992,000.00 €	1,045,800.00 €	299,200.00 €	448,800.00 €	717,120.00 €		**4,502,920.00 €**
Bucharest	Budapest	824,9	*15 years IRU*	4,124,500.00 €	2,165,362.50 €	512,450.00 €	768,675.00 €	1,484,820.00 €		**9,055,807.50 €**
Budapest	Belgrade	348,4	*15 years IRU*	1,742,000.00 €	914,550.00 €	274,200.00 €	411,300.00 €	627,120.00 €		**3,969,170.00 €**
Belgrade	Nis	248,1	*15 years IRU*	1,240,500.00 €	651,262.50 €	224,050.00 €	336,075.00 €	446,580.00 €		**2,898,467.50 €**
Nis	Skopje	198,2	*15 years IRU*	991,000.00 €	520,275.00 €	199,100.00 €	298,650.00 €	356,760.00 €		**2,365,785.00 €**
Skopje	Thessaloniki	340,8	*15 years IRU*	1,704,000.00 €	894,600.00 €	270,400.00 €	405,600.00 €	613,440.00 €		**3,888,040.00 €**
Nis	Sofia	147,3	*15 years IRU*	736,500.00 €	386,662.50 €	173,650.00 €	260,475.00 €	265,140.00 €		**1,822,427.50 €**
										31,724,537.50 €

Table 27 - Results Table, pre-filled with international routes in SEE

Annex II see file: Fibre model D.32 anonymised.xls