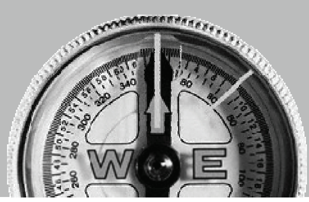
> Opinion Paper

Technical cost modelling

A practical guide

2008/05



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1 Executive Summary

Cost estimations are fundamental to every investment assessment. In that context, the level of complexity can range from a pure cost analysis of a single asset to an in-depth business case calculation. In particular cost comparisons require to specify scenarios and appropriate boundary conditions in a very detailed way and the identification of cost drivers can only be based on the exact knowledge of all complex interdependencies of the overall business strategy.

Technical cost modeling for mobile operators concentrates on the cost estimation for infrastructure investments. Systematically applied, the technical cost modeling is based on a cost modeling cycle that allows to iteratively calculate investment costs until an optimized result, typically minimized costs, is achieved. Business case calculations provide as an integral part a detailed insight into the costs of an infrastructure investment and its main cost drivers and will help to align the business with the technology strategy.

Often neglected or just ignored, the business case or cost calculation has to be compared with the implementation result. On one hand, this will lead to a continuous improvement of the used model. On the other hand, the identification of shortcomings of the assumptions made will allow to further optimize the business strategy.

As a direct result of a cost analysis, the so-called service production costs are a metric that can be used for the assessment and comparison of technology options in particular scenarios with given boundary conditions. Giving the price at which a unit of a service has to be sold in order to exceed the costs for producing one unit of this service, the service production costs cumulate all technology and business related aspects, thus, providing an end-to-end assessment of the technology to be deployed.

The technical cost modeling is typically supported by appropriate tools with an adjustable level of detail. Spreadsheet models are simple and easy to handle but provide only a very rough and simplified simulation. In contrast, topology based models allow to take spatial and temporal correlations into account by using detailed input data, e.g. of existing networks. It depends on the specific situation which of both approaches is the most suitable.

Based on the extensive analysis and discussion of the technical cost modeling framework within this paper, the following main recommendations can be given:

- Do not focus on single aspects of the cost calculation, ensure a holistic view in the sense that all technology and business aspects are taken into account. This will ensure an iterative alignment of the business and technology strategy and allows to identify the main cost drivers.
- Support the technical cost modeling by appropriate tools – spreadsheet or topology based, depending on the required level of detail. Ensure that the used model is well calibrated and understand the correlations between model input and output and its validity range.
- Don’t forget about the modeling once the strategy has been implemented. Use the implementation feedback for the continuous improvement of the cost model and the business strategy.

2 Introduction

A successful business strategy is a result of a mixture of gut feeling decisions and business case analyses. Often, the latter is tweaked or flavored just to support the former, but systematically applied, business case calculations are in general a powerful tool to not only underline what is already known, felt or desired but to obtain an objective picture of the problem and its solution.

Fundamental ingredients of every business case analysis are revenues and costs which are naturally to be maximized and minimized respectively. On one hand, costs are thereby a consequence of the underlying market, rollout, and technology strategy which directly can be mapped on a certain infrastructure required to serve the service demand associated with the revenue predicted.

On the other hand, costs also impact on the chosen technology, rollout, and market strategy. For instance, the introduction of flat fees has to be based on a sound knowledge of the service production costs and the network capabilities. It has to be answered what the minimal cost for the production of one unit of a certain service is and how many units of this service the network can offer.

To close the link between revenues and costs a sophisticated cost modeling methodology is required that provides not only information about costs but also allows to identify main cost drivers and critical success factors which can be used to adjust the underlying business strategy.

Unfortunately, the development of such a holistic approach is a time consuming and complex task so that it often can be observed that cost calculations are based on non-appropriate models and assumptions limited to certain aspects of the problem and neglecting important correlations.

Here, a standardized cost modeling methodology based on best-practice experiences can help to support such strategic decision processes by reducing the time required for the set up, validation, calibration, and execution of a cost analysis.

Several studies exist in the literature (see e.g. [1], [2], [3]) in the area of mobile networks that present results of cost modeling and business case calculations but none of them explains in detail the applied methodology and in particular the consequences for the overall business planning process.

This paper therefore aims at closing this gap by providing a comprehensive theoretical framework for cost calculations of mobile network operators. Starting with the description of the general modeling framework, it briefly explains the basic principles of radio network modeling and presents the basic steps for a successful application of such models. The paper closes with exemplary results that demonstrate the power of the approach and the capabilities and importance of cost and business case analyses.

3 Generic cost modeling framework

The objective of every cost modeling is to minimize the estimated CAPEX and OPEX associated with the network infrastructure required to serve a certain service demand under given boundary conditions. Starting with an initial set of prerequisites and assumptions, the calculation results provide first insights into the cost structure, interdependencies, and correlations. Adjustment of parameters will allow to further optimize the results, but often it turns out that fundamental changes of the underlying strategy are required. As a consequence, a re-evaluation of the strategy has often to be conducted leading to an iterative cost modeling process until predefined cost targets can be met or no further optimization of costs can be achieved.

Starting with an overview of the generic cost modeling framework, this section depicts how the overall procedure can be implemented by using different network modeling approaches. Important planning parameters like the network deployment strategy are discussed and the influence of the initial situation of a new (so-called greenfield) operator compared to an incumbent (so-called brownfield) network provider on the methodology is analyzed. Finally information on cost items and the calculation of service production costs is given.

3.1 Technical cost modeling cycle

An iterative process that allows to estimate the costs of a given deployment strategy and that uses the results for a further adjustment of the assumptions is given by the technical cost modeling cycle depicted in Figure 1.

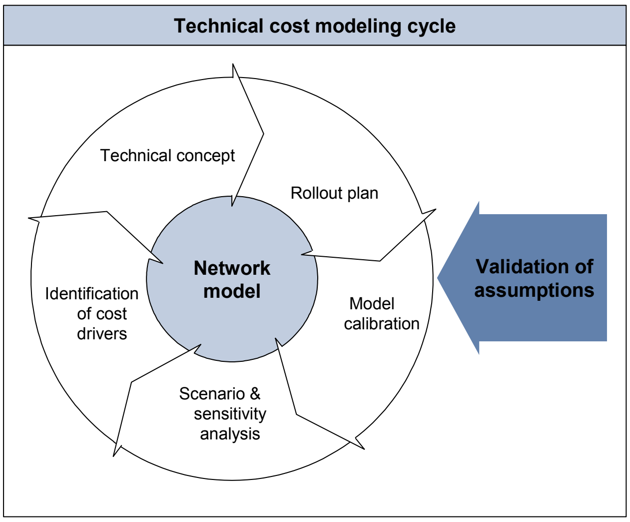

Figure 1: Technical cost modeling cycle

The technical cost modeling cycle consists of five phases:

Technical concept: subject to an existing network, to given license conditions, and to service requirements, the technical concept often is predetermined and limits the number of technology options that can be deployed. These technology options are to be economically assessed in the further cost modeling steps.

Rollout plan: as a direct result of the market strategy and the corresponding revenue prediction, the rollout plan specifies which services are required with what volume when and where.

Model calibration: a sound model calibration is indispensable for the validity of the computation results. Relying on a proven cost modeling methodology has the advantage of pre-calibrated parameters and the knowledge about critical or sensitive settings. Modeling development effort is then minimized.

Scenario & sensitivity analysis: a sensitivity analysis allows to analyze the influence of parameter changes on the overall calculation result whereby a scenario analysis depicts the consequence of fundamentally changed boundary conditions, e.g. the introduction of different technology options.

Identification of cost drivers: the knowledge about the sensitivity of results regarding particular parameters and the influence of changed boundary conditions helps to identify the main cost drivers. These are the settings that have to be optimized first and may influence the technical concept and rollout plan considerably.

Studies are conducted by using an appropriate network model that has to reproduce all parts of a mobile network to be considered. Typically, the model consists of a radio, an aggregation, and a core network module (see figure 2) that calculate the bill of quantitiy required to serve the given demand. Information of the price book then allows to estimate the costs.

After successful evaluation and the succeeding implementation of a business strategy it is indispensable to validate the underlying assumptions and of the corresponding results of the cost modeling exercise. On one hand, this will lead to a continuous improvement of the used model. On the other hand, the identification of shortcomings of the assumptions made will allow to optimize the business strategy.

In particular, the successful deployment of every radio base station should ideally be backed by an appropriate positive business case that gives forecasts of the expected revenue and the associated deployment costs. In case of a negative deviation of the predicted and the measured revenue, corresponding countermeasures have to be specified for the further deployment. This could be an improved selection of deployment areas or a refinement of the revenue forecast. In case of a positive deviation, an updated revenue forecast could also impact the overall business strategy.

3.2 Network model

A network model allows to derive the required bill of quantity and the associated network costs using a top-down as well as a bottom-up approach. While in the top-down approach the amount of infrastructure is calculated that keeps the costs in a pre-specified limit, in the bottom-up approach the bill of quantity required to serve a given service demand and the resulting costs are estimated. Both methodologies are to be used in order to achieve a consistent picture of the network. Typically, assumptions and parameters used for the bottom-up approach are optimized following the technical cost modeling cycle until pre-defined cost targets are met.

Basic input of such a bottom-up model as given in Figure 2 is the service demand given by the rollout and market strategy and the geographics of the areas the service has to be deployed. Based on this information the numbers of required radio, aggregation, and core nodes are calculated. Combining the resulting bill of quantity with appropriate price information directly leads to the associated network CAPEX and OPEX.

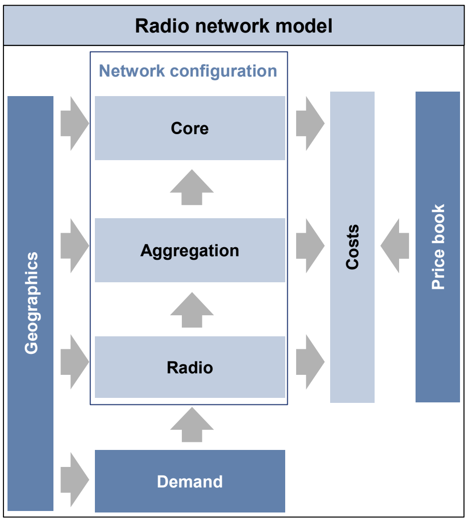

Figure 2: Radio network model

The most difficult part of such a calculation is the sufficiently accurate estimation of the required infrastructure.

In general, the model of choice depends on the required level of detail which naturally strongly influences the level of effort, i.e. time, to be spent for the analysis. Of course, more or less accurate figures can be generated by well calibrated radio and core network planning tools that assign a geographical reference to every node. However, such a detailed planning approach is most of the time too time consuming and not appropriate for a first estimation of costs and the corresponding business strategy.

Simple spreadsheet based models on the other hand allow quick cost estimations to the disadvantage of accuracy. Here, it is – to certain extent – justified to neglect any spatial correlation which eases the calculation logic tremendously.

In order to combine the advantages of both approaches – simple and quick calculations based with a limited effort of model calibration and spatial and temporal information – spreadsheet based methodologies have to be adopted by a planning tool. For this purpose, georeferenced nodes have to be generated automatically without the need of detailed network planning following the spreadsheet based approach. On one hand, this allows to quickly generate a predefined network architecture aligned to given requirements. On the other hand, this network architecture now contains spatial and temporal information that provides a much more detailed picture on the estimated rollout. If required, the level of accuracy can then be scaled arbitrarily, e.g. by the manual relocation of a specific radio site, thus allowing a smooth transition to a detailed network planning.

3.3 Spreadsheet based network model

This network modeling approach completely neglects spatial and temporal correlations. The results are therefore not as accurate as provided by a planning tool and just give a first rough estimation of the required bill of quantity and the associated costs. The spatial distribution of the estimated bill of quantity will be provided by a detailed network planning afterwards.

Following the network aggregation hierarchy from the radio to the core network (see Figure 3), the required radio nodes can be calculated per region simply using the total area to be covered with the total service demand and the coverage area and capacity per node. Different terrain characteristics can be modeled by distinguishing between dense urban, urban, suburban, and rural parts of the region to be covered – however, spatial correlations are neglected totally. It is assumed that every terrain category forms a contiguous area of homogeneous terrain type, which is of course not given in reality, but on average will lead to fairly realistic results.

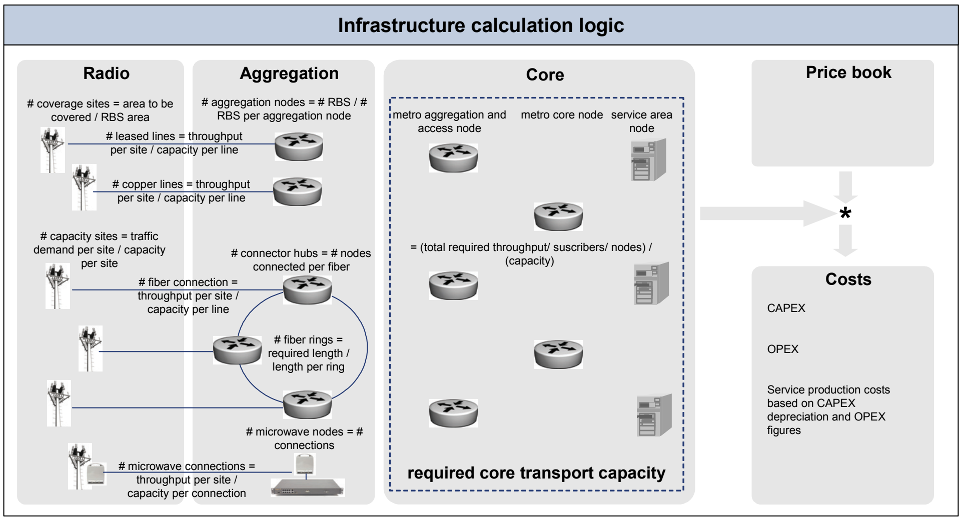

Figure 3: Infrastructure calculation logic

Network topology or geography becomes important on the aggregation level. In order to calculate costs for e.g. leased lines accurately, the length of the connection has to be known and, depending on the pricing scheme, the area where these lines are to be deployed. Although topology typically is specific to the network, standard methodologies have to be applied in order to quickly obtain results.

For this purpose network reference models have to be specified that represent a particular architecture which not necessarily coincides with the real architecture to be deployed later. Nevertheless, these reference architectures facilitate comparability of scenario calculations and give a first insight on the required infrastructure.

Similar to the aggregation network, a core network model has to rely on a predefined reference architecture. In addition to that, the core network has to aggregate all regional results independently calculated in the radio and aggregation step.

For a sound business case calculation an analysis of costs for a certain period of time is usually required – typically 10 years. Theoretically this leads to a certain complexity of the model since temporal correlations have to be taken into account. E.g., radio sites deployed in year one with a basic capacity have to be expanded in year six. As a consequence, a complicated book-keeping algorithm would be required that is able to assign every generated node a time stamp.

To overcome this difficulty in modeling, temporal correlations are typically neglected and the network state of the current year does not depend on the state of the preceding year (similar to a markov chain).

3.4 Topology based network model

This approach allows a more detailed network modeling by using information on topological data like latitude and longitude and morphological information. Actual information on size and shape of cities and coverage areas can be considered. Dependent on the amount and quality of the used information the network can be modeled in almost every detail up to the same quality sophisticated planning tools provide (see Figure 4). However, in contrast to a planning tool supported analyses and similar to the spreadsheet approach all network design steps are fully automated. In other words, the spreadsheet method is enhanced by spatial and temporal information.

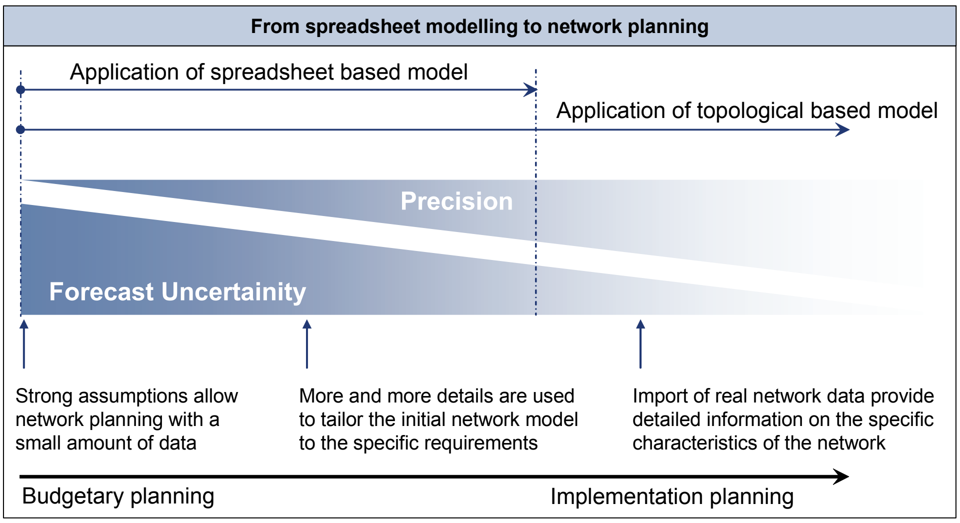

Figure 4: Spreadsheet and topology based modelling

The geographical area is ranked as dense-urban, urban, sub-urban, rural and area without coverage. Using this classification, locations for base stations are automatically proposed to cover these areas in the required manner (see Figure 5). Compared to spreadsheet based modeling contiguous areas in this approach are not required.

The spatial distribution of the base stations allows a qualified decision on locations for network concentrators, like BSC/RNC/WiAN. Fine tuning of these positions provide a very high degree of freedom for network modeling. The base stations are assigned to the network concentrators for dimensioning these nodes regarding their switching capacity and the number of required interfaces. Additional to the detailed geographical data, information about the point of time for implementing specific network elements can be stored. This allows evaluating temporal dependencies between different phases of the network deployment. In comparison to spreadsheet based models, with total numbers of base stations per year only, topological models allow to plan individual network elements.

Using the information on the actual geographical position the link lengths for connecting network elements can be calculated. Estimations of average link length for the different area types, as for spreadsheet based tools, are substituted by actual values for the planned network. This avoids errors that are often made, by mapping assumptions of one scenario to another, neglecting the different boundary conditions for both.

Depending on the level of detail the topological model allows a smooth transition from a budgetary planning where a simple bill of quantity is sufficient over a deployment modeling that allows to spatially sketch the future network design to the final implementation planning for the operating network. The application of each of these approaches is justified with regard to particular boundary conditions and limitations of the selected option have to be kept in mind when interpreting the results.

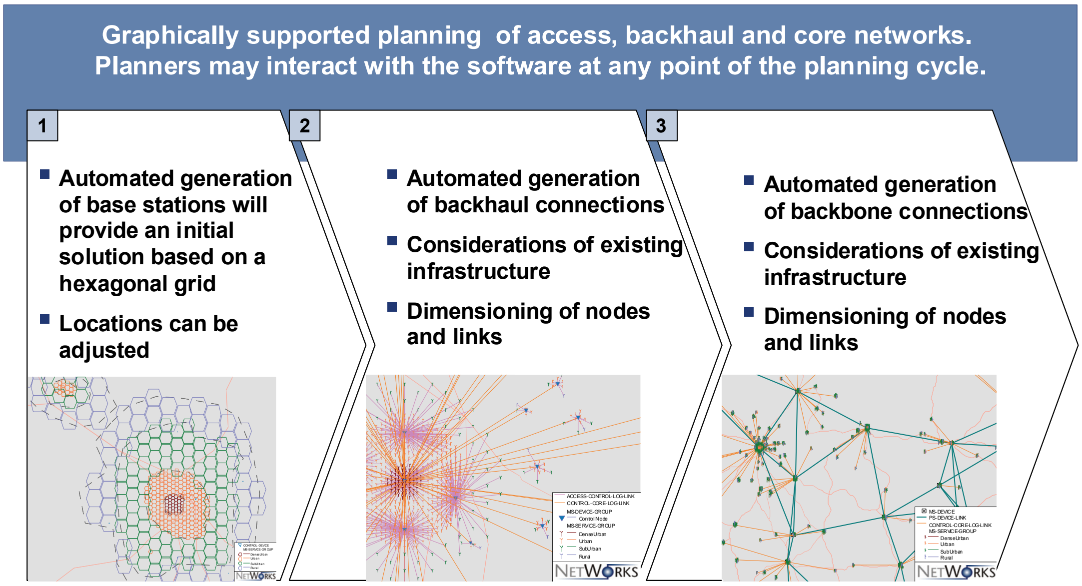

Figure 5: Planning from access to core networks

3.5 Radio coverage and capacity

Although the basic radio node calculation is quite straightforward, the difficulty is in the estimation of the coverage and capacity properties of each node type. Simple benchmark values could be used but even more control about the deployment costs is given by more sophisticated modeling of these properties.

Coverage can be estimated by means of the so-called link budget. In general, the transmitted radio wave will experience reflections, scattering, and diffraction leading to a loss of the received signal strength. Link budgets allow to estimate the resulting maximum path loss of a signal transmitted by a radio base station or a mobile by accounting of all these gains and losses. In combination with empirical or semi-empirical propagation models this maximum path loss can then directly be translated into a cell size. It has to be noted that these propagation models assume a certain average terrain morphology. Adjustments to e.g. the hilliness can be modeled by correction factors that however are very difficult to derive and in many cases require exemplary network planning exercises.

The complexity of the node’s capacity calculation strongly depends on the technology under consideration. Technologies with capacity resources that can be provided in certain fixed resource units like the time-slots in GSM, GPRS, EDGE, HSDPA, and WiMAX, do follow simpler capacity rules than those without any so-called resource quantization, like UMTS Rel.99 or HSUPA. Here, resources for users do not have a fixed size but depend on many factors determined by the connection itself, on the other connections within the same cell and on the connections in surrounding cells. Models do exist for such technologies but it is obvious that only simulations allow to capture all complex interdependencies in order to provide a realistic picture.

In case the capacity depends on the user location (i.e. the distance between mobile and the radio base station), as for technologies using adaptive modulation and coding, appropriate assumptions about the user location and the corresponding utilization of these modulation and coding schemes have to be made or simple link budget calculations have to be used in order to estimate the distribution of used schemes. The range of the performance figures can be estimated by complementing a base-case that is based on a specified distribution of user locations (e.g. homogenous) with best-case (i.e. all users located near the base station) and worst-case (i.e. all users located at the cell-edge) analyses.

The resulting capacity then has to be distributed on the users in order to obtain the throughput achievable by each connection. Here, in particular for next generation mobile systems, it has to be taken into account that the total capacity provided by the system typically is shared by the users. The efficiency of such a shared system strongly depends on the available total bandwidth as well as the burstiness of the traffic. A high bandwidth will allow a high average utilization of resources. On the contrary, a high burstiness, which means that the traffic peak is much higher than the average traffic load, results in a high peak capacity demand at a low average utilization. When estimating the capacity available for user traffic these effects have to be taken into account. Consequently, quite low average capacity utilization figures of about 30-40% are typically reached; however, exact values strongly depend on the underlying traffic profile and the targeted quality of service. In order to guarantee the required user throughput, the network therefore has to be dimensioned based on the available user throughput.

Basic input for the estimation of the number of required capacity radio nodes is given by the marketing traffic forecast. Typically, a marketing traffic forecast provides total monthly traffic volumes in combination with specific quality of service requirements. The network, however, has to be dimensioned according to a “worst case” peak – given by the busy hour traffic demand. Consequently, the given monthly traffic volume has to be mapped to busy hour demand.

3.6 Greenfield and brownfield approach

Cost modeling approaches for greenfield and brownfield mobile network operators are fundamentally different.

The greenfield operator has – by definition – no existing infrastructure that has to be taken into account by the network model. This of course eases the modeling since reference architectures and furthermore standard node configurations can be used.

Modeling brownfield operators leads to a higher complexity since typically the existing network has to be reproduced in detail in order to analyze required changes of the node configurations. This implies that ideally a georeferenced model representation of the network is required, which, however, contradicts the fundamental network modeling approach which should by no means replace a tool-based network planning.

A compromise is to introduce node configuration categories such that within each category nodes are not distinguishable within certain limits. In particular, for the radio network nodes cell load classes can be defined that range from highly loaded hot spot cells to wide area coverage rural cells. Within each of these classes it is then assumed that the load is fairly constant. The results are quite comparable to a tool-based planning but following a much simpler approach, provided that the model has been well calibrated by using measurements from the network.

3.7 Cost items

The level of detail of cost items to be provided by the network model strongly depends on the requirement of the technical analysis as well as of the financial model.

On one hand, the financial model just requires summarized CAPEX and OPEX figures for the derivation of the financial KPIs and CAPEX categories are to be distinguished according to the underlying depreciation of items.

On the other hand, a more detailed split of these figures will allow to obtain more insight into the cost structure and in particular into the cost drivers. In addition to that, fine tuning of results requires a certain level of detail of the network model.

A well-proven compromise therefore is to provide CAPEX and OPEX figures separated for each network layer (radio, aggregation, core) with the main CAPEX categories hardware, software, civil works, auxiliary, services and with the main OPEX categories rental, energy, operation and maintenance.

Costs will then be calculated based on a price book which is based on vendor quotations. If there is no precise data available, standardized calculation models will be linked to benchmark data bases that contain appropriate default figures.

3.8 Service production costs

As per definition, service production costs give the costs for the production of one unit (minute, MB, …) of a service.

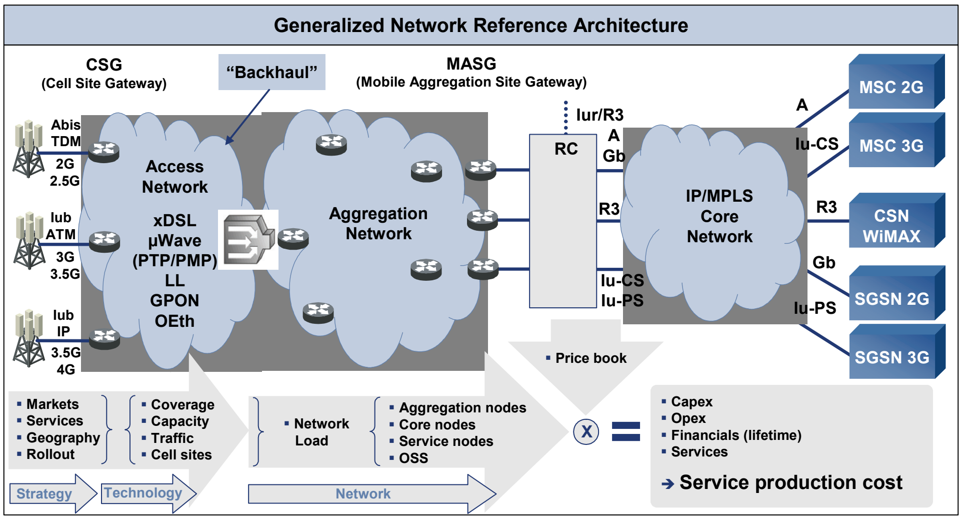

Figure 6: Generalized network reference architecture

For a single service network it is the total cost for the production of the service divided by the total service units available in the network – this is the minimal price a service can be sold at fully utilization of all resources. Analogously, the current service production cost is given by the total cost for the production of the service divided by the currently been sold service units.

For a multi service network the calculation is more complex since fixed costs have to be distributed on several services. Here, several cost assignment strategies can be used that e.g. assign costs proportional to the usage of a cost element caused by a certain service.

Per definition, service production costs provide an end to end view on the network summarizing all cost related effects of the business and technology strategy, the network dimensioning and the market price (see Figure 6). On the one hand, the service production costs help to identify inefficiencies or optimization potentials of the network infrastructure and the business and rollout strategy. On the other hand, they also have to be used as guidance for the market and pricing strategy. It turns out that in general, the strategic rather than the technical boundary conditions mainly dominate the overall scenario evaluation. Since the service production costs consolidate all strategic and technological aspects as well as their complex interdependencies, they are therefore a powerful indicator for scenario comparisons.

The concept of service production costs is already well-known in the area of financial controlling. Here, activity-based costing is used in order to break down all costs related to the business on the services produced. This further helps to fully assess the profitability of existing services. While activity based costing analyses are limited to existing services, the introduction of new services and the corresponding technology upgrades should be based on the concept of service production costs. Activity based costing therefore has to succeed the analysis of the service production costs once a technology has been selected for the deployment of a service.

4 Cost modeling in practice

The technical cost modeling cycle introduced in section 3 can be used for the comparison of technologies deployed in specified scenarios at given boundary conditions and theoretically allows to iteratively optimize the deployment strategy leading to minimized CAPEX and OPEX figures. In practice, results are often far from being optimal due to the fact that not all of the process steps have been conducted correctly. Inaccuracies of the technical concepts and rollout plan specification, insufficient model calibration and scenario and sensitivity analyses and misinterpretation of results regarding cost drivers are some of the reasons for a poor quality of the results. Additionally, communication problems of involved entities often impede the adjustment of fundamental parameters which is required to close the modeling cycle. One of the reasons for that is the lack of knowledge and understanding of the interdependencies of decisions.

This section therefore gives a more detailed description of each step of the technical cost modeling cycle and in particular focuses on potential shortcomings and draw-backs. Special attention is paid to the model calibration for adjusting the model to the specific requirements of the investigated network and to the sensitivity analysis which is indispensable for the assessment of the calculation results.

4.1 Technical concept

The technical concept has to provide information about the technology options that can be used in order to meet all requirements given by the business strategy within a target cost range.

Since costs related to the rollout of a technology option can only be estimated once the set of options is known, the specification of the technology concepts again follows an iterative process (see Figure 7).

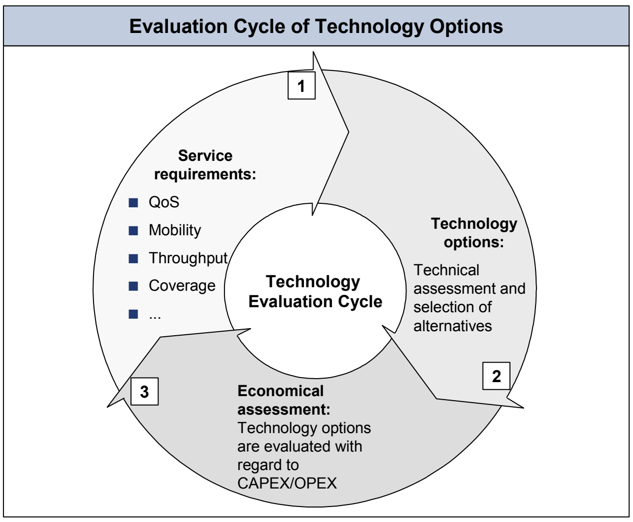

Figure 7: Evaluation cycle of technology options

Requirements are typically addressed, first, by the market and service strategy in terms of service (e.g. throughput), customer (e.g. mobility, QoS), and rollout related aspects (e.g. service reach, interoperability), and second, by given technology license conditions that have to be met.

In general, once all requirements for the technical concept are known, technology options have to be matched to these criteria. For this purpose, a limited set of KPIs has to be specified and all potential technology options have to be assessed according to them.

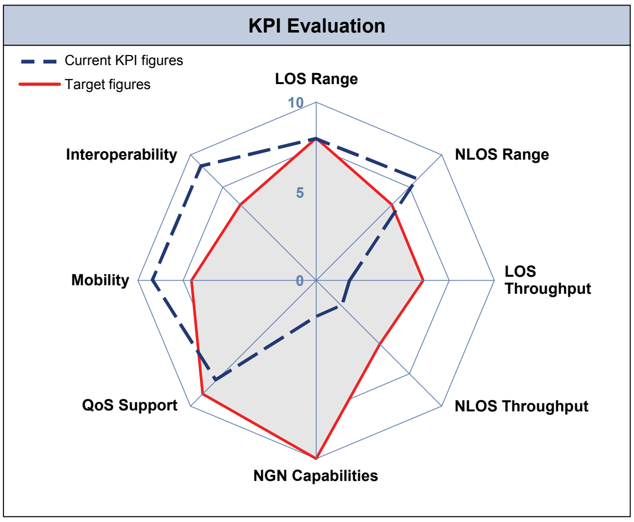

Figure 8: KPI Evaluation

Figure 8 shows a spider-web representation of such an assessment with eight KPIs as an example. Of course, the ideal technology would have a spider-web completely filled, however, this naturally has not to be the optimal solution but could also lead to an over provisioning of technology. Instead, technology options with the minimal distance to the target spider-web have to be selected.

The economical analysis of the technology options then follows the cost modeling process whose results again can be used to adjust the technology concept.

4.2 Rollout plan

Based on the service and market strategy, the rollout plan specifies the spatial and temporal provision of services with a predefined quality. Here, it has to be ensured that country specific rollout constraints are met (e.g. electromagnetic compatibility) and network related license conditions are fulfilled.

The coverage and capacity demand will then be translated into CAPEX and OPEX values for a technology option given by the technology concept using the technical cost model.

Within the technical cost modeling cycle the rollout plan and consequently the technical concept may be adjusted as a result of the cost estimations.

4.3 Model calibration

Every assessment result will be as good as the underlying assumptions. Often, insufficient input data or input data of insufficient quality but also misleading working assumptions due to a lack of knowledge or simply the unspecific definition of the problem to be modeled are the main reasons for a poor quality of cost modeling results. Even worse, the fact that results have been derived systematically by means of a sophisticated model with a huge parameter space typically increases the credibility of computation results and reduces the natural suspiciousness.

In order to avoid such a “garbage in, garbage out” situation a thorough model calibration is indispensable.

Ideally, the complexity of the model is aligned to the data availability, i.e. all model parameters can be calibrated. If this is not the case, benchmark values and their ranges can be used. However, parameters the model reacts very sensitively to, have to be calibrated in any case. The list of these parameters depends on the model, but typically these are the specification of the rollout area, the link budget, and the rollout strategy or approach.

Rollout area: every coverage estimation for a mobile network requires detailed information about the rollout area and its composition (e.g. distribution of dense urban, urban, suburban, and rural areas). A large rollout area and an unrealistically high ratio of dense urban and urban areas both lead to a large number of coverage sites which will generate costs but no revenue. To overcome this, rollout areas or polygons clearly have to be specified – ideally using a GIS. Moreover, it has to be checked whether unpopulated areas have to be covered or should be excluded from the analysis.

Link budget: link budgets used for the estimation of the cell size typically use a large set of parameters. Most of the parameters have to be adjusted according to the specific vendor equipment. Some of them, in particular the parameters that model the degree of indoor coverage, strongly influence the number of required coverage sites. Therefore, all parameters have to be calibrated by means of vendor documentation. Indoor coverage requirements have to be economically justified. Eventually, costs can be reduced by deploying an outdoor coverage first and the later densification of the network.

Rollout strategy: in general, the deployment of a mobile network can be a coverage driven or demand driven. Both strategies follow a fundamentally different approach. While the former maximizes the geographical area a service can be used, the latter targets at the maximization of the resource utilization (i.e. capacity).

For many years, mobile network operators focused on the coverage driven approach in order to provide service accessibility. Increasing throughput demand in combination with cost reduction efforts, however, lead to the transitions to the demand driven strategy. This is amongst other things motivated by the fact that backhaul costs will tremendously increase with the air interface capacity and therefore a high utilization of deployed resources is required in order to increase the revenue produced by a radio node.

4.4 Scenario and sensitivity analysis

When specifying the cost model's input parameters, boundary conditions, and the underlying assumptions, typically no single values but ranges only can be given leading to uncertainties of the computation results.

It is therefore indispensable, on one hand, to assess the influence of parameter changes on the result by means of a sensitivity analysis.

Within the sensitivity analysis, the impact of selected input parameters like coverage and quality of service requirements, the traffic forecast, equipment type and prices, and rental costs on the overall result will be studied. The knowledge of parameter value and result correlations will help to identify the main cost drivers of the deployment scenario. Furthermore, it will reveal the impact of identified risks on the key financial indicators and ratios and will provide transparency between the risk level and profitability.

On the other hand, fundamental changes of the boundary conditions can be captured by a scenario analysis. In general, a base scenario is complemented by a best and a worst case in order to capture the range of potential costs. Combined, it is possible to estimate the range of results that can be used for the assessment of the corresponding risk of each analysis. Unfortunately, the probability of each scenario cannot be estimated within this simple approach. To overcome this shortcoming, Monte-Carlo sensitivity and scenario analyses are used that assign every computation result a certain probability [4].

4.5 Identification of cost drivers

The knowledge of the sensitivity of the cost model's parameters as well as their correlation with the resulting costs allows to identify the main cost drivers. Although these cost drivers typically strongly depend on the underlying scenario under investigation, the knowledge of the cost structure of a mobile network will help to understand which potential cost drivers do exist – assuming an optimal price book of course.

As already discussed a mobile network can be deployed in a coverage and demand driven way. In contrast to the demand driven approach, the coverage driven rollout provides service accessibility to large areas without the necessity of sufficient resource utilization. As a consequence infrastructure costs are typically dominated by the radio network.

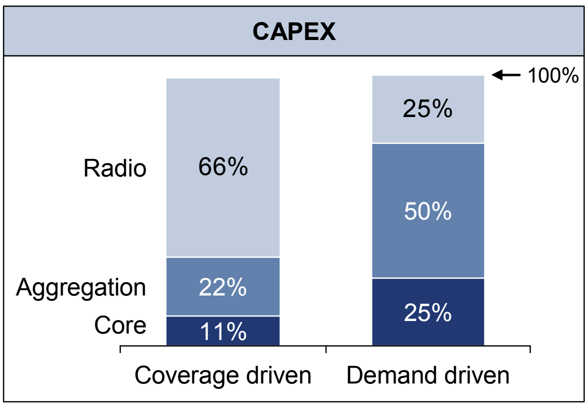

Figure 9: CAPEX for different rollout strategies

Increasing the air interface utilization leads to a higher demand of backhaul and core network capacity. While in the latter costs scale with the capacity to certain extent, prices for a radio node in general remain constant or even will decrease in the course of time. As a result, the cost ratio between the radio, aggregation, and core network will move in favor of the radio network.

Having that in mind, the following cost drivers typically have to be investigated:

Service strategy: The service strategy has to be chosen with care since high quality of service and service performance targets to be guaranteed per user strongly influence the achievable coverage and capacity per radio node. As a consequence, cost will scale with increasing QoS and service user performance requirements.

Rollout strategy: As already discussed a tradeoff between a demand and a coverage driven rollout approach has to be considered. The more the physical resources are utilized the smaller the service production costs will be. Furthermore, it is obvious that strict coverage requirement for e.g. indoor coverage will result in a higher number of coverage sites and larger costs respectively.

Technology strategy: A thorough trade off between infrastructure OPEX and CAPEX has to be made. On the long run OPEX intense investments are generally not favorable which has a consequence on the underlying technology strategy. As an example (depending on the cost structure of leased lines and microwave equipment), a self-build backhaul network is on the long run typically cheaper than a leased line aggregation network if CAPEX and OPEX are considered simultaneously.

Operational aspects: Site rental, energy, and operations and maintenance can be potential areas for cost optimization especially for larger mobile networks. Here, site sharing concepts and energy saving programs (e.g. the deployment of more efficient air conditioning systems etc.) can help to further reduce costs.

5 Modeling examples

Several studies (e.g. [1,2,3]) with detailed cost and business case analyses and even with economic comparisons of the deployment of different radio access technologies like HSDPA and WiMAX do exist. Their results thereby strongly depend on the scenario settings used, that is the revenue assumptions, rollout plan, technology settings, etc., and consequently lead conclusions impossible to compare. It is therefore neither possible to give general recommendations for the deployment of the one or the other radio access technology nor to identify the optimal technology based on a detailed comparison of various options.

However, based on the theoretical framework introduced in the previous sections some exemplary analyses and their results will be discussed in this section that demonstrate the power of a cost modeling process and that can be applied in general for the assessment of deployment scenarios. For the sake of simplicity, no details of the underlying scenario will be revealed since the focus is set on the methodology rather than on the discussion of special deployment scenarios.

5.1 Scenario overview

The task is to provide wide-area data service coverage with a mobile WiMAX network. In order to guarantee a certain minimal performance the network will be dimensioned according to a burstiness factor with a certain outage probability at the cell edge. The deployment starts with minimal 5% population coverage in the first year up to the full population coverage in year 10. During that period of time the market share as well as the service usage per customer will increase constantly. A volume based pricing scheme is applied.

5.2 Results

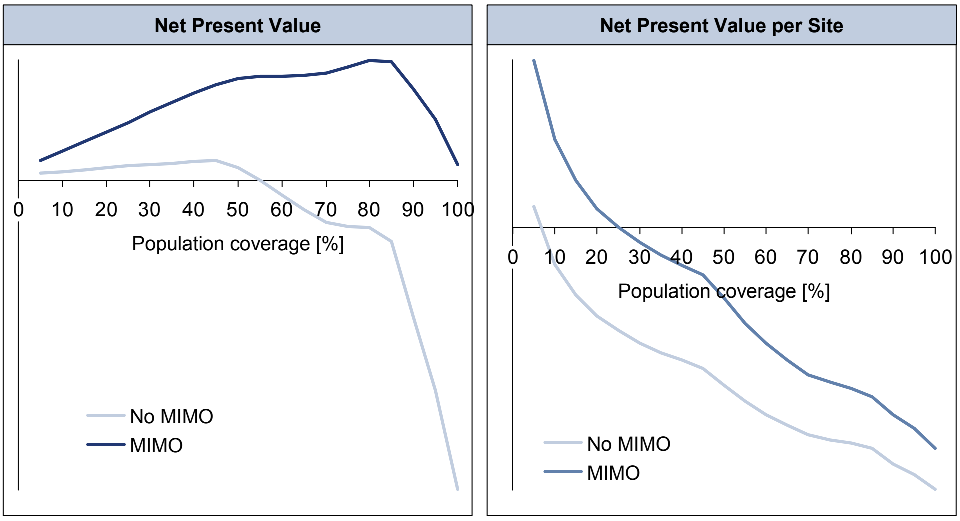

Figure 10: Population coverage profitability limit

Typically, an economical nation-wide coverage (that means a population coverage of 100% rather than an area coverage of 100%) is difficult to achieve.

Starting with the deployment in dense urban areas, the network resources to be deployed in order to meet coverage and quality targets grow stronger than the revenue generated by these additional network resources. Consequently, there is a certain economic rollout limit until the investment is positive. As can be seen in Figure 10, for the considered scenario this is the case for population coverage of about 55% (non MIMO[1] case). However, although the net present value per site started to be negative from about 7% population coverage, i.e. the costs for the deployment of an additional site are larger than the additional revenue, the total net present value still increases slightly due to the additional revenue generation. Reducing costs by e.g. the deployment of MIMO enabled WiMAX base stations (coverage and capacity per base station is nearly doubled by 2x2 MIMO) the economic rollout limit is increased to nearly 100% population coverage.

Reason for the low profitability of a nation-wide deployment is the decreasing revenue per site and consequently a low network resource utilization (see Figure 11). In general, the more the resources are utilized (assuming volume based pricing) the more profitable the deployment is. As a result, all demand driven deployment phases show a positive net present value while a purely coverage driven approach leads to negative values.

In general, this picture is more pronounced the higher the air interface bandwidth and the smaller the corresponding cell area is. Established deployment approaches of mobile networks therefore cannot be adopted for wireless broadband networks but have to be adjusted accordingly.

Resources have to be ideally utilized close to 100% in order to optimize the network related investments. To approach this, it is indispensable to have detailed information about the customer's behavior (i.e., where do customers use which services to what extent and when). An early transition from a coverage driven (which is of course initially required in order to provide a certain service footprint) to a demand driven rollout will then help to generate positive cash flows.

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[1] MIMO (multiple in, multiple out) algorithm send information out over two or more antennas and the information is received via multiple antennas as well. Doing so they provide a significant capacity gain over single antenna systems

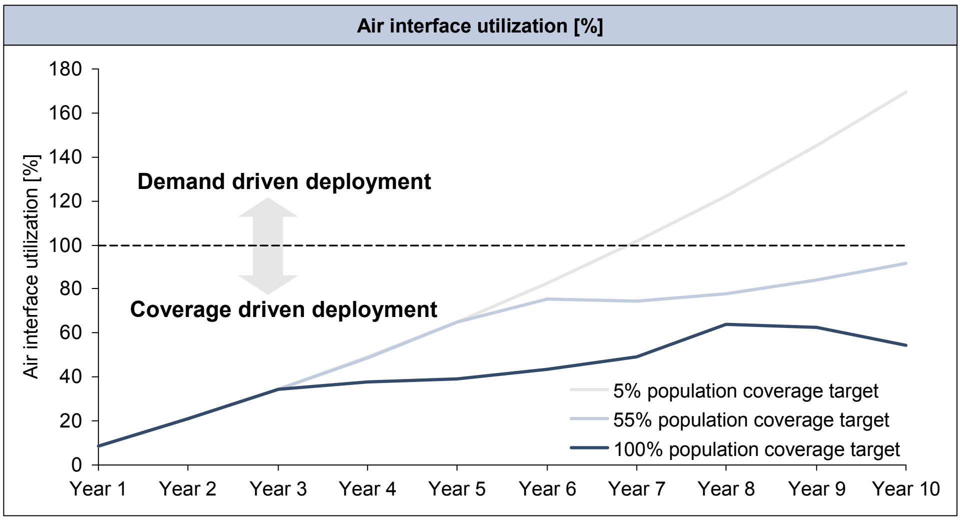

Figure 11: Utilization of the air interface

Initially reduced quality of service requirements in order to quickly achieve a large service footprint will increase the network utilization and the corresponding cash flows (see Figure 12). Localized high traffic demand has then to be served by dedicated base stations; network densification has to be aligned to the global traffic demand.

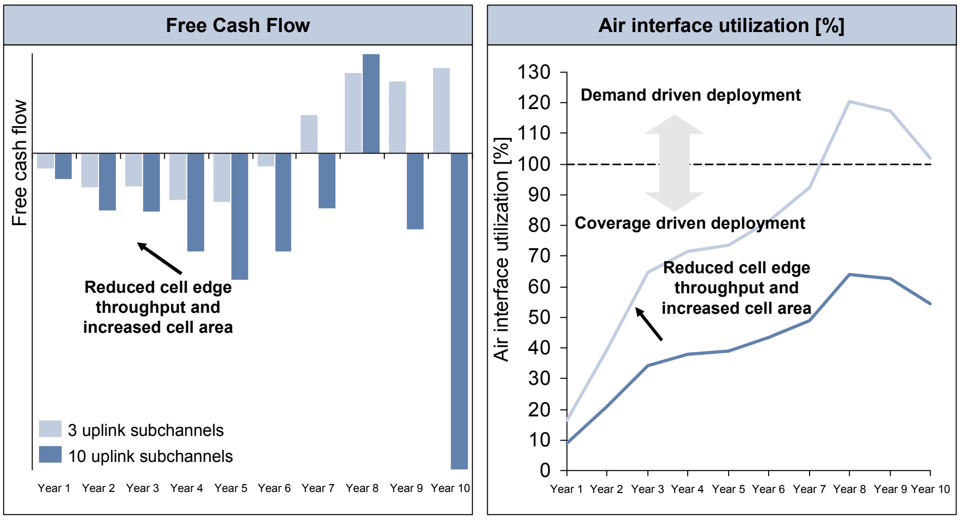

Figure 12: Free cash flow in relation to the air interface utilization

As depicted in Figure 13, similar to the total net present value of the network investments, service production costs will benefit from the increased utilization of the network resources. Initial high investments caused by the coverage driven rollout phase lead to high costs for the production of one MB of data. Increasing utilization of the already deployed resources then allow to reduce the costs per MB. Pricing schemes can be adjusted accordingly in order to stimulate additional revenue. However, the introduction of flat rate plans has to be carefully aligned to the minimal service production costs.

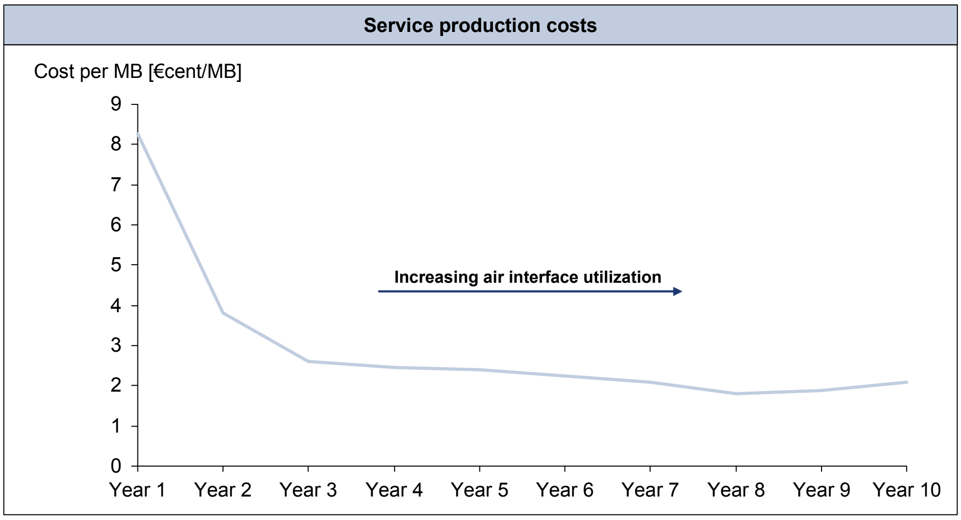

Figure 13: Service production costs

A more sophisticated analysis of the deployment scenario is provided by the application of the topological network model:

- The spatial information of network elements, the link structure and the temporal relation allows to localize cost drivers.
- The knowledge about locations allows qualified cost estimations especially for the transmission network with respect to the link lengths and their capacities.
- Topology alternatives can easily be compared in terms of performance and costs.

Depending on the transmission network topology, link lengths and capacity requirements contribute differently to the overall costs [5] – as exemplary depicted in Figure 14. New networks are typically designed as star topology, resulting in long links with low capacity. A tree network on the other hand results in short links with partially very high capacity requirements.

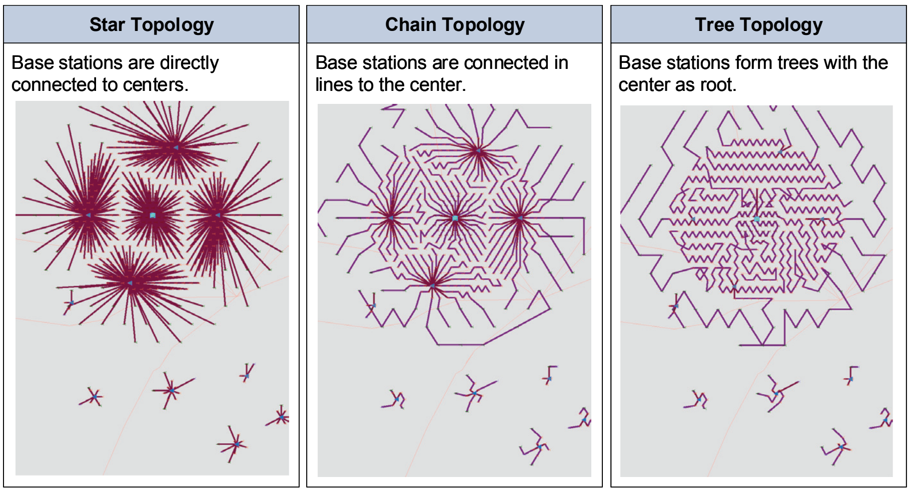

Figure 14: Network topologies

This general behavior can be theoretically motivated. The actual situation for a specific network (see Figure 15) strongly depends on the used technology, morphological data and administrative rules. The two peaks for the chain network topology result in the large number of base stations in sparsely populated rural areas. It is hardly possible to take such effects into consideration, if detailed topological data are not used.

The application of topological network models therefore helps to fill the gap between an abstract network model for an initial network plan and the detailed network planning required for the implementation of an operational network. In this way it allows to evaluate financial risks of different options and a network optimization in the initial planning phase. High costs caused by non-optimal decisions can be avoided in an early state of the network's life cycle.

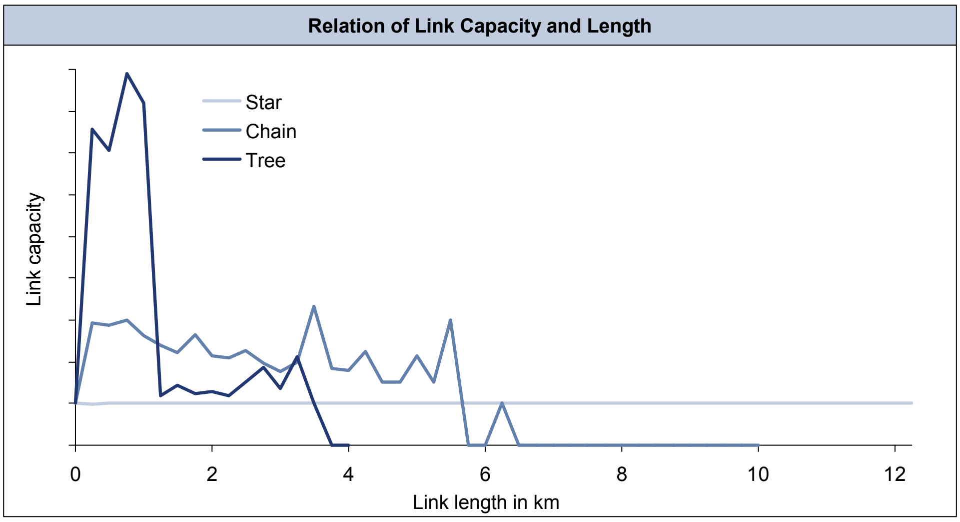

Figure 15: Influence of network topology

6 Conclusion & recommendations

Cost modeling is a complex and sophisticated task and it is not always required to conduct such an analysis to the full extent. However, the larger the infrastructure changes the more important it is to take the complex correlations of the technology and business strategy into account in order to avoid an over- or under-provisioning of technology.

Besides the calibration of a model and the interpretation of its calculation results, in particular the construction of an adequate model is a difficult and a time consuming task. Here, standardized tool solutions, spreadsheet- or topology-based, help to quickly achieve reliable results with an appropriate level of detail.

One of the key results of such a tool-based cost analysis is the service production costs which are already well known from financial activity based costing analyses. As an end-to-end key performance indicator it combines all commercial and technical aspects that are relevant for the assessment of a technology deployment. For that reason, the service production costs can be used as a metric for the assessment and comparison of technology options in a specified rollout scenario under given boundary conditions. Its value can be used as guidance for the service pricing. The knowledge about interdependencies of the technology and rollout parameters will allow the further optimization of the targeted deployment.

To follow the technical cost modeling cycle is of paramount importance in order to obtain an aligned business and technology strategy. Typically several loops are required to be conducted until a certain convergence and optimization of results can be achieved. However, this is necessary in order to fully understand the complex parameter correlations and in particular to identify the main cost-drivers. Often, insufficient communication of in particular commercial and technology parties can be observed and a misalignment of the corresponding strategies occurs.

Based on the results of a successful cost modeling exercise, the assessed business strategy will be implemented. However, the cost modeling shouldn't stop here, but a thorough validation of all assumptions made must follow. On the one hand, this will ensure that future modeling exercises are based on a well calibrated model. On the other hand, the knowledge about deviations of the business predictions to reality will help to revise the overall business strategy and to identify shortcomings of the corresponding implementation.

7 Reading on

- [1] WiMAX Forum; WiMAX: The Business Case for Fixed Wireless Access in Emerging Markets; June 2005
- [2] WiMAX Forum; WiMAX Deployment Considerations for Fixed Wireless Access in the 2.5 GHz and 3.5 GHz Licensed Bands; June, 2005
- [3] WiMAX Forum: Business Case Models for Fixed Broadband Wireless Access based on WiMAX Technology and the 802.16 Standard; October 10, 2004
- [4] Brealey/ Myers/ Marcus; Fundamentals of corporate finance; Mc Graw Hill, 2007
- [5] Schweigel/ Melcher; “1M – 10M – 100M – 1G“ Cost-optimized Design of Multiservice Access Networks; Detecon Management Report (DMR); 4/2007

8 The Authors

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9 The Company

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