Hybrid Model of Romtelecom's Wholesale Service Costs

User Reference Guide

Status: Final

InterConnect and Partners

CONTENTS

1 Executive Summary

This User Guide describes the structure and function of the Hybrid Model (HM) of Romtelecom's Wholesale Service Costs.

The purpose of the model is to provide an accurate basis for assessing the fair prices for wholesale interconnection services supplied by Romtelecom to other operators in the Romanian market.

The User Guide includes the following sections:

2 Introduction

3 Hybrid Model Fundamentals

4 Hybrid Model Structure

5 Estimating Costs in Romania

6 Modelling the Core Network

7 Updating the Model.

2 Introduction

This report describes the Hybrid Model (HM) developed for Autoritatea Nationala de Reglementare in Comunicatii (ANRC). The HM has been developed following the principles and guidance provided by ANRC. The HM was developed by first building a “bottom-up” model from principles of good network design, and then comparing it with Romtelecom’s top-down model to check inputs and verify the constraints imposed on network design by the practicalities of construction and operation in Romania.

The Hybrid Model estimates the costs that Romtelecom would incur as an efficient national operator to build and operate a core network in Romania. The HM can be used to estimate the costs of interconnection in Romania.

The HM has the following key features:

- it is based on the demand levels for 2003 and 2004. Rolling these data forward allows estimation of the costs of interconnection for the coming 3 years;
- it estimates the costs of carrying metered traffic services, as well as leased lines and data services; and
- it is forward-looking in terms of the technologies modelled.

The Hybrid Model of Romtelecom’s Wholesale Service Costs (hereinafter the HM) has been prepared to assess the costs of Romtelecom which should be allocated to specific wholesale services. The services covered by the HM are:

- Interconnection for local call origination at fixed locations;
- Interconnection for local call termination at fixed locations;
- Interconnection for regional call origination at fixed locations;
- Interconnection for regional call termination at fixed locations;
- Interconnection for national call origination at fixed locations;
- Interconnection for national call termination at fixed locations;
- Interconnection for switched single transit; and
- Interconnection for switched double transit.

This document provides a description of how the HM is structured, and of the functions performed by it.

3 Hybrid Model Fundamentals

3.1 The Scope of Services Included in the Hybrid Model

The RIO (Reference Interconnection Offer) defines the scope of services which are included in the HM. Other Licensed Operators (OLO) are likely to interconnect with Romtelecom for call termination (i.e. calls originating in the OLO's network and terminating in Romtelecom's network), call origination (i.e. calls originating in Romtelecom's network and terminating in the OLO's network) and call transit (i.e. calls using Romtelecom's network while in transit but not originated or terminated in that network). The HM produces interconnection charges on a metered (per minute) basis.

The interconnection products that are costed are:

- Interconnection for local call origination at fixed locations;
- Interconnection for local call termination at fixed locations;
- Interconnection for regional call origination at fixed locations;
- Interconnection for regional call termination at fixed locations;
- Interconnection for national call origination at fixed locations;
- Interconnection for national call termination at fixed locations;
- Interconnection for switched single transit; and
- Interconnection for switched double transit.

3.2 Estimating Demand for Romtelecom's Core Network

The HM includes all the current traffic using Romtelecom's network. This is classified as:

- Metered (voice) traffic (including interconnection traffic); and
- Leased Lines and data traffic
- Broadband.

The HM distinguishes between different products within the classes of services identified above. This is because different products use the network in different ways. For example, a local call will use, on average, fewer switches than a long distance call.

The HM produces cost estimates for a 5 years period 2003-2007. The data sent by Romtelecom and relating to demand levels for 2003 and 2004 have been rolled forward using assumed rates of growth over the assumed planning period, which needs to be added to the end-user volume of traffic. The growth rates differ from product to product.

The HM assumes that demand for the next year is used to dimension the network in the selected reference year, to the extent that next year's demand is higher than the reference year's demand.

The HM shows both annual minutes and number of calls for all the metered (voice) traffic (including interconnection traffic). The source of this information is effective minutes and number of calls recorded by Romtelecom, or estimates made by the consultants where such information was not available. The average call duration information used is a proxy of the actual average call duration and was derived from traffic data coming out of a 2002 Romtelecom study for one month.

Effective minutes and number of calls, however, do not capture the total demand for the core network because:

- effective calls do not include unsuccessful calls, i.e. calls for which a connection is established but that are not billed because unanswered;
- effective minutes do not include ringing time; and
- some calls may be blocked.

The HM makes appropriate adjustments to effective minutes. The adjustments are based on both information provided by Romtelecom and estimates of the project team, building on experience from other jurisdictions.

3.3 Adjusting Demand Information

In order to estimate the "dimensioned demand", the following adjustments are made:

- the application of routeing factors;
- the adjustments for grade of service;[1]
- allowance for resilience; and
- application of the "busy hour" estimate.

In summary, the modelled network dimensioning incorporates the actual demand from end-users and interconnecting operators, the relevant growth rate (forecasts) and the above mentioned adjustment factors (routeing factor, grade of service, resilience and "busy hour").

3.3.1 The application of routeing factors

The model incorporates three routeing factor options:

- Routeing factors estimated by Romtelecom;
- Routeing factors used in the top down model; and
- Routeing factors used in the BU model.
- Updated routing factors provided by Romtelecom

The source of all four sets of routeing factors is in the first instance Romtelecom. The routeing factors used in the BU model were derived after accounting for some optimisation adjustments to the network (e.g. replacing analogue and manual exchanges) made in the BU model. Such adjustments will have an impact on traffic routeings and for this reason the routing factors used are different to those provided by Romtelecom, although they are derived from Romtelecom's routeing factors. The routeing factors derived from Romtelecom's routeing factors, describe the way each service uses the revised network. The option to use the routeing factors of the original BU model was left in during the development of the HM but since the exchange mix in the model has now changed (in light of new data supplied by Romtelecom) use of these routeing factors is no longer appropriate. The current default scenario in the HM uses the updated routing factors provided by Romtelecom.

[1] Includes the maximum percentage of traffic that, for a given level of traffic, may be blocked between arbitrary subscriber stages.

The HM assumes that the structure of the transmission network is defined by the structure of the switching network.

The model has two options regarding the estimation of leased lines capacity. Under the non-default scenario, the HM uses routeing factors acquired from other jurisdictions.

3.3.2 Adjustments for the grade of service

This adjustment is carried out as part of the conversion of Busy Hour Erlangs (BHEs) requirements into Mb/s requirements.

The BHEs to Mb/s conversion takes into account a call blocking probability and it is operated through the usage of the "NORMINV" formula. This formula allows the transformation from BHEs into circuit requirements. The inputs of this formula are Erlangs, grade of service and parameters that increase the accuracy of the result. Erlang tables, on the other hand, list as their inputs the number of circuits and the grade of service and give as result the Erlangs that can be accommodated on the circuits, input on the vertical side of the table.

3.3.3 Allowance for resilience

In the case of transmission equipment, the adjustment for network resilience in the HM allows for path diversity to be applied to different parts of the network and to different services. Where rings are modelled, these have been equipped to allow all traffic to flow in both directions in the event of a fibre break.

An adjustment factor of two (meaning requirements are multiplied by two to take path diversity into account) is assumed for all services including leased lines.

3.3.4 Application of the Busy Hour estimate

The standard formula for calculating Busy Hour traffic is applied. For each service, including interconnection traffic:

- annual traffic is assumed to be evenly distributed over all weeks of the year (annual minutes are divided by 52)
- weekly traffic is assumed to be equally distributed over six days, because weekend days are assumed to count as one day (weekly traffic is divided by 6)
- a percentage of daily traffic is in the Busy Hour
- Minutes in the Busy Hour are then converted into Busy Hour Erlangs by dividing them by 60 (minutes in an hour).

The HM allows for different Busy Hours for different services. This is because, if the HM were to assume coincident Busy Hours, the network would be incorrectly dimensioned, especially for those elements where there is no alternative routeing (most obviously RCUs and RSUs).

The HM allows the user the flexibility to choose to use either a "universal" daily busy hour or to input for each service the share of traffic going through the morning busy hour and through the evening busy hour. In the latter case, each network element is dimensioned for the busiest of the two hours, and cost allocation is done on the basis of each service's share of traffic in that busy hour. Note that a service that uses the busy hour more intensively than another will attract a larger share of costs and will have a higher service cost. The HM results are sensitive to the busy hour shares of traffic for each service, which are inputs to the model.

The model's default scenario is using the one busy hour and not the distinction between morning and evening. If data are available, the model user can alter the inputs accordingly and check what the cost estimates are under the scenario of two busy hours.

The HM includes a surge factor, which dimensions the network needs to serve the "Busiest" Busy Hour rather than the average Busy Hour.

3.3.5 An example

The table below is an extract from the model (when using ten percent as the share of daily traffic in the busy hour for each of the services) and it demonstrates some of the adjustments in demand described above. The particular adjustments in the table are for the traffic that goes through the remote concentrators; the traffic that goes through the RCUs is shown for each product separately. Once the Busy Hour Erlangs have been calculated according to the methodology described above (dividing the respective effective minutes by 52*(BH share)/6/60), BHEs are multiplied by the growth factor, the uplift factor (to account for additional holding time) and the surge factor (to account for traffic surges caused by special events). The adjusted BHEs are then multiplied by the respective routeing factors and the resulting estimates are summed to provide the Busy Hour capacity requirements that RCUs must satisfy, as shown at the bottom of the Table. The conversion of BHEs to Mb/s requirements takes into account the requirement to achieve the specified grade of service.

Table 3.2: Example of Adjusting Demand

Service	Billed (millions of minutes per annum)	Share of Daily Traffic in the Busy Hour (%)	Busy Hour Erlangs - measured in network busy hour	BHEs uplift to account for additional call holding time and unsuccessful calls	Surge factor to account for Busy Days	Growth Factor	BHEs (adjusted - uplift mins, surge and growth)	RCU routeing factor
Local calls generated by and to all types of RTc subscribers	7,000	10%	37,393	1.01	1.2	1.03	46,680	0.934
Special Access to Internet generated by all types of RTc subscribers	2,000	10%	10,684	1.01	1.2	1.20	15,538	0.427
Long distance calls generated by all types of subscribers in RTc	900	10%	4,808	1.01	1.2	1.05	6,118	0.934
International outgoing calls generated by RTc subscribers	100	10%	534	1.05	1.2	1.08	727	0.528
Calls to mobile generated by RTc subscribers	750	10%	4,006	1.06	1.2	1.10	5,606	0.483
…	…	…	…	…	…		…	…
BHEs required for RCUs								**59,040**

4 Hybrid Model Structure

The Hybrid Model is an Excel workbook with seven worksheets:

1. Control
2. Results
3. Inputs
4. Calculations
5. GRCs and Annualisation
6. Switching
7. Transmission

The functions of each worksheet are described below.

4.1 Control Sheet

The Control worksheet enables the user to choose between multiple scenarios by specifying the values of selected key inputs. A 'master switch' at cell F3 chooses between a User Specified and a Default scenario. Since the User Specified scenario can be varied by the model user, there are a potentially unlimited number of different scenarios which can be modelled.

The key inputs which can be varied include:

- Reference Year for Inputs
- Reference Year for Growth Rates
- Cost of Capital
- Annualisation Method
- Local Exchanges Mix by Manufacturer/Model
- Busy Hour Option
- TE-TE transmission configuration
- Maximum ADM capacity deployed
- Source of Routeing Factors
- Interconnection call mix, used for interconnection routing factor
- Equipment Price Changes
- Leased Lines Capacity
- Source for Operating Costs
- RCUs Mix by Manufacturer/Model
- Access - Core Split for LEs and RCUs

4.2 Results worksheet

This sheet provides the results for each interconnection product.

4.3 Inputs worksheet

The Inputs worksheet provides for all the detailed inputs to the model. Note that this sheet calculates BHEs and BHCAs, and selects the input years etc to load demand data into the operational cells depending on the scenario specified in the Control worksheet.

The categories of input information are listed below:

Demand information:

- For each service, information for 5 years:
  - Growth
  - minutes
  - calls
  - Additional call holding time
  - Surge factor
  - % calls unsuccessful
  - Share of Daily Traffic in the Busy Hour

Routeing Factors:

- For each service, the model provides for the following Routeing Factors, distinguishing between Consolidated Routeing Factors and Routeing Factors for Cost Allocation:

Switching	Transmission
– RCU	– RCU-LE
– RCU Calls	– LE-TE
– LE	– TE-TE
– LE Calls	– RCU-LE-LE-TE
– TE	– LE-TE-TE
– TE Calls	– HCU
– IE	
– IE Calls	

The Inputs sheet calculates BHEs and BHCA requirements per Network Element.

Network Information under the following headings is required:

- Number of Nodes
  - RCU
  - LE
  - TE
  - IE
- Traffic Weightings
  - PSTN
  - ISDN 2
  - ISDN 30
- RCUs, LEs, and Lines. For each category of RCU (very small, small, medium, large), and LE (small, medium, large, very large):
  - RCU numbers

- PSTN Lines
- ISDN 2 Lines
- ISDN 30 Lines

Using utilisation factors, the inputs sheet calculates the required network element capacities.

- LEs and Erlangs. For each category of LE, a total BHE figure provided by Romtelecom.
- TE-TE: # logical "legs" by logical route, for each pair of TEs in the network
- Crow flight distances between TEs for the computation of regenerators (mm on the map), used to determine TE-TE: Regenerators requirements
- Links per Tandem (for TE-TE)
- TE-TE rings and Number of Nodes

Infrastructure information under the following headings is required:

- For national, regional and local networks:
  - FO and copper Length (kms)
  - likelihood of using the same trench
  - Total amount of infrastructure
  - % shared with access
  - % of shared with access attributed to core
  - % trenched
  - % aerial
  - % radio
  - % of trenched which is ducted
  - % of trenched which is buried.
- For national and regional networks, % sharing with RCU-LE
- For National/Regional, Local/Local, National/Local, and Regional/Local trunks, fibre cable size (number of fibres)

Leased Lines information under the following headings is required:

- Routeing Factors for LL in the "0-25" category - distinguishing between those which have 2 ends in Bucharest and those which don't
- Routeing Factors for LL for all categories other than "0-25" by distance band
- LL Demand Information by speed and LL type

LL routeing factors and total Mb/s requirements by distance band are calculated from LL demand information.

Technical information under the following headings is required:

- Factors for conversion from BHEs into Mb/s
- Tributary Slots, for each of STM-1, STM-4, STM-16, STM-64:
  - No. of Slots
  - 2 Mb/s capacity
  - STM1 capacity
  - Mb/s capacity
- Diversity Factors for switched traffic and Leased Lines
- Ports

  - Local Exchange
    - % Local to Local Ports
    - % Local to Tandem Ports
  - Tandem Exchange
    - % TE to LE Ports
    - % TE to TE Ports
- Allowance for Switching Spares
- Allocation Keys for Line Cards and MDFs
  - Access
  - Core
- Trunk Links per Exchange
  - RCU Very Small
  - RCU Small
  - RCU Medium
  - RCU Large
  - LE Small
  - LE Medium
  - LE Large
  - LE Very Large
  - TE
  - IE
- Quality of Service - Call Blocking Probability
- Miscellaneous Information for TE-TE Transmission Requirements
  - Number of physical routes
  - Scale of the map used (mm per 100 km)
  - Actual route length/straight line distance
  - Max distance before regeneration
  - Average no. of nodes between TEs
- Misc. Information for Transmission Requirements:
  - Threshold for RCU-RCU-LE rings
  - Threshold for LE-TE rings
  - Upper threshold for HDSL
  - Capacity per HDSL Link (after diversity)
- Number of Microwave Links per LE if:
  - Number of RCUs per LE <30
  - Number of RCUs per LE between 30 and 60
  - Number of RCUs per LE >60
- Site costs attributable to switching, transmission, and access
  - RCU share
  - LE share
  - TE share

Switching Costs:

- RCU costs, for each of very small, small, medium and large RCUs, cost of:
  - Frame unit
  - Processor Unit
  - Access Ports
  - Software
  - 64K Line card
  - 128K line card
  - 2Mb line card
  - MDF
- LE and TE costs, for each of small, medium, large and very large LEs and TEs, cost of:
  - Processor Unit
  - Switchblock
  - Frame unit
  - Software
  - 64K Line card
  - 128K line card
  - 2Mb line card
  - MDF
  - Access Ports
  - Trunk Ports
  - Cables & Other
  - Signalling Points
- TEs and IEs costs:
  - Processor Unit
  - Switchblock
  - Frame unit
  - Software
  - Trunk Ports
  - Cables & Other
  - Signalling Points
- Common site costs, for each type of site, cost of power supply and air conditioning

Transmission and infrastructure costs for RCU-LE links:

- STM ADMs
  - STM1 ADM
  - STM4 ADM
  - STM16 ADM
  - STM64 ADM
  - SDH Muxes
- Cross-Connects
  - 32 Port Cross Connect
  - 128 Port Cross Connect
  - 256 Port Cross Connect

- Type 5 Magazine - CC
  - Type 2 Magazine - CC
  - STM-1 Electrical - CC
  - 16x2 Mb/s Electrical - CC
- LTEs
  - LTE-1
  - LTE-4
  - LTE-16
- STM Cards
  - STM1 card
  - STM4 card
  - STM16 card
  - STM64 card
  - SDH Muxes Card
- Tributary Cards
  - STM line card 2Mb/s
  - STM line card STM1
- Per Ring Cost
- HDSL
  - Modems
  - Rack
- Microwave
- Regenerators
- Common Site Costs
  - Power supply and air conditioning

Transmission and infrastructure costs for LE-TE links:

- STM ADMs
  - STM1 ADM
  - STM4 ADM
  - STM16 ADM
  - STM64 ADM
  - SDH Muxes
- Cross-Connects
  - 32 Port Cross Connect
  - 128 Port Cross Connect
  - 256 Port Cross Connect
  - Type 5 Magazine - CC
  - Type 2 Magazine - CC
  - STM-1 Electrical - CC
  - 16x2 Mb/s Electrical - CC
- LTEs
  - LTE-1

- LTE-4
- LTE-16
- STM Cards
  - STM1 card
  - STM4 card
  - STM16 card
  - STM64 card
  - SDH Muxes Card
- Tributary Cards
  - STM line card 2Mb/s
  - STM line card STM1
- Per Ring Cost
- Regenerators
- Common Site Costs
  - Power supply and air conditioning

Transmission and infrastructure costs for TE-TE links:

- STM ADMs
  - STM1 ADM
  - STM4 ADM
  - STM16 ADM
  - STM64 ADM
  - SDH Muxes
- Cross-Connects
  - 32 Port Cross Connect
  - 128 Port Cross Connect
  - 256 Port Cross Connect
  - Type 5 Magazine - CC
  - Type 2 Magazine - CC
  - STM-1 Electrical - CC
  - 16x2 Mb/s Electrical - CC
- LTEs
  - LTE-1
  - LTE-4
  - LTE-16
- STM Cards
  - STM1 card
  - STM4 card
  - STM16 card
  - STM64 card
  - SDH Muxes Card
- Tributary Cards
  - STM line card 2Mb/s

- STM line card STM1
- Per Ring Cost
- Regenerators
- Common Site Costs
  - Power supply and air conditioning

Infrastructure costs:

- Transport costs, for each of RCU-LE, LE-TE-TE, RCU-LE-LE-TE:
  - Ducted
  - Buried
  - Aerial
  - Radio
- ODF:
  - Small
  - Medium (1)
  - Medium (2)
  - Large (1)
  - Large (2)
- Cable size, for each of RCU-LE, LE-TE-TE, RCU-LE-LE-TE:
  - 12 fibre
  - 24 fibre

Accommodation Costs:

- Rental cost of land per m^2 per year
- Percentage of Accommodation Attributed to:
  - RCU total
  - LE total
  - TE total
  - IE total
- Keys for allocating transmission's share of accommodation costs:
  - RCU-LE
  - LE-TE
  - TE-TE
- Average Size per Type of Exchange
  - RCU total
  - LE total
  - TE total
  - IE total

The inputs sheet calculates the total space and cost per type of exchange, the split of accommodation cost between switching and transmission, the split of transmission share of accommodation costs to transmission segments, and a summary of Accommodation Costs.

Network Management Costs, Overheads & Interconnection Specific Uplift Factor, as % factors:

- Network Management Costs

- switching
- transmission
- infrastructure

- Overheads
  - Non network capital costs as a percentage of Annualised Cost
  - Non network capital costs as a percentage of GRCs
  - Non network operating costs
- Switched IC specific uplift factor

Information on LE Nodes and Lines:

- For each LE site in the Romtelecom network:
  - LE Code
  - Number of RCUs per LE
  - PSTN lines per LE
  - ISDN2 lines per LE
  - ISDN30 lines per LE

Information on Traffic Volumes per LE:

- For each LE site in the Romtelecom network:
  - County
  - Exchange Name
  - Functional Type
  - Number of links
  - Number of Parent
  - Total traffic Volume - Incoming (Erlang) - average week day
  - Total traffic Volume - Outgoing (Erlang) - average week day

Calculation of Opex Mark-ups

- There is a facility to input the proportion of opex attributable to administrative staff and technicians:
  - Mix of maintenance costs
  - Hourly wage
  - Hours worked per day
  - Working days per year
  - Annual wage
- For each network element, the costs of equipment and materials, installation, FTE maintenance, power operation and air conditioning operation are input, under the following headings:
  - RCU
    - Frame unit
    - Port unit
    - 64K Line card
    - 128K line card
    - 2Mb line card
    - MDF
    - Power supply unit

- Air conditioning unit

- LE
  - Switchblock
  - Processor unit
  - Software
  - Access ports
  - Trunk ports
  - Signalling Points
  - Power supply unit
  - Air conditioning unit
- TE
  - Switchblock
  - Processor unit
  - Software
  - Trunk ports
  - Signalling Points
  - Power supply unit
  - Air conditioning unit
- IE
  - Switchblock
  - Processor unit
  - Software
  - Trunk ports
  - Signalling Points
  - Power supply unit
  - Air conditioning unit
- RCU-LE
  - Trenching
  - Ducting
  - Cabling
  - STM ADMs
  - LTEs
  - STM cards
  - Cross-Connects
  - STM cards
  - Tributary cards
  - Regenerators
  - Power supply unit
  - Air conditioning unit
- LE-TE
  - Trenching
  - Ducting
  - Cabling
  - STM ADMs
  - LTEs
  - STM cards
  - Cross-Connects
  - STM cards

  - o Tributary cards
  - o Regenerators
  - o Power supply unit
  - o Air conditioning unit
- – TE-TE
  - o Trenching
  - o Ducting
  - o Cabling
  - o STM ADMs
  - o LTEs
  - o STM cards
  - o Cross-Connects
  - o STM cards
  - o Tributary cards
  - o Regenerators
  - o Power supply unit
  - o Air conditioning unit
- – RCU-LE-TE-TE
  - o Trenching
  - o Ducting
  - o Cabling
  - o STM ADMs
  - o LTEs
  - o STM cards
  - o Cross-Connects
  - o STM cards
  - o Tributary cards
  - o Regenerators
  - o Power supply unit
  - o Air conditioning unit

NRC/GRC Ratios are input from the Romtelecom top-down model:

- RCU
- LE
- TE
- Transmission
- Infrastructure

4.4 Calculations Sheet

The Calculations Sheet calculates the total labour and equipment costs of network elements of various sizes from the smallest to the largest found in the Romtelecom network:

- MDFs
  - – RXS
  - – Quante
- Concentrators
  - – Ericsson/Intracom RSS

- Siemens RDLU
- LEs
  - Siemens Local Exchange EWSD
  - Ericsson Local Exchange AXE-10

4.5 GRCs and Annualisation Sheet

For each network element, the GRCs and Annualisation sheet calculates the total Gross Replacement Cost (GRC) and Annualisation cost for all the network elements required in the Romtelecom network. It provides depreciation options including:

- Tilted Annuities
- Straight Line
- Annuities
- Annualisation method used in the Romtelecom top-down model.

4.6 Switching Sheet

The switching sheet calculates the total capacity requirements and resultant costs for the Romtelecom network under the following headings:

- Ports
  - Port Erlangs Total
  - Port Erlangs per Node and Link
  - Number of Ports
- Overall Requirements, broken down by core and access:
  - Equipment & materials
  - Cost of Equipment & materials
  - Installation
  - Equipment and Installation Cost
  - Opex detail
  - Capex Summary
  - Opex Summary.

4.7 Transmission Sheet

The Transmission Sheet calculates the total capacity requirements and resultant costs for the Romtelecom network under the following headings:

- Demand by Link Type
  - Total required network capacity
  - Total required network demand given logical diversity and allocation keys for transmission
  - Overall share in leased lines and data services in the selected reference year
  - Allocation keys

- Transmission Requirements in the TE-TE part of the network
  - Number of Nodes

  - Number of Logical Routes
  - Capacity per Logical Route and Ring
  - ADMs per Node
  - Tributary Card Requirements
  - Intersection Node
  - Summary of Equipment Requirements
  - TE-TE: # logical "legs" by logical route
  - TE-TE: # logical "legs" by physical route
  - TE-TE: Capacity requirements by physical route
  - TE-TE: Termination equipment requirements by physical route
  - TE-TE: Tributary cards requirements
  - TE-TE: Regenerators requirements
  - TE-TE: Total Line Termination System and Regenerators requirements
- Transmission requirements in the RCU-LE part of the network
  - Estimation of capacity requirements
  - ADM and Gateway Multiplexer Requirements
  - Tributary Card Requirements
  - Summary of SDH Equipment Requirements
  - HDSL Equipment Requirements
  - Microwave Equipment Requirements
- Transmission requirements in the LE-TE part of the network
- Infrastructure
  - Infrastructure - transport
  - Infrastructure - cable
  - Infrastructure - ODF
- Summary of Transmission Requirements and Costs
  - Equipment & materials
  - Cost of equipment & materials allocated to metered traffic
  - Installation
  - Equipment and Installation Cost
  - Opex

5 Estimating Costs in Romania

5.1 Unit Costs

The HM estimates the unit requirements of the different components that make up exchanges and other network elements. Therefore the purchase cost figures need to be disaggregated to the same component level.

The HM identifies the different components making up the exchanges (e.g. switchblock unit, ports etc.), distinguishes between types of exchanges (e.g. RCU, LE etc.) and between sizes of the same type of exchanges (e.g. small RCU, Medium RCU etc.). In the case of switching the HM distinguishes between different switching technologies (Siemens, and Ericsson). Romtelecom also uses Alcatel exchanges but these are not modelled in the HM because the data provided by Romtelecom on Alcatel switches was not sufficient to allow these exchanges to be satisfactorily modelled. Alcatel switches are modelled as Siemens or Ericsson exchanges – the share of Alcatel switches in the network is split between Ericsson and Siemens based on the relative numbers of these two technologies in the network.

Note that for network components such as switchblock units, the costs of which depend on capacity the information required varies by capacity, as well. Information which varies by capacity is required for transmission systems (e.g. STM-1, STM-4 etc.).

In general, cost assumptions in the model are based on information provided by Romtelecom. In the case of switches the data comes from a presentation provided by Romtelecom on the cost of each type of RCU and RSU and on the Siemens and Ericsson processors. Some further data was provided at a later stage to fill in some of the gaps in the original presentation. .

It should be noted that while the costs used in the top-down model of Romtelecom appear to be closely related to those in the presentation they differ in some respects and, in general, are less disaggregated than those in the presentation. It was considered that the higher degree of granularity in the presentation made this a better basis for the development of the hybrid model.

Transmission equipment costs are based on information in Appendix C of Romtelecom's top-down model although this information was slightly disaggregated pro-rata to transmission equipment cost data taken from benchmark.

5.2 Operating Costs

The current version of HM estimates operating costs using the level of operating costs from Romtelecom top-down model and applying further allocation and efficiency adjustments.

Operational expenditure in the model could also be calculated by applying mark-ups to the Gross Replacement Cost of each network component. The HM offers the model user three options regarding the use of mark-ups based on Gross Replacement Costs (GRCs) and a fourth option, starting from actual level of operating costs, as presented in the top-down model, and applying further efficiency and allocation adjustments in the next years, then subtracting the level of overheads, as they are separately dealt with in the model.

One of the options is using mark-ups which were calculated on the basis of GRCs and operating costs using benchmark. The operational expenditure is the sum of the full time equivalent (FTE) maintenance costs, and the costs of the air conditioning and power supply requirements for each network component. For each cost component the model calculates the ratio:

(FTE maintenance + air conditioning req. + power supply req.)/ (equipment + installation costs)

The costs that enter this formula are the Gross Replacement Costs of the different network elements as these appear in the publicly available Danish HM.

However, this data and the calculated ratio are unlikely to be appropriate for the Romtelecom HM. The operating costs in Denmark have been derived from TDC's existing operating costs[2] and applied to GRCs, and unless adjusted, would overstate Romtelecom's operating costs because labour costs in Denmark are higher, and because Romtelecom has a higher GRC base.

To correct for this discrepancy, the operational expenditure mark-ups calculated on the basis of the Danish data are adjusted to account for the differences in labour costs. The HM adopts a bottom-up approach in estimating the mark-ups. Danish data on GRCs, operating expenditure and wage rates for technicians and administrative support personnel are used to derive estimates of man-days required for running and maintaining the each network component (switchblock unit, software

[2] TDC is the incumbent operator in Denmark.

unit etc.)[3]. Estimates of Romanian wages for technicians and administrative support personnel are used to calculate the operating cost of the estimated man days in Romania.[4] The operating cost of each component as a share of Danish GRCs is then calculated to give the mark-ups that are applied to Romanian GRCs to give each component's operating expenditure on the modelled network.

The operating expenditure mark-ups are further adjusted to account for the differences in unit costs by multiplying them by the ratio of unit costs of the relevant network components in Denmark and Romania. For example, if the estimated operational expenditure mark-up for an RCU backup power supply is X per cent, the mark-up used when running the model for estimating the costs in Romtelecom's network will be:

$$X \bullet \left(\frac{\text{Unit cost of RCU Backup Power Supply Unit in Denmark}}{\text{Unit cost of RCU Backup Power Supply Unit in Romania}} \right)$$

An alternative to this approach uses operating expenditure mark-ups based on the project team's experience in other jurisdictions.

Following the review of the top down model, the project team has included a third option which allows the user to apply operating expenditure mark-ups which have been derived using data from the top down model. For the sake of consistency between the capital cost (which reflects Romtelecom's unit prices) and the operating expenditure the default scenario is using the latter set of operating expenditure mark-ups.

Finally, the fourth option is based on a particularly different template, that is to start from the actual level of operating expenditure incurred by Romtelecom, and apply further allocation and efficiency adjustments, then subtracting the overheads (that are separately dealt with in the HM).

5.3 Annualisation

This section describes the method used to convert the Gross Replacement Costs to annual capital charges. The major assumptions that affect the annualised costs are:

- The cost of capital;
- Asset lives; and
- Price trends.

5.3.1 The Cost of Capital

There are a number of different methods for calculating the cost of capital, such as the Capital Asset Pricing Model (CAPM). The estimation of the cost of capital on the basis of these methods requires specific data the acquisition and analysis of which would be beyond the scope of the study.

The value of the cost of capital used in the model is 15.24 percent. This information has been provided by ANRC and is based on a study on Romtelecom's cost of capital. This value is a little over half of the cost of capital used in Romtelecom's top down model and is a major source of difference in the results of the two models. Latest calculations that Romtelecom has prepared during the reconciliation phase reveal a much closer result.

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[3] Data source for this kind of information is the Danish Hybrid model.

[4] Estimate of annual salary for technicians in Romania has been provided by ANRC.

The requirement to estimate costs at future dates means the cost of capital must be estimated forward. The HM uses estimates of future costs of capital. The cost of capital values for next years is assumed to be the same as for 2003 (i.e. 15.24 percent). These values can be varied if different estimates become available.

5.3.2 Annualisation methods

A number of different methods can be used to annualise costs. The HM provides the option to apply one of four different annualisation methods;

- annuity;
- tilted annuity;
- straight-line depreciation; and
- a method that resembles that used in the top down model.

The chosen method is uniformly applied to gross replacement costs of all network elements.

HMs generally use tilted annuities to annualise the capital costs of the network. The rationale for this approach is that it produces costs which approximate to those creating the correct make/buy signals. .

A tilted annuity calculates an annuity charge that changes between years at the same rate as the price of the asset is expected to change. This result in declining annualisation charges if prices are expected to fall over time; for a large enough tilt the slope of the depreciation profile will also be negative.

The annuity charge is estimated according to the following formula:

$$\frac{(\mathrm{r}-\mathrm{p})}{1-\left(\frac{1+\mathrm{p}}{1+\mathrm{r}}\right)^{\mathrm{t}}}\times \mathrm{I}$$

A standard annuity calculates the charge which would recover the purchase price of the asset (depreciation) and the financing costs, in equal annual sums. The annualisation factor is:

$$r \Big/ \left(1-(1/(1+r))^{t}\right)$$

The third annualisation option is straight line depreciation. The annualisation factor is:

$$\left(\left(1/t\right)+r\right)$$

The fourth annualisation method used uses the following formula:

$$\left(GRC/t\right)+r*NRC$$

where for the formulas above:

- GRC: gross replacement cost
- NRC: net replacement cost
- r = cost of capital
- p = rate of price change ("tilt")
- t = asset lifetime
- I = investment.

The NRCs in the model are estimated by applying an NRC/GRC ratio (estimated using top down model data) to the GRCs estimated in the model. This approach is consistent with cost recovery and reduces the incumbent's ability to engage in price squeezing (relative to tilted annuities) if the incumbent itself uses this approach in its own accounts.

Since the price trends of different types of assets used in the model are difficult to be estimated and are not likely to have a significant overall impact, the current version of HM use annuities as a default option.

5.3.3 Asset lives and price trends

Given that the model is using unit prices Romtelecom has to pay, it also needs to be using trends that these prices will follow. Under the tilted annuities scenario (non-default), different price trends have been set for different categories of network assets, based on benchmark information.

5.4 Estimating Overhead Costs

The HM includes estimates of overhead costs, defined as non-network capital costs and non-network operating costs. The estimates used for these values and the definitions have been derived from the Adaptable Bottom-up Model developed by Europe Economics for the European Commission in 2000.[5]

The estimates used take into account the fact that the overheads apply to the business as a whole rather than just the network business which is the subject of the HM. This means that the mark-ups used in the HM account for the fact that some of the non-network costs (i.e. sales and marketing) are not relevant.

5.5 Definition of overheads

5.5.1 Non-network related capital costs

Investment in non-network capital is essential for network operation and is modelled for each network element. The non-network costs in the HM include the following categories:

- **Land**: all land other than that used for laying cable and duct or any external network equipment.
- **Non-operational buildings**: all permanent fixtures, machinery, and appliances installed as a part thereof, including costs incident to the construction or purchase of a building and to securing possession and title.
- **Motor vehicles**: motor vehicles licensed to operate on public streets and highways.
- **General-purpose computers**: computers and peripheral devices designed to perform general administrative information processing activities including, but not limited to, activities such as the preparation of financial, statistical, or other business analytical reports; preparation of payroll, customer bills, and cash management reports and other records and reports not specifically designed for testing, diagnosis, maintenance or control of the telecommunications network facilities. It also includes the operating system software for computers. It does not include computers associated with switching, network signalling, and other network operations.

[5] See the default non-network cost mark-ups used in the cost input sheet of the Adaptable Model. The estimates used in the HM for Romania have been modified from those in the Adaptable Model in order to produce a single estimate rather than a local/long distance split.

- **Other equipment**: power-operated equipment, general-purpose tools, office equipment in offices, and other buildings, and furniture in offices, storerooms, and other buildings.

These investments are needed to provide conveyance services as a whole but they are not easily allocated to individual network elements. The HM estimates the amount of non-network investment required, for each network element, using ratios of non-network investments to network investments.

5.5.2 Non-network operating costs

The HM estimates the non-network operating costs for each network element using a ratio from the Adaptable Model, which in turn was drawn from the 1999 ACCC study. The non-network operating costs include:

- **Sales and Marketing**: this includes costs incurred in selling products and services, including determination of individual consumer needs, development and presentation of customer proposals, sales orders and handling; costs incurred in developing and implementing promotional strategies to stimulate the purchase of products and services. It also includes costs incurred in performing administrative activities related to marketing products and services.
- **Executive**: this includes costs incurred in formulating corporate policy and in providing overall administration and management.
- **Planning**: this includes the costs of developing and evaluating long-term courses of action for the future operations of the company, including performing corporate organisation and integrated long-term planning (management studies, options and contingency plans and economic strategic analysis).
- **Accounting and finance**: this includes the costs of providing accounting and financial services. Accounting services include payroll and disbursements, property accounting, capital recovery, regulatory accounting, non-customer billing, internal and external auditing, capital and operating budget analysis and control. Financial services include banking operations, cash management, benefit investment and fund management, securities management, corporate financial planning and analysis, and internal cashier services.
- **External relations**: this includes the cost of maintaining relations with government, regulators, other companies, and the public. Such activities may involve reviewing existing or pending legislation, preparing, and presenting information for regulatory purposes, obtaining licences, performing public relations and non-product related corporate image advertising, administrative relations with other operators, and investor relations.
- **Human resources**: this includes the cost of performing personnel administration activities, such as equal employment opportunities programmes, employee data for forecasting, general employment services, occupational medical services, job analysis and salary programmes, labour related activities, personnel development and staffing services (career planning, counselling etc), employee communications, benefit administration, employee activity programs, employee safety programs and non-technical training course development and presentation.
- **Information management**: this includes the cost incurred in planning, developing, testing, implementing, and maintaining databases and application systems for general purpose computers.
- **Legal**: this includes the costs of providing legal services such as conducting and co-ordinating litigation, guidance on regulatory and labour matters, preparing, reviewing patent matters, contracts and interpreting legislation.

- **Procurement**: this includes the cost of procuring materials and supplies, including office supplies. This includes analysing and evaluating suppliers' products, selecting appropriate suppliers, negotiating supply contracts, and placing purchase orders.
- **Research and Development**: this includes the cost of making planned search or critical investigation aimed at discovery of new knowledge. It also includes translating research findings into a plan or design for a new product or process or for significant improvements to an existing product or process.
- **Other**: this includes the cost of performing general administrative activities not directly charged to the user. This includes providing general reference libraries, food services, archives, general security, operating private exchanges, and telecommunications and mail services. Also included are settlements of accident and damage claims, insurance premiums.

5.5.3 Methodology used to estimate overheads

The HM estimates overheads as follows:

- for non-network capital costs, five per cent of annualised capital costs;
- for operating costs associated with non-network capital items, ten per cent on non-network capital costs;
- for non-network operating costs, twenty five per cent of the operating costs estimated in the model.

The overhead mark-up is defined as the ratio of the sum of these costs to the sum of these costs plus the total of other annualised network costs (i.e. capital and operating expenditure).

5.6 Interconnection Specific Costs

The HM includes an estimate of interconnection-specific costs, arising from the planning of interconnect and the management of interconnect relationships.

These costs are not modelled explicitly, but are added using mark-ups applied to the final estimated costs of the interconnection services. The value of the mark-up is common for all eight interconnection services and has been set equal to 1 percent.

This mark-up is applied only to interconnection products.

5.7 Network management costs

Network management costs have been estimated using a mark-up on the GRCs for switching and transmission and then annualising the resulting cost. The assumptions about the mark-ups, price trends, and asset lives come from the Adaptable Model developed by Europe Economics for the European Commission.

6 Modelling the Core Network

6.1 What is the Core Increment?

The Core Network is the increment modelled in the HM. Costs of the core network are driven by the volume of switched traffic, the number of call attempts, and the load imposed by leased lines and data services. In practice, the number of subscribers and the volume of traffic will be correlated. But it is possible to consider the implications of increasing the volume of traffic, holding the number of subscribers constant (implying an increase in the calling rate) or increasing the number of subscribers, holding the volume of traffic constant (implying a decrease in the calling rate).

Assets within the core network include:

- concentrators;
- exchanges;
- transmission links between the exchanges;
- optical fibre and trenching between all levels of exchanges; and
- signalling equipment.

6.2 Modelling the Switching Network

The HM considers only circuit-switched technologies, which are assumed to be more efficient in carrying voice traffic than packet-switched technologies (which are most efficient at carrying data – e.g. Internet traffic).

The HM largely follows the actual structure of Romtelecom's network as it is subject to the scorched node assumption.

The HM classifies the RCUs and the LEs in four categories each – eight in total. For TEs and IEs the HM adopts a simpler approach since the number of exchanges is significantly less than that of RCUs and LEs. For these exchanges, there is no classification in categories. The list of RCU and LE categories is shown in the table below.

Table 6.1: List of RCU and LE Categories

Type of Exchange	Class
RCUs	Very Small
	Small
	Medium
	Large
LEs	Small
	Medium
	Large
	Very Large

Romtelecom data on the type and number of lines connected to each of the RCUs and LEs is used to estimate the number of exchanges that fall in each of the categories shown above.

The classification of nodes in terms of size adds to the complexity of the HM, but has the advantage of increasing the accuracy of estimates of the equipment requirements in the network.

Other requirements affected by this classification include:

- Power and air conditioning;
- MDF;
- Frames;
- Software;
- Switchblock; and
- Ports.

Based on this classification the number of lines connected to each type of RCU and LE is calculated.

6.3 Direct Network Costs

Direct network costs for circuit switched technology in the exchange network include:

- ports;
- switchblocks;
- processors;
- software;
- signalling equipment; and
- the operating costs associated with the above.

The HM uses the scorched node assumption, which implies that the switching equipment modelled is bound by the number of nodes currently in Romtelecom's network.

According to dimensioning rules provided by Romtelecom the requirements for the components listed above are determined on the basis of lines and ports information and account for modularity issues. BHEs estimates are used to allocate switching costs to the different services.

With regard to ports and line cards,[6] the dimensioning methodology is based on demand, expressed as Busy Hour Erlangs and number of lines.

The required numbers of ports per node is derived from the BHEs per node. The total BHEs per network element derived from the routeing factors and demand for metered traffic, computed by dividing the total BHEs per node category (i.e., TEs, IEs and the different sub-categories of concentrators and local exchanges) by the number of nodes belonging to each category (or network element). BHEs per node are converted into BHEs per link per node based on assumptions on the number of links each node has. The above analysis distinguishes between access (for RCUs and LEs) and trunk ports (for LEs, TEs and IEs).

A formula that takes into account blocking margins and another parameter which varies according to the BHEs per link per type of exchange has then been applied to turn BHEs per node into number of ports per node. This formula converts, for given blocking margins, demand requirements (BHEs) into circuit/ports requirements. Its use is equivalent to the use of the classic Erlang tables.

Line cards have been modelled on the basis of the number of subscribers' lines (for different types of lines, i.e. PSTN, ISDN2 and ISDN 30) connected to either concentrators or local exchanges. Line cards are assumed to be grouped into cartridges of different sizes (this modularity factor

[6] Notice that even though line cards are dimensioned here, their cost is not allocated to the core network. Line cards are part of the access network. Dimensioning line card requirements helps determine unit requirements for other components.

assures an utilisation level lower than 100 per cent). The modularity differs depending on the technology (i.e. whether it is Ericsson or Siemens).

6.4 Common Site Costs

For each type of exchange (RCU, LE, TE) the following common site costs have been specified:

- power supply; and
- air conditioning.

The scorched node assumption implies that one power supply unit and one air conditioning unit are modelled per node. The size and cost of these units depends on the number of lines per node. Total common site costs per common site cost type (power supply unit, air conditioning unit) by type of exchange are calculated by multiplying the number of nodes (for each type of exchange) by the respective cost of the power air conditioning units. These costs are allocated to access and core (distinguishing between transmission and switching) on a pro rata basis. The transmission share is then further allocated between metered traffic products, leased line and data services products, as well as broadband. This latter allocation has been done on the basis of the relative capacity for each type of product (metered traffic, leased line and data services and broadband).

6.5 Other Costs

For each of the cost categories specified in the two previous sub-sections ("Direct" and "Common Site Costs") there are other costs in three categories:

- installation costs;
- operational expenditure; and
- accommodation costs.

6.5.1 Installation

Installation costs are estimated for each of the cost components by type of exchange by mark-ups on the total equipment cost for each of the cost components identified above.

6.5.2 Operational Expenditure

The estimation of operating costs is discussed in Section 4.

6.5.3 Accommodation Costs

To determine the total cost of accommodation in the network the HM estimates the total space requirements needed to accommodate the nodes in the network. The HM uses data from the Danish HM, estimated using a bottom-up approach which assesses the space requirements of each of the network components making up the network elements separately.

The physical sizes of similar technology and capacity exchanges are similar regardless of where they are installed and hence the estimates are good proxies for the space exchanges in Romania should take up.

The data distinguish between RCUs, LEs, TEs and IEs. The Danish data used show the average exchange sizes and refer only to switching and transmission, so there is no need to allocate part of the cost of this space to access.

The total number of RCUs, LEs, TEs and IEs of each class are multiplied by the respective average space requirements to calculate the total space requirements.

Total costs of accommodation are calculated by multiplying the total space requirements with the annual rental cost. The rental cost per square metre is estimated based on information provided by ANRC for rents in Bucharest, and in the rest of the cities in Romania.

In line with the way other common costs are allocated in the HM, accommodation costs are allocated to transmission and switching on a pro rata basis.

A different set of allocation keys is used to allocate the transmission share of accommodation costs to metered traffic products as opposed to leased lines products. These allocation keys are calculated on the basis of capacity requirements for each set of products (metered traffic – leased).

6.6 Modelling the Transport Network

6.6.1 Transmission

The modelled transmission network is similar but not identical to Romtelecom's network.

Table 6.3: Modelling the transmission network

Hierarchy Level	Transmission Segment
Lower Level	Transmission between RCUs and LEs
Intermediate Level	Transmission between LEs and TEs
Higher Level	Transmission between TEs and TEs

6.6.1.1 The lower level of the transmission hierarchy

The lower level of the network connects RCUs and LEs in rings. Information on number of lines connected to each concentrator (by type of line, i.e. PSTN, ISDN2 and ISDN30) is matched with information on the parenting arrangements of each concentrator to its own local exchange.

The total BHEs over this part of the network (RCU-LE) is adjusted to match with the corresponding figure coming from assumptions on demand (annual minutes and conversion factors into BHEs) and routeing factors. The HM spreads the total voice (metered) traffic going over the network element RCU-LE over links between RCUs and LEs in order to dimension the transmission rings.

Total capacity over this part of the network for leased lines (calculated on either the basis of assumed routeing factors for leased lines or transmission capacity split in Romtelecom's network), is spread over each link in proportion to voice traffic per link. Requirements for path diversity are taken into account.

The total capacity over this part of the network for broadband services is calculated taken into account the expected distribution of demand for this type of services within the Romtelecom network, only the concentrators situated in highly populated area being enabled to provide broadband services.

All links are modelled in rings. Equipment is modelled on the basis of average capacity per link and assumptions about the capacity thresholds of STM-1, STM-4 and STM-16. The following components are modelled on each single node:

- the chassis (generally called multiplexer in the model)
- the cards which connect the chassis with the optical fibre making up the ring
- the tributary cards which add and drop traffic channels into the ring.

Tributary cards provide 2 Mb/s or 155 Mb/s channels. All traffic at this level of the transmission hierarchy is assumed to use 2 Mb/s tributary cards. 155 Mb/s cards are assumed only where STM-64s are required, but these are not required at this transmission level.

The HM distinguishes between nodes on the ring and the gateway node through which the nodes on the ring are connected to the LEs. Tributary cards for the nodes on the ring are estimated on the basis of capacity per node once the extra capacity for path diversity has been excluded. Additional tributary cards are also accounted for in the HM.

Chassis are dimensioned on the basis of total capacity flowing over the ring including differentiated paths for diversity, and the maximum number of slots per chassis. If the number of required slots exceeds the maximum number of slots per chassis, then an additional chassis is put in place. Slot requirements are derived from capacity per node excluding the extra capacity for path diversity.

Cards are dimensioned on the basis of the number (two per chassis) and dimension of the modelled chasses.

6.6.1.2 The intermediate level of the transmission hierarchy

At the intermediate level of the transmission hierarchy, it is assumed that rings connect LEs with other LEs and TEs. The equipment dimensioned for this level is add-drop multiplexers (ADMs), STM cards and tributary cards.

For each of the LEs, Romtelecom has provided information on average daily incoming and outgoing Erlangs[7].

Total BHEs over this part of the network (calculated on the basis of demand information and routeing factors), are spread over each LE on the basis of the average daily total Erlangs (incoming and outgoing).

Eight different tandem exchange pairs have been identified and each local exchange is assigned to one of these pairs. The pairs are as follows:

Table 6.6: TE parent pairs and indexes

Exchange Pair	Number
Bucharest-Craiova	1
Timisoara-Cluj	2
Brasov-Bacau	3
Brasov-Galati	4
Bacau-Galati	5
Dacia-Sud Vest	6
Dacia-Sud Est	7
Sud Vest - Sud Est	8

The parenting arrangements are similar, but not identical, to those of Romtelecom's. Differences arise because Romtelecom has a somewhat more complex mix than shown in the table above. Where differences arise from Romtelecom, the HM makes sure that the parenting arrangements are (geographically) sensible i.e. an LE is parented to the TE pair closest to it.

Romtelecom information suggests that each LE is parented to two TEs except those in Bucharest which are connected to all three TEs there. Therefore, all LEs other than those which have been assigned to pairs 6, 7 and 8 have two links; those LEs for pairs 6, 7 and 8 have three links.

On the basis of this information, the HM estimates BHEs per link, which are converted to Mb/s per link and Mb/s per LE. The Mb/s per LE are then grouped in Mb/s per TE pair depending on the

[7] For the new LEs (see section on optimisation), it has been assumed that the Erlangs for each of them are equal to the average of the non-backbone LEs that already existed in Romtelecom's network.

index number (see table above). Assuming that a ring can have up to 12 LE nodes plus the relevant TE parent nodes (two or three as determined above) the HM estimates the number of LE rings connected to each TE "pair".

The HM calculates the required type of these rings (STM-1, STM-4, STM-16)[8] and the number of ADMs (and consequently the number of ADMs per ring) on the basis of Mb/s per ring and capacity thresholds the same as those considered in the lower transmission level. The HM also estimates the number of ADMs required at the gateway nodes, assuming two ADMs per gateway node (one for each parent TE). Similarly to the lower level hierarchy, STM cards are dimensioned on the basis of the number (two per chassis) and dimension of the modelled chasses.

Tributary cards for this transmission level also distinguish between tributary requirements for nodes on rings and gateway nodes. The tributary card requirement estimates depend on the capacity per node, node numbers and ADMs per node. In addition to these tributary cards, two tributary cards are modelled for each gateway node.

Tributary card requirements are estimated on the assumption that where an STM-64 is used (this implies that the STM-64 option is chosen), the tributary cards are assumed to be STM-1s. On the other hand, where sub STM-64 multiplexers are used, 2 Mb/s tributary cards are assumed.

6.6.1.3 The top level of the transmission hierarchy

The HM models the top level of the transmission hierarchy as two rings. One of the rings has 5 nodes on it while the second has 6 (five plus one of the nodes of the first ring – the one that connects the two rings). Under the default scenario for the HM, the rings do not use any capacity greater than STM-16. This is based on Romtelecom's response. However, the HM has the option to use STM-64 where traffic would justify it.

At the top level, the HM estimates the unit requirements for ADMs, tributary cards, and regenerators.

The HM estimates the number of logical routes for the nodes on each ring. Using the capacity requirements for TE-TE transmission, as calculated using demand information and routeing factors, the HM estimates required capacity per route[9]. The total capacity requirements for transmission in the top level of the network (adjusted for path diversity), including metered (voice) traffic, leased lines and data services, as well as broadband traffic, is divided by the number of logical routes to obtain average traffic per logical route. The capacity for each of the two rings is estimated on the basis of the number of routes per ring. The capacity per ring determines the type of ADM required for each of the two rings.

The required numbers of ADMs are determined on the basis of Mb/s per ring and capacity thresholds the same as those considered in the lower transmission level. Under the default scenario (of equipment with capacity no more than STM-16), per node capacity required in addition to the STM-16 threshold is satisfied by extra STM-16s.

Tributary cards are estimated assuming twenty-one 2 Mb/s per ADM. Therefore, once the per-node capacity requirement is worked out it is divided by the number of ADMs per node and the assumed twenty-one 2 Mb/s per ADM[10].

[8] The HM has the functionality to consider STM-64. However, given that there are no STM-64s in Romtelecom's network the default scenario under which the model runs does not consider STM-64. The model user can check the impact on network costs by selecting the STM-64 option in the control sheet.

[9] The total number of routes is calculated using the following formula: (number of TE nodes)*(number of TE nodes-1)/2.

[10] Lastly, notice that the HM also divides over 2 so as to get the Mb/s rather than 2 Mb/s requirements.

This analysis is carried out distinguishing between the nodes on the rings and the intersection node. At the intersection node, extra provision is required for the traffic that is directed from one ring to the other. The distinction is based on the logical routes for intra-ring capacity and capacity for traffic to intersection node and to the other ring.

Regenerators have been included in the HM in the TE-TE part of the transmission network. The usage of repeaters depends on the length and distribution of routes around the average. The distances between the tandems are first measured on the map on a straight-line basis and are then adjusted to reflect actual distances[11]. The HM assumes that signals need to be regenerated every 70 Km.

Cross-connects provides flexibility to the network. They may only be justified for higher parts of the network and perhaps even limited to some services, such as leased lines. However, the model does not currently model cross-connects as Romtelecom's response suggests that it uses distributed cross-connects (the ADMs themselves or modified ADMs with more cross-connect functionality than normal ADMs) rather than dedicated cross-connects (it is apparently in the process of introducing ADMs configured as cross-connects – the cost of these is small relative to traditional cross-connects).

6.6.1.4 Infrastructure

Duct and trench requirements are based on the actual amount in Romtelecom's network.

The matching of the hierarchical levels used by Romtelecom against the network elements to which their cost is allocated to in the HM is indicated in the following table.

Table 6.7: Modelling infrastructure

Romtelecom	Local/Local	Regional/Local	National/Local	National/Regional
Element to which model allocates the cost	RCU-LE	RCU-LE-LE-TE	RCU-LE-LE-TE	LE-TE-TE

The "Regional/Local" and the "National/Local" have been matched against the network element RCU-LE-LE-TE. This has been defined as the summation of the network elements RCU-LE, LE-TE and TE-TE, and the corresponding routeing factors, which are used to allocate costs to services, have been calculated by adding up the routeing factors of these three network elements.

Similarly, the LE-TE-TE element requires the summation of the routeing factors corresponding to LE-TE and TE-TE before allocating the cost of this element to services.

Information on the percentage of cable that is buried ducted or on poles, distinguishing by segment of the transmission network, has been provided by Romtelecom.

With regard to optical fibre cable used, the model has the functionality to distinguish between different cable sizes depending on the transmission level. However, Romtelecom's response to a data request indicated that 2, 4 and 6-fibre cables are no longer commercially available. Romtelecom notes that it is not economical and functional to provide sub-equipped FO buffers. Romtelecom had provided the cost of 12-fibre cable per kilometre. As a simplification it is assumed that 12, 24 or 72-fibre cables are used throughout the different levels of the transmission network.

[11] The adjustment assumes a ratio of 1.7 of actual to straight-line distance.

6.7 Allocating Costs to Services

The first step in estimating the costs of the various interconnection products is to estimate the costs of "network elements". This approach provides valuable additional information on the make up of the costs of the various interconnection products.

The process of estimating the cost of the network elements consists of allocating the costs of the various cost categories to the various network elements. The cost allocation of the majority of cost categories to the various network elements is straightforward due to the level of detail in the HM, e.g. the cost of LE ports is allocated to LEs.

The HM allocates the cost estimates of the network elements to the different services that use them – PSTN and non PSTN (leased lines and data services and broadband). These costs are allocated on the basis of information estimated within the HM. Overall, core transmission costs are divided between costs attributable to metered traffic and costs attributable to non PSTN traffic on the basis of capacity requirements for metered traffic and non PSTN traffic. The capacity requirements are generally determined using demand information supplied by Romtelecom and routeing factors.

The network elements are combined as required to create each LRAIC-based product and the costs of the network elements are combined accordingly to derive the cost of each product. These combinations are determined by the routeing factors for the particular product. For example, for the interconnection products estimated by the model, local level interconnection will, on average, use less than one remote concentrator, to the extent that some customers may be directly connected to the local switch, and one local switch. To the extent that a remote concentrator is used, the service will also require a transmission link between a remote concentrator unit and local switch. Local level interconnection will not require a tandem switch, or the use of any other transmission links.

The calculated costs per minute of interconnection products are shown in the sheet titled "Results".

7 Updating the Model

The terms of reference required that the HM, being a "multi-year" core network model, it can produce estimates of per minute interconnection costs for a period of five years (2003, to 2007).

The HM can be used to produce estimates of interconnection costs for a number of years without the need of changing/updating of the inputs. To improve the accuracy of forecasts for future years, a number of inputs to the HM should be updated each year if data are available. The updates mostly relate to demand data, unit cost data and the cost of capital estimate.

The inputs (shown in light green background) to the HM are concentrated in three of the six sheets of the model; the Control sheet, the Calculations sheet and the Inputs sheet.

Other types of input data that can be updated if new information becomes available, ranging from the number of lines connected to Romtelecom's network to unit cost inputs. Updating these data is a straightforward exercise, as the HM user simply needs to replace existing inputs with more up to date ones. However, this updating may prove to be more complicated in a few cases because of the categorisation/grouping followed in the HM. For instance, the list of local exchanges, the number of RCUs as well as the number of PSTN, ISDN2 and ISDN30 lines connected to each local exchange are all inputs to the HM. However, the model also uses, for example, information on number of remote concentrators connected to each LE. In the project team's view, this would require some processing of raw data in order to put them into the appropriate format.