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ISP Cost Model (ICOMO) Design

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Institut für Technische Informatik und Kommunikationsnetze
Computer Engineering and Networks Laboratory

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Market Managed Multi-service Internet

M3I

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Deliverable 8
ISP Cost Model (ICOMO) Design

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1 Introduction

Today, the Internet Service Provider (ISP) market is characterized by a set of new services and interactions, thus differing significantly from the traditional telecommunications market. This is mainly due to the fact that basic communication network access is extended in the case of the Internet with service offerings and content provisioning. In this situation, charging and accounting have become central network management functionalities, and there are several major research projects, e.g. M3I or CATI, investigating this area. These efforts have resulted in the design of new architectures for Charging and Accounting Systems as well as various new pricing schemes for Internet services. Balancing these developments, also the cost models for ISPs require a fundamental reshaping. Traditional ways of modelling costs in a communication network do not hold any more, and the inclusion of services needs to be considered explicitly. Hence, the main focus of an ISP cost model is to identify all relevant parameters and their mutual relationships which contribute to the cost for providing network services to a variety of users. In a competitive market, cost modelling is helpful in two ways:

- Firstly, a suitable cost model serves the ISP with respect to its internal cost management as it helps to understand its own costs, which may have crucial influence on marketing decisions as well as operational processes.
- Secondly, a cost model provides a solid basis for calculating tariffs and charges for value-added Internet services.

The latter issue is based on the assumption that the way services are charged is determined by the cost for these services, i.e. it is supposed that services are not cross-subsidized. Finally, the cost model may be viewed as being the starting point for building a tool that allows ISP's to decide on the cost of additional Quality-of-Service (QoS) and the cost of service in general. Hence, the cost model design is concerned with the clear identification of services and its associated costs in addition to formalized description of its relationships.

1.1 Designing an ISP Cost Model

Cost models for telecommunication service providers have been studied for quite some time and are a well-established traditional way of dealing with connection-oriented services and lines. Unfortunately, this body of work cannot be applied directly to the Internet as its services use a packet-based and connectionless technology. Moreover, the range of offered services in the Internet is completely different from traditional telecommunications. Especially, it turns out that only a combination of value-added services provisioning and IP access seems to describe a realistic business case, whereas pure IP access (comparable to the “carrier service” in traditional telecommunications) does not represent a revenue case any more. Therefore, both the technical infrastructure and the value-added services provisioning need to be modeled separately, since different services require different technical resources to be provided.

For an ISP cost model to be useful, cost parameters related to an ISP have to be identified in a very specific manner. This requires the technical modelling of the various components an ISP uses for providing services, including hardware (e.g., modems, routers, switches, servers, LANs, WAN accesses, leased lines) and software components (e.g., specific protocols, routing tables, name services, address resolution services) as well as complete network management tools (e.g., account management, fault management, security management). On the other hand, parameters like personnel, support, and maintenance costs are usually described in terms of more general economic models which, therefore, have to be included, too. Moreover, also the consideration of compound effects (i.e. existing equipment may have additional features which were not intended and hence are available “for free” for different services) and the discrimination of implicit vs. explicit costs requires the application of respective economic models.

Having specified different parameters influencing ISP costs, a sensitivity analysis has to be performed. As it is to be expected that the number of those parameters is enormous, in this way it becomes possible to distinguish between crucial and negotiable parameters, thus facilitating the application of the cost model. Identifying parameters that are more or less identical for different service types will further reduce the number of relevant parameters. Applying the model to real business cases afterwards will allow to estimate the “real” cost for a given ISP. Obviously, the degree of accuracy of such numbers depends on the availability of details about the ISP considered: the less parameters have to be estimated, the more accurate the results are.

A second way to apply the ISP cost model will be the determination of cost for setting up new Internet services. To this end, it turns out to be useful for the cost model to have the form of a two-dimensional spread-sheet (as preliminary version of a new management tool). Applying this spread-sheet to specific competitive services (e.g., IP telephony, e-mail, VPN, Web-hosting, DNS, general IP QoS, or DiffServ/RSVP technology) for instance will give sound and transparent indications about their profitability. Moreover, the application of economic theory like “Yield Management” to ISPs will be simplified to a large extent by having such a spread-sheet available.

1.2 Cost Model Dimensions and Requirements

Before starting with the actual cost modeling, it has turned out helpful to loose some thoughts about the framework it is supposed to be put into. To this end, Figure 1 summarizes some central dimensions of any ISP cost model.

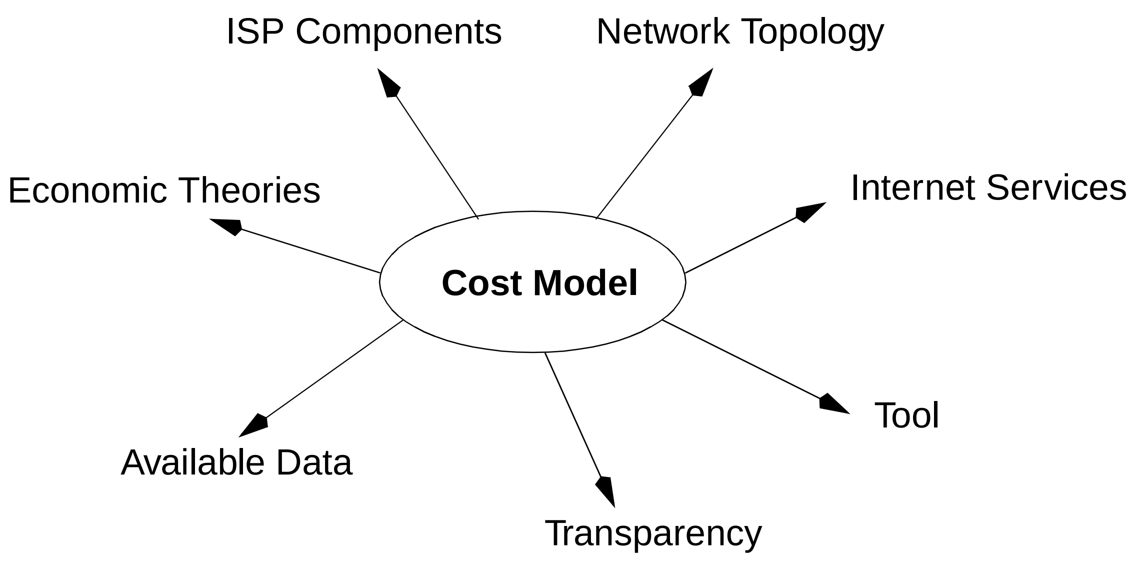

Figure 1: Cost Model Dimensions

According to Figure 1, an ISP Cost Model has to deal with

- the variety of ISP components. This includes technical equipment as well as organizational structures, enterprise departments etc.
- the underlying network topology. Even if the ultimate aim is to develop a cost model that is independent of the network structure, this will always be an important point to keep in mind.
- basic economic theories. Any cost model must comprise a balanced mixture between engineering and economy.
- the offered Internet Services. As outlined above, service-orientation is one of the main features of the new cost model.
- its applicability in form of a resulting tool.
- the issue of simplicity and transparency. Cost modeling is about hierarchical structure, not parameter details.
- the available data. Orientation along real-life cases is an essential requisite of successful cost modeling, and having respective data available is vital for that. Unfortunately, getting them is not always an easy job.

Based on these considerations, we may derive as requirements on ICOMO that it should be based on

- an analysis of the various (technical and non-technical) components of an ISP;
- an analysis of the various offered Internet Services;
- relevant economic theories;
- the available data for concrete ISP cases.

Furthermore, ICOMO should aim at creating

- a transparent model for understanding ISP cost;
- a simple and practical tool for applying the model.

1.3 Structure of this Document

This deliverable is structured as follows: The first part deals with basics of ISP cost modelling. After evaluating related work in Section 2, Section 3 introduces into accounting methods that are relevant for ISPs. Section 4 presents a market and provider segmentation, before Section 5 introduces the new cost model ICOMO in detail. The second part of the report is devoted to the implementation of ICOMO in terms of a concrete case study. Section 6 describes the relevant parameters. After describing the Analytica implementation of the model in Section 7, Section 8 presents a couple of concrete modeling result for the business case. Finally, Section 9 demonstrates shortly a different form of implementation, before some concluding remarks finish the deliverable in Section 10.

2 Evaluation of Related Work

2.1 Cost Model According to Leida

One of the most fundamental relevant works is Brett Leida's M.Sc. thesis [15]. After a general introduction and an introduction to Yield Management techniques, the services offered by the ISP are distinguished as follows:

- dial-in analog access
- dial-in ISDN access (128 kbps)
- 56 kbps leased-line access
- T1 leased-line access

Strictly speaking, the offered Internet services belong to Internet access services classes, as Leida distinguishes according to the way the customer accesses the network, without further differences among the services. Hence, the differentiation is based solely on different bandwidths of the local loop.

- In a next step, five types of customers are defined:
- residential dial-in subscribers
- business dial-in subscribers
- business ISDN subscribers
- business leased-line subscribers (56 kbps)
- business leased-line subscribers (T1)

The interplay between customer types and offered access services is sketched in Figure 2.

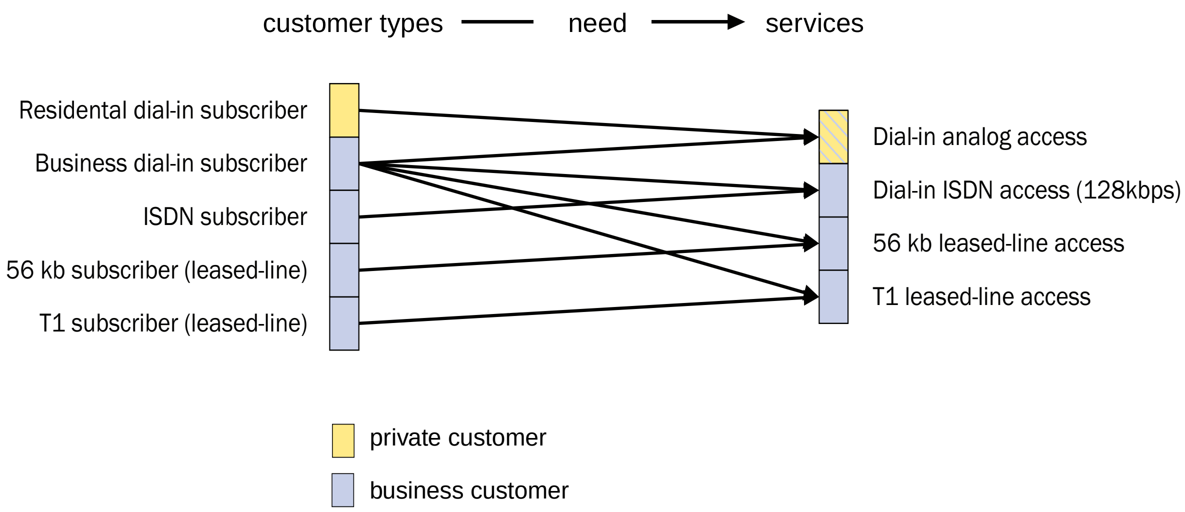

Figure 2: Customer Types and Access Services

On the customer side, Leida distinguishes between private and business customers, using basically all services except for the analog dial-in. It is assumed that residential customers only use the analog Internet access, whereas the business dial-in subscribers may use all offered services. Moreover it is presumed that the ISDN and leased-line subscribers are members of a corporation or institution in a wider sense. Note that from the marketing point of view the customer segmentation could have been performed in a slightly more efficient, because Leida mixes product-related (bandwidth of local loop) and customer type-related segmentation (business vs. residential customers). The product-related segmentation here causes certain problems, as it is difficult to react to service changes on the market. The same is valid for the ISP market as well. E.g. in 1998 it has been too expensive for private customers to surf in the Internet via ISDN, in contrast to its heavy use by private customers today (even if it is no longer estimated to be a high-speed Internet access). Moreover note that more and more new technologies (like ADSL, TV cable modem, powerline or WLL) for the last mile enter the market.

With respect to the providers, Leida distinguishes two types:

- pure Internet provider
- IP phone provider.

This distinction is based on customer behavior, as the offered Internet access services of both ISP types do not differ. Customers can use their Internet access for different IP based services. In this sense, Leida distinguishes the following two scenarios:

- Baseline scenario: The customers use their Internet access solely for WWW (i.e. all transport protocols except IP telephony, e.g. HTTP, FTP and SMTP).
- Internet telephony scenario: The customers use a third of their access for IP telephone and two thirds for WWW.

Leida restricts all further investigations to these two scenarios. Obviously, the customer behavior has direct influence to the generated amount of data traffic, which in the second scenario is higher than in the first one. Higher data traffic corresponds to larger requirements in terms of network resources. But despite of this distinction, only Internet access services are investigated, there is no individual IP phone service defined, nor is the respective customer segment. Instead, the access service class is offered in some sort of “example world”.

One of the weakest points of the investigation concerns the issue of a general or abstract representation of the model which is not performed at all. Instead, Leida operates from the very beginning with numbers. To model this “example world” requires making very simplifying assumptions, a method that is basically alright for examples used for illustration purposes. Leida, instead, bases all his investigations on these presumptions, thus limiting to a large extent the general usability of his results.

As an example, Leida restricts his topology to nine backbone nodes, representing tier 1 and tier 2 POPs, where tier 2 POPs consist of several tier 1 POPs. Tier 2 POPs are connected among themselves by T3 circuits. Using these two POP types, the customer access according to the four services defined above is realized. The Network Access Points (NAPs) serve as connections or peerings to other ISPs. Figure 3 illustrates this topology more closely.

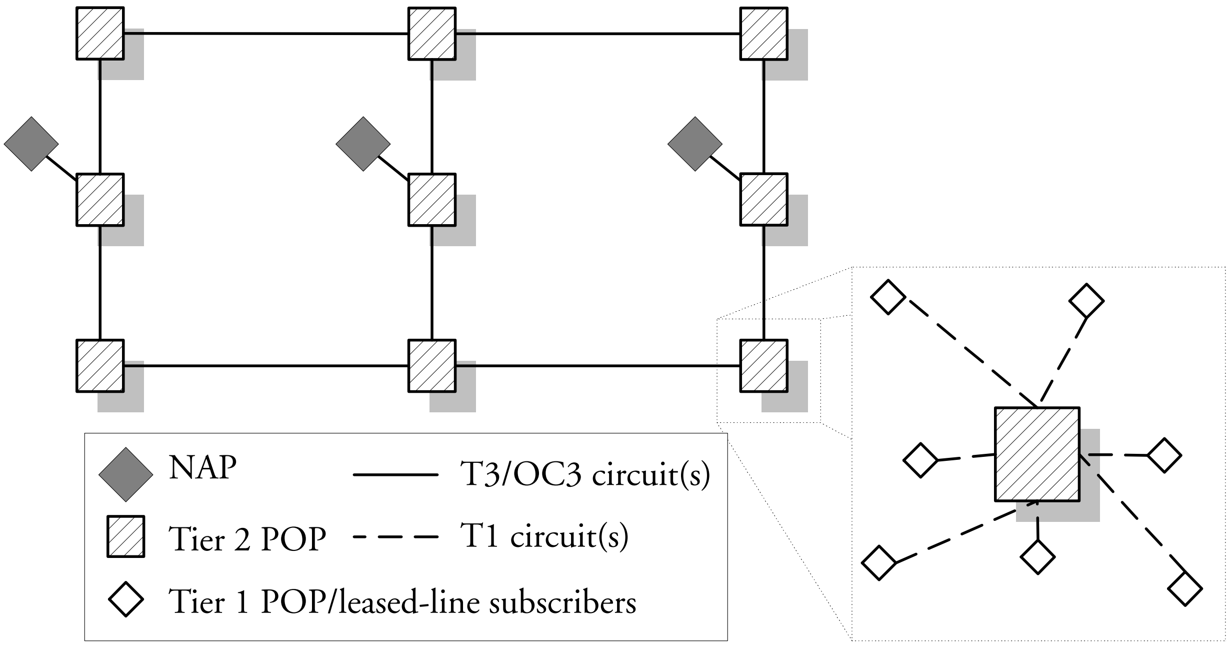

Figure 3: Leida's Network Topology

The network of Figure 3 is used for separate investigations of both the baseline and the IP phone scenario, i.e. there is offered one single service class over that network. This service class is relatively homogeneous, consisting of more or less identical services which differ merely by the way the customers access the Internet. Hence, the purpose of this network basically is the transmission of a single service used by the customers for different purposes (e.g. WWW and IP telephony in the IP scenario). As the whole costs refer to only one service class, the question of allocating them is simplified enormously. Especially the distribution of the common costs is no longer necessary. As it is demonstrated in section 3, it is exactly these common costs that are typically very high in telecommunication networks, as usually there is no global network which is used only for offering one service or one service class. Instead, one network offers a multitude of services, all of them based on IP, but with huge differences concerning their further characteristics. Leida´s model turns out unable to cope with scenarios like these.

Moreover, Leida has made much more simplifications, especially concerning customer segmentation, market structure, customer behavior, capital investment etc. we currently will not investigate in greater detail here. Concerning the capital investment for the network infrastructure, very detailed assumptions on traffic volume and characteristics are made. With the help of these figures the network is dimensioned and the financial amount for the infrastructure determined. Obviously, the data traffic depends on different parameters, most importantly the size of the market (number customers per market segment), market structure and customer behavior (who uses which service how often). All the important input parameters first are assumed to be static and are afterwards investigated by a sensitivity analysis. It has already been mentioned that an abstract representation of the different parameters and their influence on respective functions are heavily missing in Leida´s model.

2.2 Cost Model According to Gillett

A second relevant thesis by Sharon Gillett [16] investigates the costs for Internet access using cable modem vs. ISDN. As an example, Figure 4 illustrates the modules of the cost model for the cable modem access.

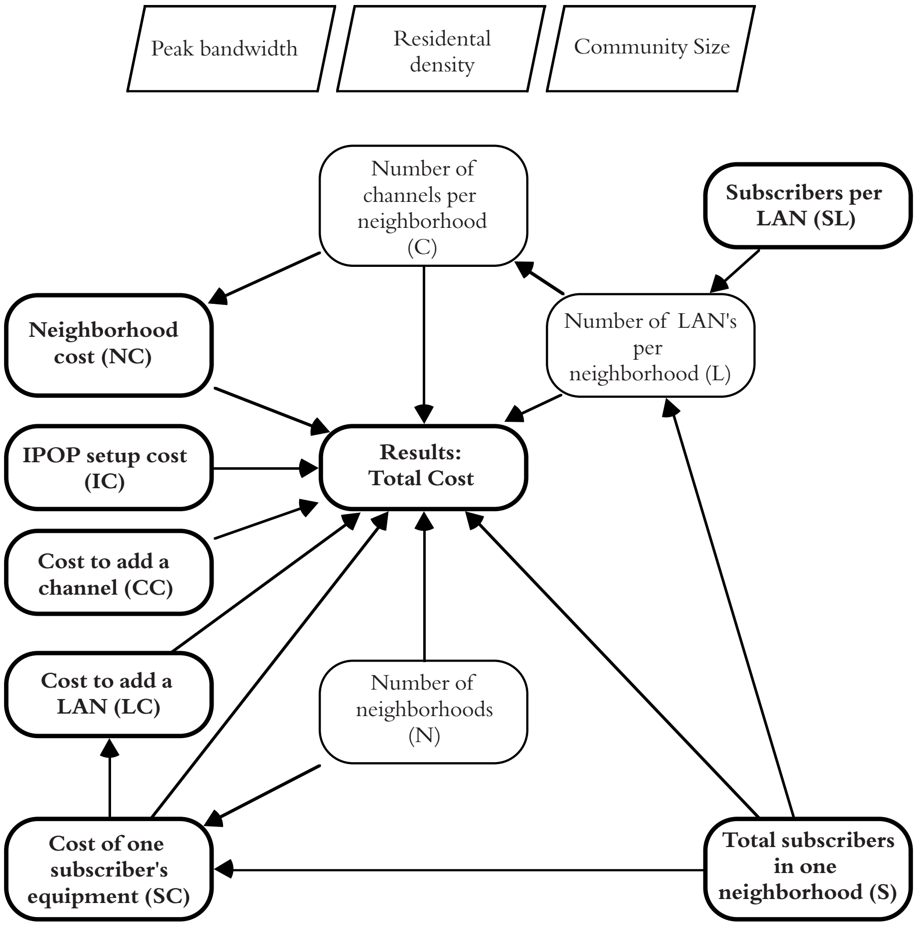

Figure 4: Gillett's Cost Model

This figure is the top-level view. One level of hierarchy below, there are three sub-models, i.e. a traffic, a demand and a technology reference model. Note that the "subscriber per LAN" node consists of different traffic models for the users. Within the "Total subscriber in one neighborhood" node the demand curves are defined as well as the geographical distribution. The five nodes in the left half of the figure (NC to SC) serve for technical modelling. In the course of the thesis, very concrete details of technical realization as well as economic figures are presented and evaluated. Especially, various sensitivity analyses are performed, where the most important parameters are playing with one another, and different scenarios are investigated. Figure 5 illustrates an example of such an analysis. Note that the x-axis resembles the fact that the number of customers may increase over time.

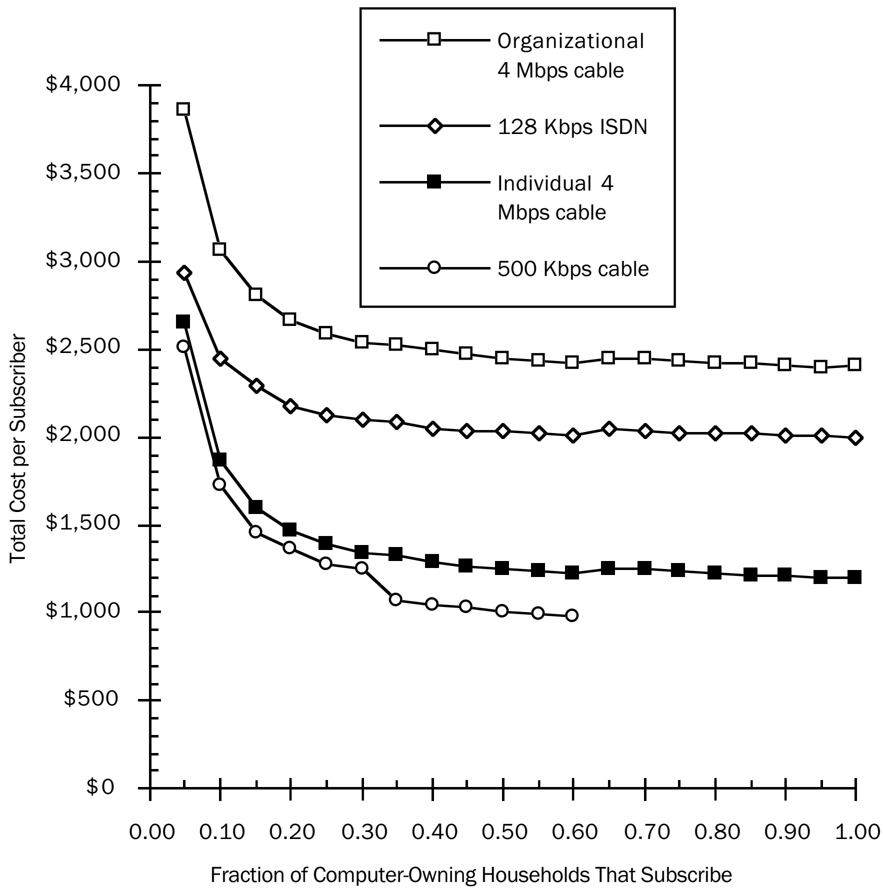

Figure 5: Typical Example for Gillett's Evaluation

2.3 The OPTIMUM Tool

OPTIMUM [10], developed under the participation of Telenor, is a tool for investment calculation, hence the main goal is the investigation of investment in the telecommunication business. Further features of the tool include especially network dimensioning. The major steps for its application are:

- specification of offered services
- Network topology
- Investment cost for network infrastructure
- Life-cycle cost of NE
- Market development and customer behavior

Using these informations, OPTIMUM calculates the following parameters:

- Cash flow
- Pay back duration
- Net present value (NPV)
- Internal rate of return (IRR)

The latter three parameters are the most important figures for investment calculation. The functional view is presented in Figure 6.

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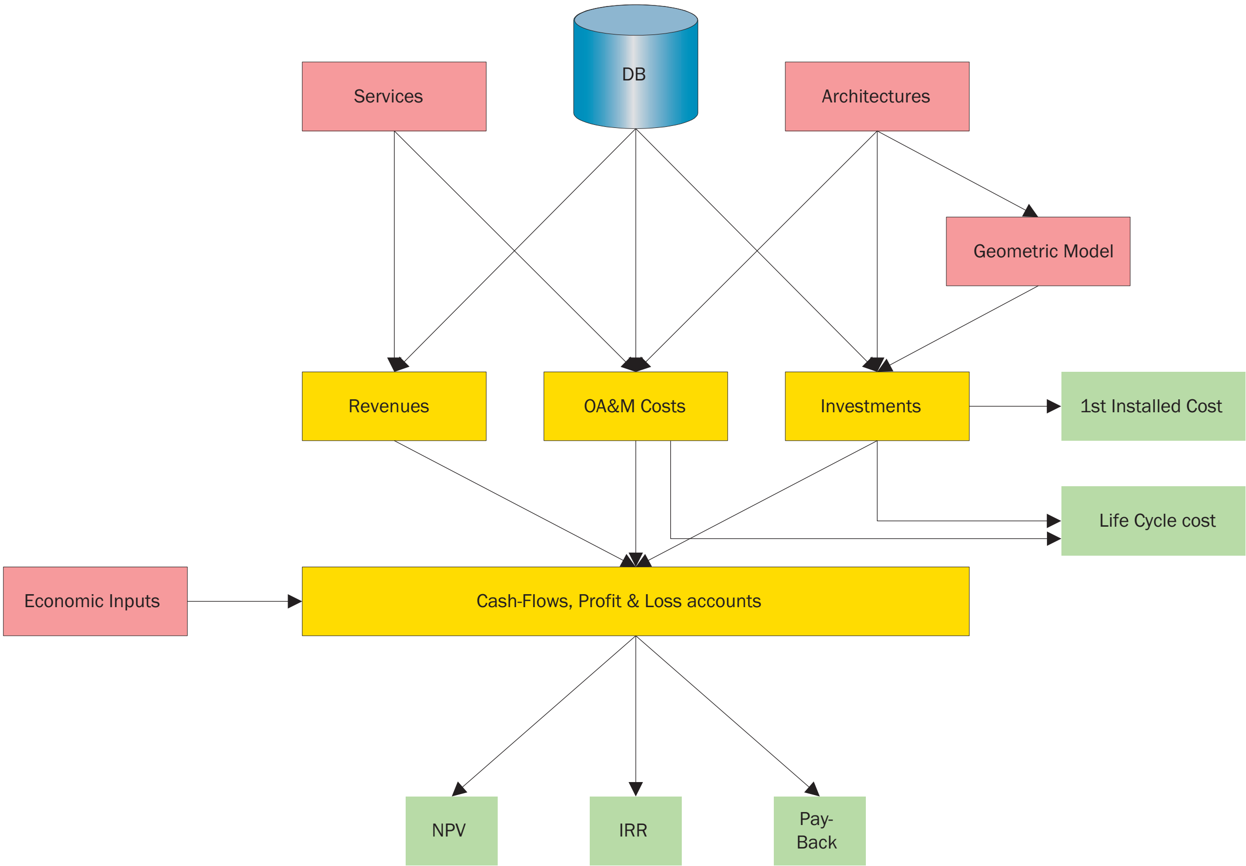


Figure 6: Functional View of the OPTIMUM Tool (simplified version)

The tool is built in a rather abstract and formal matter, especially due to various mathematical models which are used to describe the cost evolution of network elements. A major disadvantage of these investigations concerns the time scale of about 10 years which is to be considered way too long for most parts of the telecommunications business.

2.4 Yield Management

This section provides some remarks about the Yield Management (YM) approach that has become very popular in various business fields dealing with capacity planning. YM itself is not a genuine cost modelling instrument but provides some similarity with our issue. Hence, it has been investigated as well in order to get some more insight in the general field.

2.4.1 Introduction

Among the first to use YM as a planning tool were various airline companies, especially after the deregulation of traffic markets from 1979 (USA) onwards. As a consequence, new providers were allowed to enter the market, and moreover existing price-fixing agreements became obsolete. Therefore, the increasing overcapacities on the market forced the prices of the providers going down, and the providers had to start flexible and active pricing policies. YM in some sense is the result of this development. It has been used since also in other business fields like travel companies, transport and car rental, hotels etc. YM seems to be very efficient especially in the tourism branch with its well-known ruinous price battles. Here it is especially important to give priority to a suitable planning of the existing capacity.

Exhausting the capacity to early using low prices may force later customers to be rejected, even if they were willing to pay higher prices. This is but one face of YM.

A general definition of YM can be based on [12] and reads as follows: “YM is an approach for integrated capacity and price planning and aims at distributing a given total capacity into shares by creating price classes such that the total revenue or the total turnover is maximized... The central question hence is how to assign the number of units of a certain capacity type towards customer types such that the turnover is maximized. Hence, YM deals with realizing an optimal compromise between utilization and turnover per customer...”

2.4.2 Requirements

The most important requirements for YM application are as follows:

- Inflexible capacities
  Adaptations of capacity on any larger scale may only be realized with high capital expenses. E.g. an airline company can increase the number of seats on a particular route only by buying a new airplane. Certainly, all bottlenecks can generally be removed on a sufficiently large time-scale, but in a short-term perspective capacity bottlenecks are well possible. Removing bottlenecks needs sufficient time and money, e.g. building the new airplane in our example itself needs a certain amount of time as well.
- High demand fluctuations
  These fluctuations force the companies to take care of the customer demands concerning capacity adaption. The size of the fluctuations depends on the offered services as well as the market situation and the customer behavior. In market situations with a large number of providers and a small number of customers typically the price competition is rather high. Usually, these markets are characterized by a high price sensitivity of the customers, as they may choose from a huge range of offers for similar goods or services. Decreasing prices therefore easily yield an unproportional demand increase, hence these markets are called “elastic”. Fluctuating demand may also depend on time, e.g. seasonal differences in the travel business. Note that usually it requires detailed market investigations to determine the eventual causes for those fluctuation phenomena.
- Perishable goods in case of non-utilization
  This requirement describes the fact that goods cannot be stored, i.e. capacity not utilized cannot be saved for later use. E.g. seats in an airplane are useless if empty as soon as the plane has started. Optimizing capacity utilization therefore is of eminent importance in many service enterprises, i.e. the so-called volume-oriented businesses with a high proportion of fixed costs. Figure 7 provides a typical Swissair example. Generally, the optimization of capacity is equivalent to maximizing the revenues, i.e. to changing idle cost into usage cost.

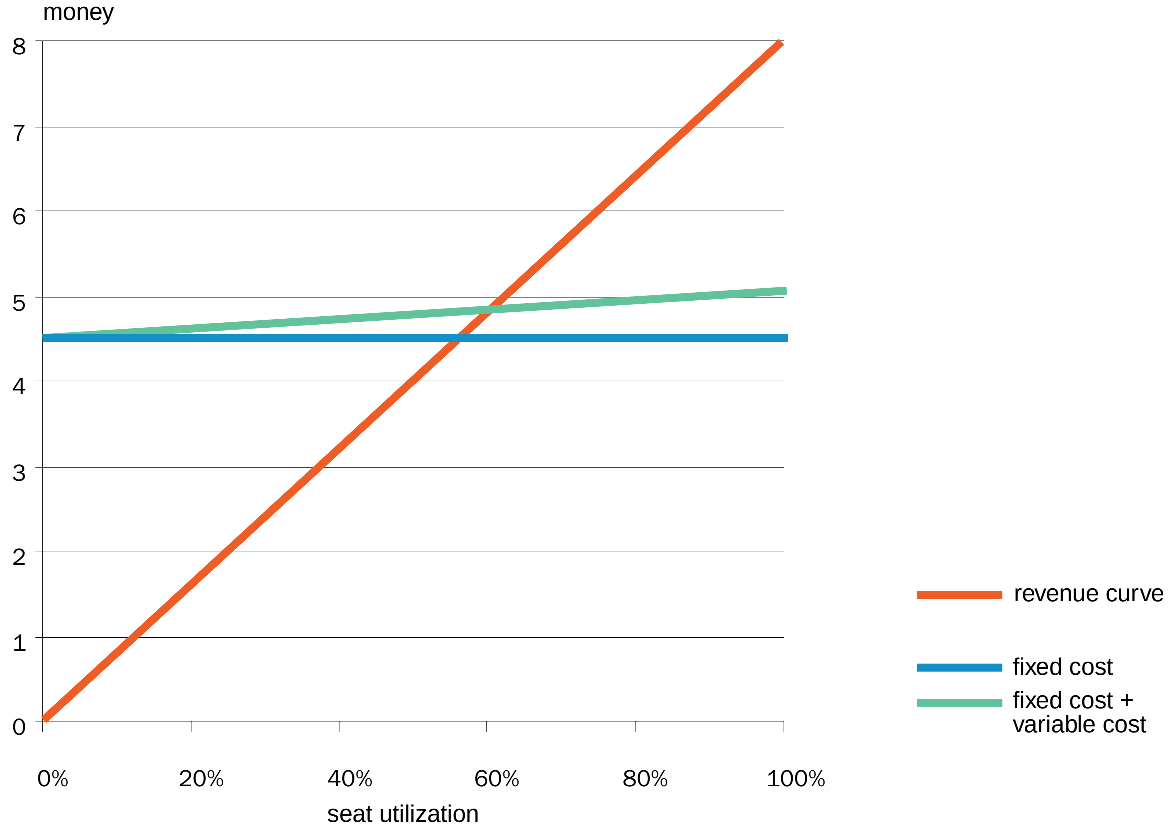
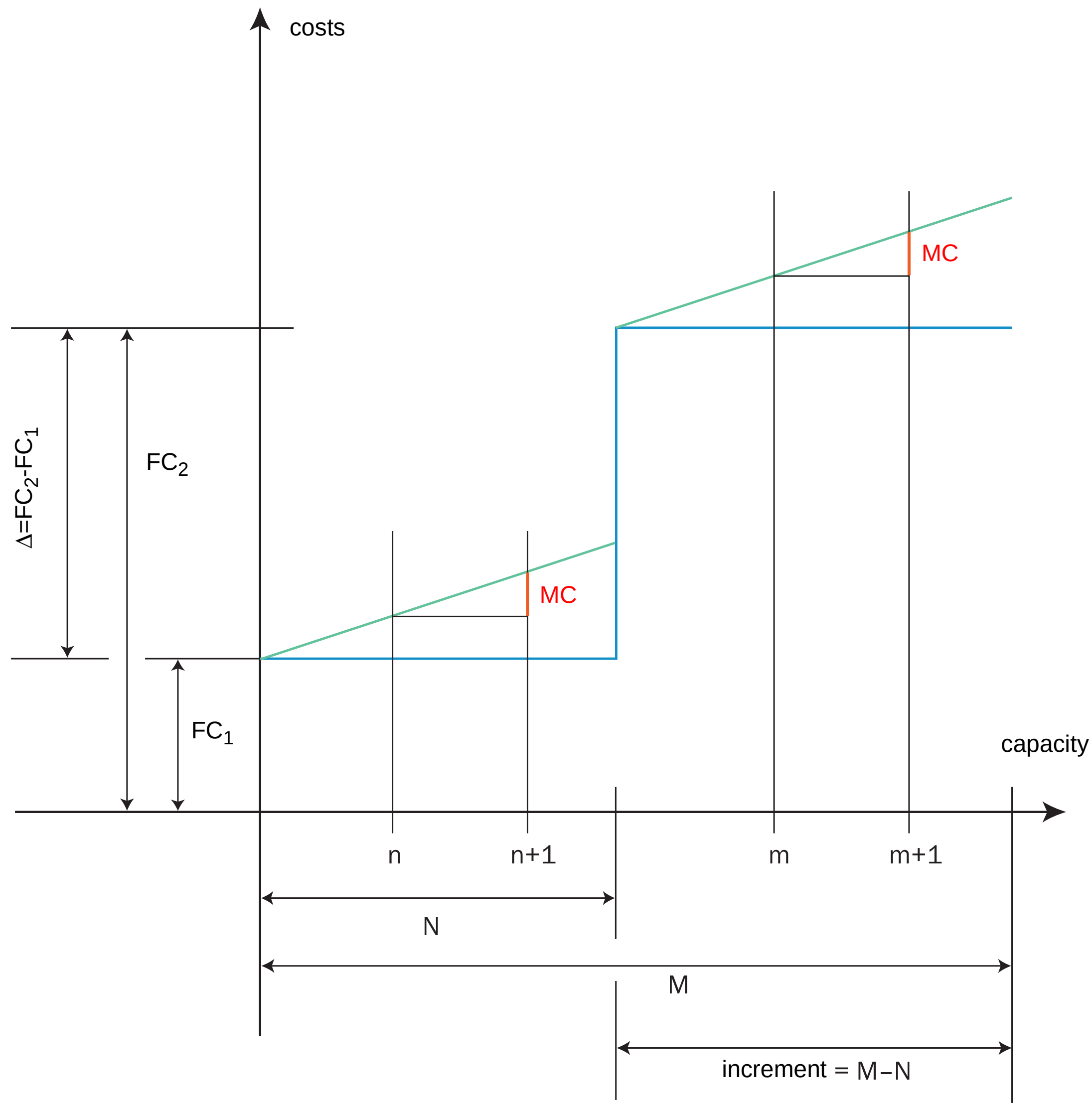


Figure 7: Break-Even Diagram of a Volume-oriented Enterprise: The Swissair Example

- High jump fix costs in case of capacity adaption, low marginal cost, and low proportion of variable cost
  It has already be mentioned that increasing capacity requires high capital expenses, depending on the size of demand increase as well as the size of the increment itself. E.g. if an airline decides to buy a new plane, the additional fixed cost depend primarily on the airplane size, i.e. the number of seats (the increment). Large increments yield large jump costs, and large jump costs yield the proportion between marginal cost per unit and fixed cost to be small. This fact is displayed in Figure 8, assuming that the devolution of the variable cost is not changed due to the capacity adaption. Note that this assumption is not completely consistent with reality as due to the economy-of-scales effects the proportion of variable costs typically will decrease, i.e. the proportion between marginal and fixed cost becomes even smaller.



MC: Marginal cost
FC: Fixed costs
Δ: Size of jumping fixed costs

Figure 8: Cost Increments

- Advance reservation of the goods
  Booking goods in advance refers to the instrumental level and includes the usage of reservation systems. Using the service or good then is equivalent to “exercising” the respective event in advance at the moment of reservation. Generally, there is no deterministic rule about who will use a service when and how often. Reservations are an important tool to reduce this uncertainty by assigning as much of the capacity as possible in advance, yielding eventually to only a small proportion of capacity left at the time of actual use. This relatively complex task, especially the issue of overbooking, will be treated in the next section.

- Possibility of market segmentation
  Generally, market segmentation is possible in any market implicitly. The basic idea is to split the market into homogeneous segments as far as possible in order to assign optimal services to each customer group, optimal in the sense that the customer requirements within a segment are fulfilled as good as possible. Market segmentation may be realized due to different factors, e.g. prices (first vs. economy class), time (day vs. night), geography (urban vs. rural) or customer type (business vs. residential customer).

2.4.3 Capacity Planning

Capacity planning is equivalent to deciding whether to accept a customer request at a given moment or to reject it. There are obviously two types of risk: either to loose turnover (as the enterprise might eventually not be able to use the saved good) or to diminish turnover (as later arriving customers must be rejected even if they were willing to pay more). The first risk is taken by enterprises hoping that they might sell the goods later for a higher price, the second risk is taken by enterprises preferring to be on the safe side. Moreover, in any case there is always danger to loose a rejected customer to a rival forever. Apparently, exact prognostics about future demand increase the probability of making these decisions optimally and reaching maximal capacity utilization.

In order to find a feasible trade-off between minimizing the mentioned risk and maximizing the enterprise revenue at the same time, YM has created two important instruments for capacity planning:

- Price-/Capacity Planning
  This requires market segmentation according to prices. The price-/capacity planning determines then by itself the marketing mix, price classes and the assignment of partial capacities to these classes. Further segmentation dimensions include quality, flexibility and level of guarantees. Note that the segmentation is performed such that customers interchange between segments as few as possible. The perfect market is defined such that customers never ever change between segments, therefore this assumption simplifies the customer behavior model. An enterprise has to try to come as close to this hypothetical goal as possible. As soon as too much customers change between segments, the market segmentation should be a matter of debate.
- Overbooking
  There are areas of service enterprises with up to 50% “no-shows”, i.e. customers having booked a service but not using it. This yields additionally the risk of loosing turnover due to free capacity. Overbooking is a means for evening out the risk between loosing and diminishing turnover. For each tariff or price class, an overbooking policy of its own has to be defined, as usually each customer segment will have an individual “no show” rate. Note that the size of offered capacity shares has to be defined carefully in order to be able to decide correctly about accepting or rejecting a customer request.

2.4.4 Yield Management in Telecommunication

Comparing the YM requirements with the situation in the telecommunication market easily shows that more or less all of them are fulfilled, since deregulation has started here in 1998. Besides traditional phone and mobile phone services, the resulting high price pressure exists also for IP based services. Therefore, it is more or less obvious to try to transfer YM ideas to telecommunication services.

Let us have a closer look to the individual requirements:

- Network capacities are not adjustable arbitrarily. Capacity here is meant in a rather broad sense and may include bandwidth (transatlantic link TAL), buffer sizes (e.g. in routers), service rates (e.g. video servers) or storage capacity (e.g. of a web server). Certainly, there are capacity bottlenecks that may be easily removed (e.g. the storage capacity can be increased by installing a new hard disk), but there are other types of bottlenecks in telecommunications that need high capital expenses for their removal. Another typical characteristic of capacity adaption here is the big size of the increment. The common migration from STS-3 to STS-48 links, e.g., is equivalent to multiplying the bandwidth from 155 Mbps to 2.4 Gbps.
- Demand fluctuations correspond to fluctuations in data traffic volumes. Note that the traffic generated by a single user is much more non-deterministic than its aggregation over multiple users. Therefore, at the local loop there won't be too much of periodic patterns to be recognized and used for sound prognostics. Further off the user, patterns will appear more steadily due to traffic aggregation.
  In this context, it is also important to relate the duration of usage to the generated traffic volume. Voice service (POTS) is characterized by constant data rates of 64 kbps over the complete holding time, independent of actual speaking or being silent. With using dial-in services for Internet access, the generated traffic is no longer constant, but bursty. Hence, with voice traffic there is a clear relationship between the duration of usage and the generated data volume, therefore statistical means allow good models for predicting this volume. With online-time, the situation is apparently different, but at least multiplexing sources reduces the aggregate fluctuation of data volume to a certain extent.
- Telecommunication capacity obviously is perishable, even if there is a certain graduation to be found. E.g. free storage room on a web server cannot perish, whereas unused bandwidth becomes useless instantaneously. This requires distinguishing time-dependent and time-independent capacity. Time-dependent capacity cannot be moved from time unit *n-1* to time unit *n*, as it is the case e.g. with free bandwidth. This case corresponds directly to our earlier example of the airplane transporting any seat, independent of whether the seat is occupied or not. In the same sense, also the capacity of a server, i.e. the number of users being served per time unit, may be viewed as perishable.
- The issue of jumping fixed cost is a bit more delicate, but certainly there are many situations where adapting capacity requires extensive input of capital. But especially characteristically for telecommunications enterprises are the relatively low variable and high fixed costs. Once the fundamental provision of transport services works – usually a huge one-time investment (sunk cost) – additional services can be offered at very low costs over the same basic infrastructure. Hence, the increment from the basic service to value-added services is usually rather small and implies practically only variable cost.
- The only real critical requirement for applying YM in the telecommunication field is the issue of reserving capacities. This is due to technical reasons as well as utilization habits. Booking a flight requires knowledge about future travel plans, but no private Internet user will know about future capacity requirements for downloading file abc.doc from server www.xyz.com. Although there may be a small market for customers buying capacity for basic services in advance, in general it is probably not worth introducing reservation and overbooking systems for basic services. Value-added services are a different story, as provider look for utilizing their capacities as uniformly as possible. E.g. with teleteaching, the dates for lecture transmission are known well in advance, and bandwidth reservation appears to be meaningful.

- Market segmentation certainly is possible with the telecommunication market and already is wide-spread. This point is investigated in much more detail in Section 4.

Summarizing we can state that at least for a part of the services and resources in the telecommunication network, the YM requirements are fulfilled. Indeed, implementing a telco-YM system is far from being possible today, apart from the fact that it does not make sense for every service class anyway

2.4.5 "Yield Management Light"

If at all, reservation and overbooking systems can only be applied to value-added services or to services requiring huge resource volumes, e.g. high-speed Internet access, Video-on-Demand, Streaming Services or multicast. Moreover, YM should only be applied to those NEs with high operating cost and/or high jump fixed cost.

A further restriction for the YM concerns the fact that probably only aggregated data traffic may be considered. Multiplexing many individual sources yields predictable traffic patterns, e.g. on the TAL operated by Switch (see Figure 9).

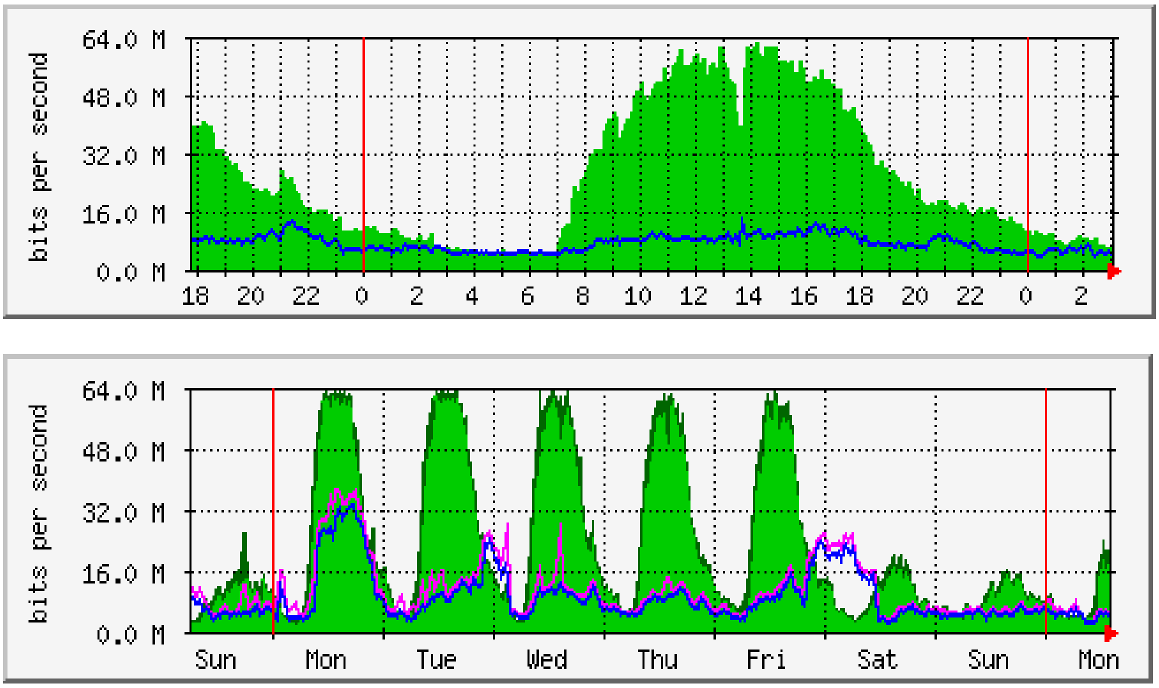


Figure 9: Utilization of the Switch TAL over one day (above) and one week (below)

Note that the fluctuation patterns here are tightly coupled with certain customer segments. Switch customers represent Swiss universities and are comparable to standard business users. They arrive in their offices early in the morning (8 am), are using the Internet throughout 6 pm and spend their evenings at home. The same measurements for the segment of private users would yield a completely different result, as their utilization peak will be during the evening hours.

Moreover, there is also an apparent distinction between downstream and upstream. The downstream features much larger fluctuations than the upstream, due to the classical Internet usage behavior consisting of much more extracting data than injecting into the network.

Summarizing these considerations, YM in the telecommunication can only be used for certain services, cost intensive NEs, aggregated data traffic, certain traffic stream directions and larger customer segments. Generally, applying YM would require extending the individual services into so-called service classes, offered to individual customer segments each. To conclude our example, the result could be that a provider with traffic patterns according to Figure 9 could offer its free evening capacities to private users rather cheaply.

2.5 Evaluation of the Approaches

Characteristic for all relevant approaches of ISP cost models as described above is their focus on concrete cases instead of developing abstract models. Leida, e.g., investigates the “IP telephony” case, and Gillett the case of “cable modem access”. But concrete models use to lack flexibility and independence. A second characteristic for these approaches is their depth in technical and economical details; Leida, e.g., eventually uses more than 300 parameters for describing his model, which has major consequences w.r.t. the transparency of the model.

In contrast to these approaches, our model is required to be abstract, flexible, simple and independent. Certainly, there are trade-offs, e.g. between abstraction and simplicity (as it is basically possible to develop a purely formal model for all possible types of providers and services, but only by using an immense number of parameters in contrast to the requirement of simplicity). In order to cope with them, the model proposed here starts from a purely formal and abstract view, but aims at concrete cases, which are used to feed the model and reduce its complexity. Hence, our approach is to be located in between formal representation and concrete case studies, as it is illustrated in Figure 10. It will turn out that this goal is reached by a subtle mixture of classical accounting and abstraction.

2.6 Proposed Approach: Accounting + Abstraction

We have seen in Section 2.5 that the existing work on ISP cost modeling appears to be strongly focussed towards certain applications, usually IP telephony. This characteristic prevents these results from being usable in a much broader context. On the other extreme, a purely formal model, placed on a high level of abstraction, is equally useless. Therefore, our aim is to combine these two levels, i.e. place our ISP cost model in an intermediate level as sketched in Figure 10.

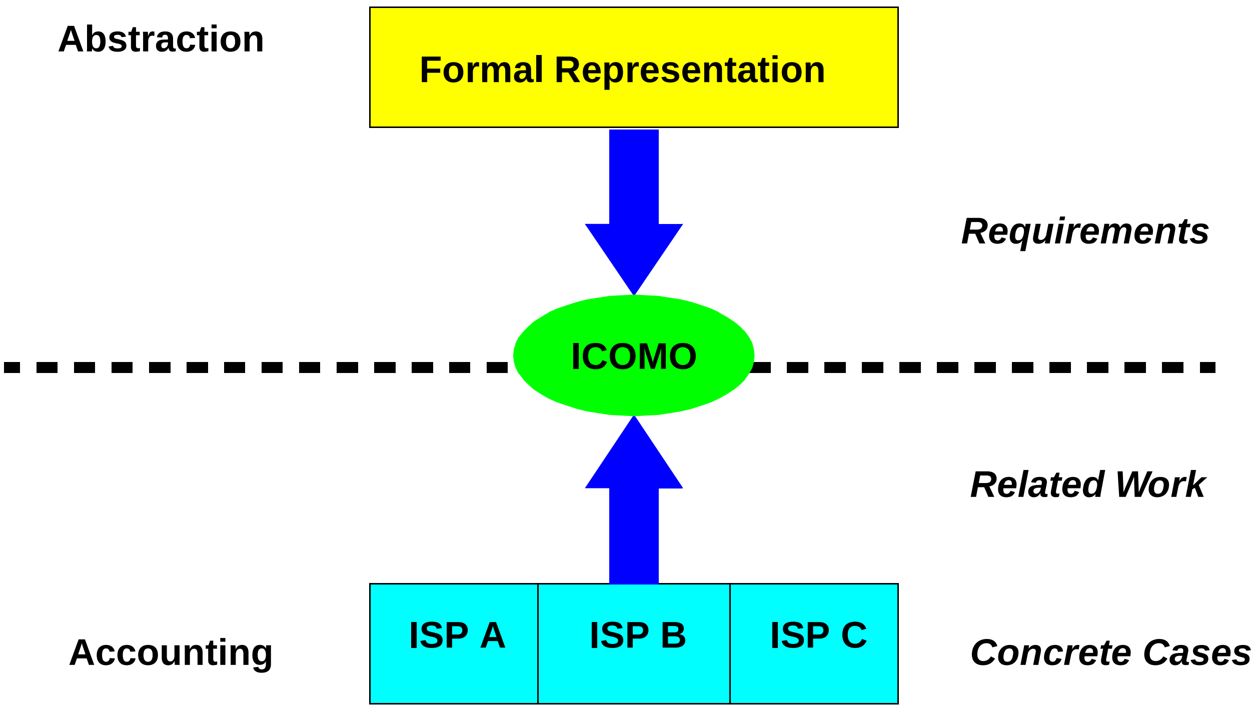


Figure 10: Accounting + Abstraction

In this sense, the ICOMO model presented here is strictly oriented on real-life cases, but at the same time aims at a semi-formal representation. This goal is reached by a suitable segmentation of both the provider and the customer market as well as the application of abstraction principles in terms of cost categories, cost locations and cost units.

3 Accounting

The evaluation of the related work has demonstrated that a useful cost model can be derived by mixing classical accounting with suitable abstraction. In this section, an introduction into accounting techniques is provided and one special example, the LRIC scheme, is explored in larger detail.

3.1 Classical Accounting

Accounting has been developed to find out why corporations work profitably or not. Hence, the main aim is the understanding of costs. It is investigated which factors are most influential for cost development and hence are considered to be cost bulls. Full cost accounting has a long-range characteristics and tries to find out the complete (full) costs of products or services. To this end, full cost accounting distinguishes

- types of costs
- cost locations
- cost units

The respective interplay is illustrated in Figure 11.

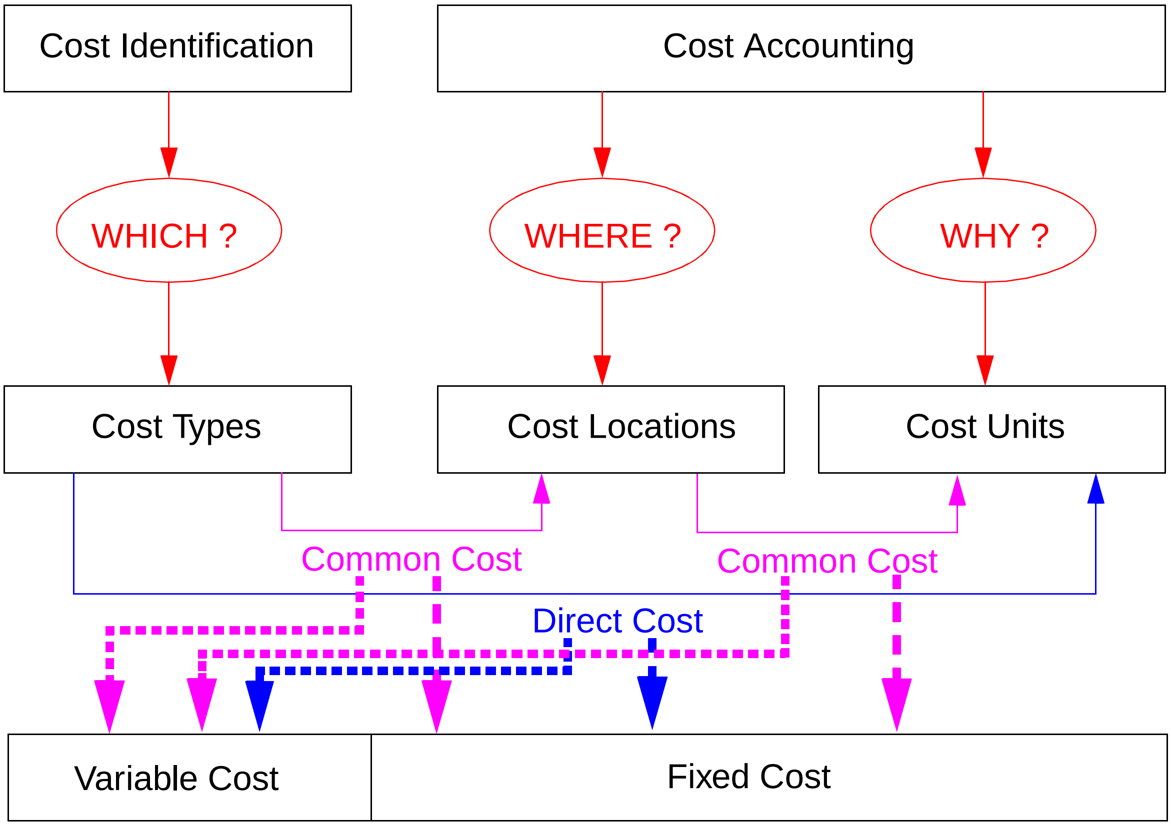


Figure 11: Cost Flow

3.1.1 Cost Types Accounting

Cost types accounting answers the question of which costs have appeared. The following types are distinguished:

- Direct costs: These can be related directly to the production of a single product (or service, resp.).
- Common costs: There is no direct relation between these costs and products. Hence, common costs have to be distributed between the products according to suitable keys.

Another important distinction is the following:

- Fixed costs: These are independent of the volume of production or number of customers using a service.
- Variable cost.

Typically, a big proportion of direct costs are variable, whereas a big proportion of common costs are fixed. But there are, of course, also fixed direct costs, e.g. certain hardware suited only for realizing a special service, as well as variable common cost, e.g. wages for support staff (as the amount of support increases with the number of customers). On the other hand, it is very difficult to determine which support staff member has used how much of his time for which support service, hence average values will be used for calculation. E.g. customers of service A may use approx. twice as often the support division as customers of service B. Hence, the common cost for support will be divided among A and B in proportion to the number of customers per service.

Note that the distinction between fixed and variable costs depends of the relevant time-scale as well. In the very long range, more or less all costs are variable. In the short range, a big proportion of direct costs is fixed, as they cannot be changed from one day to the other. Figure 12 summarizes these relationships.

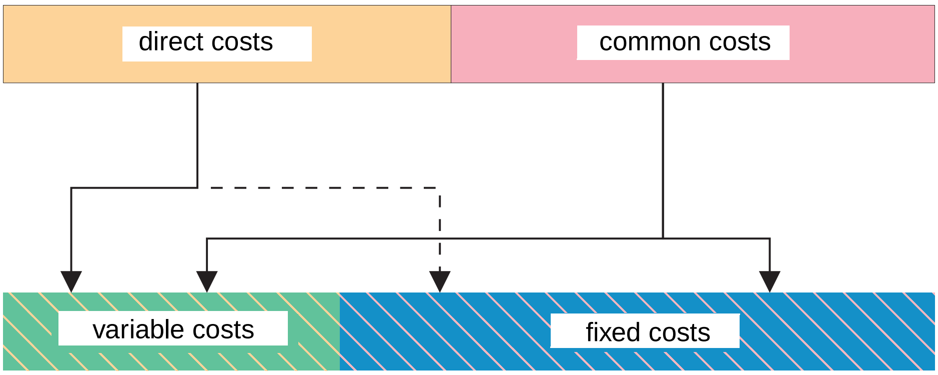


Figure 12: Relationship of Different Cost Types

3.1.2 Cost Locations Accounting

Cost locations accounting answers the question of where costs have appeared. This allows an evaluation of profitability for various corporation departments. Cost locations are defined as parts of a firm that are separable according to work or organizational criteria, while it is possible to allocate common costs to the locations according to the principle of causality. Within industrial plants, the division into cost locations is performed according to the way of producing goods. In an abstract manner, this approach may be generalized to service firms, as here, too, clear subdivisions may be determined.

3.1.3 Cost Units Accounting

This third step of accounting is responsible for distributing the direct costs coming from cost types accounting as well as the common costs coming from the cost locations among the cost units. Here, cost units are defined to be the products or services, resp., that are offered by a corporation.

3.2 Long Run Incremental Costs LRIC

LRIC is a cost model widely used within the telecommunication business. It has been devised by the American telecommunication regulation authority for the case of interconnection pricing. The European regulation authorities have started using this framework as well.

In principle, interconnection services can be priced by a classic full cost accounting. But in the age before deregulation, the big telcos used to be monopolists and therefore could make big profits. The idea was to prevent these companies from abusing their market position after the deregulation to the disadvantage of newcoming providers. For those the interconnection prices play a big role as usually in the beginning they do not possess a sufficient network of their own. Therefore, the interconnection prices should lie beyond the original full cost (something the established providers have tried to prevent, but finally the supporters of LRIC succeeded). One of the main arguments has been that in a free market the competition in the long run drives the prices exactly to where LRIC would place them anyway, whereas in the short run the market price may deviate from LRIC. From a commercial point of view, LRIC is the investment criteria, i.e. a price above LRIC corresponds to a signal for increasing the capacity.

3.2.1 Costs with LRIC

The starting point for LRIC is full cost accounting (or full cost per service). The long run incremental costs then are derived from these full costs as illustrated in Figure 13.

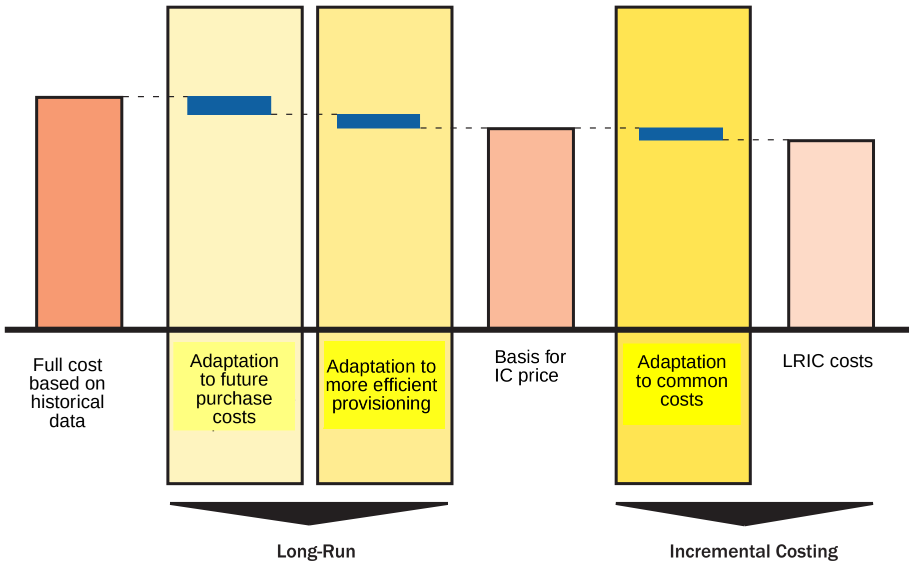


Figure 13: LRIC Calculation

The size of the necessary adaptations is prescribed legally. Of special importance is the notion of incremental costs, which are defined to be the costs for increasing the current volume by one unit. The incremental cost are equal to the variable cost if the cost develop linearly and the fixed costs do not change (i.e. there are no leaping fixed costs). This is demonstrated in Figure 14.

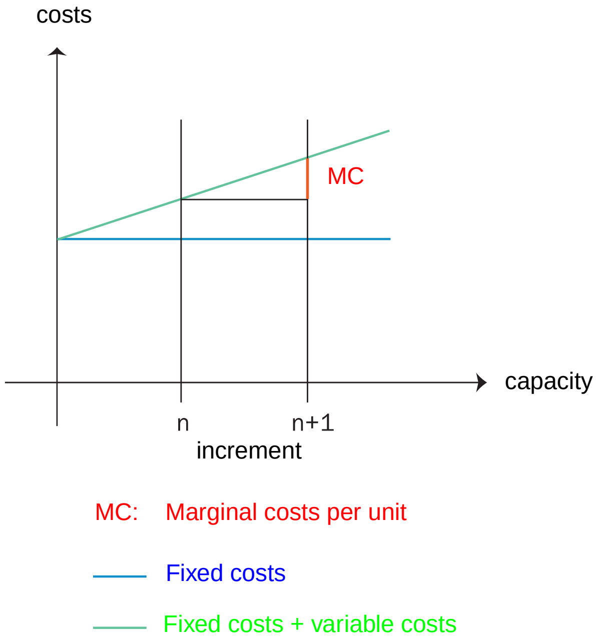


Figure 14: Marginal Cost per Unit

The notion of increment itself is important. In the simplest case, an increment corresponds to an increase of the capacity by one unit. Note that in a network, incremental cost typically will depend upon "location" in some sense (e.g. while adding new subscribers to a service, where the incremental costs also depend upon the sequence at which the subscribers are added). Moreover, in a more abstract form, one could also view to the "increment" from a simple to a value-added service (depending on the sequence at which services are added).

In distinguishing between fixed and variable costs, the time-scale is of vital importance. LRIC has a clear long-range character, hence all costs are supposed to be variable. In this sense, the long-run incremental costs are equivalent to the (mostly variable) limiting costs.

4 Market and Provider Segmentation

This section deals with the segmentation of the customer and provider market, i.e. the question of how to split customers and providers into consistent segments. As an example, we investigate customer segmentation for the case of Switzerland, based on a detailed study about Internet usage in Switzerland [14]. Section 4.1 analyzes the customer market structure, and Section 4.2 derives details about the socio-demographic characterization of customers. As a result, Section 4.3 introduces the actual market segmentation. Afterwards, Section 4.4 deals with the segmentation of providers and ends up with introducing the distinction between “Telecommunication ISPs” (TISP) and “Pure ISPs” (PISP).

4.1 Analysis of Market Structure

Knowledge about market structure and customer behavior are prerequisites for any market segmentation. The more detailed these investigations have been conducted, the more precise predictions can be made about the future market. It is obvious that access to the Internet is a necessary condition for using ISP services. The major part of the revenue, however, will not be a result of the Internet access itself, but of its actual usage by the customer. This usage has been investigated by the WEMF[1]. In 1997, this enterprise has started to perform a “Media Analysis” about the number of persons using the Internet in Switzerland and Liechtenstein, allowing even the analysis of short-term trends. Besides describing the Internet user quantitatively, they are also characterized in socio-demographic terms. Data on usage frequency and usage motivation supplement the investigated structures. The results of this study are representative for the resident population of Switzerland and Liechtenstein having age 14 or more. The investigations themselves are conducted each half of a year in so-called “waves”:

- 1st Wave: May to October 1997
- 2nd Wave: November 1997 to April 1998
- 3rd Wave: May to October 1998
- 4th Wave: November to April 1999
- 5th Wage: March to September 1999

Within this study, two user groups are defined as well as the notion of daily usage scope:

- Narrow User Group (NUG): Internet usage at least twice a month
- Broad User Group (BUG): Internet usage within the last 12 month
- Daily Usage Scope (DUS): Internet usage “yesterday”

Figure 15 provides an overview on the size of the market and its development by presenting the percentage of total population using the Internet. Note that the number of users has increased by a factor of 2.5 over the last two years, i.e. approximately 1.7 million of users are “surfing” regularly in the Internet as of fall 1999. On the other hand, the speed of growth has decreased during the last waves investigated. E.g. the increase per wave of the BUG during 1998 and 1999 has been approximately a quarter each, whereas during the last wave this rate has decreased to about 10%, marking probably the entry into a saturation phase. The same observation is valid concerning the NUG. As far as the DUS is concerned, approx. 750,000 Swiss persons are using daily the Internet, whereas this number has been 250,000 at the starting point of the study.

1.AG für Werbemedienforschung, see [14]

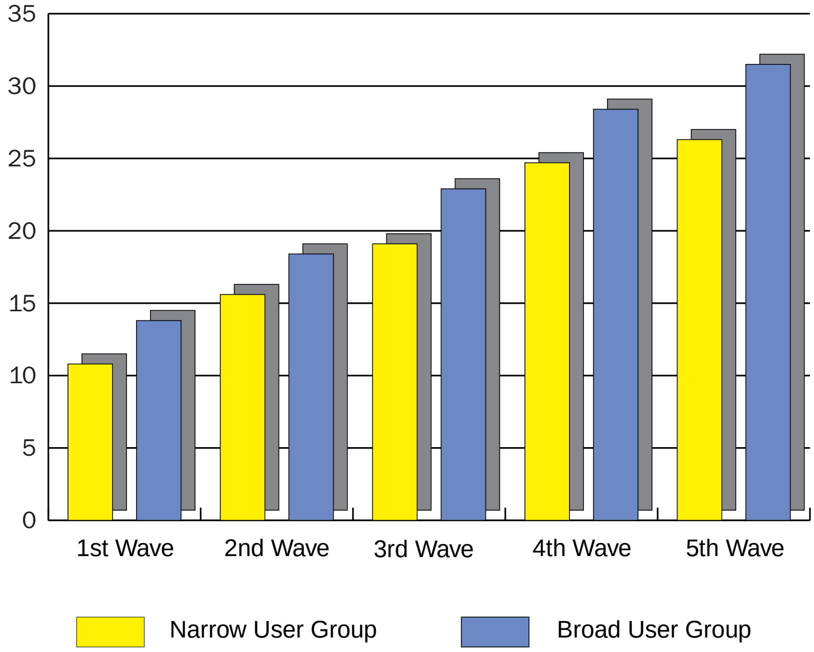


Figure 15: Internet User Groups

Figure 16 presents the location where the Internet is being used, with distinguishing usage at home vs. usage at work. It is interesting to note that the private usage has increased approximately by a factor of 3 and the business usage by a factor of 2 during the investigation period of two years.

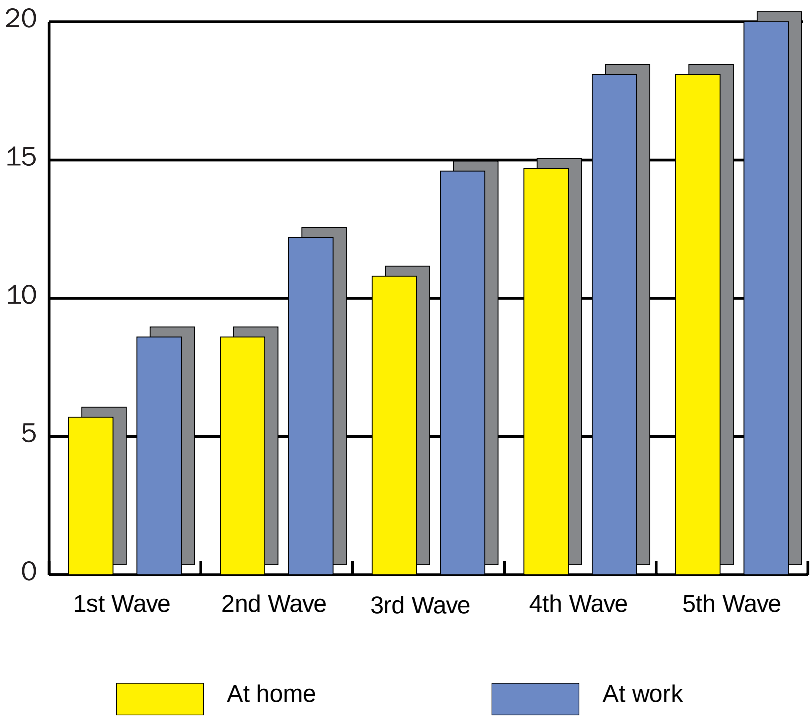


Figure 16: Internet Usage Location

In the next step, the main motivating reasons for using the Internet have been investigated. Figure 17 introduces the four most important usage types, i.e. News (on-line newspapers and journals), Ads (job and apartment rental advertising), E-banking (electronic banking) and Online Shopping. Note that web access to newspapers turns out to be by far the most wide-spread usage motivation, followed by Ads and E-banking, whereas during the observation period online shopping facilities were used only hesitatingly.

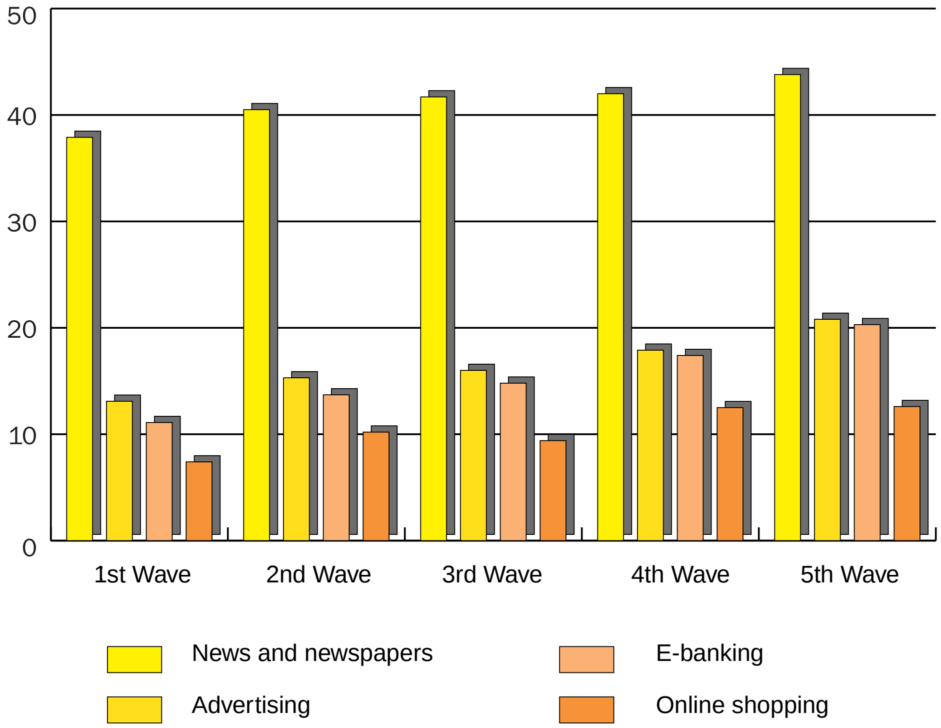


Figure 17: Motivation for Internet Usage

4.2 Socio-demographic Characterization of Customers

The Internet user in Switzerland can be distinguished also according to socio-demographic characteristics, based again on the Media Analysis and the studies on Internet usage as presented in a very detailed manner in [14].

Table 1 presents the most important characteristics of Internet users. Investigating the NUG with respect to their household income, it turns out that lower income stratums are using the Internet significantly less than higher ones. Main reason for this distinction is the fact that the cost for Internet access is still relatively high compared to other countries. Note that the boundary for Internet usage is approx. 4,000 CHF monthly income. The higher income classes also show the strongest increasing usage rates, compared to the two preceding waves.

Concerning the gender structure of Swiss Internet users, female users are represented significantly less than male users (approx. 34% as of fall 1999), but the ratio is definitely increasing (compare the 25.8% of 1997).

Age is also an important criterion for distinction. There is a significant peak with persons of age 20–29 years, whereas in the largest population group (age 50–59) the usage ratio is lower than 10%. With this age structure it is obvious why the Internet is a very interesting medium for the advertising industry.

Target Group	Percental proportion in NUG	Percental proportion in total population[a]	Affinity
Male	65.6	49.1	**134**
Female	34.4	50.9	68
age 14–19	12.9	8.7	148
age 20–29	30.4	19.4	**157**
age 30–39	23.6	18.9	125
age 40–49	19.3	17.6	110
age 50 and more	13.8	35.4	39
obligatory school	14.7	27	54
Berufsschule	41.9	49	86
Matura	27.8	16.5	168
University studies	14.7	6.5	**226**
income below 4000 CHF/month	6.9	18.1	38
4000–8000 CHF/month	33.5	38.9	86
more than 8000 CHF/month	39.7	22.5	**176**
no income statement	19.9	20.4	96
living in city areas or agglomeration	73.8	67.9	**109**
living in rural areas	26.2	32.1	82

a. To be precise, this is the percental proportion within the sample of the MA-Net study. The sample size and the sampling method allow nevertheless representative statements on the Swiss population as a whole.

Table 1:

Finally note that these socio-demographic characteristics need to be set in the respective relation to the total Swiss population. Quantitatively this is expressed by the so-called “affinity measure” as follows: Looking at a small target group within e.g. the NUG and the percentage proportion of that very target group within the total population (i.e. the whole sample), the affinity index for that target group is calculated according to

$$\text{Affinity} = \frac{\text{Percentage proportion within NUG} \times 100}{\text{Percentage proportion within the whole sample}} \quad (1)$$

The larger this affinity index, the closer is the relationship between target group and Internet. As an example, we investigate education as a further socio-demographic parameter. Table 1 presents the percentage proportions of school education for Internet users as well as for the total population. Using (1), we can calculate the respective affinities and find out that the highest affinity results for persons with a university degree. This may be interpreted very easily: most of Swiss Internet users possess a good education. Calculating similarly all relevant affinities, the “typical” Swiss Internet user may be described as

- young (age 20–29)
- male
- well-educated
- living in the city or agglomeration
- earning high income.

4.3 Market Segmentation

It is not useful to perform a segmentation of the customer market based on only one socio-demographic characteristic, rather the segmentation should combine various of the characteristics. Note that however each customer segment should be homogeneous with respect to the defining factors. In this sense, we define the following customer segments and investigate them in more detail afterwards:

- Private Customers:

  The classical consumers, i.e. the ISP services here have consumption character. There are two subgroups to be distinguished here:
  - Internet Surfers: Very price-sensitive customers needing only low QoS
  - Premium Internet User: Rather deliberate usage of the Internet, preferring special services. Therefore an interesting subsegment, especially for content providers.
- Business Customers:

  Business customers belong to the producer side. Subsegmentation is not necessary, due to missing clear transition points.

4.3.1 Private Customers

Private customers clearly belong to the consumers. This can be easily derived from the fact that downstream traffic volume here is much larger than upstream traffic volume. The information this segment puts into the web usually consists of clicking the mouse or sending emails. The only relevant exception is the production of information by private customers in the form of homepages.

It is noteworthy that private customers use services with consumption character. This customer segment uses the Internet only for personal purposes.

4.3.2 Internet Surfer

The first subsegment of the private customers can be described as follows:

The Internet surfer wants and needs only basic service supply. This includes web access with personal email address and space for an own homepage on the provider’s web server. Basic supply includes further access to newsgroups and support for all popular Internet protocols. Generally, all age and gender categories are represented in this segment, and in the course of time probably also the “older generation” will be found here more and more. Gender is no distinguishing parameter.

The Internet is used often for recreational or leisure purposes, comparable to TV zapping. The Internet surfer clicks from site to site without having specific predisposition. Except for search engines and a few special sites, this customer segment rarely chooses specific services.

The enormous price sensitivity of this subsegment has two causes. There is still the widespread opinion that the Internet basically is for free, i.e. with free access, free usage and free information consumption. This is due to the fact that many web sites are sponsored by public money, e.g. university or public organizations, and therefore are in fact for free. Indeed this picture is about to change right at the moment. The second reason for price sensitivity is based on the current oversupply of Internet providers on the market. The offers of many providers aim at the Internet surfer who in turn has free choice among them. Therefore, price battles are still ongoing and will remain typical for a long time.

Normally, this customer subsegment is also very multi-media sensitive. To get the attention of the more or less passive Internet consumer, especially content providers put a lot of effort into the presentation of their products. Integrating multimedia elements in a web site has two purposes: the customer shall be brought to remain longer at the site, and he shall be prompted to return later on.

Hence, the Internet server is more seduced by multimedia than she looks for the quality of a certain service. As these customers perceive the Internet to be for free, their QoS requests usually are low and can be satisfied by best effort services. This is moreover in direct relation to their low valuation for consultancy-type services, whereas in the contrary the Premium Internet User possesses a much higher esteem for hotlines etc.

4.3.3 Premium Internet Users

The second subsegment of the private Internet users is the group of Premium Internet Users that may be characterized as follows:

Basic supply is not sufficient for this subsegment, instead they require additional services like

- real-time stock prices (as offered e.g. by banks)
- online archives
- data base access (e.g. electronic telephone books)
- individual web portals exceeding the possibilities of traditional portals as offered e.g. by search engines
- access to individual discussion groups, e.g. newsgroups for technical problems.

Most of these services are charged, but the additional value for the customer is obvious, and the customer is therefore willing to pay for the service.

It is obvious that with increasing charges QoS becomes more and more important. Note that QoS in the customer’s perception comprises two components:

- Quality of the offered service, i.e. quality of the received information, downtime, reliability etc. Note that the value-added service may be offered either by the same ISP or by a different one (the so-called content provider).
- Quality of the Internet access. Important aspects include transmission speed, error rate, data security, congestion control etc. This second component still exists if the ISP offers access as well as value-added service.

Moreover, the customers request guarantees for the QoS agreed upon. The generally higher QoS level includes finally the request for consultation, e.g. a toll-free 24 hours hotline providing experts for solving all kinds of problems is essential for this subsegment.

4.3.4 Business Customers

The last customer segment comprises the business customers. It turns out that this group is rather heterogeneous, hence subsegmenting it further would violate the principle of homogeneity.

For the business customers, offered services possess the character of investments. Using ISP services they can produce new services and offer them to third parties. Hence, business customers are on the production side, whereas private customers are on the consumption side.

For the business customer, there is a huge range between simple and complex offered services. “Simplicity” here includes technical demands as well as the complexity of the produced services. Some examples for produced services that are based on basic ISP services but sold from the business customer to his own customers are:

- online consulting
- train or airplane time-tables
- web shops.

There is a natural correlation between the provider’s requirements and the complexity of the offered service. Setting up a small company web site is by far not as demanding as building a web shop with online ordering facilities.

Whereas the offered services appear relatively similar in the case of the private customer, they are rather different for business customers. As long as the services are similar, they are also easily comparable, e.g. by provider tests in computer magazines. The providers’ service offers for business customers usually are individually very different, as can be seen especially for complex services like web shops etc. If the complexity of an Internet solution exceeds a certain threshold, the enterprise should perhaps decide to adopt itself the role of a provider.

4.4 Provider Segmentation

Segmenting also the provider market allows to improve the cost model simplicity and transparency. After motivating the provider segmentation in Section 4.4.1, the two resulting segments are described in Section 4.4.2, whereas Section 4.4.3 provides an example.

4.4.1 Motivation

There are generally three starting points for a segmentation of the provider market: different cost structures, the value chain and the vertical market structure.

Cost Structures

The cost model aims at mapping the real cost structures of the enterprises as detailed and accurate as possible. Investigating the current ISP market has revealed rather quickly that there are basically two big groups, i.e. the classical network providers including the former monopolists, and the pure Internet Service Providers. It is obvious that each enterprise has an individual cost structure, but within these two groups, important common characteristics for their respective members may be found. Especially there are only minor differences between the most relevant cost categories, cost locations or cost units within each group.

Value Chain

A totally different point of view in segmenting comes from the value chain in telecommunications. The simplest case as shown in Figure 18 consists of four functional levels that have to be connected by the market entities with respect to the final user. In order to develop a clear understanding, we look at the four central basic functions of an enterprise: investment, production, charging & billing and sales & marketing. In a second step, the tasks (depicted as arrows in Figure 18) are mapped onto these basic functions.

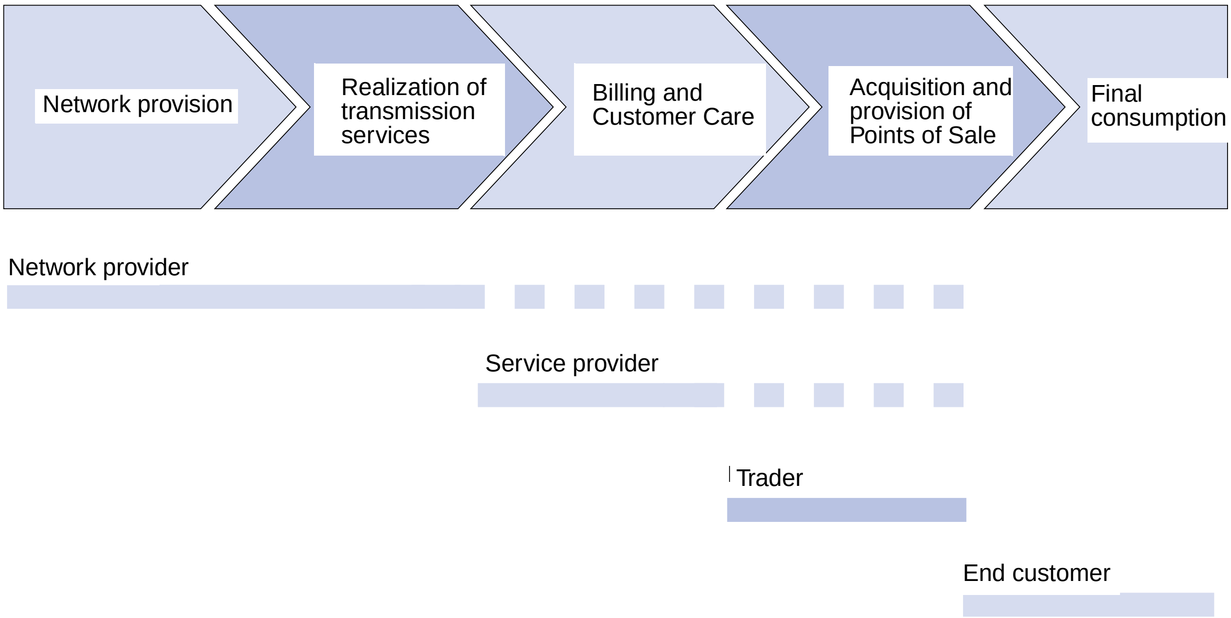


Figure 18: Value Chain

Providing the network infrastructure which allows transporting bits and bytes on the physical layer belongs to the investment sector in a wide sense. Further elements of this sector include the purchase of relevant licenses (e.g. for WLL), installation and maintenance of systems, network planning, further technical equipment etc.

The production function includes the realization of the transmission services. This includes primarily the process of the technical transformation and transmission of customer information data. Metering and accounting belong to this function, too. Note that these data are essential prerequisites for the billing function, but may also be used for insight into customer behavior from the marketing point of view.

Charging and Billing performs the monetary evaluating of the services as used by the customer, i.e. the mapping of technical accounting data into units of money, as well as summing up the charging records in order to issue the respective bill. As the billing enterprise serves as contact point for the customers, this includes further responsibilities especially with respect to customer care.

Sales & Marketing includes all operations concerning customer acquisition, especially the provision of a physical or virtual point of sales.

Mapping these functions of the value chain to the various telecommunications enterprises yields the following insights:

- The network provider is primarily concerned with providing the network infrastructure and the realization of transmission services, corresponding to the investment and the production function. As already shown in Figure 18, forward integration of the network provider is possible without overjumping single steps in the value chain.
- The service provider fulfills primarily the billing and customer care functions. Due to financial reasons, they are not able to perform backwards integration, hence service providers typically draw services from the network providers.
- The virtual sales function usually is performed by traders. These may include also enterprises with operational focus in different areas.

In this way, the value chain reveals a hierarchy, i.e. a vertical structure. Service providers need products or services from the network providers. Traders have – if at all – only minor points of contact with rendering a telecommunication service. Hence, the focus has to be directed to network and service providers, and traders will therefore be neglected for the rest of this section. Note that in the current market situation most network providers already have realized forward integration as this allows them to reach directly the end customer. Therefore, from the point of view of end customers, the distinction between these two types of enterprises makes a lot of sense. For the rest of this deliverable, we will call the one type “Telecommunications Internet Service Provider” (TISP) and the other “Pure Internet Service Provider” (PISP).

Vertical Structure

In the simplest case, the mentioned hierarchy consists of two levels: the lower level represents the TISPs which offer their services to the PISPs located on the upper level (see Figure 19). It is well possible that some TISPs participate as hybrid providers in the market, i.e. the reach directly the end customer, but offer also their services to other PISPs, as it is the case with. $TISP_4$.

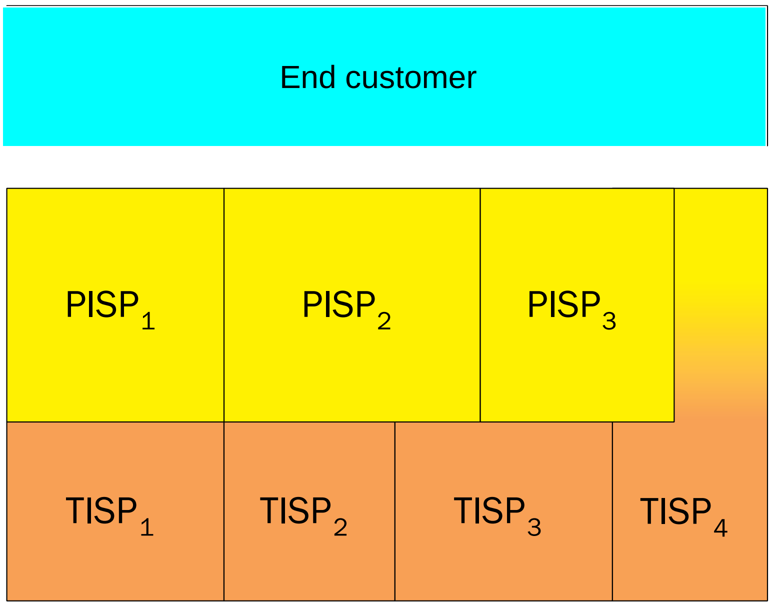


Figure 19: Vertical Structure

4.4.2 Definition of TISP and PISP

Using the considerations of Section 4.4.1, we can now define the two provider segments as follows:

- A TISP (Telecommunication Internet Service Provider) is an enterprise that possesses a network as well as an infrastructure of its own. This own network and infrastructure includes virtually “everything”, i.e. starting from the local loop over backbone and links to other backbones to peerings with other network providers etc. Hence, the TISP segment certainly includes the former monopolists, as they became the only ones having a transmission network of their own after the market has been deregulated. Additionally, there are enterprises that have used the opening of the market for building networks of their own. These enterprises usually offer on their fixed network IP services as well as voice and phone services. As already mentioned, all TISPs offer their services originally to the PISPs, but by means of forward integration the may reach the end customer directly as well.Typically, these providers possess also the toughest stamina in the market. They possess the largest customer base and are able to deal relatively easy with their telephone subscribers as potential IP customers. Moreover, these enterprises possess sufficient financial background to survive some tough times, too.
- The PISPs (Pure Internet Service Providers) basically own nothing of the TIPSs’ possessions. Especially they miss a network infrastructure of their own and therefore have to rent one from TISP enterprises. Instead, their equipment is service-specific (e.g. web servers). Moreover, these enterprises usually operate call centers, help desks and hot lines in order to care for the customers. The customer ought to be confident in the quality of the offered service and wants to be treated politely and promptly in the case of errors or problems. Current market conditions allow for the customer to choose among many similar offers or to change the provider, even if the transparency of the market has significantly decreased since the deregulation due to hard price battles among the enterprises.‘

4.4.3 Example for a TISP/PISP Structure

Figure 20 illustrates the TISP/PISP structure with an example including one TISP and two PISPs in order to reflect the considerations of the previous sections. On the one side, the vertical structure is presented (i.e. who draws which service from whom), but the cost structure and cost flow is illustrated as well.

The TISP acts as an access provider and offers three services with different bandwidths:

- T3 rental line with Internet access (44 Mbps)
- ADSL Internet access (256 kbps downstream)
- rental line without Internet access (2 Mbps duplex)

The first service offers Internet access via T3 line. Target customers for this high-speed dedicated line into the Internet are providers that are able to produce further services using this access. The second service includes Internet access with ADSL on the last mile. The access provider (TISP) offers this service to the Internet provider ($PISP_2$) and enables him thus to offer Internet access with ADSL to his end customers. The third service is a pure rental line, i.e. an end-to-end connection without Internet access. This service is drawn by “Customer 3” in order to connect to sites of his enterprise directly (thus creating a MAN). Through this service, the access provider reaches directly the end customers, from whose point of view the offered TISP service is conceptually located within the upper provider level.

The Internet Provider ($PISP_2$) offers two services with different bandwidths:

- Internet access via T3 line
- Internet access via ADSL

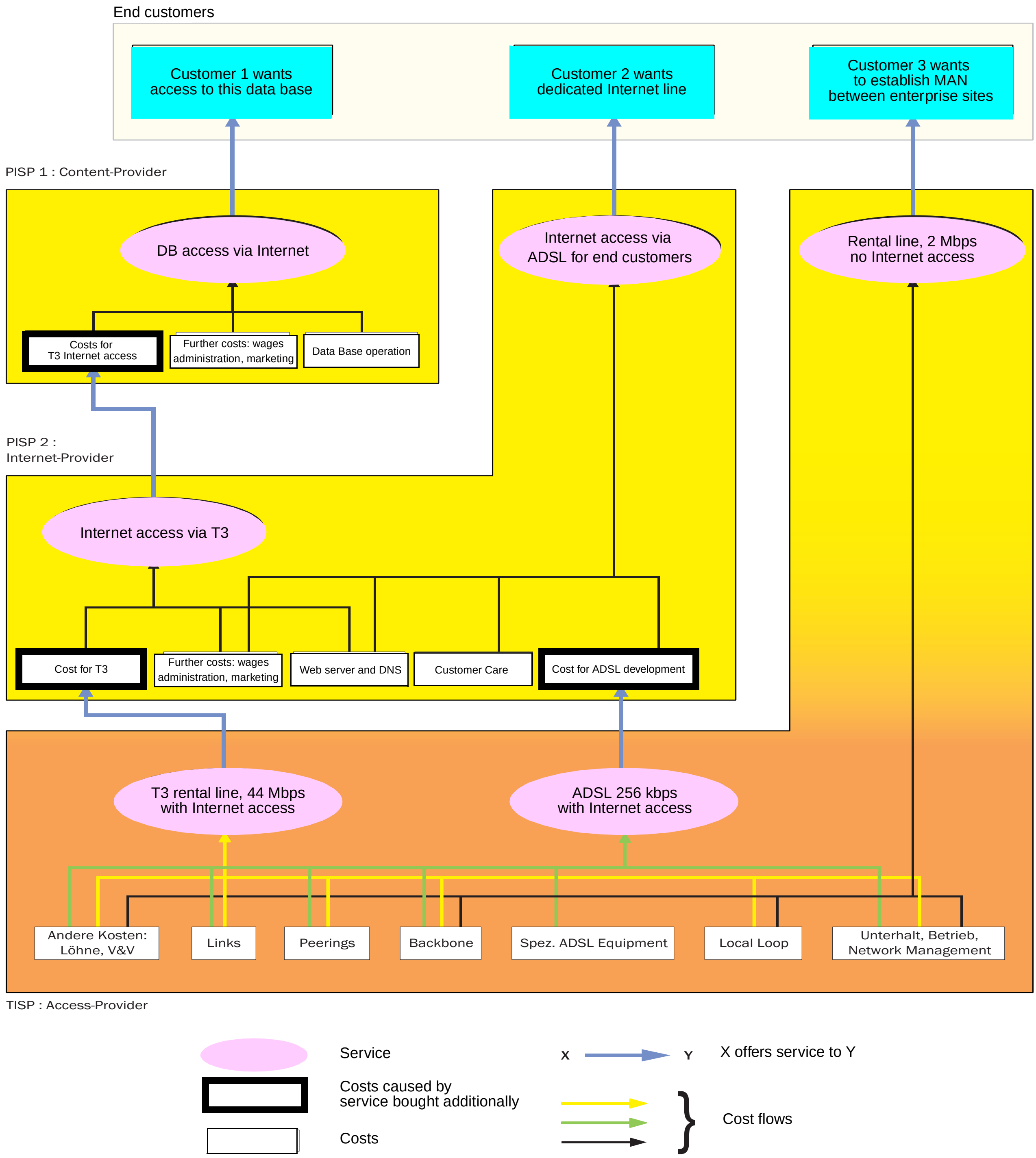


Figure 20: Example for Provider Segmentation

Both $PISP_2$ services are based on TISP services which allow the physical connection. In order to offer Internet access, the physical access is not enough, instead specific equipment (e.g. web server) as well as additional operational units like customer care etc. In our example, the Internet Provider $PISP_2$ offers its T3 access only to a content provider $PISP_1$. Generally it is also possible for it to reach the end customers directly. The ADSL access obviously is interesting for the large segment of private customers, represented here by “Customer 2”.

The content provider ($PISP_1$) represents the last hierarchy level. He offers (for the sake of simplicity) only a single service, i.e. web access to a data base. Central for the content provider are the expenses for data acquisition and operation of the data base. Moreover, he has to develop a so-called web interface in order to enable his customers to access the data base. Another possibility is to allow the virtual data base access for free and subsidize it with different income sources, e.g. through advertising or peering agreements with further enterprises. But the most important prerequisite for the content provider is a fast connection between his data base and the Internet, as provided by $PISP_2$ in this example.

Regarding the cost flow it is shown that via the services the cost flow from the bottom to the top, i.e. from the producer to the consumer. The access provider (TISP) has a different cost structure than the Internet Provider ($PISP_2$). The different cost types for the ADSL access are not visible to the Internet Provider, but are hidden within the “cost for ADSL development”. The cost types (or cost categories) will be explained in much more detail in the following Section 5 where the new cost model is being developed.

5 Cost Model

5.1 Basic Cost Model

This section describes the basic approach for ISP cost modelling as used within the project. Later on, we will have to distinguish between a model for TISPs and a model for PISPs. Of course, it is possible to unify these two cases, but the resulting model might soon become too complex to handle. Therefore, we prefer to specify two separate models which obviously will differ only in terms of cost categories, cost locations and certainly cost units. The mapping of cost to cost units is performed basically in the same way.

Defining a universally valid ISP cost model to be used 1 to 1 by each ISP is not possible. A cost model for a specific ISP always has to be individual. Hence, our approach mainly develops a framework and demonstrates which cost typically are to be considered as soon as IP based services are concerned. To adapt this general framework to specific providers is way beyond the project goals and will be performed only with a specific example as case study.

The cost model we have developed may be characterized as modified full cost accounting, where the modifications mainly concern cost categories and cost locations. They have turned out to be necessary in order to allow an exact cost allocation. The basic point of view starts from network elements (NE) which are used by services either partially or totally. The cost of a service per NE are determined according to the load put on the NE by the service. Of course, this requires that respective measurements can be performed at the NE, otherwise it might be necessary to use suitable estimates.

5.1.1 First Step: Cost Categories (CoCa)

Full cost accounting distributes the common cost of a cost category among the cost locations, and afterwards their sum per cost location is calculated in order to map these common costs per cost location onto the cost units. Hence, all common costs per cost location are mapped as a whole, which is too inflexible for our purposes. Therefore we put cost categories together into groups, where a group consists of those costs that belong together either because of their vicinity within the company or their logical similarity. Introducing such groups allows to sum the common cost per cost group and per cost location and distribute the sum afterwards among the cost units. Hence, it is possible to use different distribution keys per cost location and thus distribute the common cost with finer granularity. If within one cost location all groups use the same distribution key, this is identical to classical full cost accounting where only one distribution key per location is used.

Cost categories are subdivided into direct costs and common costs. Direct costs are allocated directly to the cost units, common costs flow across the cost locations to the cost units. The boundary between single and common costs should be drawn as exactly as possible, i.e. direct costs should be allocated without using estimations, equivalences etc. Assume e.g. that certain equipment is used only for realizing one specific service (or service class), for example the costs of a video server for video on demand. Moreover one could also allocate content-based costs (i.e. licence fees for the movies) directly to the cost unit “video on demand”. In this case, it is not correct to declare these content-based costs as common costs and distribute them via cost locations to all other services, as this could be viewed as cross-subsidizing and is not consistent with the principle of causality-oriented cost allocation.

Table 2 and Table 3 demonstrate the basic procedure of cost allocation using hypothetical examples. Note that in a very strict view one would have to distinguish between two different tasks performed by cost location accounting and cost unit accounting. I.e. cost unit accounting distributes the direct costs among the cost units, cost location accounting distributes the common costs of all cost categories among cost units. Here, both these tasks are performed simultaneously.

It is important to note that for each cost category two similar tables have to be produced. Of course it is possible that a specific cost category consists of either single or common costs only. In this case, one of the two tables can be omitted.

Direct Cost for Cost Categories ABC			
Influenced Cost Unit	**Fixed Cost per Cost Unit**	**variable Cost**	
		Parameters	**Function**
Service A	2,000	Number of Customers for Service A	S-curve
Service A Service B	5,000	Monthly Data Volume per Customer A and B	Monthly increase by 2%
Service C	20,000	none	none
...	...	...	...
...	...	...	...

Table 2: Direct Cost for Cost Categories ABC. Note that generally for each cost category a table like this has to be produced

Common Cost of Cost Categories ABC			
Influenced Cost Unit	**Fixed Cost per Cost Unit**	**variable Cost**	
		Parameters	**Function**
Core	100,000	Number Backbone Routers	Linear
M&S[a]	50,000	none	none
...	...	...	...
...	...	...	...
...	...	...	...

a. Marketing and Sales.

Table 3: Common Cost for Cost Categories ABC. Note that generally for each cost category again a table like this has to be produced

5.1.2 Second Step: Cost Locations (CoLo)

A second difference to traditional full cost accounting is the distinction between fixed and variable costs at the cost locations. On the one hand, this allows flexible direct costing, on the other hand in the telecommunications business fixed as well as variable costs play an important role: Before a new service class can be offered at all, typically huge one-time investments are necessary that must be amortized over a couple of years. Within this service class, services have to be determined that cover the full costs (consisting primarily of fixed costs). Should, after some time, a new service within this class be offered, then usually no (or only minor) additional investments are necessary. In this case, marginal costing is very interesting, and this requires the distinction between fixed and variable costs.

One could as well make further distinctions while distributing fixed and variable costs per group of cost categories and cost locations using different keys (especially in case of very high costs, e.g. for transatlantic link (TAL) or access to the commercial Internet in the US). For example, the fixed costs for these links could be distributed equally between all services of the service class “Internet access”. The variable costs, on the other hand, could be distributed according to the effective oversea traffic as caused by each of these services (if respective measurements exist).

The cost locations belonging to the transport are defined according to the logical way of a data packet travelling from A to B. Hence we start with the local loop, then backbone, links to further backbones etc. Additionally, cost locations rooted in the company itself have to be referred, too, e.g. customer care, administration etc.

Again, the basic procedure is demonstrated in Table 4. Experience shows that cost locations use to have only a fixed part of common costs, therefore only fixed costs are shown in the table. Note again, that for each group of cost categories one such table per cost location has to be prepared.

Cost Category Group “Transmission” and Cost Location “Core”		
Influenced Cost Units	**Sum for this Cost Category Group**	**Mapping Parameter**
Service A	2,000,000	Estimated Backbone Data Traffic per Customer A
Service B	1,000,000	Estimated Backbone Data Traffic per Customer B
Service C	not influenced	
...	...	...
...	...	...

Table 4: Mapping from Cost Locations to Cost Units. For each Cost Category Group and each Cost Location a Table like this has to be produced.

Accounting handles the mapping from cost locations to cost unit accounting. Conceptually, this task has been moved to this second step, in order to leave enough flexibility in the third step for defining and designing services and service classes. This freedom is necessary in order to take account also of market segmentation and customer requirements and hence to be able to offer optimal services.

5.1.3 Third Step: Cost Units (CoUn)

Generally speaking, the offered services provide the cost units. Similar services can be put together to form service classes. E.g. pure Internet access may be such class, comprising analog, ISDN and ADSL access as three individual services.

Classification may be based on different factors, like technical requirements, market segmentation and customer requirements. More than one service per class is also helpful in better utilization of the network resources. It must be observed that introducing a new service within one class may have direct (negative) consequences for another service from a different class, as the new service may steal capacity of the existing services and hence cause bottleneck behavior in certain NEs which may shrink the efficiency or quality of other services. Therefore, pure direct costing may be dangerous within one service class.

As already mentioned, classification can be performed according to factors like

- geography
- technical requirements (e.g. bandwidth of local loop, ISDN vs. ADSL etc.)
- market segments
- basic services
- value-added services, either network dependent ones (like SMS, voice mail etc.) that require changes in the network basis, or network independent ones (ticket service, e-shopping, telebanking) that do not require specific abilities of the network basis, but are performed outside the network as additional service (usually offered by PISPs).

Within service classes, as far as possible basic services and products should be defined, comprising those services that shall cover the full costs totally. If at a later stage new services within the same classes are introduced, the additional costs will be very close to the marginal costs, i.e. the increment for the new service will be relatively small.

5.1.4 Summary

The three steps as presented are well-suited for putting together all cost-relevant information about an ISP. Figure 21 demonstrates the functional view of these steps. It is shown how the direct costs influence the cost units directly, whereas the common costs are distributed indirectly via the cost units.

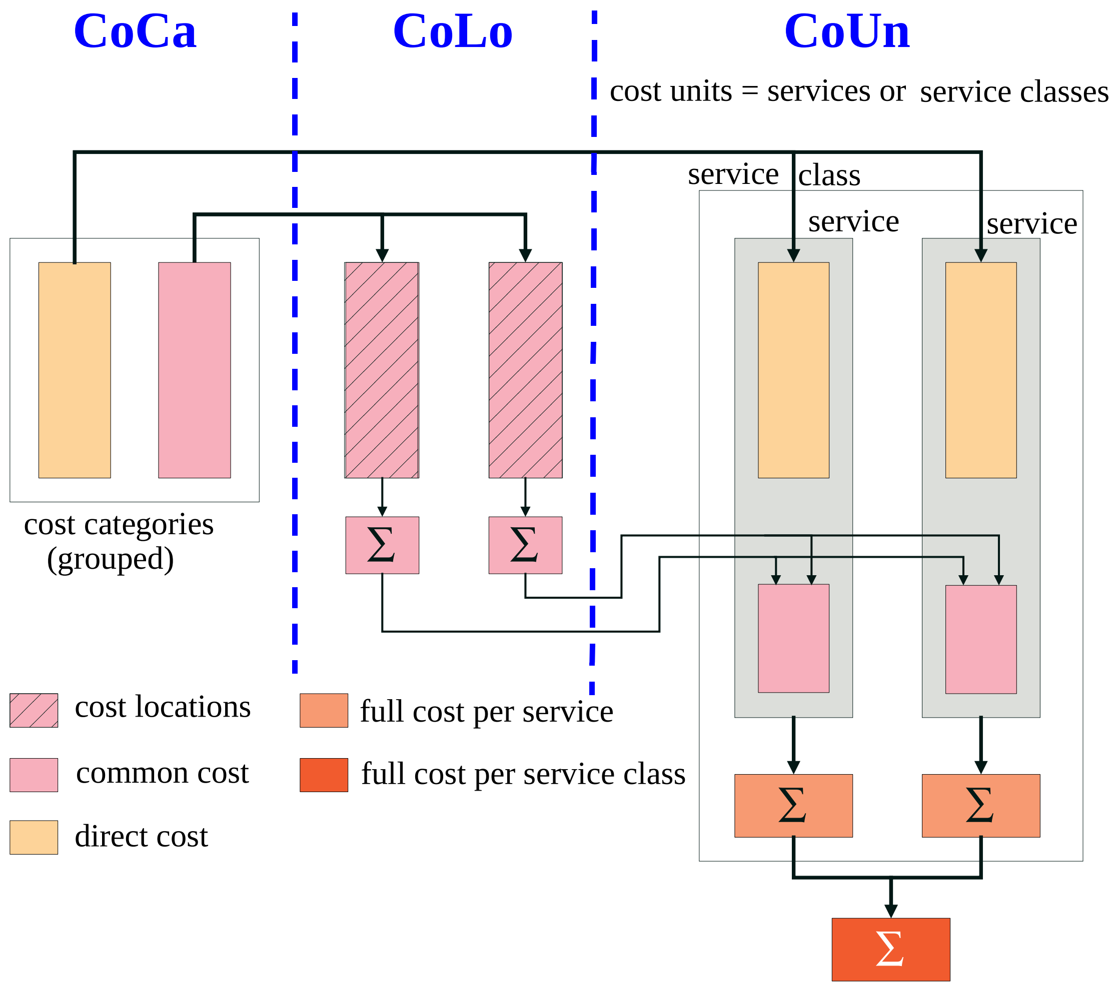


Figure 21: Cost Model: Functional View

Finally, these three steps may be summarized using a spreadsheet as shown in Figure 22.

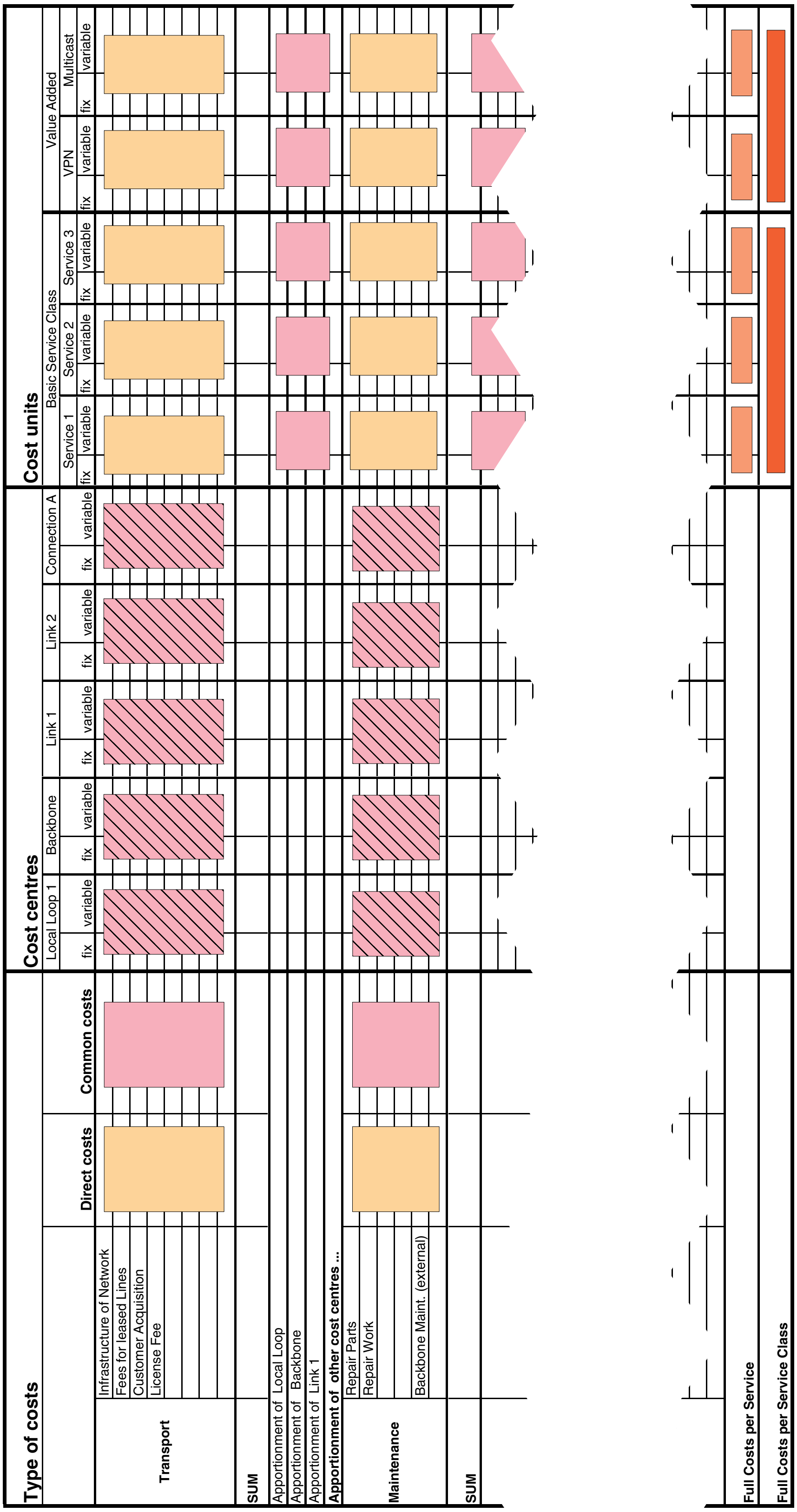


Figure 22: Spreadsheet

5.2 TISP Cost Model

5.2.1 Cost Categories

As demonstrated in Section 5.1, the cost categories are put together in cost groups, i.e. each cost group comprises different cost categories. As the cost categories represent the most important input parameters of the model, they ought to be determined as clearly as possible.

Transmission

This group contains all cost categories relevant for the transmission of data packets. These cost categories are:

- Network Infrastructure
  These costs comprise all NE necessary for transmission purposes, i.e. routers, switches, hubs, optical fibre, coax cable, links, multiplexers etc. Note that these costs typically are huge one-time investments (sunk costs). Amortizing the sunk costs runs over several years, hence they represent an important component of the fixed costs. Moreover, costs for the network infrastructure may also contain bank rates for financing the huge investments.
- Line Rental
  Typically, an TISP will not possess all links and cables himself, but will have to rent some of them from other carriers. For European TISPs, e.g., renting the TAL is of special importance.
- Peerings
  This category contains all costs coming from peering agreements with other providers.
- Customer Acquisition
  Here, the main cost for a TISP concern the infrastructure for the last mile, i.e. mainly building costs (cable etc.)
- License fees
  Customers will have to pay for all or at least a part of license fees, like e.g. for WLL. It will depend on the business philosophy, how much the customer and how much the share holder will have to pay.

Operation and Maintenance

This group contains costs for maintenance and repair. Concerning the maintenance, each business has got the choice between own repair teams or outsourcing agreements with special companies. The latter case is contained within the cost category “external agreements”

- Spare Parts
  All parts that must be renewed during the repair process.
- Repair costs
  These consist mainly of the wages for the necessary staff.
- External Agreements
  This category contains the costs from outsourcing repair work. Typically, a fixed amount comprises smaller repair activities, whereas the renewed material is calculated separately.

- Testing
  These costs come from testing NEs before integrating them into the network infrastructure.
- Network Management
  Of special importance for our project context are the cost for running a charging and accounting tool which are to be found here.
- General Maintenance Costs
  Mainly wages.

Further Costs

- Wages
  These wages are for administration staff.
- Immobiles
- Calculatoric Costs
- Other Cost

5.2.2 Cost Locations

Within the cost locations, fixed and variable costs are separated. The cost locations have been identified by tracing packets travelling through the network: local loop, edge, backbone. Moreover, on its way the packet may have contact to some servers like proxies, DNS servers etc. Furthermore, there are cost locations not directly linked with data transport, but nevertheless representing clearly separated parts of the company, e.g. administration and customer care.

- Local Loop or Access
  This is the real access network, without customers' equipment. Those costs may be modeled as direct costs and thus are flowing directly to the cost units.
- Edge
  This represents edge routers and further equipment. The border between access and core has to be defined clearly once and not changed any more, in order to avoid confusion.
- Backbone or Core
  Here we find the backbone and important links to other networks, including the peering agreements.
- Administration and Customer Care
  This comprises the marketing as well as the sales department, call centers etc. Larger ISPs may decide to define cost locations of their own for the marketing.

5.2.3 Cost Units

Cost units are those products and services that are offered by a provider. Cost units are divided into classes which contain services with somehow similar characteristics.

Internet Access

- Analog Dial-In
- ISDN Dial-In
- ADSL Access

Direct Access to the Backbone

- T1, T3
- ATM

Value-added Services

- Virtual Private Network
- Multicast

6 Case Study: Parameters and Accounting

The case study provides an example for the cost model of a TISP. After stating some simplification and assumptions, the model is realized using the ANALYTICA software. Afterwards, the results are evaluated and interpreted.

6.1 Simplifications and Assumptions

Realizing a cost model for a real ISP has to deal with some difficulties, as the necessary data usually serve as the secret core of each ISP and therefore are not publicly accessible. As a first step, we aim at developing the cost model of a virtual ISP with data being as realistic as possible. The most important data have been taken from two Swiss ISP, a major one and a small one.

6.1.1 Network

First of all, our TISP needs a network to be operated. Figure 23 shows the backbone topology that forms the basic of the example TISP. The topology has been chosen such that all major scientific centres in Switzerland are connected, especially the different universities and computing centres.

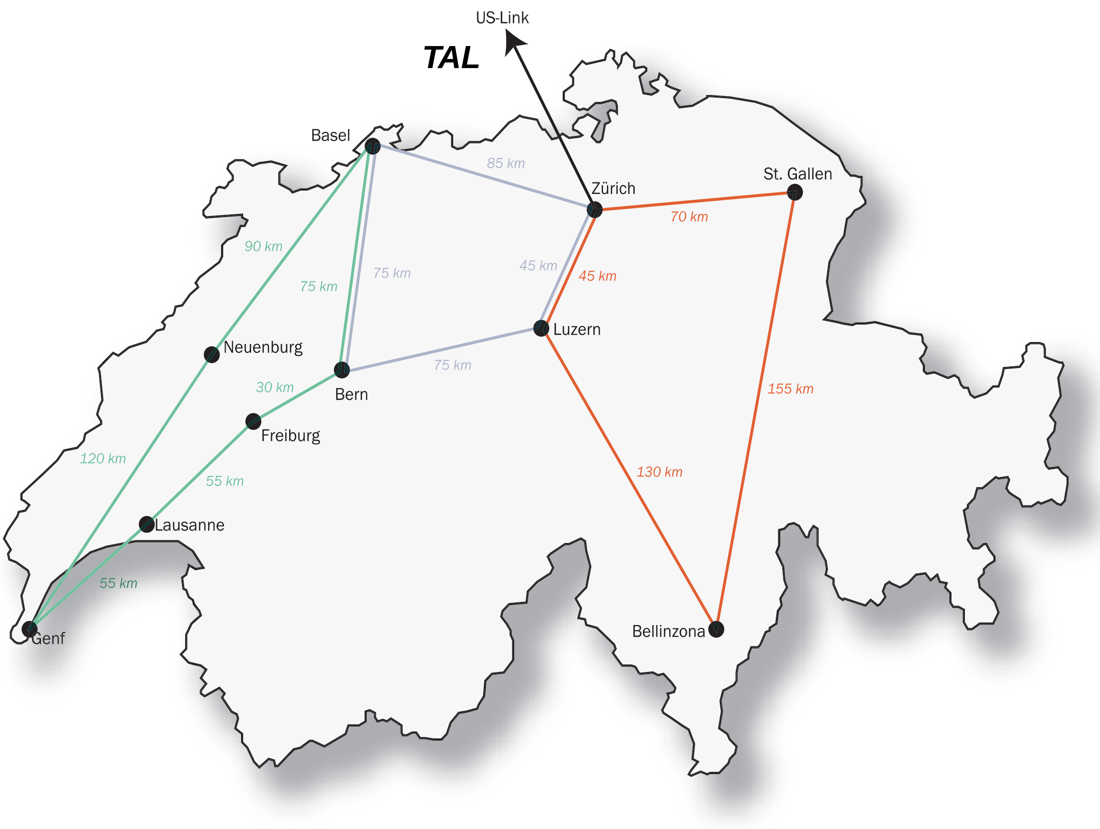


Figure 23: TISP Backbone Topology

The backbone consists of three rings and ten nodes representing the locations of research centers in Switzerland. The distances between the nodes correspond to the direct distances. The node in Zurich has special meaning as the router for the TAL are located here which allow the connection to the commercial Internet. In addition to the link, it is necessary to provide the respective peering agreements to a suitable provider, e.g. UUNET. For our

TISP we assume that access to European sites runs via the US, too. Hence, peerings between European providers are not necessary. As concerning the bandwidth of the TAL as well as of the peering, we assume it to be 64 Mbps.

Each connection between two backbone nodes is operated using two fibre cables, one for each direction of the link. Hence, the total length of a ring is twice the total physical length, see Figure 23. For redundancy and security reasons the links Basel-Bern and Zurich-Lucerne have been doubled, i.e. use four fibre cables per link. At each node, usually a backbone router with two line-cards each is operated, whereas in Basel, Bern, Lucerne and Zurich four line-cards are necessary. Finally, each 50 kilometers, every fibre cable needs an optical regenerator in each direction. The technology of the backbone is based on SDH/SONET with STM-16/OC-48 and a theoretical maximal transmission rate of 2.4 Gbps. Without going too much into detail, we assume that an IP-network is operated over the SDH/SONET. Moreover we can suppose that on the backbone there is always sufficient capacity for the customer traffic volume available. This assumption allows us to neglect expensive network dimensioning.

There is at least one edge router connected to each backbone router, and at least one ATM switch connected to each edge router. Moreover, each ATM switch is connected to two or more DSLAMs. We assume that to be the minimal configuration per backbone node as it is sketched boldly in Figure 24. Additional equipment may be added as shown.

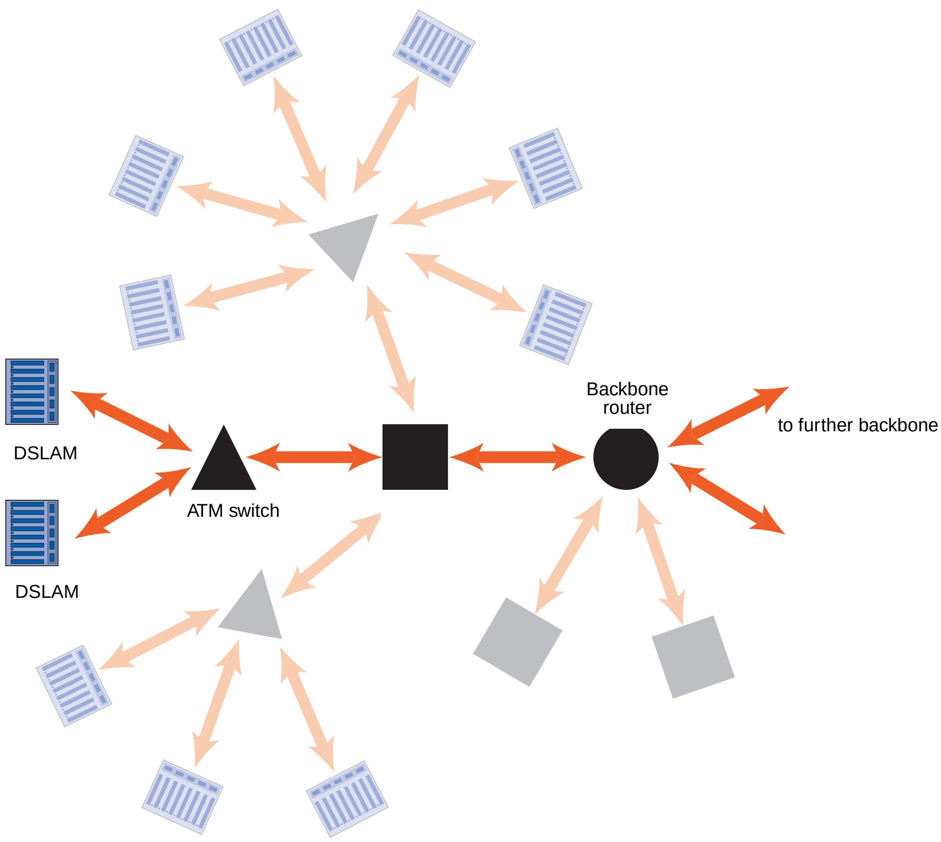


Figure 24: Backbone Node Configuration

The idea behind this hypothetical IP network consists in making all major departments of Swiss universities accessible for broadband ADSL. Figure 25 shows the ADSL access in greater detail. Note that for each customer, one ADSL line card has to be inserted in the DSLAM. The costs for ADSL customer equipment are not considered in this cost model.

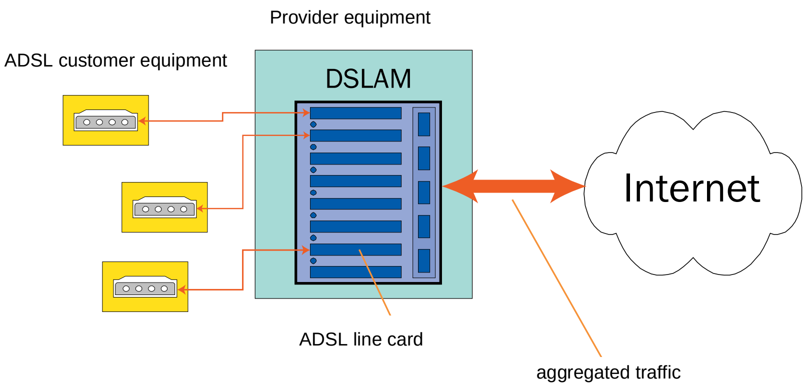


Figure 25: ADSL Access

In the next step it has to be determined how much of additional equipment (besides the minimal configuration) is necessary to make the customers accessible. In Switzerland, the number of customers is[1] approx. 4000 – 6000, making some 400–600 customers per node on average. The ADSL downstream capacity has been assumed to be realized with 8 Mbps, and the connection between the DSLAM and the ATM switch with 622 Mbps.

According to [3] it is custom to operate the DSLAM with a multiplexing rate of 10:1 or even 20:1. This allows us the following rough calculation:

$$M = \frac{a \cdot r}{b}$$

with *M* being the maximal number of customers per ATM switch, *a* the downstream bandwidth of the ATM connection, *r* the multiplexing rate and *b* the downstream bandwidth of the ADSL. For *a* = 622 Mbps, *r* = 10 and *b* = 8 Mbps, this yields approximately *M* = 779. As each backbone node is configured to access a maximum of 600 customers, the capacity of an ATM switch with one ATM connection per node can be assumed to be sufficient.

The number of DSLAMs can be estimated in analogy. Per DSLAM we can certainly plug in 128 customers with 8 Mbps downstream[2], giving approximately five DSLAMs per backbone node on average. Table 5 gives a summarizing overview for the necessary network equipment. It is assumed that the whole network is set up with all mentioned Network Elements (NE), even if this might result in certain overdimensioning at the beginning.

1.according to Swisscom estimates
2.Note that the CISCO 6120 IP switch, e.g., has 32 ports with space for one 4-port line-card each. Hence, by using the maximal capabilities of this switch, far more than 128 ADSL ports may be used. See [4] for further information.

Table 5

Network Elements	estimate	+%	total
Backbone routers	10	–	10
Edge routers	12	+ 20%[a]	15
ATM switches	10	+ 50%[b]	15
DSLAMs	50	+ 50%	75
Optical Regenerator	30	–	30
Length of fibre cable for all three rings	2210 km	–	2210 km

a. Note that certain regions, e.g. the Zurich location, requires more edge routers than the average. Because of their huge capacity, it is sufficient to estimate this supplement to be 20%.

b. The number of ATM switches depends directly on the the number of connected DSLAMs. As the physical distance between DSLAM and customer equipment is restricted to a maximum of 3–5 km, we have to assume far more DSLAMs and ATM switches.

6.2 Cost Categories

Having defined the network and its topology, now the annual costs per NE have to be determined. Estimates for the most important parameters have been delivered by a major Swiss ISP but cannot announced publicly here. At least we can summarize the cost categories and their subdivision into single and common cost according to Table 6. Section 6.3 deals with breaking down the common cost into cost locations. Note that the single cost of the TAL as well as the peerings are distributed among the cost locations in a usage-based manner, based on respective measurements that are performed for each individual customer at her network access point.

Table 6

Cost Category	Single Cost	Common Cost
Backbone Routers		✔
Edge Routers		🗐
ATM Switches		🗐
DSLAM[a]	🗐	
Optical Regenerator		🗐
Fiber Cables		🗐
ADSL Line-Card per ADSL customer	🗐	
repair and spare parts, 2.8%[b] in total		🗐

Table 6

Cost Category	Single Cost	Common Cost
Transatlantic Link and Peerings	🗐	
Basic Software, IT Tools and Network Management Systems		🗐
Basic Operation		🗐
Customer Care		🗐
Overhead, 5%[c] in total		🗐
Other Costs[d]		🗐

a. To be used exclusively for ADSL customers.
b. according to internal discussion
c. according to ISP estimates
d. e.g. additional infrastructure like web servers etc. plus any other cost that have not been mentioned at another place.

As further simplifications in our example there are no groups of cost categories, as grouping would not make sense for this relatively low number of cost categories and locations. Therefore, the distribution of the common cost is equivalent to traditional full cost accounting. This does not make the approach of grouping cost categories as developed in Section 5.1.1 meaningless, especially for the case of modelling a real ISP with much more cost categories and locations.

Basically we have assumed that the time horizon for the evaluation is limited to two years and that the network infrastructure does not change within this period, i.e. follow-on investments are neglected. Moreover we assume that the network is in full operation from the very first day onwards, without any delays due to technical problems or customer development. Rising costs due to inflation are negotiated as well.

Our estimates for the NE include depreciation and a share of interests for the necessary capital for financing the investments. All investments are depreciated linearly over a period of two years, i.e. the annual expense remains constant over this period. This approach appears to be the most pragmatic one, but note that there are certainly possible alternatives (cf. especially the LRIC model in Section 4.2)

The cost for the TAL and the peering to UUNET have been estimated according to discussion with ISPs and are composed according to Table 7.

Table 7

Element	Monthly Cost in CHF
Line Rental, 64 Mbps	205,000
Local Loops and ATM Ports	24,000
Peering to UUNET, 64Mbps	130,000

It is obvious that renting links becomes cheaper and cheaper, i.e. it is possible to get more capacity for less money. This already has led to trading “free” bandwidth, e.g. [5]. On the other hand, it can be justified to assume that the fixed costs within the two year period do not change, as it is custom to make one-year contracts, and the monthly financial expenses are to remain constant. Hence the provider is not capable of having profit from the decreasing market prices for bandwidth. Note that it is exactly here where the new contract form of “Forward Pricing” [6] comes into the play where the annual contract prices are continuously adapted. E.g. a contract for a certain capacity is placed over five years, where the annual price for the following year is determined as follows: Each quarter the monthly price according to the market is measured, averaged over the whole past year and projected to the next year. If the prices for the transatlantic are calculated according to this new method, they must be adapted over time. Such considerations are reflected in the sensitivity analysis of Section 8.2.

6.3 Cost Locations

The cost model for our example consists of the following four cost locations:

- Core
- Edge
- Access
- Administration, Marketing and Sales (AMS)

The following Table 8 defines the distribution of common costs to cost locations:

Table 8

Cost Categories	**Cost Locations**			
	Core	**Edge**	**Access**	**AMS**
Backbone Routers	100%			
Optical Regenerator	100%			
Fiber Cables	100%			
Edge Routers		100%		
ATM Switches			100%	
Repair and Spare Parts[a]	(–)	(–)	(–)	
Basic Software, IT Tools and Network Management Systems	60%	20%	20%	
Basic Operation	70%	10%	20%[b]	
Customer Care				100%
Overhead[c]	(–)	(–)	(–)	(–)
Other operational costs	10%	10%	10%	70%

a. Total cost for network infrastructure of the individual cost location plus 2.8%.

b. The operational cost of the many DSLAMs are significantly higher, as they require on-site work, whereas the operation of the few edge routers usually can be performed remotely.
c. Added to the total cost at the very end.

The distribution of the network infrastructure among the cost locations does not need further comment. Repair and spare parts are calculated as percentile supplement of the respective share of the network infrastructure. Expenses for the basic software are significantly higher in the core area. The same is valid for basic operation cost. Customer Care is attributed completely to AMS. The other operational costs are distributed equally over the first three cost locations, but are accumulated at A&CC.

According to [7], this distribution of common cost may now assumed to be constant and is no longer varied in the following. The pre-calculation only needs varying single costs.

6.4 Cost Units

Our example model investigates two different services:

- ADSL Service, i.e. access to the network via the ADSL technology as described in Section 6.1
- IP-direct Service for business customers, i.e. business customers generating high amounts of traffic are connected directly to the Internet via the ATM switch.

The number of potential business customers for the IP direct service in Switzerland has turned out to be approximately 600. The ADSL service primarily aims at Swiss university departments. Estimates for this customer type yield a number between 5000 and 6000. Note that we do not consider narrowband ADSL access for private customers as it is about to be realized in Switzerland as of autumn 2000.

The first step in cost unit accounting consists of distributing the common cost (from the cost locations) among the cost units. This is based on Table 9.:

Table 9

Cost Locations	**Cost Units**	
	ADSL	**IP-direct**
Core	to be calculated	to be calculated
Edge	50%	50%
Access	90%	10%
Administration and Marketing	70%	30%

The distribution to the cost location “Core” is based on the traffic volume of the two services that takes place on the backbone. Therefore, we get the share for cost unit “ADSL” according to

$$\mathrm{Cost}_{\mathrm{ADSL}} = \frac{\mathrm{traffic}_{\mathrm{ADSL}} \cdot \mathrm{cost}_{\mathrm{Core}}}{\mathrm{traffic}_{\mathrm{ADSL}} + \mathrm{traffic}_{\mathrm{IP\text{-}direct}}}$$

and accordingly for the core share of IP-direct service

$$Cost_{IP-direct} = \frac{traffic_{IP-direct} \cdot cost_{Core}}{traffic_{ADSL} + traffic_{IP\text{-}direct}}$$

with

$traffic_{ADSL}$ traffic of all ADSL customers on the backbone (in MB)

$traffic_{IP-direct}$ traffic of all IP-direct customers on the backbone (in MB)

$cost_{Core}$ total sum of cost at cost location “Core”

The other three cost locations (featuring a significantly smaller share of common costs) are distributed with fixed percentage rates to the cost units. Certainly, it could upgrade the result if the common costs of these three cost locations among the two cost units were distributed according to measurements, too. In our example, it is only measured how much of the generated traffic remains on the backbone. These realistic measurements as performed by ISPs like Switch allow only to distribute the common cost of the core. The functionality of the edge routers is used by both services equally. The access area is rather different, as this cost location is mainly used by the ADSL service. Concerning AMS, we have assumed that the IP-direct services contributes significantly less than ADSL.

In contrast to the common cost, single cost are assigned directly to the cost units. This distribution has to take place in a usage-based manner per definition (otherwise these costs were common costs) and is based on Table 10.

Table 10

Direct Costs	**Cost Units**	
	ADSL	**IP-direct**
Fix cost of transatlantisc link and peerings[a]	in proportion to transatlantic traffic of the ADSL customers	in proportion to transatlantic traffic of the IP-direct customers
ADSL-Line Card	per customer	–
DSLAM	number DSLAMs[b]	–

a. The distribution is performed according to the distribution of the Core cost location to the two cost units (see above).

b. In our model, the number of DSLAMs is constant and therefore not directly dependent of the number of customers.

6.5 Further Input Parameters

Completing the cost model requires a couple of more parameters which are not related to the cost categories. They include e.g. the size of customer segments as well as parameters characterizing the customer behavior. In detail they are

- number of ADSL customers
- number of IP-direct customers
- traffic volume per month per ADSL customer
- traffic volume per month per IP-direct customer

- Percental proportion of ADSL traffic on backbone
- Percental proportion of IP-direct traffic on backbone

These parameters will have a significant influence on the cost composition of the cost units. On the other hand they represent exactly the figures that are to be determined least exactly, not to speak from predicting them over the next two years. They will be described and investigated in much more detail in Section 8. The following Table 11 summarizes all parameters mentioned in this chapter and indicates their possible variation in the course of the two-year period investigated here.

Table 11

Parameter	Variation?
Backbone Routers[a]	–
Optical Regenerator[a]	–
Fiber Cable	–
Edge Routers[a]	–
ATM Switches[a]	–
Repair and Spare Parts	–
Basic Software, IT Tools and Network Management Systems	–
Basic Operation	–
Customer Care	–
Overhead	–
Further operational expenses	–
Fixed Line Rental for Transatlantic Link (TAL)	🗐[b]
Local Loops and ATM Ports	🗐[b]
Peering to UUNET	🗐[b]
ADSL-Line Cards	–[c]
DSLAM[a]	–
Number ADSL customers	🗐
Number IP-direct customers	🗐
Traffic volume per month and ADSL customer	🗐
Traffic volume per month and ADSL customer	🗐
Percentual Proportion of IP-direct Traffic on Backbone	🗐
Percentual Proportion of ADSL Traffic on Backbone	🗐
Breaking Down Common Costs to Cost Locations	–
Breaking Down Cost Locations to Cost Units	–

a. Includes annual costs as well as the number.
b. Summarized to a fixed tariff unit and varied afterwards.
c. The number of ADSL line cards is directly dependent on the number of ADSL customers. The costs per line-card are assumed to be constant..

7 Case Study: Analytica Model

Having defined all important input parameters and clarified the fundamental cost flow, the next step consists of implementing the cost model using suitable software. As for simple spreadsheet calculations it is not necessary to develop an own program including a user interface, we have decided to use existing software. Among different possibilities, the final choice has been Analytica 2 by Lumina Decision Systems [8].

In this section, only a very brief introduction in Analytica will be given; for more details we refer to the referenced web-site where the tutorial and the extensive user guide may easily be downloaded.

For understanding the models it is sufficient to introduce the concepts of nodes and modules. Analytica provides nine node types, but we restrict our usage to three of them (the others partially are generated dynamically and refer e.g. to sensitivity and importance analysis). Figure 26 introduces the relevant node types.

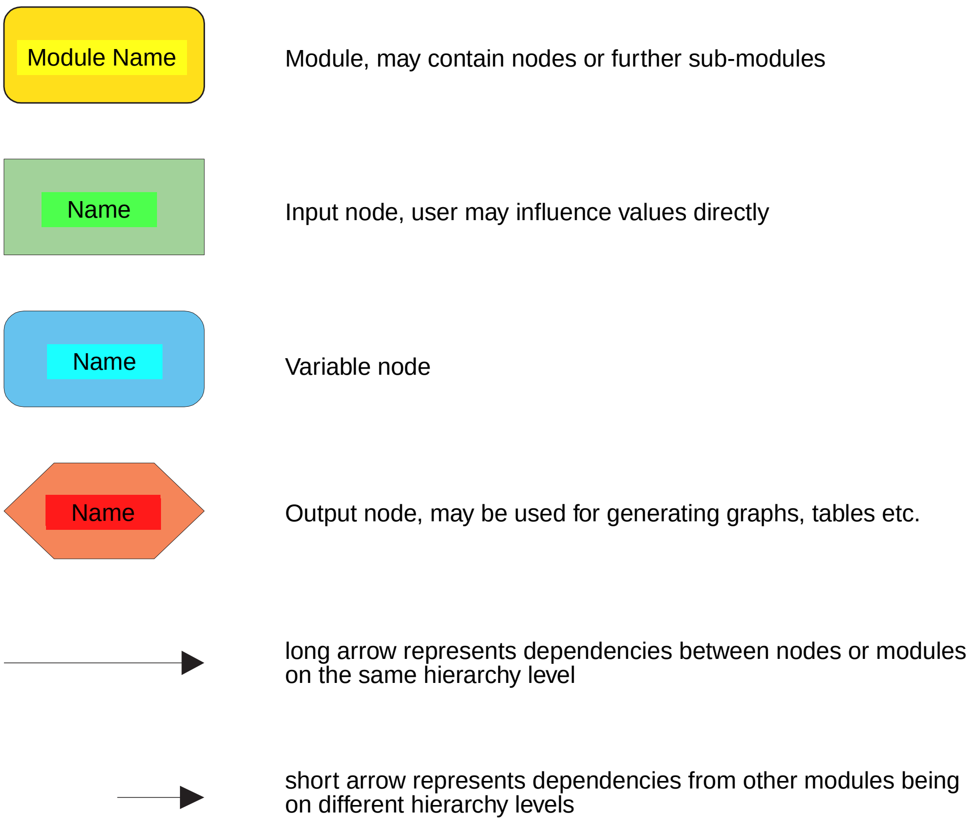


Figure 26: Analytica Node Types

The functions are defined directly in the variable nodes and output nodes. The short or long arrow, resp., visualizes the dependencies between modules and nodes. The possibility of defining modules is very helpful for structuring the model in a hierarchical manner.

The top level of the model hierarchy is shown in Figure 27. The COST CATEGORIES module contains the definitions for direct and common costs. It is easy to recognize how the common costs are distributed via cost locations, whereas the direct costs are flowing directly towards the cost units. The size of the different cost types depend on the network topology and the market situation (see respective arrows). From the logical point of view, the generated traffic volume should influence the cost types as well, but for our purposes we have decided to distribute the single cost to the cost units within the cost unit module. The sharing of the common costs takes place in the COST LOCATIONS module. For attributing the network infrastructure costs, input from the network module is necessary.

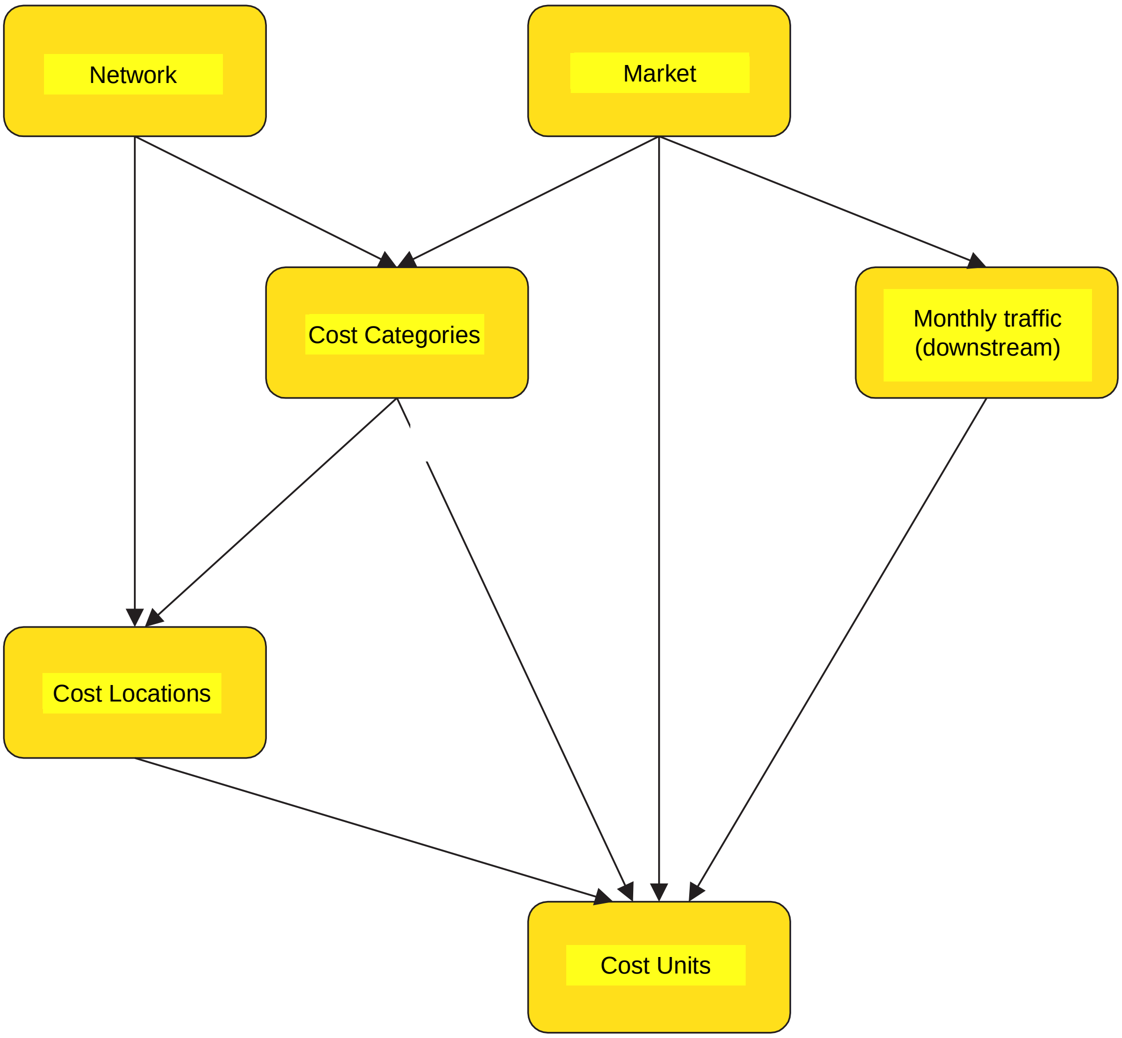


Figure 27: Top Level of the ICOMO

The first module to be looked at in greater detail is the NETWORK module as shown in Figure 28. The input parameters of this module include the annual costs as well as the number of backbone routers, edge routers, ATM switches, DSLAMs, optical repeaters and fibre cables, and finally the total length of the fibre cables. As all of these parameters relate to further modules, too, they bear a small arrow on the right-hand side each. As a result, this module delivers the total network cost per year.

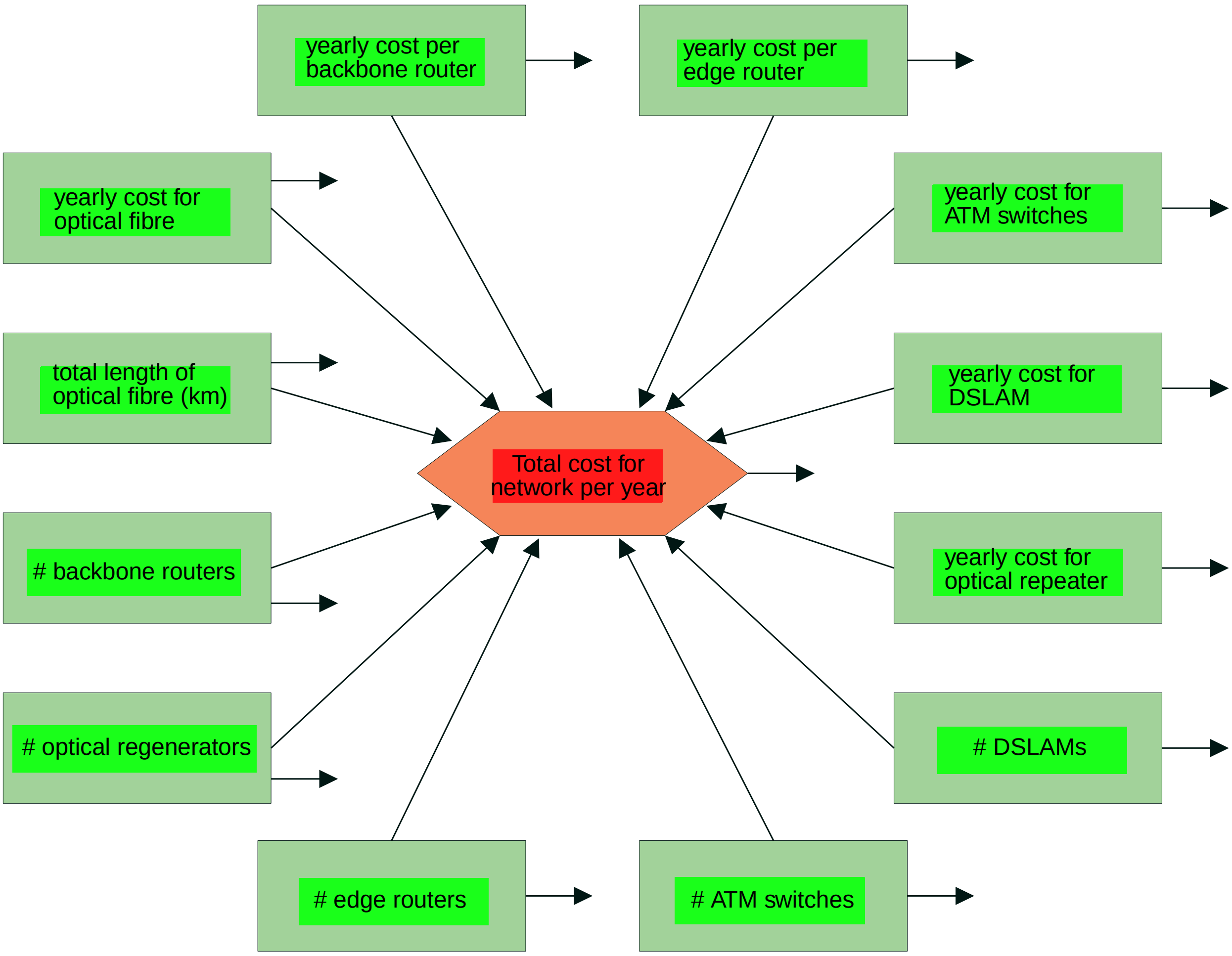


Figure 28: NETWORK Module

The next module concerns the market and is shown in Figure 29. In the context of market prognostics it is custom to simulate the increase of the market using a so-called “S curve”. The basic idea here is to distinguish the market development into three different phases [9], [10]:

- introduction phase
- growth phase
- saturation phase

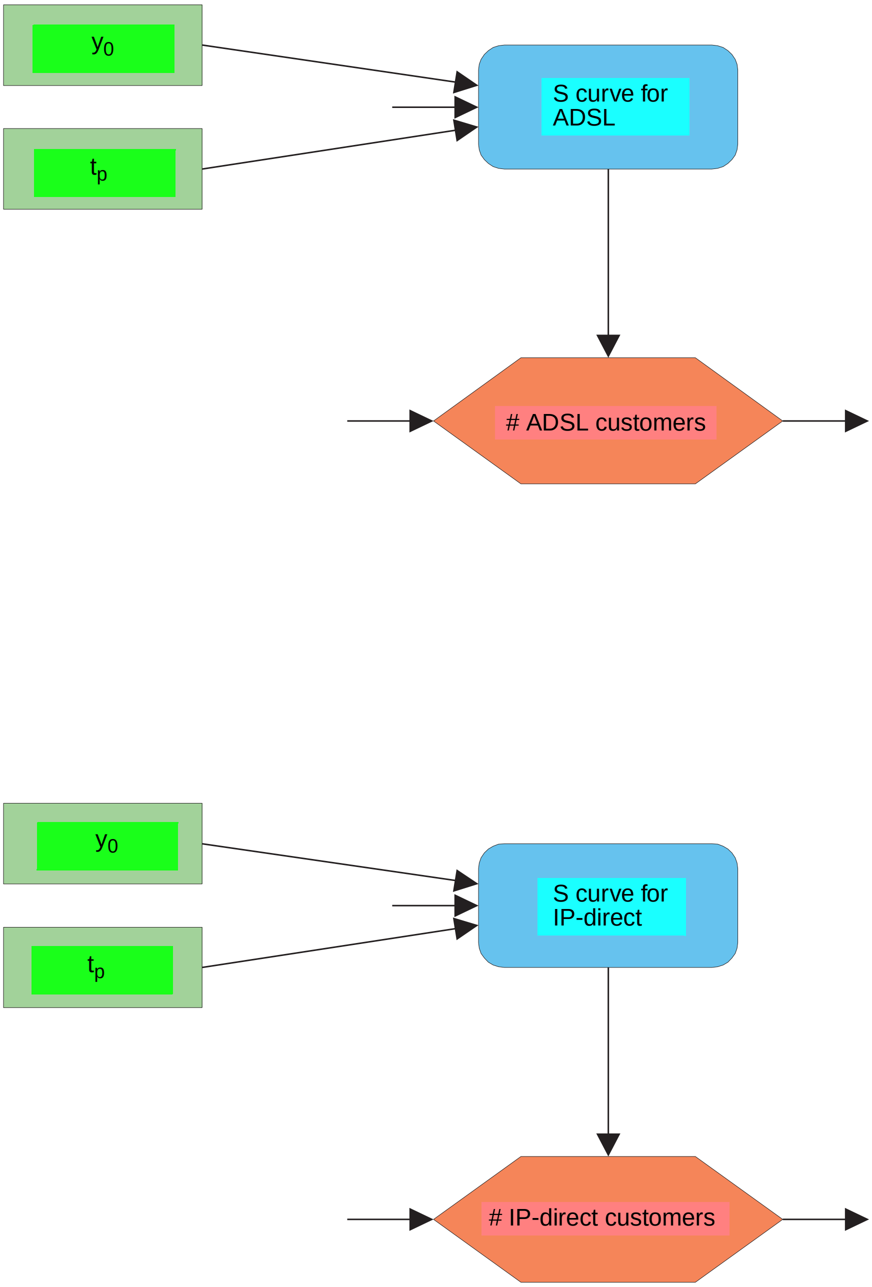


Figure 29: The MARKET Module

During the introduction phase of a new product or a new service it is assumed that the number of customers increases only slowly, whereas during the following growth phase the number of customers is supposed to grow rapidly. Obviously, not all companies will use a rapid penetration strategy, but in our example we can take that as an assumption, due to several reasons: ISPs are volume-oriented companies, having a huge proportion of fixed costs, compared to a small proportion of variable costs[1]. Therefore, the ISP should try to develop a clientele as rapidly as possible, in order to quickly reach the zone of profit. Secondly, the concurrence on this market is rather high at the moment, and thirdly the customers – especially in the ADSL segment – are very price-sensitive. Based on these facts, the growth phase ideally should have a rather steep shape. As in the telecommunication business, new technology enter the market very fast, it is realistic to assume a saturation phase following the rapid growth. Therefore, the resulting S-curves typically look like in Figure 30.

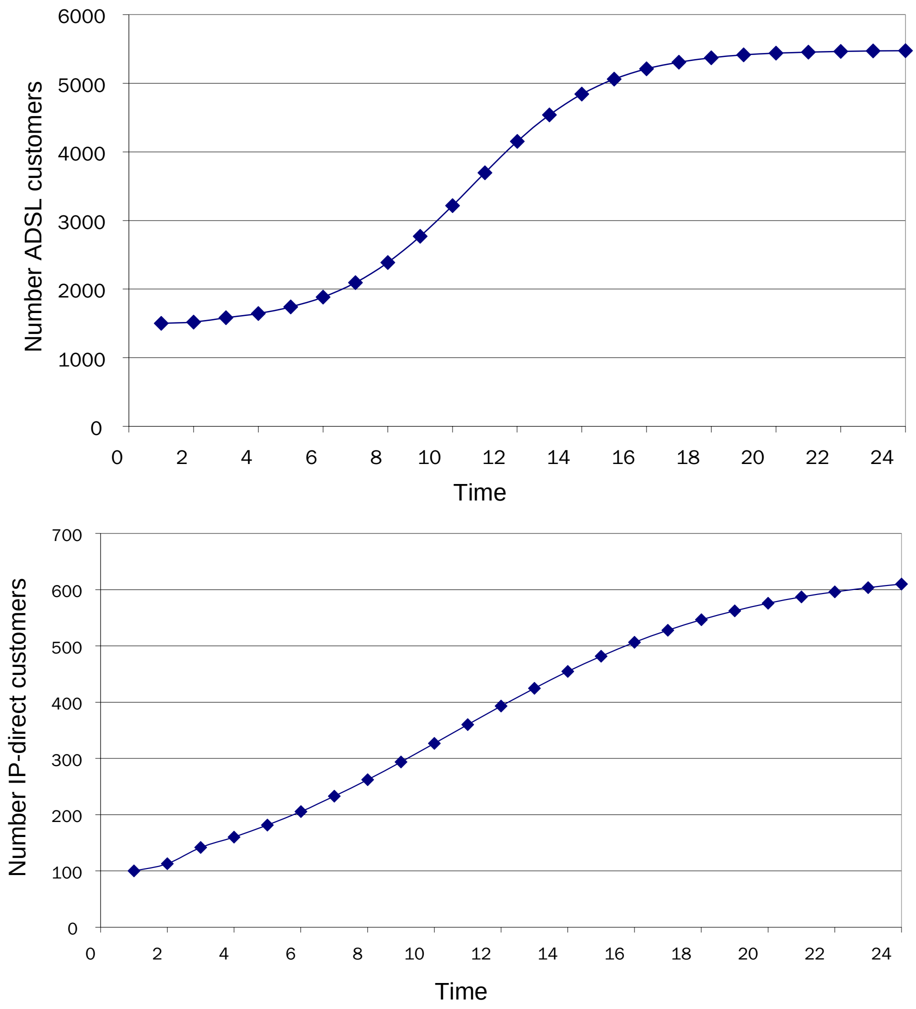


Figure 30: S-curves for the ADSL (above) and IP-direct (beyond) Segment

Note that the curve of the ADSL segment is significantly steeper than the IP-direct one, because in this segment the predominant strategy is an absorption strategy. Apart from that, both S-curves have an identical definition, differing only w.r.t. their input parameters which determine their shape:

$$y(t) = \frac{1}{1 + \left(\frac{y_0}{1 - y_0}\right)^{1,99 \cdot \frac{t}{\xi - 1}}}$$

where y_0 describes the initial size at time $t = 0$ and the shape parameter ξ determines the steepness of the curve.

1. see Figure 7

The next module to be investigated is the COST CATEGORIES module as shown in Figure 31. The structure of this module is rather straightforward, note that the left-hand side shows the annual costs, whereas the monthly costs are to be found on the right-hand side.

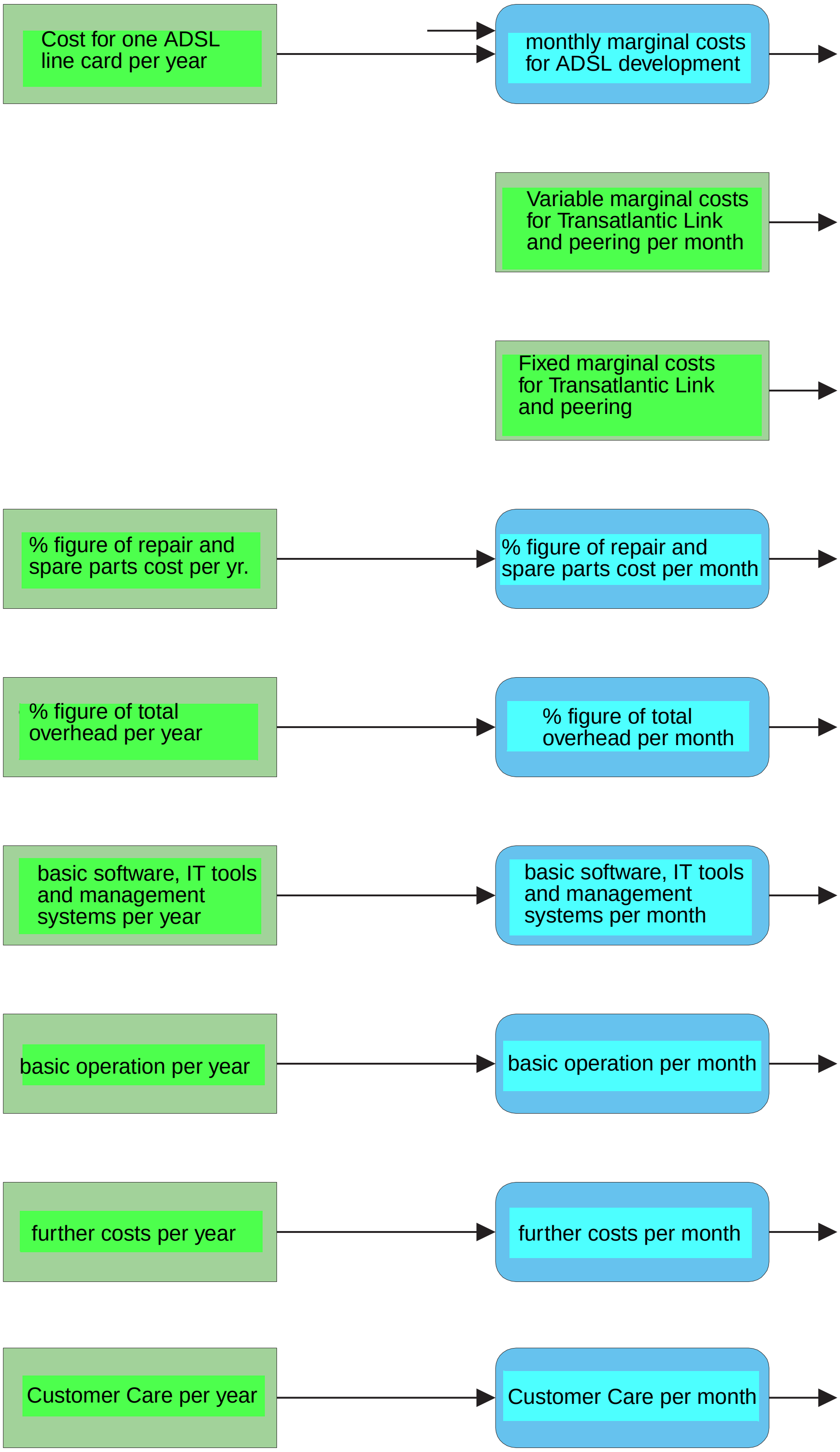


Figure 31: The COST CATEGORIES Module

The MONTHLY TRAFFIC module consists of two additional sub-modules for the ADSL and the IP-direct traffic as depicted in Figure 32

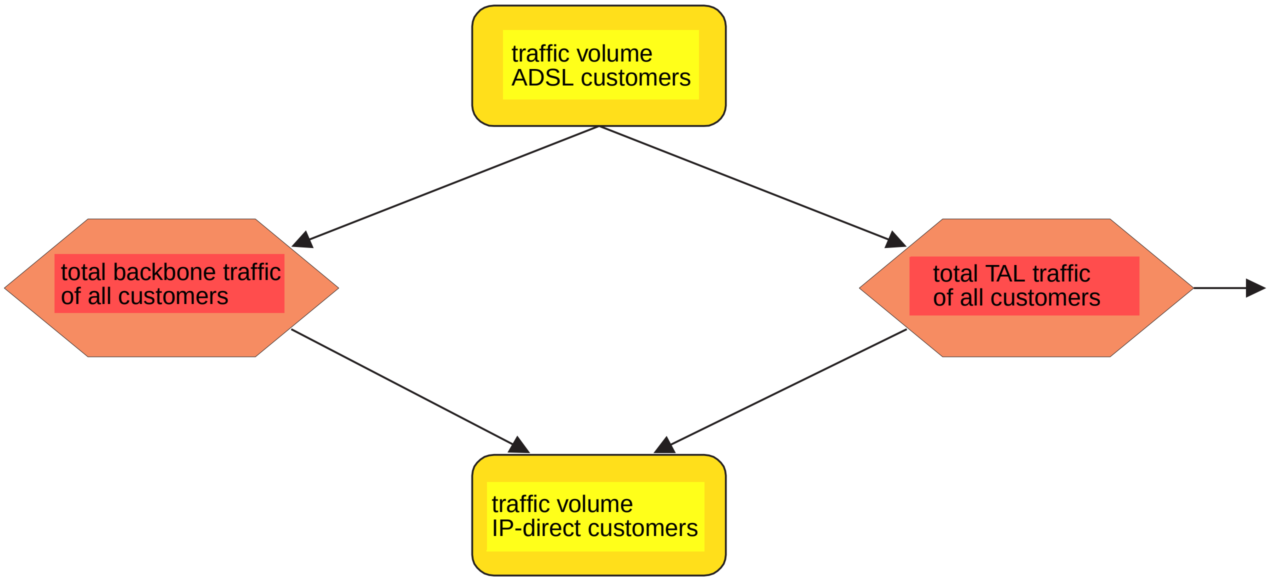


Figure 32: MONTHLY TRAFFIC Module

In our cost model, only downstream traffic (i.e. from the Internet to the customer) is treated, because typically downstream traffic is much higher than upstream traffic, as may e.g. be seen in the respective statistics [11]. The heavy fluctuations of the traffic in the course of time are not taken into account in this model.[1] It has been assumed that the network consisting of backbone, edge and access area has been dimensioned sufficiently generously. With a capacity of 2.4 Gbps there won't probably be a bottleneck on the backbone. Concerning the edge and access zone, the ATM technology with 622 Mbps used here appears to offer sufficient reserves. In the access area, broadband ADSL with 8 Mbps is used, whereas the IP-direct customers are connected directly to an ATM switch or an edge router. The TAL uses 64 Mbps. Note that the monthly data volume transmitted over that link by SWITCH sums up to approx. 5.1 – 5.9 TB/month[2]. As the SWITCH customers are comparable to the customers of our model, we can assume that in principle the traffic pattern on the TAL will possess comparable features. The total traffic volume on the US link hence should not exceed 6 TB/month, otherwise bottlenecks could appear, requiring an increase in capacity. In the reverse direction, it may be supposed that there won't be bottlenecks in the network otherwise.

We have already mentioned that the MONTHLY TRAFFIC module consists of two sub-modules defining the traffic for ADSL and IP-direct customers, resp. Both these sub-modules are shown in Figure 33:. Important input parameters include the monthly traffic volumes of each individual customers. Extensive discussions with ISPs have revealed that a distinction between the traffic on backbone and the US traffic has to be made. These considerations have been expressed in terms of the two "% on backbone" parameters. As an initial value, we may calculate with 60% on backbone traffic and 40% US traffic.

1. see Figure 9.
2. Volume corresponds to downstream January till June 2000. Since July 2000 SWITCH uses a new 155Mbps link.

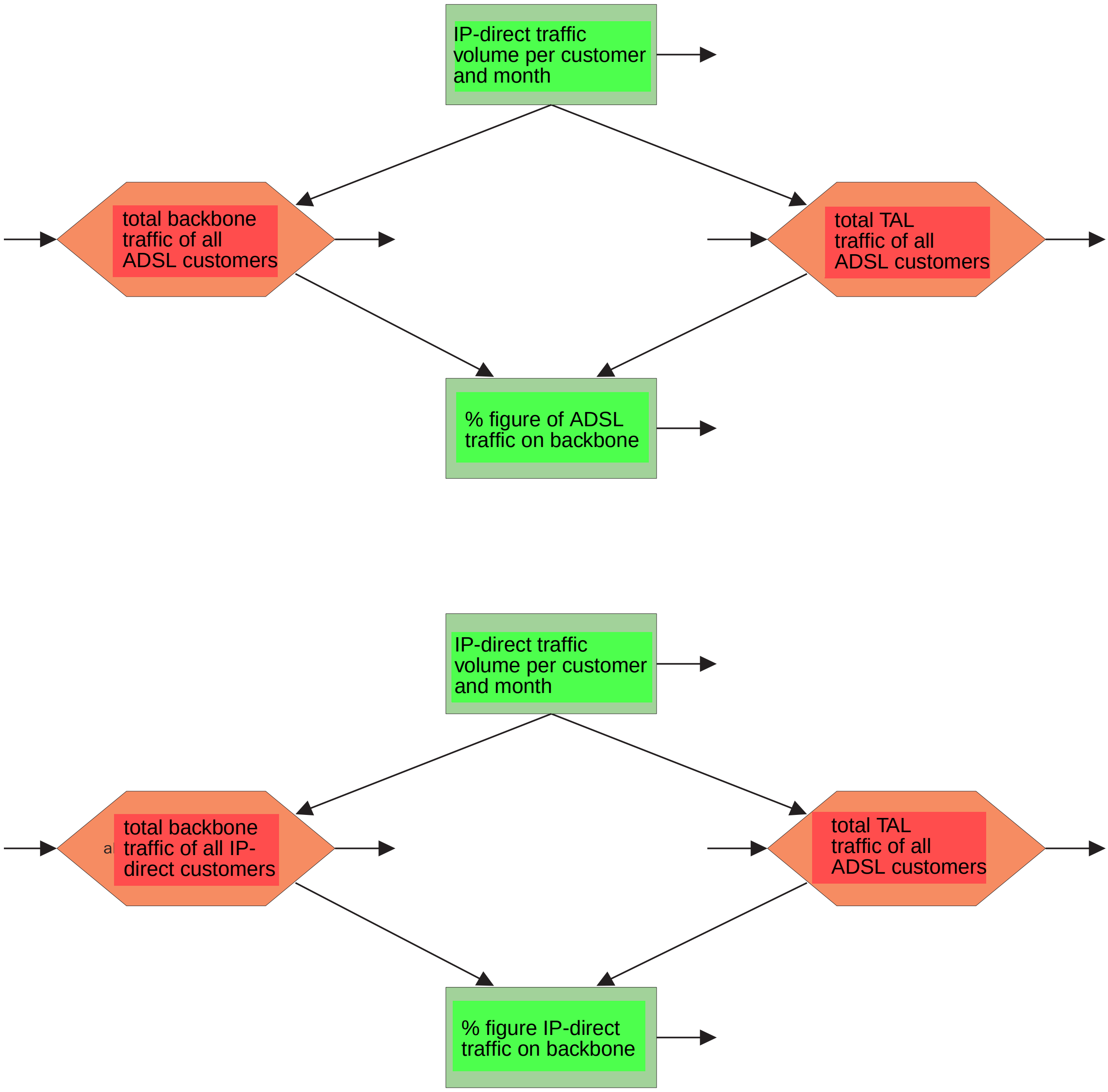


Figure 33: Submodules of the MONTHLY TRAFFIC Module

Next is the “Cost Location” Module. Here, each cost location has been modelled as a sub-module of its own and afterwards included into the Cost Location Module. As all these sub-modules are structured very similarly, Figure 34: shows as an example the submodule for the cost location (CoLO) “Core”.

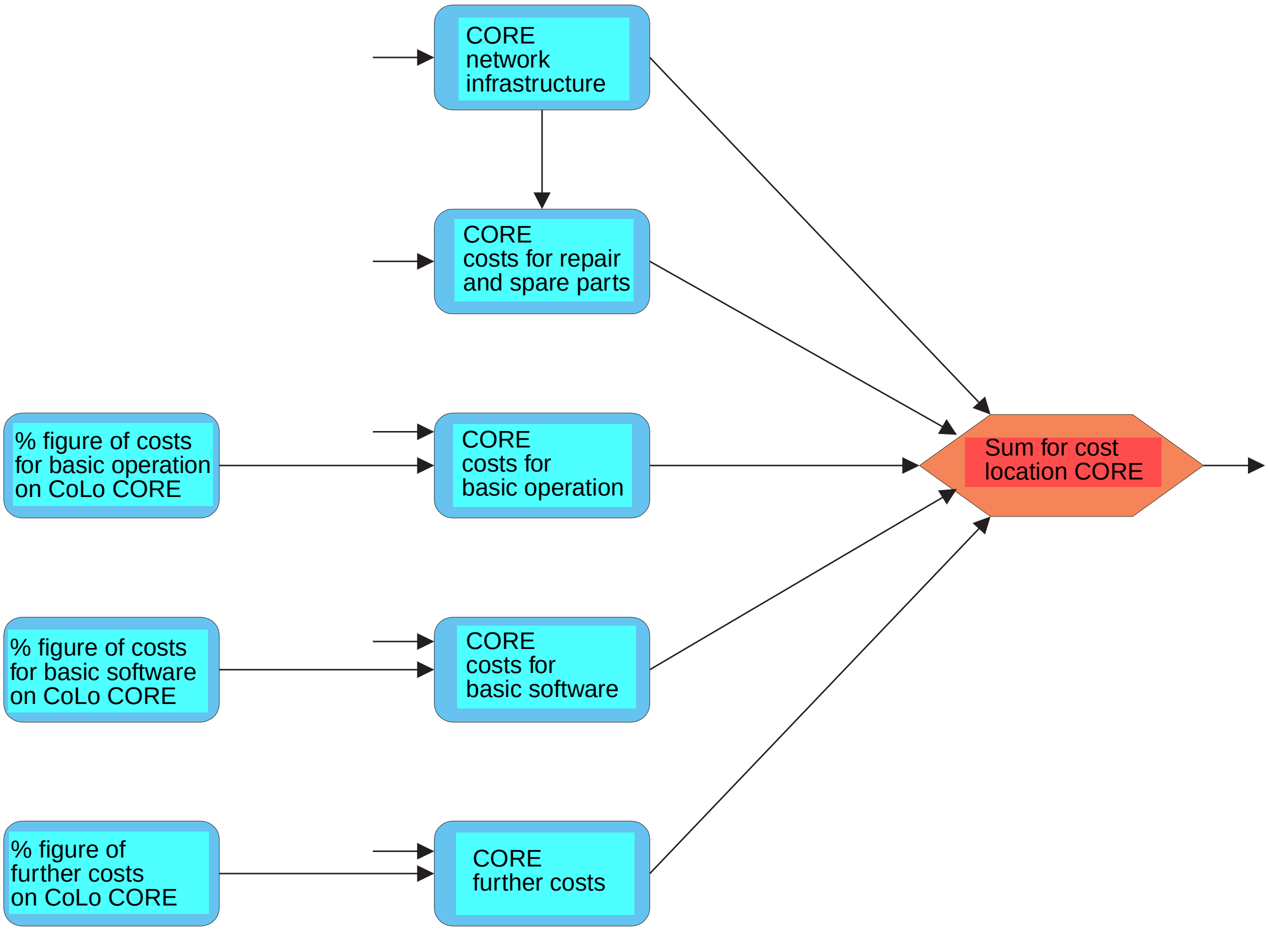


Figure 34: COST LOCATION Module

The last module is the COST UNITS module as shown in Figure 35. There have been defined two submodules for the two offered services.

Figure 35: COST UNITS Module

Figure 36 demonstrates the structure of the ADSL submodule. The IP-direct submodule is set up very similarly and is therefore not shown here. The left-hand side demonstrates the distribution of cost locations to cost units. The upper half concerns the determination of direct costs and their usage-based attribution. The resulting output values give the total cost as well as cost per customer.

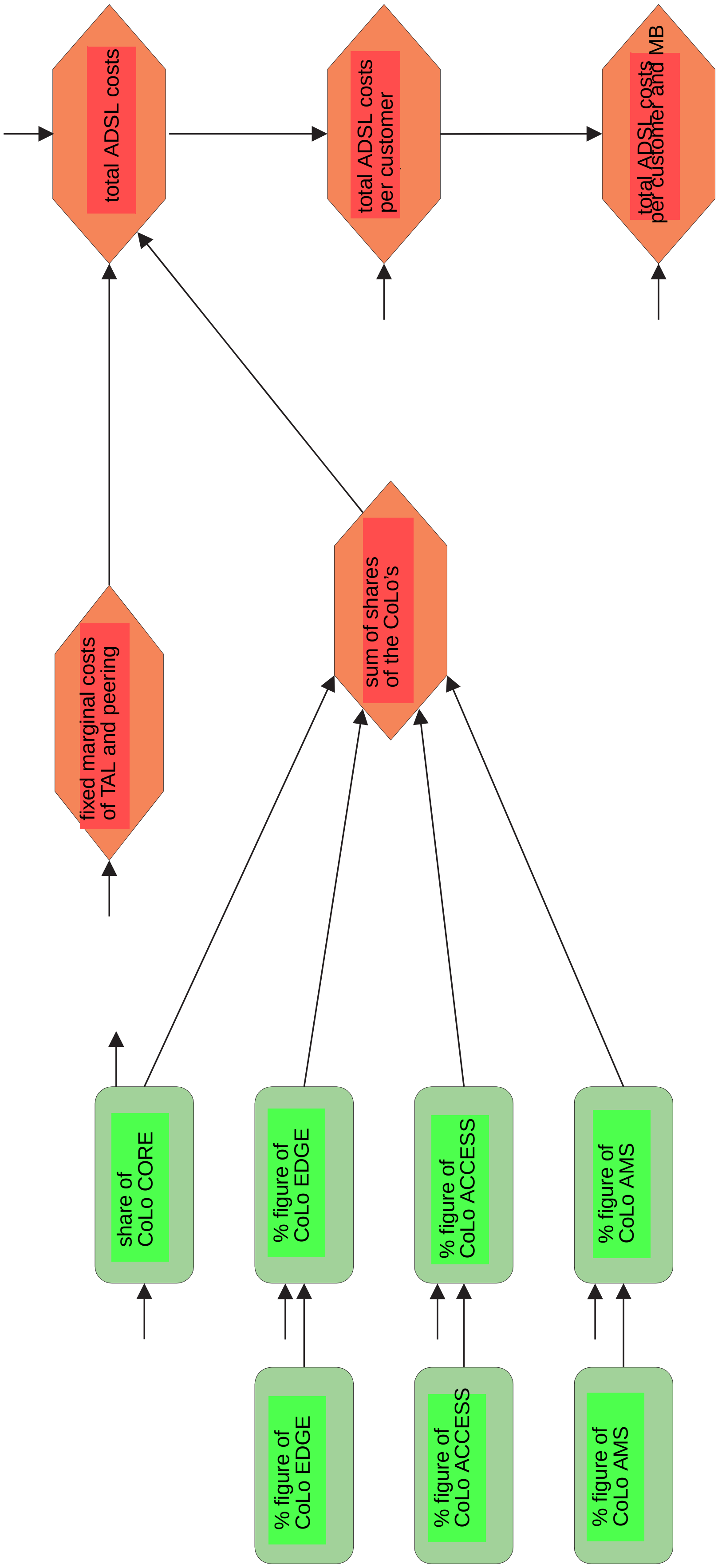


Figure 36: ADSL Submodules

8 Case Study: Parameter Analysis

This section investigates the variable parameters identified in Table 11. To this end, Analytica is capable of importance and sensitivity analyses.

8.1 Importance Analysis

The first step is to determine initial values for all parameters. Note that the only interesting parameters are those that may vary, because all other parameters cannot be influenced anyway. It is not possible to determine the initial values exactly, instead they may move within a certain interval. If the distribution within this interval is not known exactly, it can be approximated using the normal distribution, i.e. deviations from the mean value are possible in both directions. This assumption is valid for all parameters except for the costs of the TAL and the peering. It is extremely unlikely that the TAL costs will increase in the future, on the contrary more and more bandwidth will become cheaper and cheaper. Therefore, this parameter is modelled with a beta-distribution[1].

Table 12 summarizes the variable parameters, their initial values and the deviation interval. All values correspond to the first month of the period investigated.

Table 12

Variable Parameters	Mean Value	Deviation
Cost for TAL and peering	beta distribution with x=2, y=6, Lowerbound=300000 Upperbound=400000	
Number ADSL customers	1500	200
Number IP-direct customers	100	20
Traffic volume per ADSL customer in the first month	1000 MB	500 MB
Traffic volume per IP-direct customer in the first month	3000 MB	1000 MB
Proportion on backbone of ADSL traffic	0.6	0.1
Proportion on backbone of IP-direct traffic	0.6	0.1

It is assumed that the TAL and the peering cost contain no variable costs. Later on, we will investigate their variation during the sensitivity analysis. Concerning the number of customers, the deviation is allowed to be approx. 20%. Note that the most uncertain parameter in this analysis is the generated traffic volume per customer. Therefore, this number may fluctuate by around 50% of its mean value. On the contrary, the proportion of on backbone traffic may determined relatively exactly with 0.6, with only small possible deviation. The results of the importance analysis is depicted in Figure 37 or the case of total ADSL cost and in Figure 38 for the case of total cost for the IP-direct service. Note that in each case, a high value in the importance analysis corresponds to a high correlation between the respective input parameter and the final result, i.e. the total cost for ADSL or IP-direct, resp.

1. The market price for a 155 Mbps link (STM-1) between New York and Switzerland has been between 161,000 and 178,000 CHF per month as of 8/8/2000. Compared to that, for the old 64 Mbps link 205,000 CHF/month had to be paid.

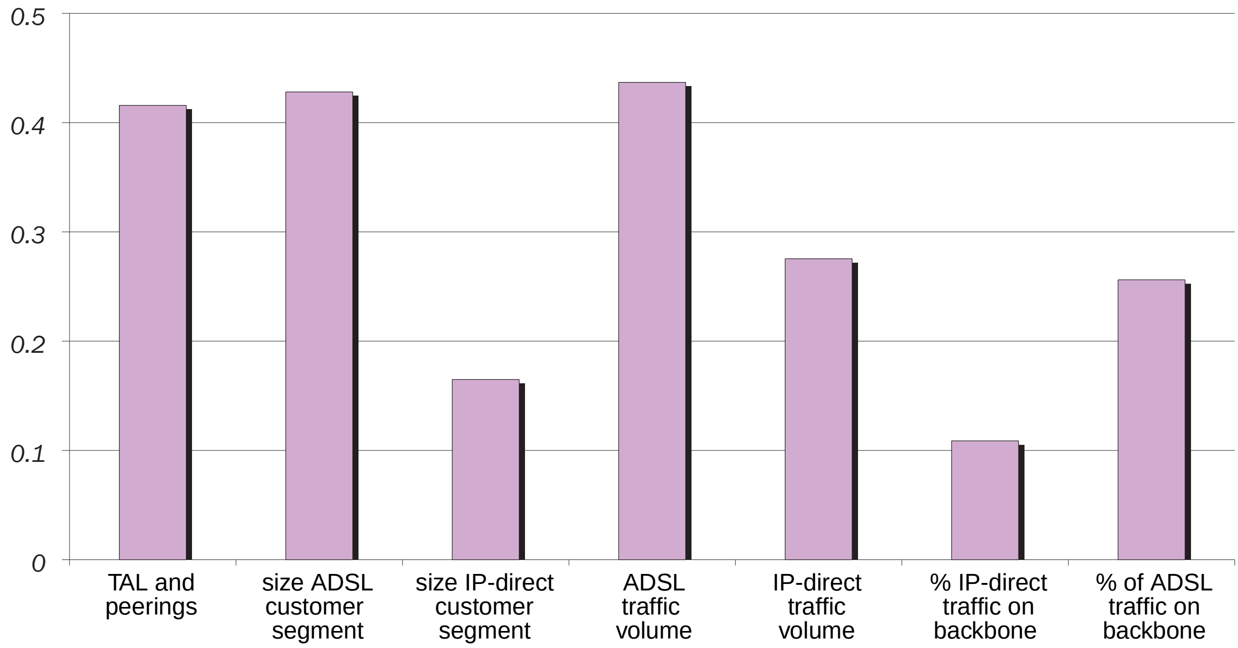


Figure 37: Importance Analysis of ADSL total costs.

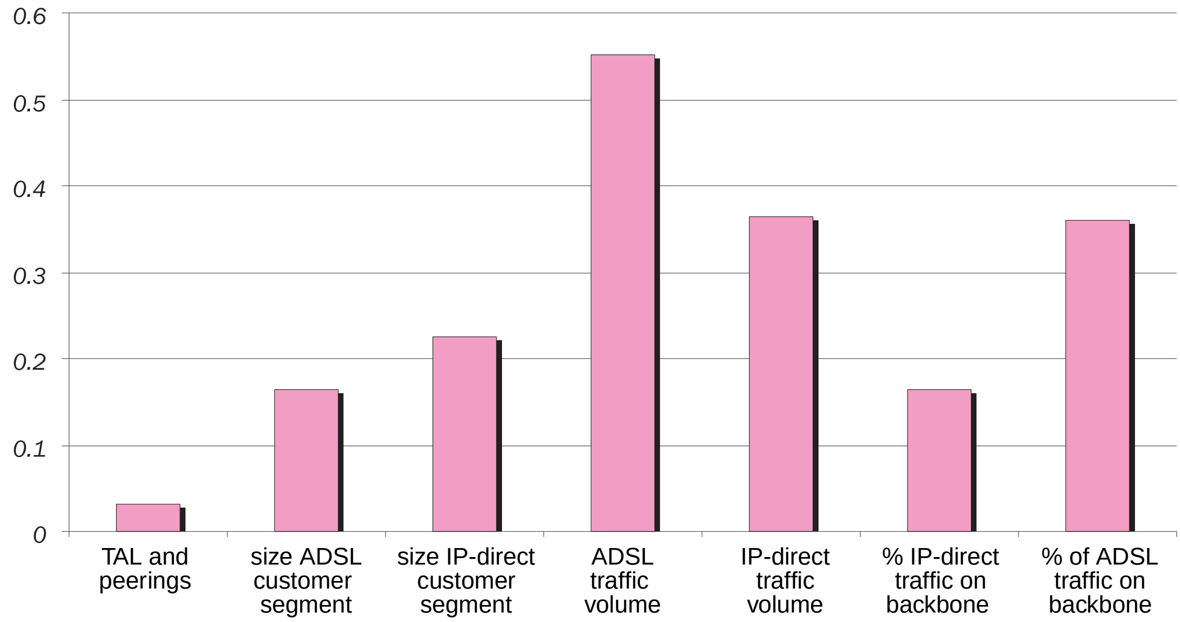


Figure 38: Importance Analysis of IP-direct total costs

Generally, an Importance Analysis answers the question about the influence of an isolated input parameter w.r.t. the output result. The Analytica software provides a package of statistical functions for answering this type of questions. High results correspond to a big influence of the respective parameter. An "Importance Value" of 1 corresponds to total correlation between input and output parameter, i.e. the uncertainty of the output is completely determined by the uncertainty of that input parameter.[1]

It is interesting to note that the ADSL traffic volume appears to have the biggest influence to the IP-direct total cost as well as to the ADSL total costs. This is due to the fact that the Importance Analysis does not say anything about whether the correlation is positive or negative – it just states that it is there. According to Table 10 the high fixed cost of the TAL plus peering are shared between the two services according to their respective generated traffic volume. As the total traffic volume of the ADSL service in our scenario is five times as big as the total IP-direct traffic, this parameter has the biggest influence on the total cost of both services – one time in terms of a positive correlation, the other time as negative correlation.

Finally note that the relatively high influence of the ADSL segment size may be explained by the so-called operating leverage [7]. Based on the results of the Importance Analysis, the second step of the analysis, i.e. the Sensitivity Analysis, may be performed.

8.2 Sensitivity Analysis

For the further analyses, we assume that the monthly volume per customer increases over the period of two years, according to Table 13.

Table 13

Parameter	Initial Value	Final Value	Devolution
Number ADSL customers	1500	5470	S-curve [a]
Number IP-direct customers	100	610	S-curve
Traffic volume per ADSL customer and month	1000 MB	1970 MB	+3% per month
Traffic volume per IP-direct customer and month	3000 MB	4730 MB	+2% per month

a.according to Figure 30

Before starting with the analysis itself, we have to clarify whether the TAL could become a bottleneck, as we have earlier stated that the maximal monthly volume should not exceed the limit of 6 Terabyte. We have assumed that the proportion on the backbone traffic of the IP-direct customers equals 60%. Figure 39 demonstrates that the limit of 6 TB only might be exceeded during the two-year period, if the proportion of backbone traffic sinks below

1. For details w.r.t. importance analysis see the Analytica Tutorial [8]

50%. Therefore, the following analysis will be performed with a proportion of 60%, as long as the parameter itself is not varied and nothing else is stated explicitely.

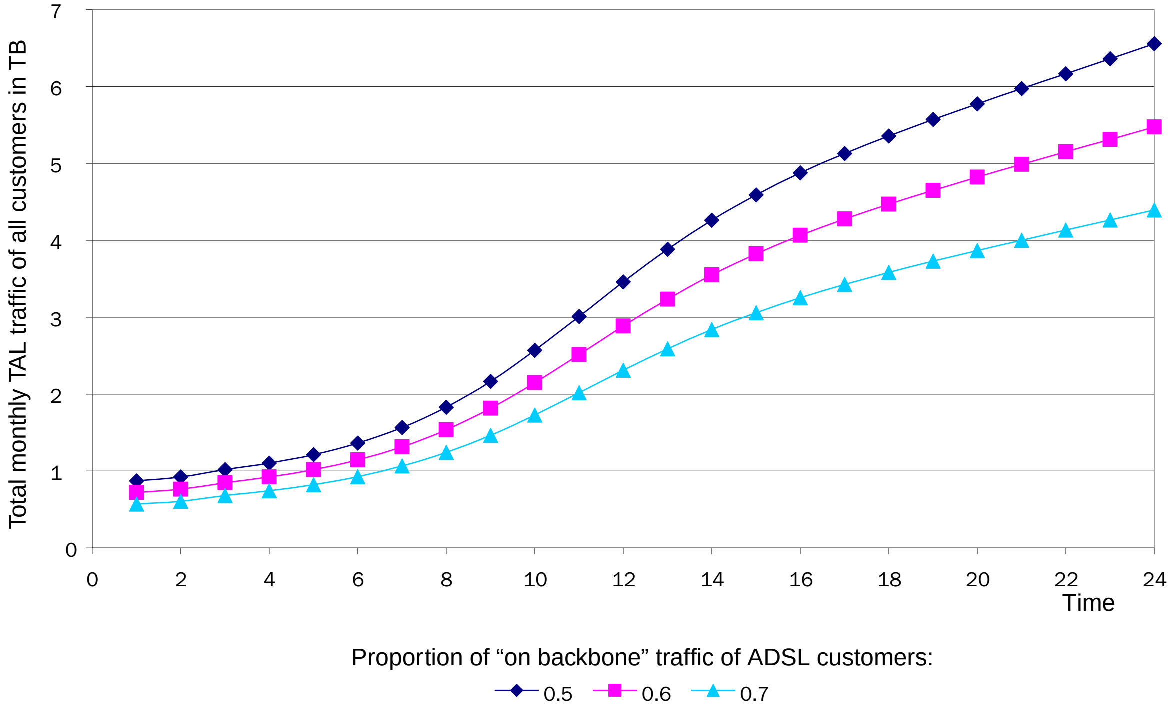


Figure 39: Total Traffic Volume on the TAL in TB

Figure 40 shows the monthly total costs of both services, the three curves differing w.r.t. the monthly fixed costs for the TAL. From there it becomes obvious that our hypothetical provider has a very small proportion of variable costs and a high proportion of fixed costs. The devolution of this curve obviously reflects the evolution of the market according to Figure 30.

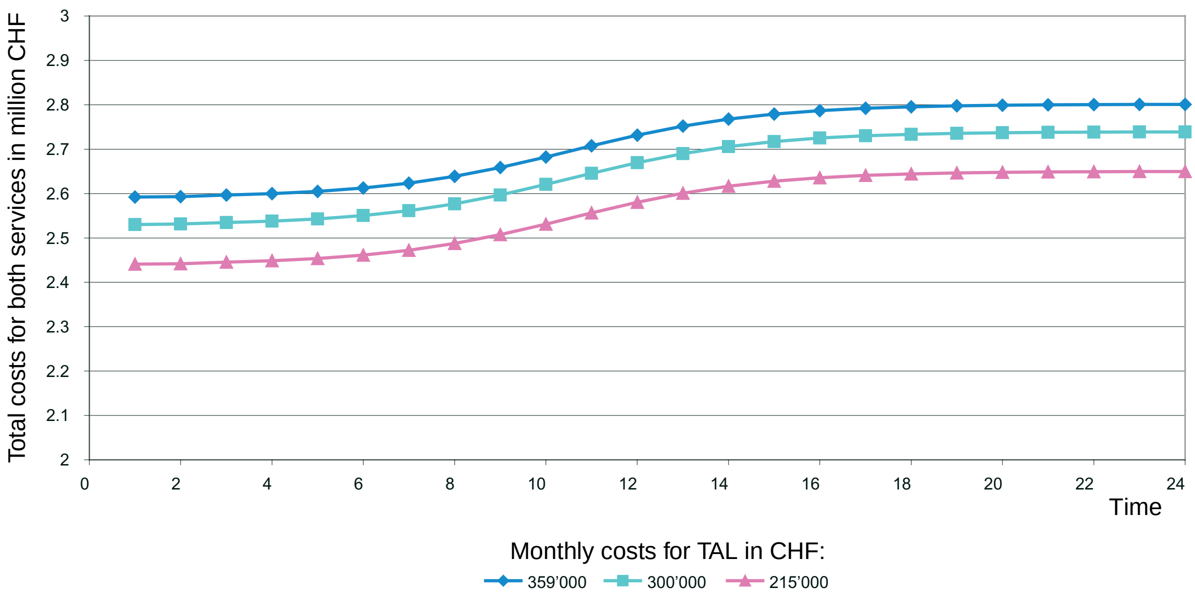


Figure 40: Monthly total costs of both services. The proportion of backbone traffic for both services equals 60% each.

The following Figures 41 – 43 investigate the evolution of ADSL total cost, depending on the cost for the TAL, the proportion of ADSL on backbone traffic and IP-direct on backbone traffic, resp. Afterwards, Figures 44 – 46 show the parallel results for the IP-direct total costs.

Finally, Figure 47 and Figure 48 show the monthly cost per MB “downloaded”. Here again it becomes apparent that only large numbers of customers yield acceptable cost.

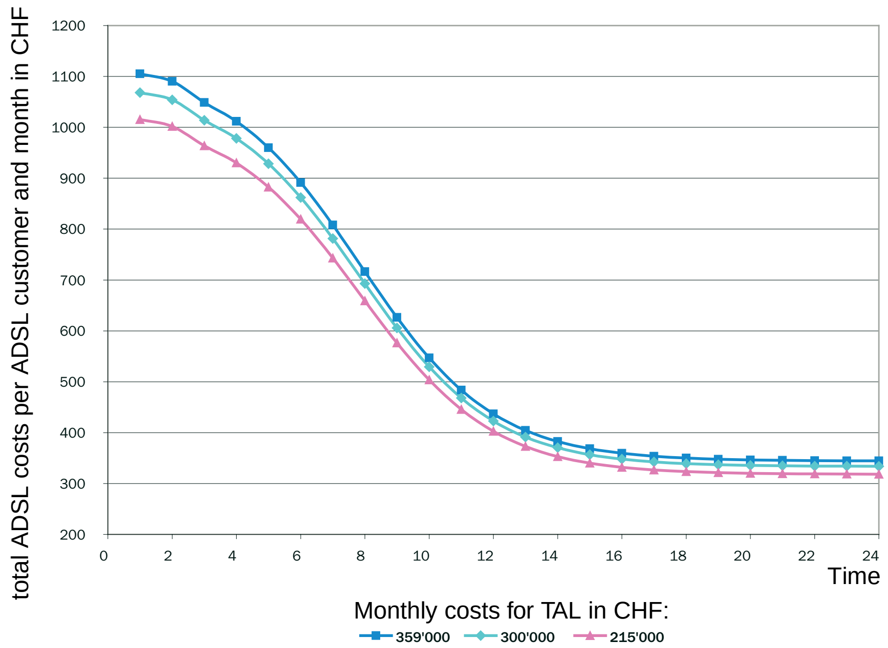


Figure 41: ADSL total costs depending on cost for TAL. The proportion of backbone traffic for both services still equals 60%

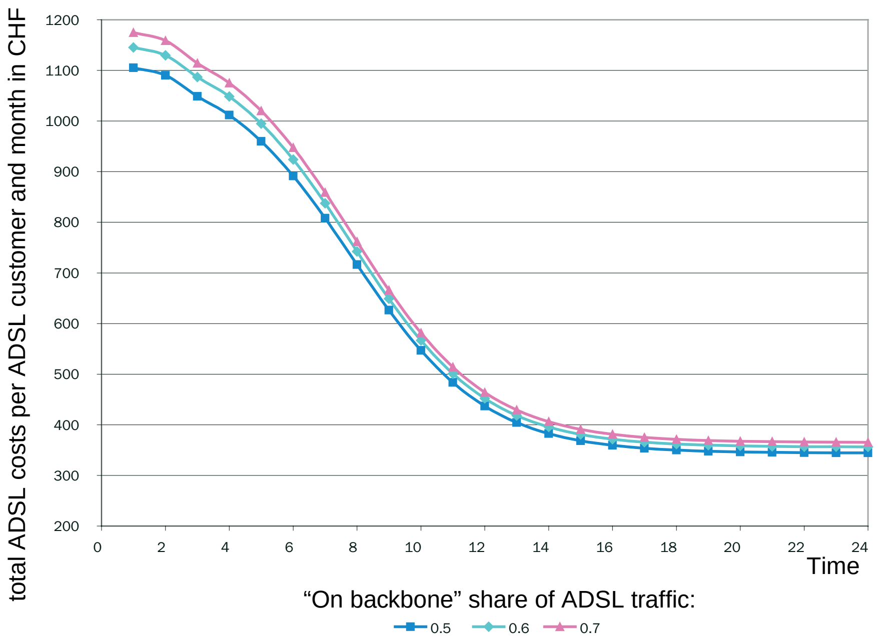


Figure 42: ADSL total cost depending on proportion of ADSL on backbone traffic. The IP-direct proportion of backbone traffic equals 60%, the TAL costs are fixed at 359,000 CHF per month.

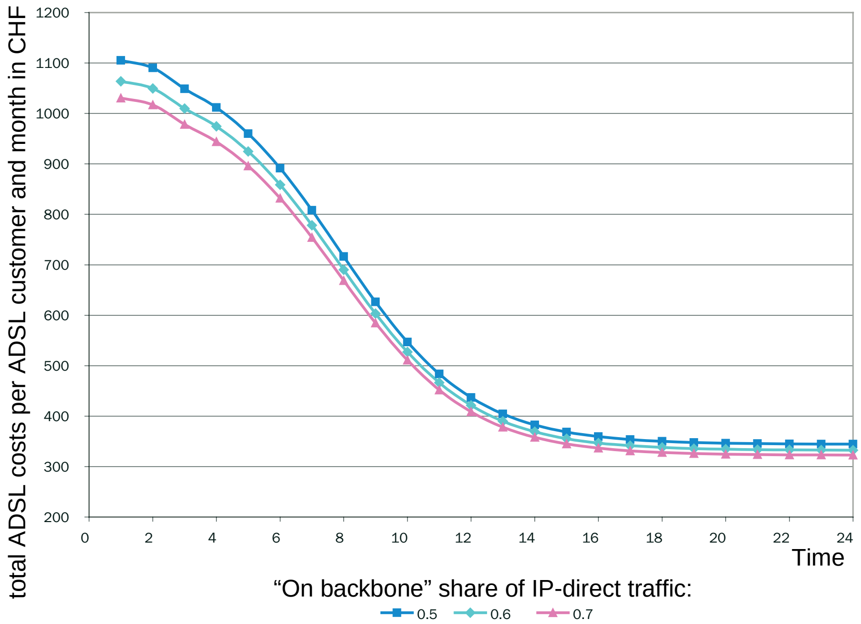


Figure 43: ADSL total cost depending on proportion of IP-direct on backbone traffic. The ADSL proportion of backbone traffic equals 60%, the TALTAL costs are fixed at 359,000 CHF per month.

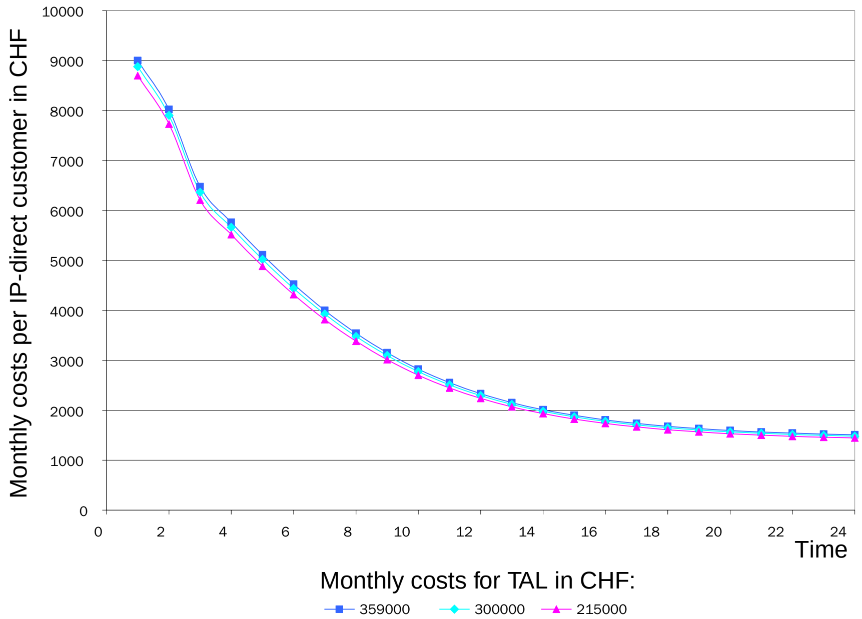


Figure 44: IP-direct total costs depending on cost for TAL. The proportion of backbone traffic for both services still equals 60%

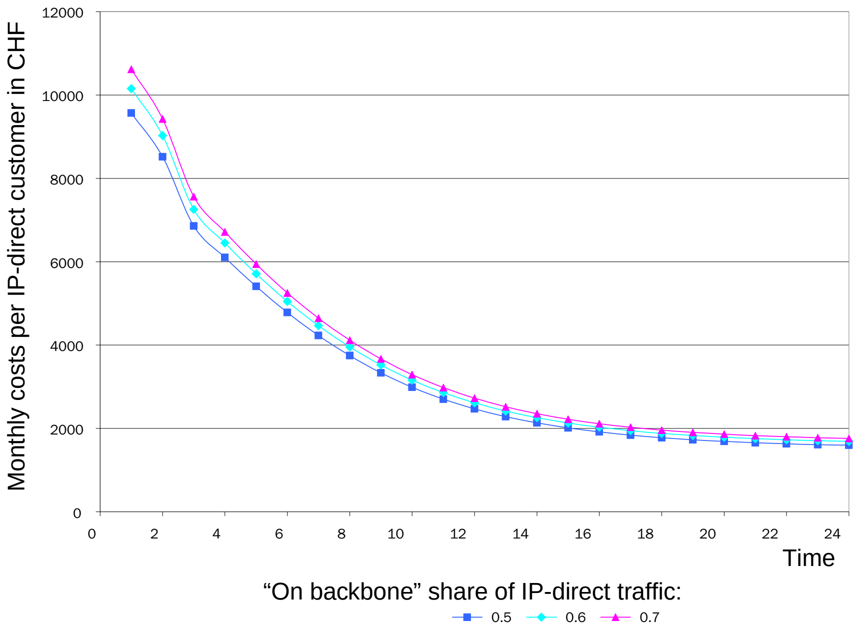


Figure 45: IP-direct total cost depending on proportion of IP-direct on backbone traffic. The ADSL proportion of backbone traffic equals 60%, the TAL costs are fixed at 359,000 CHF per month.

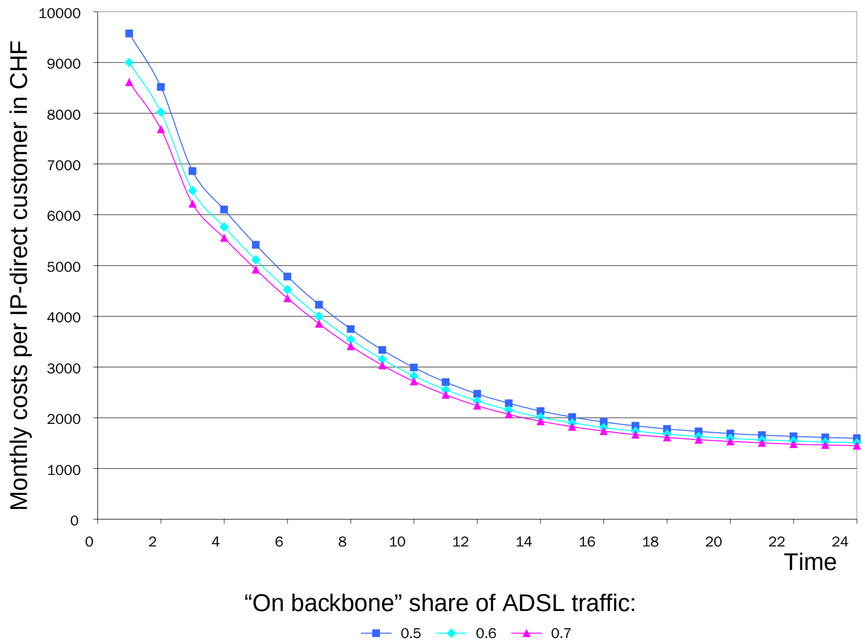


Figure 46: IP-direct total cost depending on proportion of ADSL on backbone traffic. The IP-direct proportion of backbone traffic equals 60%, the TAL costs are fixed at 359,000 CHF per month.

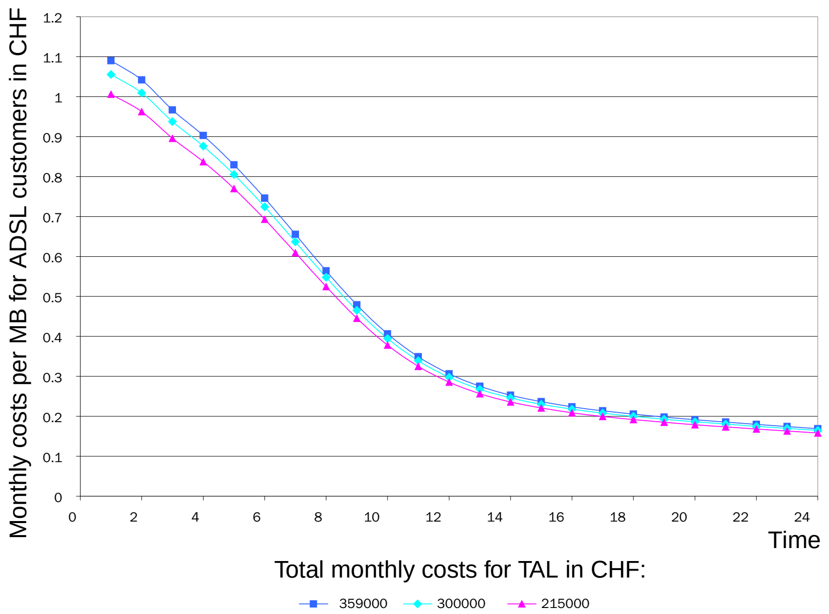


Figure 47: Monthly ADSL cost per customer and downloaded MB. The proportion of on backbone traffic equals 60% for both services.

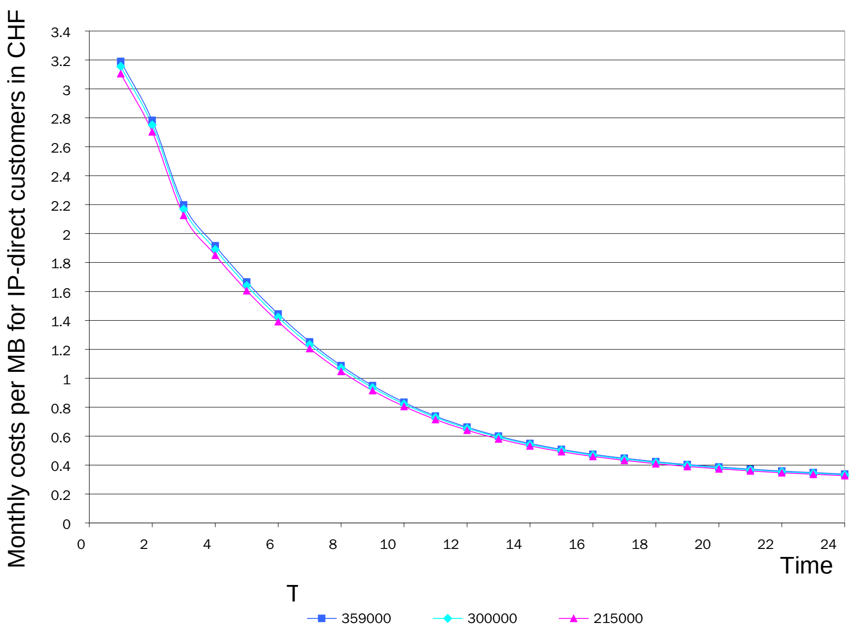


Figure 48: Monthly ADSL cost per customer and downloaded MB. The proportion of on backbone traffic equals 60% for both services.

The Sensitivity Analysis for our example is finished with Figure 49, a three-dimensional illustration of the monthly ADSL costs per customer. Here, the costs for the TAL and the peering have been varied continuously in order to study the cost evolution during the two-year period.

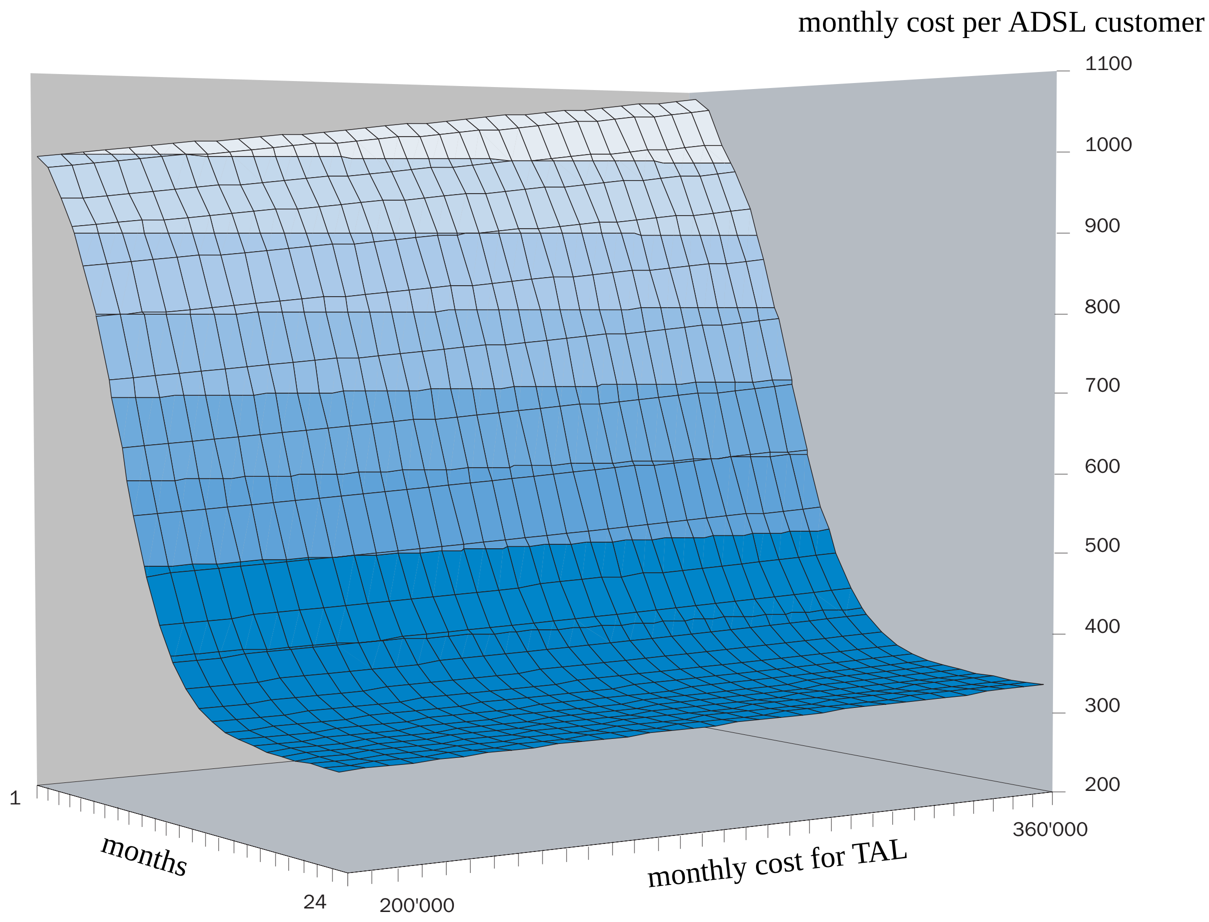


Figure 49: Monthly cost per ADSL customer with the costs for the TAL varying continuously from 200,000 CHF to 360,000 CHF.

9 Accounting Spreadsheet

Having investigated the monthly costs over a two year period in great detail, now the spreadsheet version of our approach is presented. The calculations have been made according to the deliberations presented earlier in this report, based on the data of the Analytica model. This concrete case allows us to recognize many of the theoretical aspects as presented in Figure 21.

One special result concerns the proportion of common and direct cost. We can see that the common cost are larger than the direct cost, but only by approximately 30%. Due to the relatively simple measurement of the transatlantic traffic, a reasonable share of the costs can be assigned directly and usage-based to the respective cost units. The “Core” cost location represents by far the largest part of the common cost. Generally, one would aim at reducing the proportion of common costs as far as possible in order to yield a fair and usage-based accounting. But among the common cost, there are a couple of positions that never can be assigned “directly”, e.g. the basic software and the basic operation costs. Therefore, one could probably further reduce only the common costs of the NEs. To account for these 3.4 millions CHF as direct costs, there are suitable measurements at each NE necessary. One of the fundamental questions here is the issue of basic measurement unit, i.e. should one count IP packets or measure volume, which is the role of the time-of-day etc. Apart from these conceptual questions, there are also a couple of technical issues to be solved for metering these data efficiently. Moreover, this metering and the following technical accounting, mediating etc. can be complicated and henceforth cost-intensive. Therefore, the question is whether the positive effect for the customer outweighs these additional expenses. With all these issues in mind, one must never forget that it is the customer and her requirements who stays in the centre of attention.

Summarizing we can state that the effort to construct this cost model has turned out to be worthwhile. The result allows a clear understanding of costs, the Analytica model helps with the identification of cost bulls, and the spreadsheet finally supports the transparency requirement posed at the very beginning. Hence, the result of this work yields the basis for a solid price policy for Internet services.

Cost Categories (CoCa's)			Cost Locations (CoLo's)				Cost Units (CoUn's)	
	Marginal Costs	Common Costs	Core	Edge	Access	AMS	ADSL	IP-direct
Fibre Cables		5'525	5'525					
Backbone Routers		1'500'000	1'500'000					
Edge Routers		450'000		450'000				
ATM Switches		900'000			900'000			
DSLAM	1'500'000						1'500'000	
Optical Regenerator		600'000	600'000					
ADSL Line Card	2'490'000						2'490'000	
Transatlantic Link (TAL)	2'460'000						1'943'400	516'600
Peering	1'560'000						1'232'400	327'600
Local Loops ATM-Ports	288'000						227'520	60'480
Repair and Spare Parts		96'760	58'960	12'600	25'200			
Basic Software		2'000'000	1'200'000	400'000	400'000			
Basic Operation		2'500'000	1'750'000	250'000	500'000			
Customer Care		1'000'000				1'000'000		
Further Costs		1'500'000	150'000	150'000	150'000	1'050'000		
Sum	8'298'000	10'552'285	5'264'485	1'262'600	1'975'200	2'050'000	7'393'320	904'680
Share Core							1'421'410	3'843'074
Share Edge							631'300	631'300
Share Access							1'777'680	197'520
Share AMS							1'435'000	615'000
Sum of Common Costs							5'265'390	5'286'894
Total							12'658'710	6'191'574
Overhead 5% **of** Total							632'935	309'578
Total Costs per Service							**13'291'645**	**6'501'152**
Total Costs of Both Services							**19'792'797**	

Figure 50: Accounting Spreadsheet

10 Summary and Conclusions

The main aim of this deliverable was to design a service-oriented, simple and transparent ISP cost model that is oriented on real-life cases but at the same time general enough to be easily adaptable to new services as well as changing ISP structures. After an in-depth evaluation of existing literature has revealed that none of the ISP cost models so far is able to fulfill these requirements, the decision has been made to develop ICOMO, a semi-formal model based on modified traditional accounting plus several steps of abstraction, e.g. market and provider segmentation. The model is based on describing the cost flows between cost categories, cost locations and cost units. After describing the various components of ICOMO in large detail, the model has been implemented using the Analytica tool. Again, each of the relevant modules has been described precisely. The implementation has been used to perform various importance and sensitivity analyses, thus demonstrating the feasibility of the approach as well as its usefulness of the derived results.

This deliverable concludes the first phase of ISP cost modelling activities within the M3I project. Future research topics in this area include a further refinement of the model for including additional available data as well as modelling selected areas of the cost model up to very small details.

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12 Abbreviations

ADSL	Analog Digital Subscriber Line
AMS	Administration, Marketing and Sales
BUG	Broad User Group
CAS	Charging and Accounting System
CHF	Swiss Franks
CoCa	Cost Category
CoLo	Cost Location
ICOMO	ISP Cost Model
CoUn	Cost Unit
DUS	Daily Usage Scope
ISP	Internet Service Provider
M3I	Market Managed Multi-service Internet
MB	Megabytes
NE	Network Element
NUG	Narrow User Group
QoS	Quality-of-Service
RSVP	Resource Reservation Protocol
TAL	Transatlantic Link
TB	Terabytes

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