Mobile network cost study

Analysis of cost drivers related to the construction, operation and maintenance of mobile networks

4 September 2013

pwc

Table of Contents

List of tables

List of figures

1. Management summary

This Report – Summary for publication (hereinafter also the ‘study’) compares the investment cost and running cost for constructing, operating and maintaining mobile networks (the ‘network mobile costs’) on a per capita basis between Switzerland and its neighbouring countries, Germany, Austria, France and Italy, in order to provide a fact-based foundation for the public discussion on the cost of providing mobile services in Switzerland. PwC was commissioned by the three leading Swiss operators and Alcatel Lucent (hereinafter referred to as ‘Swiss operators’) to conduct this study on network mobile costs. To analyse the cost drivers and to quantify their impact, we have applied a comprehensive cost-calculation model to simulate costs in comparable scenarios. Actual data from the Swiss operators and publicly available sources form the basis of the model.

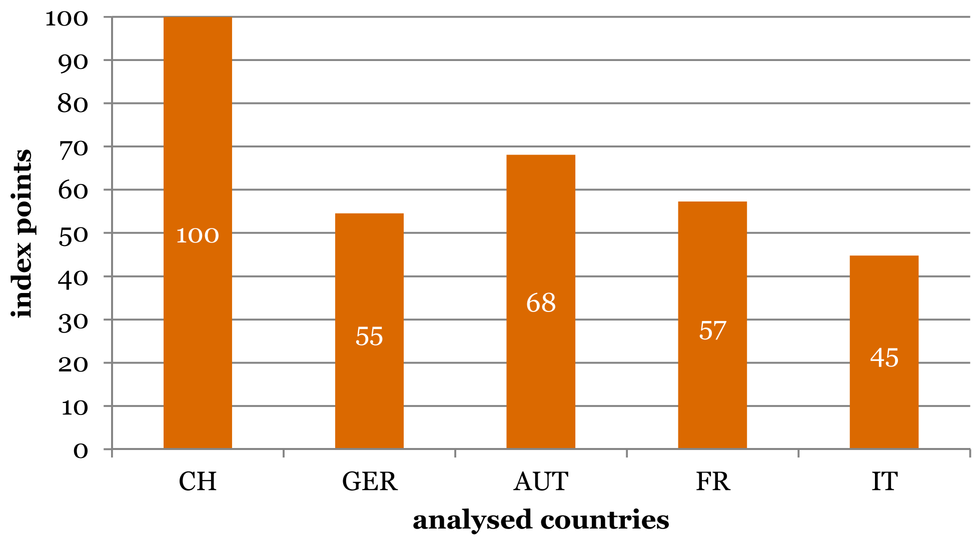
Mobile network costs are driven by several factors which differ and have a diverse impact from country to country. Such factors as market structure and product offering, technology and spectrum availability, topography, geography, population distribution, customer behaviour and, even, accounting rules may vary widely. Hence, while a direct cost comparison would certainly highlight the differences between countries, it would not allow us to identify and quantify the underlying reasons for such differences. Attempting such a direct cost comparison therefore would be like comparing ‘apples and oranges’.

The cost-calculation model we use takes into account these national characteristics and conditions by creating a normalised starting position (e.g. in terms of technology and available spectrum) and by using a consistent set of rules to build (in a virtual sense) a comparable network from scratch (i.e. a ‘Greenfield’ approach) under local geographical and population distribution constraints. The basis is a comprehensive data set from Switzerland (e.g. the site locations, frequency bands used and permitted and built transmission power of all Swiss sites) which enables us to derive a set of building rules based on data for the entire Swiss network (e.g. the distribution and the number of frequency bands, the number of sites needed to cover a one square kilometre of mountainous territory, the coverage radius of the sites and the number of additional sites required to provide coverage along railway tracks). This allows us to build a realistic network which serves as a solid basis for an expedient cost comparison. Such a model enables us to calculate a comparable value for mobile network costs among different countries and to simulate the impact of changes to the constraints (e.g. what would happen to mobile network costs if Switzerland’s population distribution in border regions were the same as in France), thus allowing us to quantify the drivers of the cost differences.

The study demonstrates that mobile costs in Switzerland are 45 to 120 per cent higher than in the neighbouring countries.

The figures below show the Swiss mobile network costs, indexed at 100 points, and the relative base-cost points of the comparison countries.

Country comparison of relative mobile costs



The entire cost difference between Switzerland and each of the comparison countries is divided into the different key cost drivers listed in the table below. For each country, the relative shares of each cost driver sum to 100 per cent, representing the full difference between Switzerland and the given country.

Analysis of impact of cost drivers on total cost differences

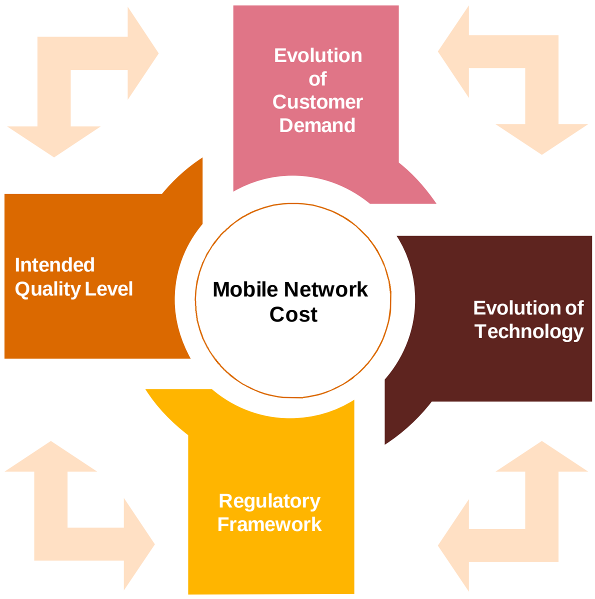
Cost drivers	CH/GER	CH/AUT	CH/FR	CH/IT
Regulation of non-ionizing radiation (NIR)	30.1%	34.5%	31.5%	24.9%
Borders	20.7%	18.5%	22.1%	21.1%
Mountains	14.1%	0.9%	13.6%	10.8%
Rental costs	11.1%	14.7%	11.0%	11.0%
Labour costs & civil works	8.8%	10.6%	6.3%	12.9%
Coverage of railways	6.8%	7.9%	2.2%	13.3%
Energy costs	4.8%	5.5%	6.7%	2.9%
Capacity for rural areas	2.1%	6.4%	4.9%	2.0%
Coverage of tunnels	1.5%	1.0%	1.7%	1.1%

The individual cost drivers are interdependent. For example, the number of antenna sites required determines the energy costs and rental costs, while the country-specific regulation on non-ionizing radiation (NIR) and the extent of coverage of mountains and tunnels influences the number of antenna sites. Our study takes such interdependencies into account by eliminating overlapping costs in the analysis of total costs per country, without eliminating them in the analysis of the individual key cost drivers (as described in the specific chapters below).

Key findings of the study:

- The current NIR regulations have the largest impact on the network cost differences between Switzerland and each of the other countries. Furthermore they influence also several of the other cost drivers due to the increased number of required sites to overcome limitation in capacity.
- The topographical and geographical characteristics as well as the NIR regulation of each country have a larger impact on mobile costs than the classical cost factors like labour cost, energy cost and rental cost.
- Differences in the topographical and geographical characteristics and the NIR regulation of the specific countries have a significant impact on cost differences. In particular, the difference of the population density in border regions, in combination with the country's topography, is a significant driver of the cost differences between Switzerland and its neighbours.
- The coverage of railway tracks and roads is a significant cost factor; however, the proportionally lower number of railway tracks in Switzerland in rural areas compared with the other countries reduces the impact of this cost driver on the total cost differences between Switzerland and the other countries in our study.

We designed our study in such a way as to reduce the complexity of the interdependencies of cost factors in producing quantitative outcomes; therefore, the results do not explicitly reflect some relevant qualitative factors.
Besides the cost drivers considered in the calculation model, the cost structure of mobile networks is influenced by a complex ecosystem of different highly interdependent and dynamic factors. One such factor, for example, is the evolution of customer demand in relation to the availability and capacity of mobile data services. Such demand does not always grow linearly, but also in bursts and waves, mainly driven by external events (new services, different pricing models). Other factors are the ability of technology to meet demand; the regulatory framework (which directly or indirectly speeds up or slows the extension of the mobile network and



the quality level at which mobile operators are able and willing to serve existing demand within a specific time range.

It follows, therefore, that future discussions on cost developments in the construction, operation and maintenance of mobile networks should also consider such qualitative elements.

2. Notice

This ‘Report – Summary for publication’ has been established by PwC on request and behalf of the four telecommunication operators, Alcatel Lucent, Orange, Sunrise and Swisscom (hereinafter referred to collectively as the ‘Swiss operators’), as a deliverable based on their respective engagement agreements with PwC. Any management decisions or communication activities based on this ‘Report – Summary for publication’ are the sole responsibility of each of the Swiss operators.

This ‘Report – Summary for publication’ and any other accompanying deliverables produced by PwC are provided solely to the Swiss operators and for the purposes set out herein and in the respective engagement agreements with PwC. Such deliverables shall not be used for any purpose other than the purpose stipulated in the respective engagement agreements with PwC. This ‘Report – Summary for publication’ may not be published in an altered or modified form without the prior written consent of PwC, and will remain subject to the conditions regarding the deliverables stipulated in the respective engagement agreements with PwC.

Notwithstanding any consent that PwC may grant in accordance with the above conditions regarding the deliverables, PwC shall not be liable for any loss or damage suffered due to the use of the deliverables for any other purpose or by any third party, or due to the publication, alteration or modification thereof.

The information used in preparing this ‘Report – Summary for publication’ was obtained from publicly available sources and information as provided lawfully by the Swiss operators. PwC has not sought to establish the reliability of such sources nor has PwC verified such information. Accordingly, no representation or warranty of any kind (whether express or implied) is given by PwC as to the accuracy, completeness or fitness for any purpose of this document.

This document is for information purposes only and it should not be relied upon for any other purpose. Accordingly, PwC accepts no liability of any kind and disclaims all responsibility for the consequences of any person acting or refraining from acting in reliance on this document.

This ‘Report – Summary for publication’ has been developed by using a cost-calculation tool developed and adapted for the purposes of this study by WiTech S.p.A., Via Giuntini 25, I-5023 Cascina (Pisa), Italy. PwC has not sought to establish the reliability of this tool nor has PwC verified this tool. Accordingly, no representation or warranty of any kind is given by PwC as to the accuracy, completeness or fitness of this tool for any purpose of this ‘Report – Summary for publication’.

3. Introduction and goals of the study

3.1 Introduction

PwC was commissioned by the Swiss Operators to conduct a study on mobile network costs. For the purposes of the study, we modelled, calculated and compared the costs of the construction, operation and maintenance of the Swiss mobile network infrastructure with the corresponding costs in Switzerland's neighbouring countries, Germany, Austria, France and Italy.

Switzerland has a powerful, high-quality mobile telecommunications network. Over the years, it has been developed under consideration of the regulatory and geographic constraints and of future technological developments and user requirements. However, the costs of building, operating and maintaining such a mobile network are high – and consumer demand is steadily increasing. The cost drivers may be classified as commercial (e.g. market shares, customer behaviour), technical (e.g. technology, spectrum usage), geographical (e.g. topography, population distribution) and regulatory. This study attempts to identify the non-commercial and non-technical cost drivers (i.e. those that do not depend on different technological choices and technology stages) in order to highlight and, potentially, quantify the drivers of the differences in mobile network cost between Switzerland and its neighbours. The focus of our study is therefore not on the costs *per se*, but on the quantification of the impact of the identified cost drivers on cost differences between countries. Hence, our study attempts to answer the key question of what makes mobile network costs higher in one country compared with another and what are the drivers of significant cost differences.

Although some of the factors driving mobile network costs are known, their impact has yet to be systematically analysed and quantified. Several factors that drive costs in Switzerland are intuitively known: labour cost, NIR (non-ionizing radiation) regulation, quality requirements, in particular requirements concerning the coverage and capacity of mobile networks have an impact on the quantity and architecture of the network sites/antenna sites and the backhaul network (distribution, antenna power, frequencies, etc.). But the factors mentioned here are just some of the cost components which influence the total cost to build and operate mobile networks in Switzerland. Moreover, it is a highly complex undertaking to ensure a fair and comprehensible comparison of the costs between Switzerland and its neighbours. To date, we lack a broad fact-based analysis that would explain the higher cost of mobile networks in Switzerland, taking into consideration the underlying cost drivers.

It is in this context that PwC conducted its study of mobile network costs.

3.2 Goals of the study

The goal of the study is to make a fair comparison of the costs in Switzerland of constructing, operating and maintaining mobile networks with the corresponding costs in the neighbouring countries of Germany, Austria, France and Italy. The aim is to provide a sound fact base for the public discussion about the relevant factors influencing the costs for a mobile network in Switzerland. This study focuses on the access and the backhaul network and does not include the core IT or network systems of the operators because of their lower per capita cost; it explains the essential cost drivers in quantitative and qualitative terms (e.g. geographic factors, regulatory frameworks and requirements concerning the design/dimensioning of the network) using different case scenarios. To achieve our goal, a cost-calculation model was used that allowed us, on the one hand, to set the basis for a fair comparison and, on the other hand, to simulate the impact of the various cost drivers we identified.

4. Study design

The study compares investment cost (CAPEX) and running cost (OPEX) for constructing, operating and maintaining mobile networks on a per capita base[1] between Switzerland and its neighbouring countries. To analyse the cost drivers and their impact, an extensive cost-calculation model is used. Actual data from Swiss operators and a broad, reliable dataset form the basis of the calculation model.

4.1 Advantages of a model-based cost analysis

Country-specific characteristics and various accounting and deployment conditions make it difficult to compare directly the cost positions of operators in different countries. Reality shows us that cost structures and details of cost positions are not recorded consistently by the different operators and, therefore, are not directly comparable. Despite costs are generally assigned to regulatory, structural or commercial cost positions, different general ledger coding and accounting policies and rules of the various operators make it difficult to compare costs directly or to reallocate them according to common rules. Furthermore, the differences in the available frequency bands for operators as well as the timing and the extent of technology rollouts lead to differences in costs. Hence, it is not possible to allocate clearly the cost differences to the individual cost drivers. Any direct comparison, therefore, would be like comparing 'apples and oranges'.

The cost-calculation model we use takes into account the national characteristics and conditions by creating a normalised starting position and by using a consistent set of rules to 'build up' the same network from scratch (a 'Greenfield' approach) under local constraints. For example, the use of one type of technology (UMTS: Universal Mobile Telecommunications System) for all countries or applying the same rule to divide each country into rural, urban, suburban and mountainous areas enables comparative simulations and quantitative evaluations. This approach allows for the allocation of the identified cost differences to comparable cost drivers.

The approach also allows us to calculate the impact of changes on the cost drivers (e.g. NIR regulation or geographical characteristics) and not just to compare the cost positions (e.g. cost of material).

[1] The entire population of a country is considered as the user base

4.2 Description of the model

Our chosen approach enables a reduction in the complexity of the cost analysis by using a simplified but still realistic model. Using the model, the various cost drivers are evaluated independently and their impact on costs in Switzerland is simulated and compared with the impact in other countries.

4.2.1 Modelling approach

The first step is to design a normalised model within a professional 'network cost calculation tool'. This normalised model can be applied to all countries in the scope of the study and it forms the basis to compare the cost elements between countries. The model is normalised by selecting a combination of technological and architecture characteristics for the mobile network based on the real characteristics and specifications of the networks in Switzerland (e.g. the actual distribution of antenna sites).

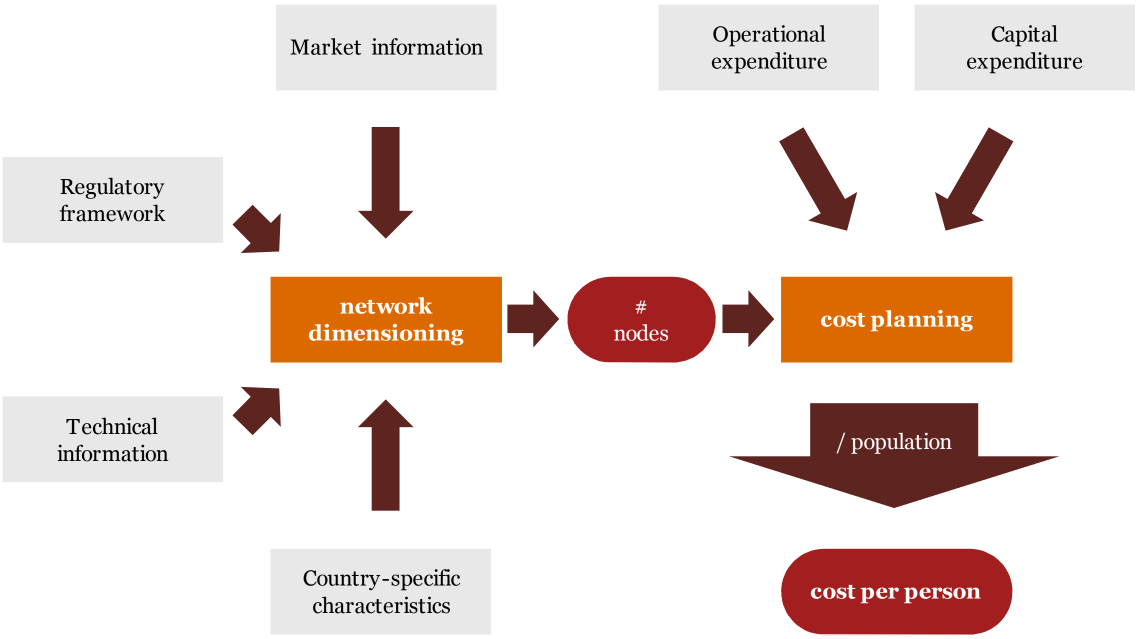
As a second step, a mobile network is dimensioned based on the normalised model. The dimensioning evaluates the number of sites and the equipment required. By varying the input values, a homogenous dimensioning for each country is possible while taking into account the country-specific characteristics. The parameters used for the dimensioning are calibrated based on the current mobile networks in Switzerland. Thus, in summary, we use a Greenfield approach with fact-based real conditions.

The third step in the modelling is to calculate the cost per capita for each country based on the dimensioned networks. For this, we summed the costs of building and operating the dimensioned network and divided the amount by the number of people living in the country. We derived the costs for resources partially from the costs in Switzerland (e.g. the cost of technical equipment). In other cases, we applied actual country-specific costs (e.g. energy, labour and rental cost).

Lastly, by varying the input values, the model allows a simulation to analyse the effective impact of the cost drivers with a 'what if' analysis of Switzerland and of each neighbouring country.

4.2.2 Cost calculation model for the mobile network

Figure 1: Cost calculation model



Normalisation of the model

To ensure the comparability of the network dimensioning between countries, some values need to be normalised (such as the structure of the network, technology and demand). Thus, for example, our model illustrates a pure UMTS network, calibrated to represent the reality in Switzerland as closely as possible. Each neighbouring country is at a different stage of its network rollout. To reflect this, our model considers the mutual influence of the UMTS and GSM (Global System for Mobile Communications) rollout and its limitations. For example, current bandwidth demand is incremented in a UMTS-only network (deployed in place of the UMTS/GSM network). Thus, for European countries, the neutrality of frequency usage (GSM, UMTS, LTE, i.e. Long Term Evolution) is also considered. In the process of calibration, we considered information about the actual Swiss mobile networks in the model.

Furthermore, the calculations of the model are based on the current number and distribution of antenna sites in Switzerland. This data allowed us to consider information concerning the real evolution of the network in the model. For example, the current number and distribution of antenna sites in the different geographical areas takes into account the information and the solutions developed by the Swiss operators in the past relating to the optimal build of a mobile network under consideration of existing constraints as the limitations of the NIR regulation. This information has been considered in the dimensioning process.

On the one hand, modelling in this way allows us to apply a Greenfield approach to build a network that is close to reality and, on the other hand, it lays the foundations for a fair comparison between countries. For example, based on the model, it is possible to calculate the impact of an increase/reduction in UMTS coverage in Germany, irrespective of its technological deployment.

Inputs of the cost-calculation model

The model reproduces the construction of a UMTS network over the frequency bands 900 MHz and 2100 MHz, whereby the current constraints of GSM networks in Switzerland are considered. The dimensioning of the network based on country-specific characteristics in Switzerland forms the basis for a comparison of mobile costs between countries. To this end, different key determinants (cost drivers) are considered. These key determinants are the input parameters within the model and they can be varied depending on country-specific characteristics, thus allowing the calculation of the impact of the cost drivers.

Table 1: Input factors

Country-specific characteristics	Detailed, uniform, basic data from all the countries such as the size of the population and information concerning topography is included in the model. All the countries are split into urban, suburban and rural areas using the same conditions/rules. Additionally mountain and border regions have been considered according to an identical rule and the total length of tunnels and railways were identified. The share of population living in border regions and the share of mountain area compared to the entire area of all countries are calculated in the model. The same dimensioning rules as derived from Switzerland are applied to all countries.
Market information	The country coverage or the consumer demand for mobile data (capacity), the Smartphone penetration and the number of inhabitants are considered input factors from the market, which have an impact on the dimensioning of the mobile network.
Regulatory framework	Swiss restrictions concerning non-ionizing radiation (NIR) at places with sensitive use (e.g. apartments or schools) are a limiting factor for the transmission power of a mobile site. Thereby an average value of the transmitting power is used, which is determined from all the authorised values of the existing antennas in Switzerland. The radiation values in the countries compared are modelled in relation to the local exposure limits. These restrictions have an influence on the number of antenna sites required.
Technical information	Technical parameters (e.g. gains and losses, interference margins or sensitivities) are included in the model to dimension the mobile network. Moreover, characteristics of the mobile network such as the distribution of macro- and micro-sites, the distribution of antenna sites within the country, used frequency bands and the existing network architecture are considered in the model. Current data from Swiss operators for the entire Swiss network were used as input factors.
Capital expenditure	Capital expenditures contain the costs for the antenna sites construction, including the permits, acquisition and related legal cost, engineering cost and cost for transmission equipment. These costs are derived from Swiss data, adjusted with European reference indexes (for example, labour cost).
Operational expenditure	Operational expenditures contain maintenance and operation costs, rental costs, energy costs which differ from country to country. These costs are derived from Swiss data, adjusted with European reference indexes. Costs are discounted over eight years.

4.3 Description of the essential assumptions, parameters and cost-driver dimensions

4.3.1 Assumptions for the modelling

The model does not evaluate nor reflect the quality of the specific network of the mobile operators in each country. It assumes the same quality level for each country and operator.

The model calculation assumes that the current deployment of sites, including the location and technical parameters, are the optimal solution, as identified by the Swiss operators, to provide mobile services to Swiss users, addressing the key historical requirements and constraints. We apply this 'optimal' solution in the model for the dimensioning in the other countries.

The study and its modelling approach is based on a comparison of cost drivers, with costs calculated assuming a Greenfield approach for all the countries, rather than historical costs.

We have assumed the same efficiency level for all activities in all countries; thus, the same activities require the same number of person-hours everywhere.

4.3.2 Overview of the relevant cost drivers

Analysing the different input factors and calibrating the simulation results of the model allows us to identify the following cost drivers as relevant for the analysis of cost differences between Switzerland and the other countries.

Table 2: Cost driver overview

Cost drivers	Description
Borders	Border regions have additional constraints to reduce interactions with the operators in neighbouring countries, such as a restricted available frequency spectrum. To avoid interactions, fewer carriers per antenna site are deployed and antennas in border regions have a stronger tilt and, with that, a limited range of coverage. To meet the current demand of mobile services, more sites compared to cities outside border areas are required. Additionally, neighbouring countries, leveraging higher NIR limits and the protective effect of hills and mountains not far from the border on Swiss side (e.g. in the Jura mountains), transmit stronger signals across the border. In doing so, they rival the Swiss signals; hence, in Switzerland, more antenna sites are required to allow Swiss customers to remain within the Swiss mobile networks. The construction and operation of these additional sites increase mobile network costs. Consequently, border regions are identified as one of the most significant cost drivers.
Mountains	The number of antenna sites in mountain regions is determined by the size of the region and by the characteristics of the mountains and of the valleys to be covered. Several characteristics of mountains, going beyond simply their height, have a significant influence on the distribution of sites. For example, a single antenna on the top of a mountain could have a much larger coverage than several antenna sites placed in the valleys; however, a single site might leave several white spots on mountain roads that would require several additional sites. There are additional costs to provide coverage in mountain areas. The installation of antenna sites under difficult conditions and problems of accessibility increase the costs of construction and operation of the access network and backhaul in the mountains. However, additional costs are mainly driven by the costs of connecting antenna sites. Even if, in mountain areas, the population density is lower and therefore fewer antenna sites are required to satisfy capacity demand, the additional costs to provide coverage are not be fully offset by the lower number of sites needed. Cities and villages (population centres) over 1500 metres above sea level have not been classified as mountain areas, but as urban or suburban regions.
Coverage of tunnels	Another driver of mobile network cost is the coverage of tunnels. Tunnels exceeding a given length cannot be covered with external antenna sites and require additional antennas inside the tunnels. Consequently, the number and the length of tunnels in a country influences the mobile network cost if they need to be covered.
Coverage of railways	Another cost driver is the coverage of railway lines. Capacity demand along railway lines increases in temporary bursts when a train passes carrying a high number of simultaneous users of mobile devices. To meet this higher capacity demand, more antenna sites along railway tracks are required. In urban areas, the increased demand can be satisfied by the existing infrastructure, but additional sites are required in rural areas. The construction and operation of these additional sites causes extra costs.

Capacity for rural	Costs to meet increased demand in rural areas are expected to be higher than in urban/suburban regions. The key reason is that, in rural areas, the current deployment of antenna sites mainly satisfies basic coverage but not capacity demand. Additional demand affects these sites more than the more 'compact' demand in suburban regions. To meet the widespread demand in rural areas, more antenna sites are required if the population density in rural areas is higher. Consequently, high population density in rural regions is a cost driver of mobile networks.
NIR regulation	Differences in NIR regulations have a significant impact on mobile network cost. Strict regulations and measurement methods state that – in compliance with the maximum permitted radiation – fewer carriers per site can be built or lower coverage can be attained. Therefore, to provide the coverage and capacity demanded by customers, more antenna sites need to be built. The NIR regulations affect the current cost structure and the demand-driven expansion of the mobile network in the future. NIR exposure limits or precautionary installation limits have the highest impact on mobile network costs compared to the other cost drivers.
Labour costs & civil works	This cost driver is represented by the cost of people measured either directly as cost per hour or aggregated in the cost position of the civil works needed for the deployment of sites. Constructing, operating and maintaining mobile networks makes up the labour costs. Cost per working hour varies from country to country.
Energy costs	Energy cost is a cost component related to the operation of mobile networks. The costs for energy vary from country to country.
Rental costs	This cost driver is represented by the different costs of renting a location for a site. Differences between rental costs between the countries in the scope of the study were identified and these have an impact on mobile network costs.

4.4 Restrictions

The following aspects are **not** taken into account in the current model:

- Direct, international comparison of cost positions between operators.

  Rationale: Reliable data are difficult to collect and not publicly available. Furthermore, the networks in the countries in the study differ and are not directly comparable; therefore, the cost positions are not directly comparable.

- The rollout of LTE.

  Rationale: The reference data used for the cost calculation are not yet stable or large enough to be included in the study.

- The consequences of an incremental development of mobile networks and the consequences due to currently existing reserve capacities for future expansion as well as past investments in old technologies and their migration cost.

  Rationale: Information on historical costs for all countries and on capacity reserves was not available when the study was planned. A comparison of historical costs between the different countries would have suffered due to different accounting rules and approaches.

- Cost reductions due to site sharing.

  Rationale: The number of operators varies among countries, whereas, for simplification purposes, the dimensioning of the network is based on a unique single operator per country covering the whole population.

- The cost of frequency licenses.

  Rationale: Licenses have been assigned in the different countries at different points in time using different approaches (e.g. 'beauty contest', extensions of licenses, auctions); hence, it is not possible to give a fair comparable value to the frequency bands used in our model.

- Time component (e.g. delays in obtaining authorisation).

  Rationale: Reliable and comparable data for the countries in scope are not available.

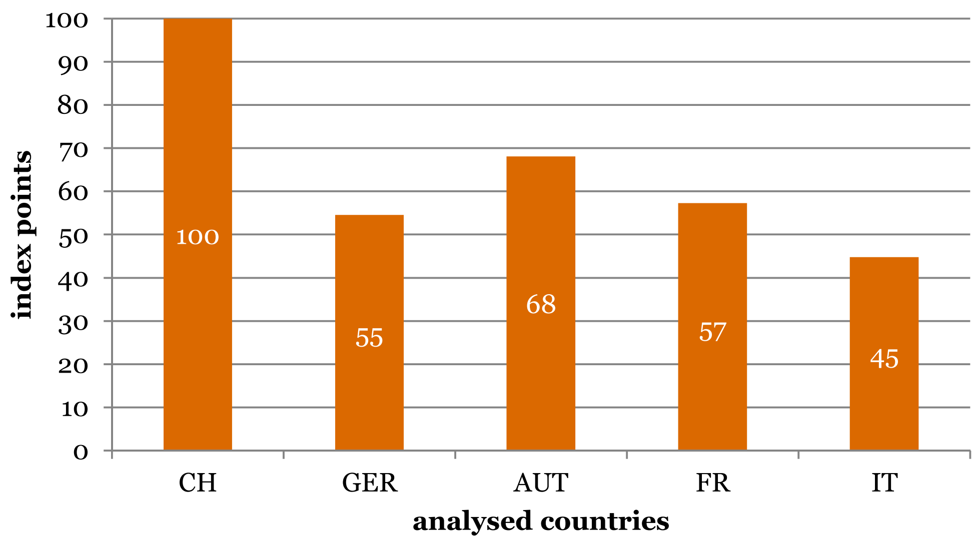
5. Results of the study

5.1 Overview of the key insights

The study demonstrates that the costs for constructing, operating and maintaining the mobile network infrastructure in Switzerland are 40 to 110 per cent higher than in the neighbouring countries.

The figures below show the Swiss mobile network costs, indexed at 100 points, and the relative base-cost points of the comparison countries.

Figure 2: Country comparison of the relative costs



The cost drivers listed in Table 3 have the strongest impact on the cost structure of the analysed countries. The entire cost difference between Switzerland and each of the countries in the comparison is divided into the different key cost drivers (listed in the table below). For each country, the relative shares of each cost driver sum to 100%, representing the full difference between Switzerland and the given country.

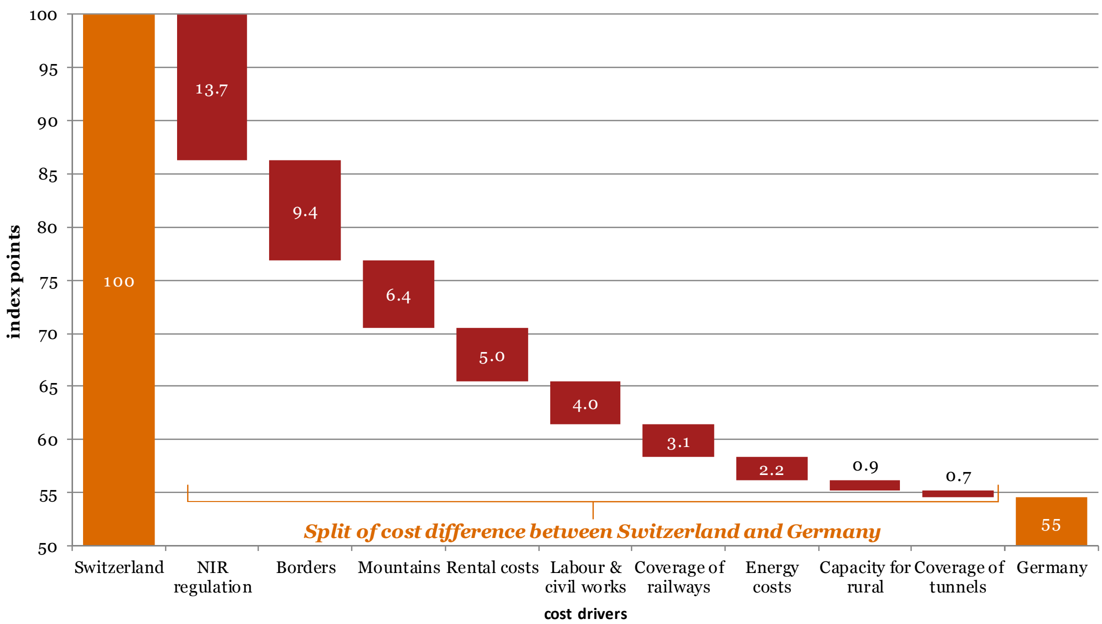
The individual cost drivers are interdependent. For example, the number of antenna sites needed determines the energy costs and rental costs. However, the number of sites is influenced by the country-specific NIR (non-ionizing radiation) regulations and the coverage of mountains and tunnels. Such interdependencies are taken into account by eliminating overlapping costs in the analysis of total costs per country, but without eliminating them in the analysis of the individual key cost drivers in the specific chapters below.

Table 3: Cost drivers

Cost drivers	*CH/GER*	*CH/AUT*	*CH/FR*	*CH/IT*
NIR regulation	30.1%	34.5%	31.5%	24.9%
Borders	20.7%	18.5%	22.1%	21.1%
Mountains	14.1%	0.9%	13.6%	10.8%
Rental costs	11.1%	14.7%	11.0%	11.0%
Labour costs & civil works	8.8%	10.6%	6.3%	12.9%
Coverage of railways	6.8%	7.9%	2.2%	13.3%
Energy costs	4.8%	5.5%	6.7%	2.9%
Capacity for rural	2.1%	6.4%	4.9%	2.0%
Coverage of tunnels	1.5%	1.0%	1.7%	1.1%

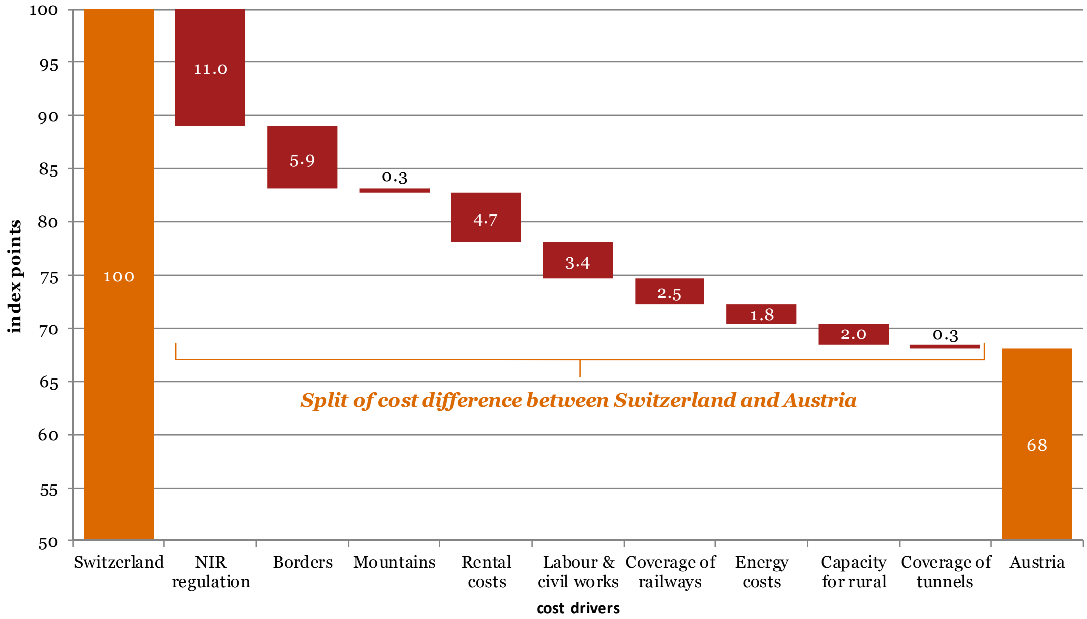
Figure 3: Comparison Germany-Switzerland

The figure shows the entire cost difference between Switzerland and Germany and splits the cost difference between the base cost points into eight cost drivers. The other cost driver figures are created similarly.



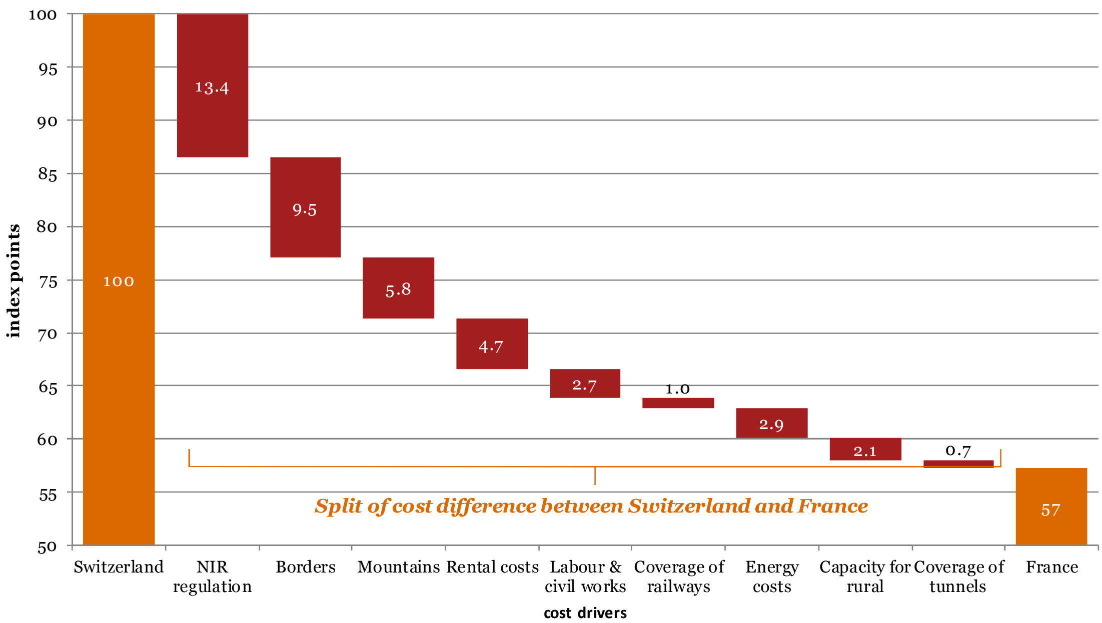
Note: 13.7 points for NIR regulation represent 30.1 per cent of the full difference of 45 (100-55)

Figure 4: Comparison Austria-Switzerland



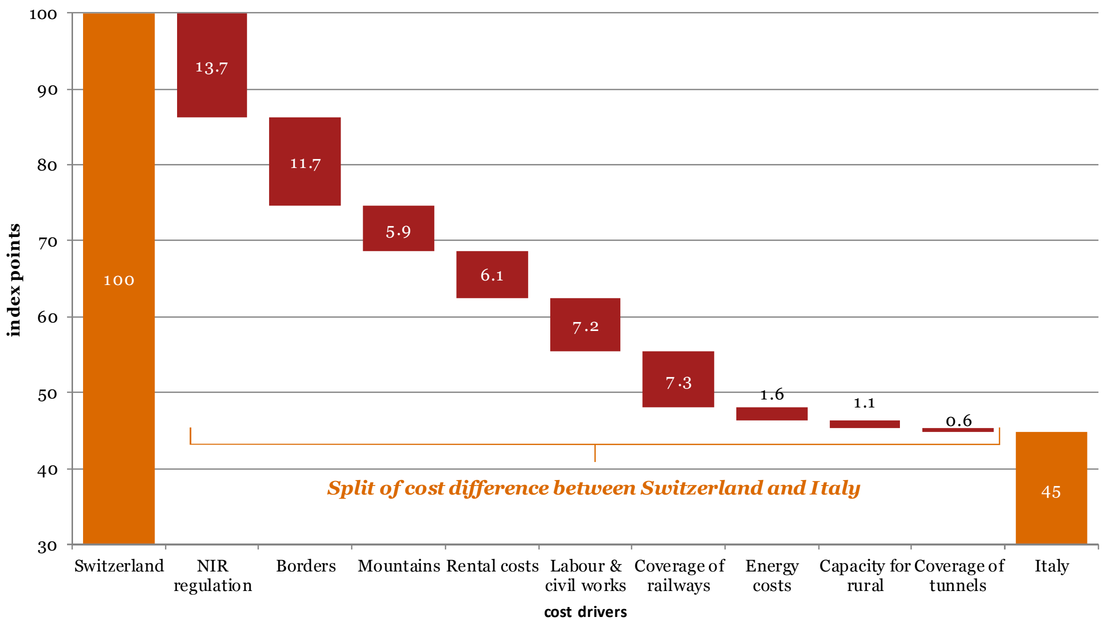
Note: 11 points for NIR regulation represent 34.5 per cent of the full difference of 32 (100-68)

Figure 5: Comparison France-Switzerland



Note: 13.4 points for NIR regulation represent 31.5 per cent of the full difference of 43 (100-57)

Figure 6: Comparison Italy-Switzerland



Note: 13.7 points for NIR regulation represent 24.9 per cent of the full difference of 55 (100-45)

5.2 Cost driver: NIR regulation

5.2.1 Background

All countries have defined rules governing the protection from non-ionizing radiation (NIR). The scope and content of the rules vary between countries. They include country-specific regulations concerning maximum exposure limits, additional precautionary measures and measurement methods of electromagnetic fields and cover the maximum allowed electromagnetic field, whether measurements are required and, if so, how these have to be performed. Additionally, authorisation constraints (e.g. authorisation required only for sites exceeding a predefined transmission power or height), authorisation requirements (documentation, site description, radiation calculation) as well as authorisation processes and administrative costs also differ from country to country.

The ordinance on non-ionizing radiation protection (ONIR) is the Swiss regulation of 23 December 1999 on the protection from non-ionizing radiation. ONIR determines, in particular, the maximum permissible exposure level in the form of exposure limit values at any accessible point and additional precautionary installation limit values at places with sensitive use (e.g. apartments or schools). It also requires regular and continuous controls of the radiation level. The Federal Office for the Environment (FOEN) defines the rules of measurement of NIR.

Table 4: NIR regulation overview

	Basis of regulation	NIR limits in V/M		
		900 MHz	2100 MHz	mixed
Switzerland	ICNIRP and additional precautionary principle: Verordnung über den Schutz vor nicht-ionisierender Strahlung (NIS-V)	4	6	5
Germany	ICNIRP: Bundesimmissionsschutzgesetz (BImSchG)	41	61	-
France	ICNIRP: Décret Nr. 2002-775, 3.5.2002	41	61	-
France (Paris)	Nouvelle charte parisienne de la téléphonie mobile	5	5	5
Austria	ICNIRP: ÖVE/ÖNORM E 8850	41	61	-
Italy	DECRETO MINISTERIALE n. 381, 10.9.1998	6	6	6

Switzerland has the strictest NIR-regulation, compared with its neighbouring countries, concerning NIR exposure and installation limits, the worst-case principle and the prescribed measurement method. Switzerland is the only country that requires a continuous monitoring system to check that all technical parameters that have an influence on NIR exposure levels do not exceed the permitted value.

The exposure limits have been defined differently in the countries we analysed. Austria, Germany and France determine their exposure limits based on the recommendations of the ICNIRP (International Commission on Non-ionizing Radiation Protection). The maximum exposure limits recommended by ICNIRP are about ten times higher than the precautionary limits in Switzerland. Italy has a stricter limit compared to the other neighbouring countries, but it is still higher than in Switzerland.

The measurement of NIR, and with it the effective NIR exposure, depends on the place of the measurement, on the method of measurement and the calculation/analysis of the radiation. The measurement methods used in the neighbouring countries tend to deliver lower measurement results than the method used in Switzerland. In the countries analysed, there are no uniform standards for measuring radiation. Differences can result, for example, from diverse regulations about the place of measurement or the method and duration of measurement (e.g. to determine a maximum value among the measurements or to calculate an aggregated value over a period). Only some of the differences in the ways/methods of measurement (those that are more quantifiable, like spatial averaging against absolute maximum value of measurement) have been considered in the study. Applying more ‘aggressive’ assumptions could lead to even bigger gaps between Switzerland and the countries compared[2].

[2] Different measurement outcomes, which result from variations in the method of measurement, were shown by means of a measurement executed by BAKOM (Bundesamt für Kommunikation) in Austria based on Swiss measurement methods (http://www.bakom.admin.ch/dokumentation/zahlen/00545/00547/00548/index.html?download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCDdH17f2ym162epYbg2c_JjKbNoKSn6A--&lang=de)

We did not consider further limitations/restrictions indirectly related to NIR limitations in our Greenfield modelling. For example, limitations on the optimal positioning for the site locations in relation to lower NIR exposure or installation limits are not taken into account while modelling the Greenfield networks.
The following definitions of limitations have been used in the study:

- *NIR limits*: these are the limits for electromagnetic fields. Exposure limits ('Immissionsgrenzwerte') must be respected in any places that people may access. Installation limits ('Anlagegrenzwerte') are more restrictive precautionary limits that need to be respected in sensitive places where people live, work or stay regularly for a longer period of time (e.g. apartments, schools). The installation limits exist only in some countries; in the others, the exposure limits are used. In our study, we use as the NIR limit the lower value of exposure and installation for the given country.
- *Permitted transmission power*: this is the maximum authorised transmitting power for a site with its installed antennas, taking into consideration antenna gains and all losses. NIR limits must not be exceeded when maximum transmission power is activated. In our study, we assume that the permitted transmission power available for all Swiss sites corresponds to the NIR limits, meaning that this transmission power cannot be exceeded. According to the Swiss operator's data, this assumption is valid in most cases in urban and suburban regions, where high capacity is demanded. In the other regions, the assumption is no longer relevant because lower capacity demand does not require exceeding current permitted transmission power.
- *Measured values*: measurements aim to confirm compliance to the NIR limits. Due to differences in measurement standards and requirements, the same site under the same circumstances may have different measured values depending on the measurement standard applied. Such measurement differences imply an additional difference among countries in the NIR limits; for example, measuring average values instead of maximum values allows NIR regulation to be met at higher permitted transmission power.
- *Built transmission power*: this is the current transmitting power of all Swiss sites. The difference between built transmission power and permitted transmission power represents the reserve used in our study to add resources to cover capacity demand.

The following process steps and costs are considered as relevant for the cost calculation and considered to be related to regulatory compliance:

- *Authorisation for building a site*: Differences among countries exist, thus influencing costs.
- *Authorisation for operating a site and transmitting*: Some countries require a simulation of exposure levels to obtain authorisation, while, for others, authorisation is only an application process.
- *Electromagnetic field measurement*: This is not required in all countries or for all sites.
- *Legal costs*: Authorisations are subject to litigation, which causes legal cost and additional supervision costs (e.g. for information exchange).

5.2.2 Brief explanations about the modelling

We calculated the impact on mobile costs driven by the differences in NIR regulations as follows. Firstly, we configured the dimensioning of the mobile network to ensure land coverage. Secondly, for each site, we added more resources (carriers) to provide the necessary capacity. If the NIR limits are reached without satisfying data demand, then new sites need to be built. Lastly, the higher the definition of NIR limits and, therefore, of the permitted transmission power, the fewer sites are required. In those countries where transmitting power is limited only by the ICNIRP, the limitation in our calculation was reduced by setting a limit on the maximum number of carriers, since the ICNIRP values would allow for non-realistic values in a Greenfield approach. Differences in the costs of mobile networks between countries are then quantified by calculating the cost in Switzerland using both limits (i.e. the Swiss limits and the limits of the country compared) and by comparing the calculated costs.

The resulting cost difference due to the different NIR limits, together with the differences in administrative costs (including those for measurements) and additional legal costs, is considered as the difference due to the 'NIR regulation' cost driver.

5.2.3 Key findings Switzerland

Strict NIR regulations and measurement methods in Switzerland result in lower maximum transmission power on a site and therefore limit the transmission power per carrier or the number of carriers compared to its neighbouring countries. To provide the coverage and capacity demanded by customers, more antenna sites need to be built. If Switzerland were to adopt the same NIR regulations as in all other countries in our study, it would require 21.5 per cent fewer antenna sites than compared with the existing regulations.

Furthermore, the lower NIR limits in Switzerland have an indirect negative impact on costs due to additional constraints on the planning and rollout. For example, there is less freedom to position the antenna sites. As a result, in urban areas, longer and more difficult negotiations are needed, which increase the cost of the search for suitable sites and rental costs (due to a very limited supply of potential sites). Furthermore, more opposition and, thus, higher legal costs and longer delays for deployment must be taken into account.

Moreover, lower NIR limit values means the transmission power per carrier is lower, leading to weaker reception within buildings and offices and higher data-traffic error rates in urban areas.

Site sharing would reduce the costs of deploying a network (if more than one operator were considered). On the other hand, costs would increase since every operator would have to fulfil coverage requirements in parallel. The application of higher NIR limits abroad would allow for a larger percentage of site sharing, further increasing the cost difference with Switzerland. We do not consider site sharing in the model calculation because a single operator is assumed.

5.2.4 *Results of the international comparison of the cost drivers*

We present the cost differences between the countries compared as follows:

- The relative share due to one cost driver in relation to the whole cost difference between Switzerland and the country compared – This represents, in percentage terms, how the cost difference between Switzerland and the comparison country is split among the different cost drivers, taking into account that some cost drivers partially overlap. Overlapping is caused by the fact that some cost drivers are calculated as an increase in the number of sites and the direct cost drivers (energy, labour and rental costs) are related to the number of sites.
- The absolute cost impact of a single cost driver without taking into account the interactions between the cost drivers – This shows the impact on cost when changing one cost driver and it is presented as a variation in index points, where the full cost per user in Switzerland is indexed at 100 points.

Our analysis reveals that the higher NIR limits applied in the surrounding countries represent the largest driver of the cost differences between Switzerland and these countries.

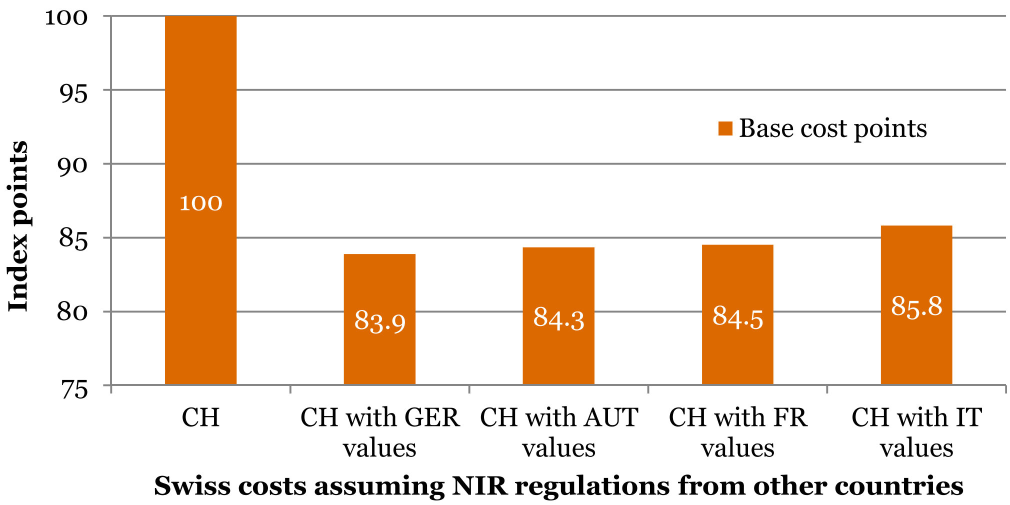
In all the situations we analysed, the cost difference between Switzerland and the neighbouring countries exists largely as the result of the different NIR regulations in the countries compared. The relative impact as a percentage of the total difference in mobile costs is listed below (for each country).

Table 5: Relative shares

Cost driver	*GER/CH*	*AUT/CH*	*FR/CH*	*IT/CH*
Relative share of the whole cost difference due to different NIR regulations	30.1%	34.5%	31.5%	24.9%

As illustrated above, 30.1 per cent of the entire cost difference between Switzerland and Germany, for instance, results from different NIR limits in those countries.

Figure 7: Impact on cost in Switzerland due to differences in NIR regulations



In the figure above, the costs in Switzerland are indexed at 100 base-cost points. The chart shows the decrease of costs in Switzerland if the country were to apply the same NIR regulations as its neighbouring countries[3]. Hence, as illustrated above, if Switzerland had the same NIR regulations as Germany, for instance, mobile network costs in Switzerland would fall from 100 to 83.9 index points.

Legal and administration expenses related to NIR regulation (authorisation, legal, quality monitoring systems) account for between zero (Italy) and 12 per cent (Germany) of the NIR regulation-related cost differences between the different countries.

Switzerland is the only country that requires a continuous monitoring system to check that technical parameters that have an impact on NIR exposure level do not exceed the permitted values. This system accounts for approximately 2 per cent of NIR regulation costs.

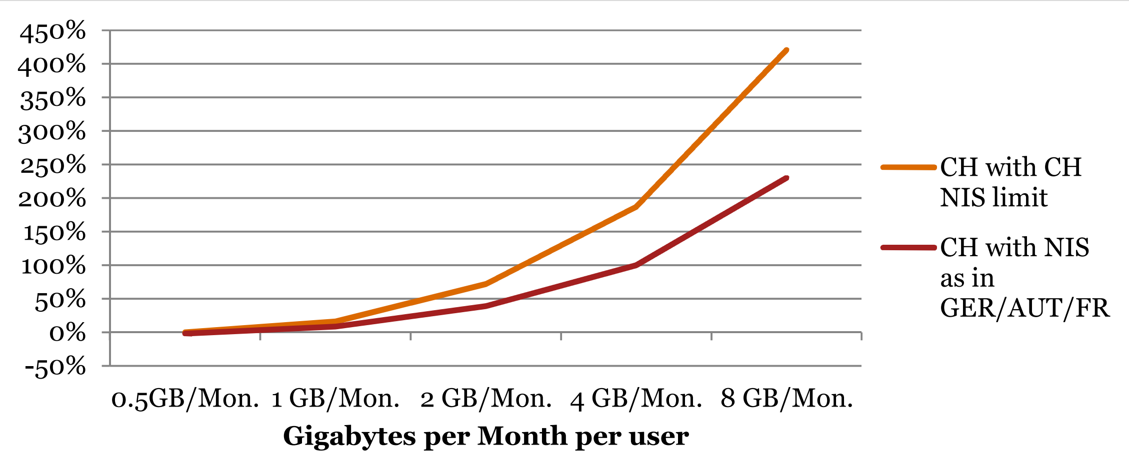
[3] The full impact of the given cost driver is presented, regardless of all others that may have a correlation to it.

5.2.5 *Additional analysis: incremental cost*

The Greenfield approach used in our study was applied on the basis of current capacity demand. Although the calculation of the impact on all the cost drivers of increasing capacity demand was out of scope of this study, we decided to analyse the cost evolution related to NIR regulations as this is the single largest driver of cost differences.

The current regulations in Switzerland (with stricter NIR limits) affect not only the current cost situation/structure but also the demand-driven expansion of the mobile network in the future. The cost to satisfy growing data demand under the same (current) technical conditions will increase the cost difference between Switzerland and the compared countries. The chart below shows the development of mobile network costs in Switzerland compared with Germany while improving the delivery capacity to satisfy an increase in capacity demand[4].

Figure 8: Impact of NIR regulations as data demand rises



The cost increase under current NIR limits is almost twice that under the limits applicable in Germany. Considering the current doubling of data capacity demand almost every nine months, in less than four years costs could be 400 per cent of their current level. As it is unlikely to expect this level of investment in the short term, the most probable effect will be a call for the faster introduction of LTE and other developing technology. If the deployment of these technologies is prevented or delayed (e.g. by a lack of transmitting power in urban and suburban regions due to the NIR limits in Switzerland), the network may be unable to satisfy the growth in demand and the perceived quality of service may suffer a decline. Our figure is a theoretical illustration based on UMTS. LTE is not taken into account in our model. Even if the deployment of LTE were considered, the increase in cost would still only be partially compensated.

[4] To meet the increased demand in capacity, the progressive implementation of HSPA 42.4 across the whole of Switzerland as well as the progressive implementation of a new UMTS frequency band in urban areas has been considered. An increased penetration of fibre in backhauling has also been considered.
This is an application of the model based on current conditions. The effective illustration of a rollout over time is not taken into consideration. Hence, migration costs or other factors which may compensate the cost increase are not considered (e.g. cost of equipment, which becomes more efficient, or the application of new technologies).

What does this mean?
A demand-driven expansion of the mobile networks under the current regulatory framework will lead to significantly higher costs in Switzerland than in its neighbouring countries, where the NIR regulations are less strict. Furthermore, the low permitted capacity due to stricter NIR regulations can slow the time-to-market of new technologies. New positions for antenna sites need to be found and significant administrative delay and cost must be expected.

NIR regulation is the largest single cost driver for mobile networks. Amendments to the NIR regulations in Switzerland, therefore, might represent the 'easiest' route to reduce the growing costs of satisfying rapidly increasing capacity demand.

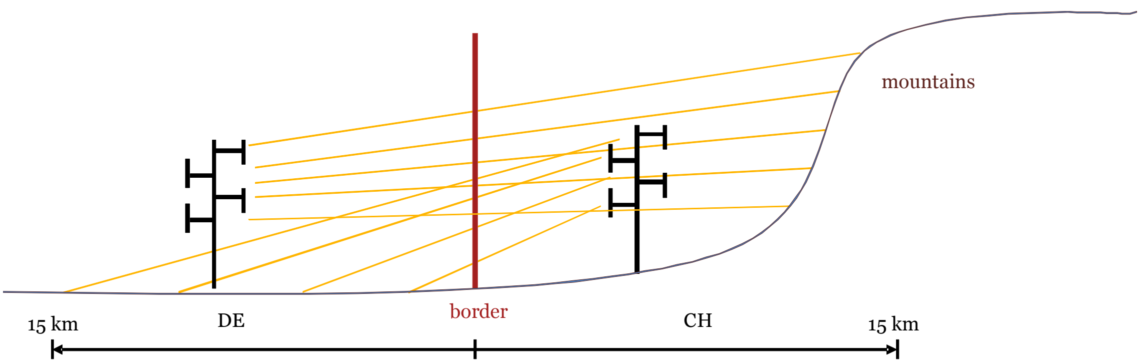
5.3 Cost driver: Borders

5.3.1 Background

Border regions have been identified as one of the most significant cost drivers. Border regions have additional constraints because of the need to reduce interactions with neighbour countries. Hence, fewer carriers per antenna are available and the antennas in border regions have a stronger tilt and, with that, a lower range of coverage. In border regions, there are also limits on the frequency spectrum, since neighbouring countries may use the same frequency band(s).

The operation of mobile base stations along a country's border line is restricted by international agreements to avoid any harmful interference due to the use of the same frequencies by different operators in the same area. The agreements define field strengths limits to restrict signal levels originating from a mobile operator's base station in one country. The limits shall not be exceeded within a defined distance on the other side of the border. For GSM, this distance is 15 km from the border line; other distances apply for UMTS or LTE. This approach is useful for technical reasons but it has a disadvantage for Switzerland. Due to the topographic situation, with hills and mountains near the border, foreign operators may generate higher signal levels without violating the international agreements.

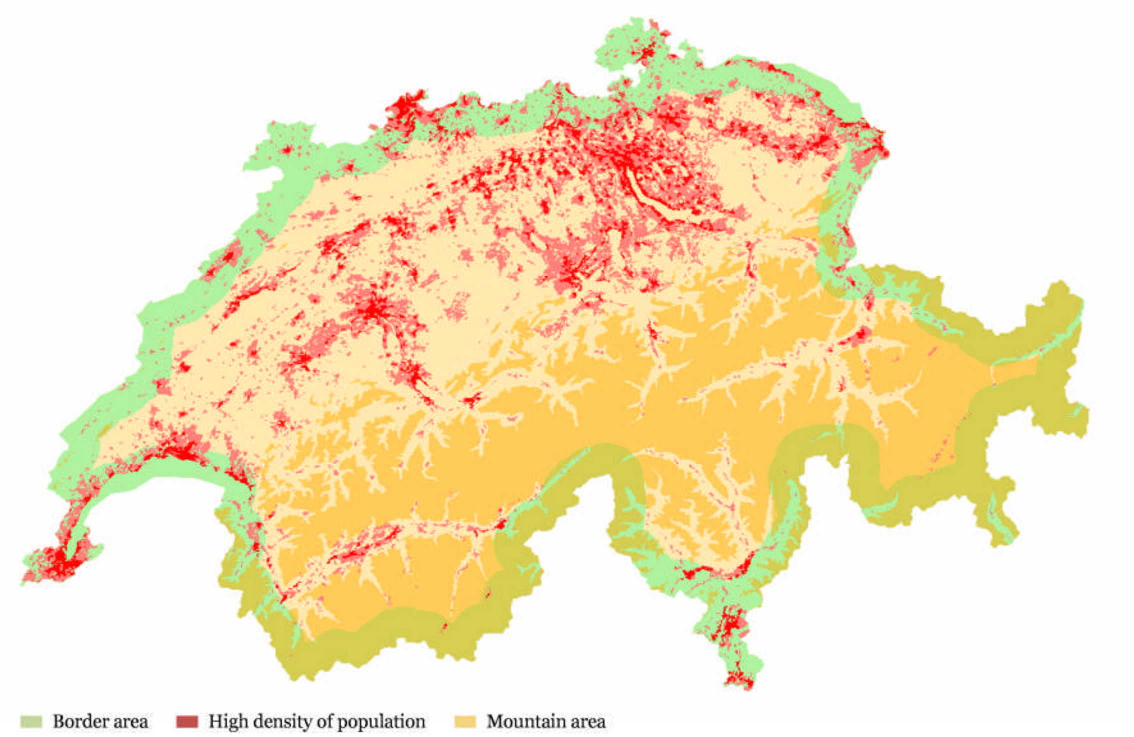
Figure 9: Antennas near the border (15 km rule)



Additional costs arise mainly from the higher number of antenna sites required. After discussions with technicians of the Swiss operators, we selected for our modelling an area of 10 kilometres from the border. We consider all urban and suburban regions within this band as a separate land cluster layer ('border' region). We then compared the density of antenna sites between urban/suburban regions within the border region and outside this region.

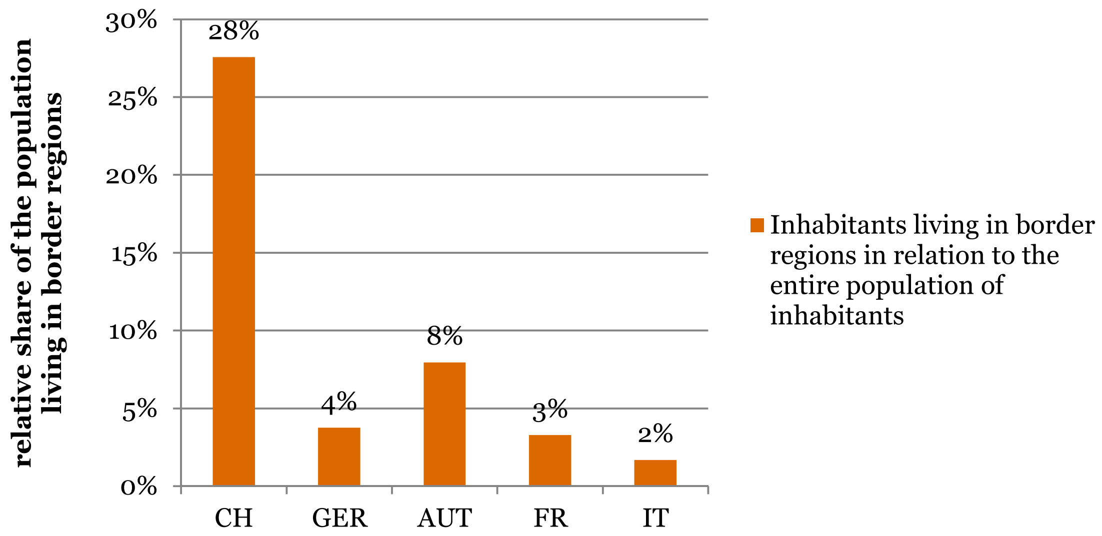
In Switzerland, a higher percentage of the population (an estimated 28 per cent) lives near a border (Basel, Geneva, Leman region, Schaffhausen or the Lake Constance region, Lausanne, Chiasso, etc.). The larger number of sites required to cover this urban and suburban population represents one of the most significant cost drivers of mobile network costs in Switzerland.

Figure 10: Areas of high population density near the border [5]



[5] Source WiTech

Figure 11: Percentage of population living in border regions



The coverage of border regions has been identified as a significant cost driver within the model. We quantified the percentage of extra costs required to cover border regions in the countries in our study. For our calculations, we compared current Swiss costs with the hypothetical cost if Switzerland were to have the same share of population living in border regions as its neighbours.

5.3.2 Key findings Switzerland

Our study reveals that, based on the data for all Swiss sites, in the border regions of Switzerland, 30 per cent (urban areas) to 50 per cent (suburban areas) more antenna sites are necessary in order to cover optimally the border areas.

The key finding is that the average transmission power is similar in both border and non-border areas, but the density of sites differs. The higher density of antenna sites in border regions reduces the possibility of building additional antenna sites in cities near the border (like Basel or Geneva) in order not to exceed the NIR limits. This situation is confirmed by the current smaller average number of carriers in urban/suburban regions near the border.

Figure 12: Antennas in Switzerland located in cities within border regions compared to non-border [6]

The figure above (based on Swisscom's antenna sites) is illustrative to show that the density of antenna sites is higher in Basel and Geneva compared with Bern and Zurich.

If Switzerland's population living near the borders were lower, costs would be reduced by 12 per cent.

[6] Source WiTech based on Swisscom data

5.3.3 *Results of the international comparison of the cost drivers*

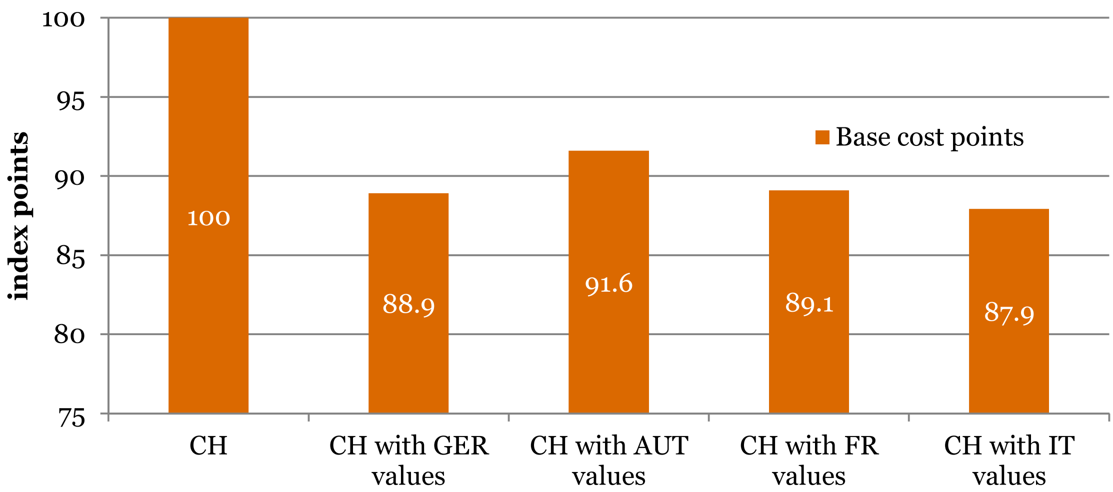
The relative impact in each case, as a percentage of the entire difference in mobile costs, is listed below.

Table 6: Relative shares

Cost driver	*GER/CH*	*AUT/CH*	*FR/CH*	*IT/CH*
Relative share of the entire cost difference due to additional costs to cover the border regions	20.7%	18.5%	22.1%	21.1%

As illustrated above, 20.7 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of additional costs due to the coverage of border regions.

Figure 13: Impact on cost in Switzerland due to different coverage in border regions



In the figure above, we have indexed Swiss costs at 100 points. The chart shows by how many points costs would fall in Switzerland if the country's border area (relative to its entire territory and its population) were the same as in the countries compared in our study. Thus, as illustrated above, if Switzerland had the same proportion of border area as Germany, mobile network costs in Switzerland would fall from 100 to 88.9 index points.

5.4 Cost driver: Mountains

5.4.1 Background

The study identified topographic factors as key cost drivers for the construction, operation and maintenance of mobile networks.

To quantify this cost driver, we defined a mountain cluster by overlaying an elevation grid on the urban/suburban/rural cluster map. We define the 'mountain' area as being all of the rural area with an elevation over 1500 meters. This definition is applied consistently to all countries in the study. Cities and villages (population centres; coloured red in the figure below) over 1500 meters above sea level are not defined as mountain areas (coloured orange), but as suburban regions.

Figure 14: Mountain areas in Switzerland[7]

[7] Source WiTech

The approach used in our study is to consider the impact of mountain area coverage in addition to the coverage of the rest of the country. The study compares the cost of covering and not covering the mountain areas within the countries in the study. For our calculations, we assume that the neighbouring countries have the same mountain are coverage as Switzerland.

Our analysis reveals that several characteristics of the mountains, in addition to height, have a significant influence on the distribution of sites. For example, a single antenna site on the top of a mountain might provide much larger coverage than several antennas placed in valleys. On the other hand, a single antenna site could leave several white spots on mountain roads that would require several additional sites. The Swiss operators have taken into account several factors in driving forward and optimising the current positioning of antenna sites in mountain regions. Therefore, we assume for our model that the current number of sites per square kilometre and the number of carriers per site in the Swiss mountains is 'optimal'[8] and we use this information as a basis for the model calculation[9]. The current distribution of antennas in Switzerland covers 74 per cent of the country's mountain region with a basic service and 30 per cent of the population in the mountains can make use of data services. The provision of wide coverage in mountain areas is due to demand for a high quality network from users.

Figure 15: Share of land area

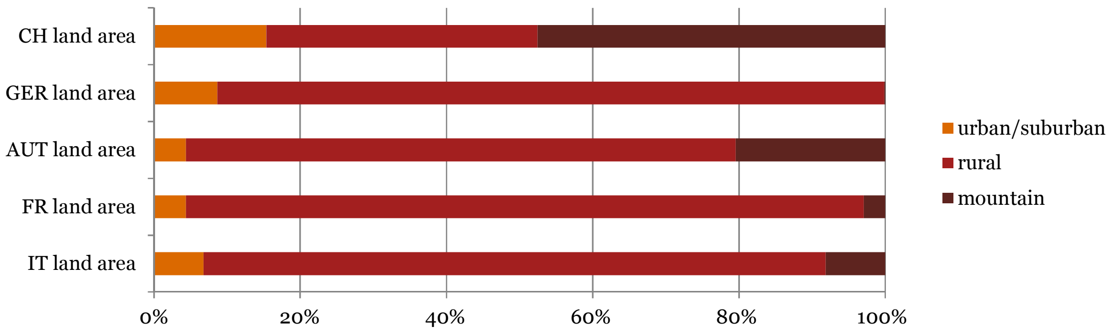
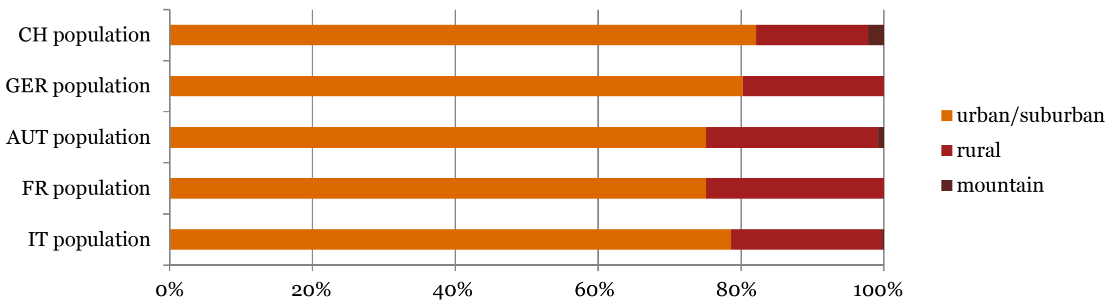


Figure 16: Percentage of populations within land areas



[8] Under the current Swiss NIR regulation constraints

[9] In the model, the basic (for land coverage purpose) number of macro and micro sites for the mountain area has been set as a fixed value per square kilometer.

5.4.2 *Key findings Switzerland*

Dividing the entire land area of the respective countries into these defined standardised categories shows that Switzerland has a higher percentage of mountain area than its neighbours do. Switzerland also has the most people living in mountain regions at over 171,000 inhabitants. However, the population density within mountain areas in Switzerland is lower than in non-mountain areas. Thus, in rural areas, an antenna site serves 1,270 people on average, whereas an antenna site in the mountains covers only 850 people on average according to our model calculation. It should be noted at this point that cities and bigger villages in the mountains (e.g. Davos, Andermatt and St. Moritz) are treated as suburban area and they are not included in the analysis of the mountain areas. Hence, our findings relate only to the rural areas above 1,500m.

If fewer people live in mountain areas, the implication is that the dimensioning of sites in such areas is driven essentially by coverage requirements and not by considerations of capacity. High capacity is less relevant in mountain areas. This is confirmed by the current number of sites in the mountain areas according to Swiss operators' information. The number is considerably lower than in the rural areas.

Installations of antenna sites under difficult conditions and problems of accessibility increase the costs of construction and operation of the access network and backhaul in mountains. Additional costs for mountainous regions are driven largely by the costs of connecting the antenna sites. Our study reveals that the costs of linking antenna sites via wireless in the mountain area are four times higher than in the rural area. Connections via optical fibre are eight times higher in the mountains compared to rural areas.

At present, 35 per cent of all the connections in the mountain area between antenna sites are fibre based, whereas fibre-based connections already account for a 50 per cent share in rural areas. In the future, the rollout of fibre-based access networks will extend to all areas in order to handle the increasing volumes of mobile data. New technologies, like LTE, will require fibre. However, covering the rising demands of mobile network customers will lead to higher costs to build and operate the mobile network.

5.4.3 *Results of the international comparison of the cost drivers*

Providing coverage in the mountains involves additional costs in all the countries we analysed. Switzerland has more square kilometres of mountainous area in relation to the country extension compared to its neighbours and a higher population (in absolute value) living in the mountains (although fewer live in mountain areas than in rural non-mountainous parts). The higher mobile network costs in Switzerland reflect these country-specific circumstances.

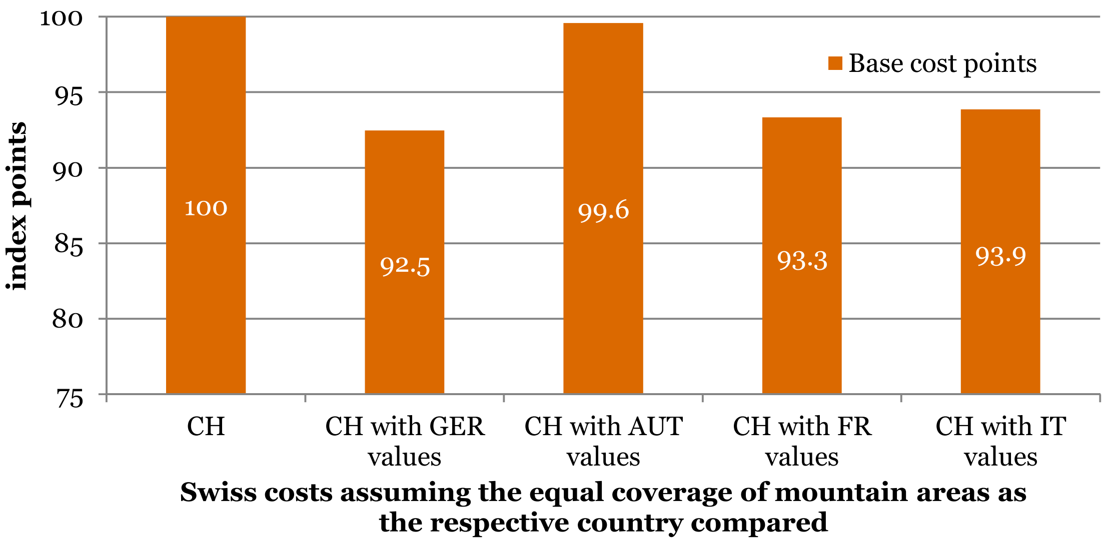
Countries with less extensive mountain areas, lower population density in mountain areas and low user expectations of coverage within isolated mountain areas have lower costs to build and operate their mobile networks. For example, in Germany, just a few rural areas are over 1,500 metres above sea level. A comparative analysis of the mobile network costs of Switzerland and Germany reveals that a share of 14.1 per cent of the entire cost difference is due to the country-specific mountain conditions. In our calculation, we assume Germany has the same mobile coverage in the mountain area as Switzerland. If the current coverage provided in Germany were lower than in Switzerland, the cost difference between these countries would be even higher.

Table 7: Relative shares

Cost driver	*GER/CH*	*AUT/CH*	*FR/CH*	*IT/CH*
Relative share of the whole cost difference due to different surface of mountain area	14.1%	0.9%	13.6%	10.8%

As illustrated above, 14.1 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of additional costs due to the coverage of mountain areas.

Figure 17: Impact on cost in Switzerland due to different coverage in mountain areas



In the figure above, we index the costs in Switzerland at 100 points. The chart shows by how many points the costs would fall if Switzerland had a surface of mountain area[10] relative to its entire territory equal to that of its neighbours.

As illustrated above, if Switzerland had the same relative surface of mountain area as Germany, mobile network costs in Switzerland would fall from 100 to 92.5 index points.

[10] The mountain area is defined as all rural area over 1500 meters, excluding population centres.

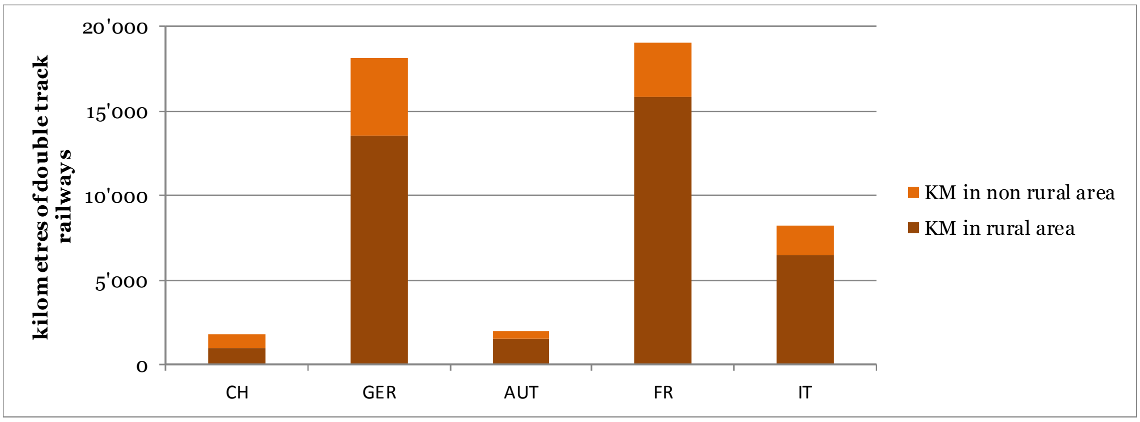
5.5 Cost driver: Coverage of railway lines

5.5.1 Background

Another cost driver is the coverage of railway lines. Capacity demand along railway lines increases in temporary bursts when a train passes transporting a higher number of users connected to the network simultaneously through their mobile devices. Figuratively speaking, it is the equivalent of a mobile suburb!

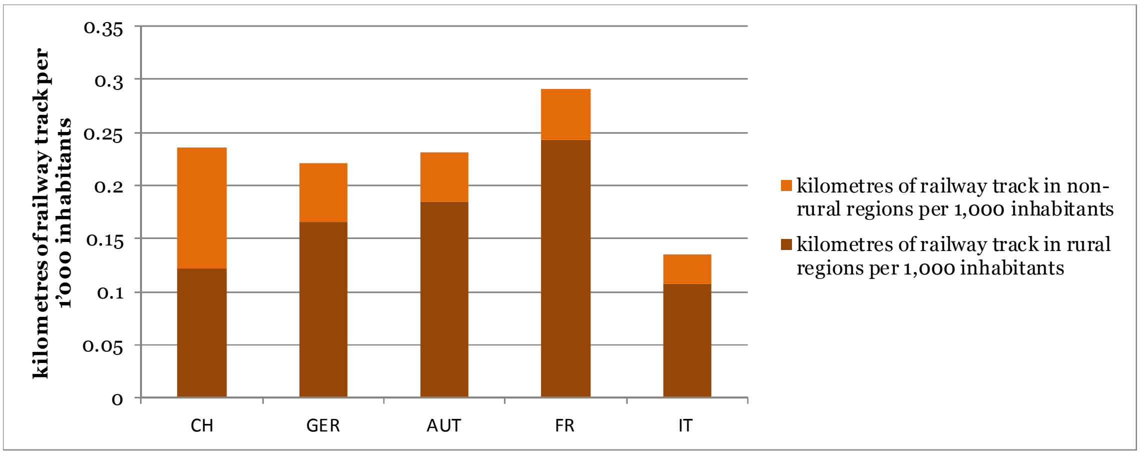
To meet the higher capacity demand, an increased number of antenna sites along railway tracks is required. In urban areas, the increased demand can be satisfied with the existing infrastructure, while additional sites are required in rural areas. The current number of macro sites around railway tracks in rural areas is six times higher than the number of sites in normal rural areas in Switzerland. The construction and operation of these additional sites causes extra costs.

Figure 18: Number of kilometres of double track railways



In absolute terms, Switzerland has fewer railway lines in rural and non-rural areas compared with neighbouring countries. Nevertheless, total railway length in Switzerland relative to its population (i.e. the number of kilometres railway track per inhabitant) is comparable to its neighbours (see Figure 19).

Figure 19: km of railway track per 1,000 inhabitants



We only consider coverage of double-track railways in the model. For our calculation, we have used the number of double-track kilometres in the rural area. Along these railway tracks, we assume 100 per cent coverage.

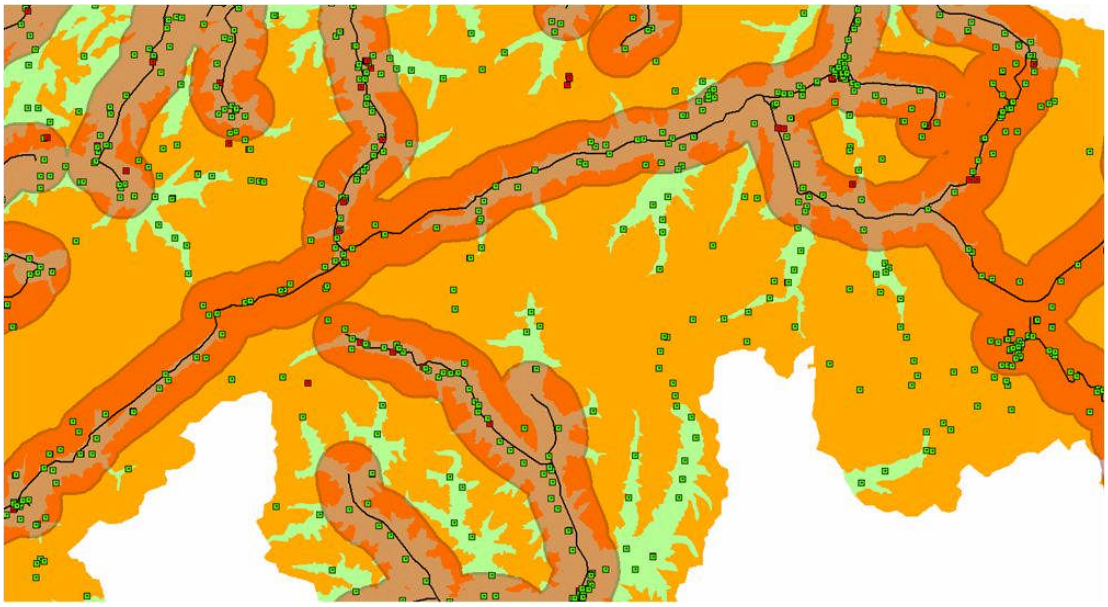
Providing coverage along railway tracks is quantified as an additional cost component. The model calculates the percentage of additional costs to meet the increased demand along the railway tracks in the rural areas of the countries analysed. To this end, we compared the country-specific difference in the costs of covering and not covering railway tracks.

We assume the additional antennas along railway tracks provide road coverage, since highways and railway lines are often within the coverage area of the same antenna sites considered in the railway coverage calculation. Currently, the additional network load per kilometre of highway is not as high as the additional network-bursting load caused by a fully occupied train.

5.5.2 Key findings Switzerland

In Switzerland, there are 1,826 km of double-track railways, of which 52 per cent (about 950 kilometres) are in rural areas. To cover the demand along the 950 kilometre railway tracks in rural areas requires additional antennas. The current number of sites along double-track railways is calculated as six times higher than in rural areas without railway tracks.

Figure 20: Antennas along railway lines in Switzerland[11]



5.5.3 Results of the international comparison of the cost drivers

Our calculations demonstrate that the extra cost to cover the 'batch-wise' increases in demand along railways is one of the biggest drivers of the relative cost differences between Switzerland and its surrounding countries.

The relative impact as a percentage of the entire difference in mobile costs is listed below (for each country).

Table 8: Relative shares

Cost driver	GER/CH	AUT/CH	FR/CH	IT/CH
Relative share of the whole cost difference due to additional costs to cover the data demand along railway tracks	6.8%	7.9%	2.2%	13.3%

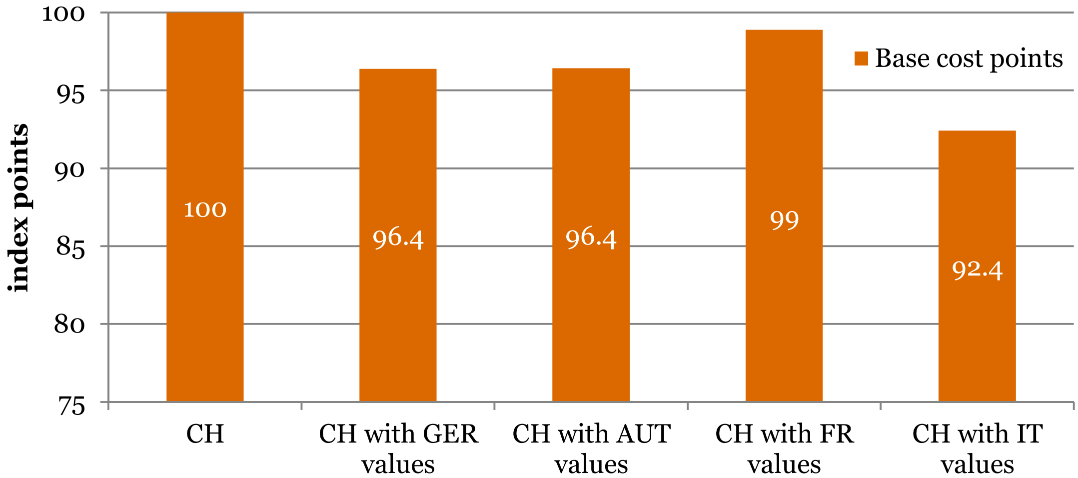
As illustrated above, 6.8 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of additional costs due to coverage along railway tracks.

Even if Switzerland does not have the highest number of railway kilometres per 1,000 inhabitants, the cost of providing coverage along railways is higher than in the other countries

[11] Source WiTech based on data of the Swiss operators (for illustrative purpose)

we compared. To provide the same coverage in Switzerland requires more antenna sites due to the stricter NIR regulations in force in the country.

Figure 21: Impact on cost in Switzerland due to different coverage along railway tracks



In the figure above, we index the costs in Switzerland at 100 points. The chart shows by how many points the costs would fall if Switzerland had the same railway network relative to its entire territory as its neighbours.

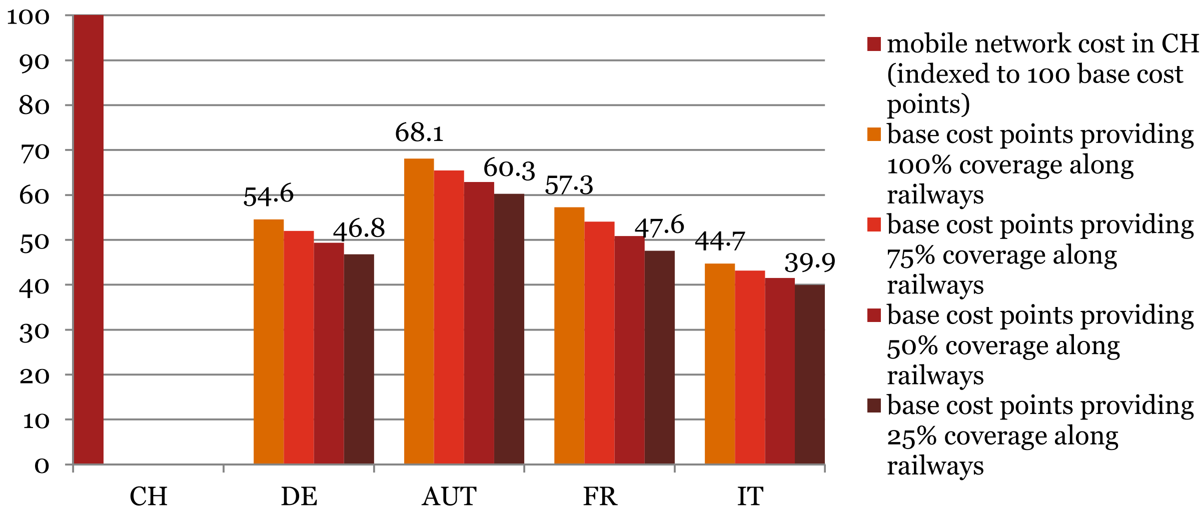
As illustrated above, if the railway network in Switzerland had the same characteristics as Germany, for instance, mobile network costs in Switzerland would fall from 100 to 96.4 index points.

5.5.4 Scenarios (assuming different railway coverage)

For our calculations, we assume the same coverage of railway tracks as in Switzerland for all the countries compared (100 per cent coverage of double-track railroads in rural areas)[12]. The assumption that the neighbouring countries cover double-track railroads to the same extent as in Switzerland may not reflect reality. In light of this, we performed a simulation assuming that rural railway coverage in the other countries would be lower (respectively 75 per cent, 50 per cent or 25 per cent of the double-track railroad kilometres in rural areas). The total costs under these assumptions would change as shown in the figure below (compare with Figure 3).

[12] 100% coverage does not mean that there are no white spots for coverage along the tracks, but refers to the general coverage of double-track railways as attempted by the Swiss operators.

Figure 22: Changes in base cost points providing 100 per cent, 75 per cent, 50 per cent or 25 per cent coverage along railway lines for the countries compared



The table refers to total base cost points assuming full coverage in Switzerland and, respectively, 100 per cent (full), 75 per cent, 50 per cent and 25 per cent coverage along railway lines in all the other countries.

Table 9: Relative base cost points

Railway coverage/base cost points	*GER*	*AUT*	*FR*	*IT*
Base cost points providing 100% coverage along railways	54.6	68.1	57.3	44.7
Base cost points providing 75% coverage along railways	52.0	65.5	54.1	43.1
Base cost points providing 50% coverage along railways	49.4	62.9	50.8	41.5
Base cost points providing 25% coverage along railways	46.8	60.3	47.6	39.9

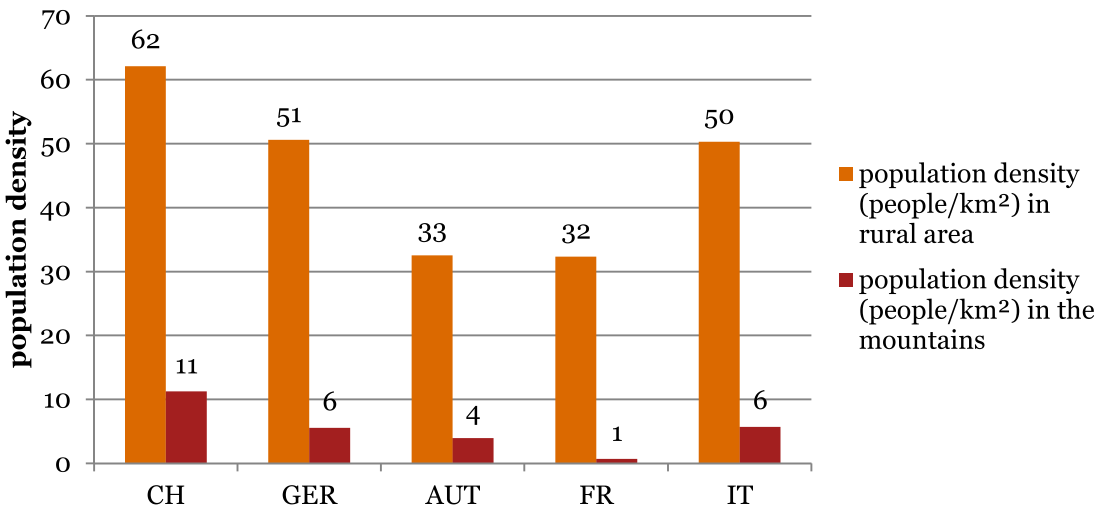
5.6 Cost driver: Capacity for rural areas

5.6.1 Background

High population density in rural regions was identified as a cost driver for mobile network costs. The cost to meet increased demand in rural areas has been found to be higher than in urban/suburban regions. The key reason is that the current deployment of antenna sites in rural areas mainly satisfies basic coverage, but not the capacity demand. Additional rural demand has a more significant impact on these sites than the more compact demand in suburban regions.

The population density in rural and mountain regions varies strongly from country to country as illustrated below:

Figure 23: Population density (in rural and mountain areas)



This cost driver represents the additional costs to provide capacity in the rural area of a country. We calculate the impact by changing the proportion of persons living in the rural area to the same value as in the other countries. For calculation purposes, the people 'relocated' due to this process are considered to be living in the suburban area.

5.6.2 Key findings Switzerland

In Switzerland, it is estimated that around 2,130 people are covered by one antenna site in urban/suburban regions, while only around 1,270 persons are covered by one antenna site in rural areas.

The additional number of antenna sites required is calculated by assuming that Switzerland has the same population density in rural and mountain areas as the other countries in our study. Our results indicate that, if we assume the same rural and mountain population density as in Germany, the reduction of antenna sites in mountain and rural areas would be two times greater than the simultaneous increase of antenna sites required in suburban areas (to handle the ‘relocated’ population). Consequently, mobile network costs per user would decrease by about 1 per cent.

5.6.3 Results of the international comparison of the cost drivers

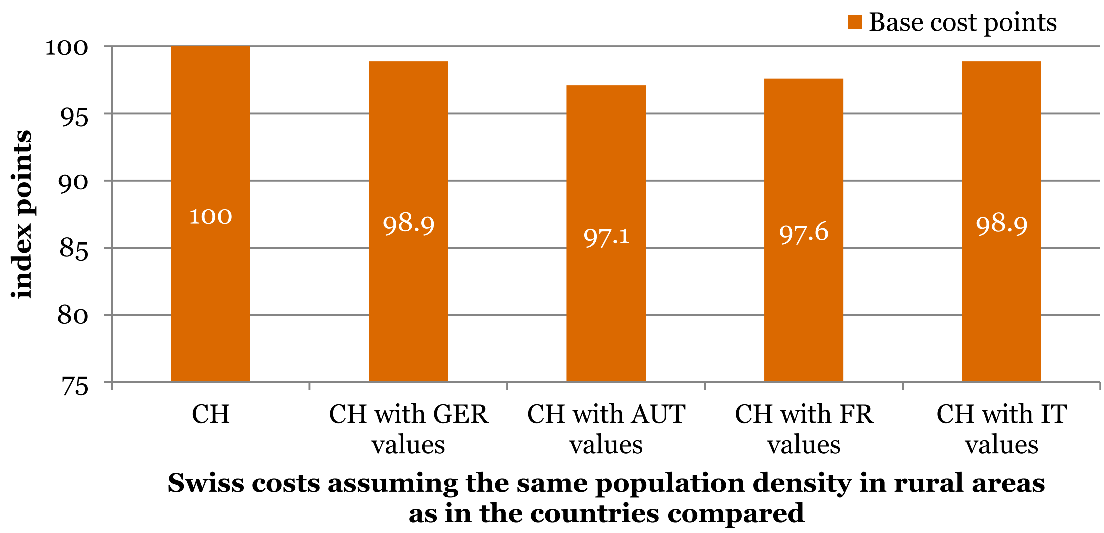
The relative impact as a percentage of the entire difference in mobile costs is listed below (for each country).

Table 10: Relative shares

Cost driver	GER/CH	AUT/CH	FR/CH	IT/CH
Relative share of the entire cost difference due to additional costs to provide capacity in rural areas	2.1%	6.4%	4.9%	2.0%

As illustrated above, 2.1 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of additional costs due to providing capacity in rural areas.

Figure 24: Impact on cost in Switzerland due to different population density in rural areas



In the figure above, we index the costs in Switzerland at 100 points. The chart shows by how many points the costs would fall if Switzerland had the same population density in rural areas as its neighbours.

As illustrated above, if Switzerland had the same population density in rural areas as Germany, for instance, mobile network costs in Switzerland would fall from 100 to 98.9 index points.

5.7 Cost driver: Rental cost

5.7.1 Background

This cost driver represents the different costs of renting a location for a site in the different countries.

Rental costs have been evaluated from benchmark data obtained from the Swiss Federal Statistical Office (BFS)[13] and other sources, like the OECD Purchasing Power Parity data and cost of living data,[14] to check their credibility and identify cost differences between countries.

The following correction factors were used to accommodate the cost differences between the countries compared:

Table 11: Correction factors

Country	Rental Cost Correction Factor
Switzerland	1.00
Germany	0.52
Austria	0.46
France	0.56
Italy	0.49

5.7.2 Key findings

The impact of this cost driver is determined by the difference in rental costs compared with the other countries in our study.

The relative impact as a percentage of the entire difference in mobile costs is listed below (for each country).

Table 12: Relative shares

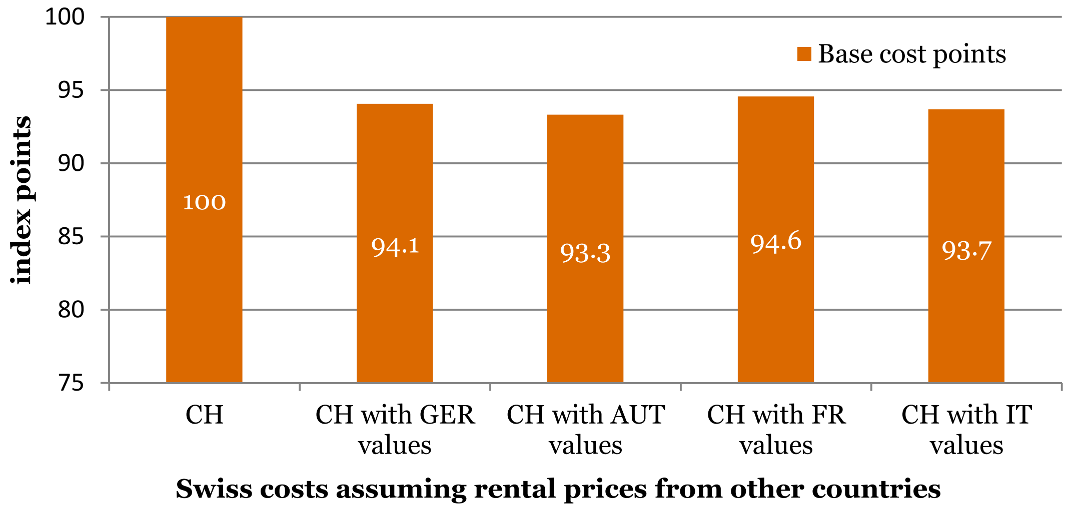
Cost driver	GER/CH	AUT/CH	FR/CH	IT/CH
Relative share of the whole cost difference due to lower rental cost in the countries compared	11.1%	14.7%	11.0%	11.0%

[13] http://www.bfs.admin.ch/bfs/portal/de/index/themen/05/07/blank/key/01.Document.20903.xls?sc=1

[14] Numbeo.com

As illustrated above, 11.1 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of lower rental costs in Germany.

Figure 25: Impact on cost in Switzerland due to different rental costs



In the figure above, the cost in Switzerland is indexed at 100 points. The chart shows by how many points the costs would fall if Switzerland had the same rental costs as its neighbours.

As illustrated above, if the rental costs in Switzerland were the same as in Germany, for instance, mobile network costs in Switzerland would fall from 100 to 94.1 index points.

5.8 Cost driver: Labour cost

5.8.1 Background

This cost driver represents the cost of the workforce either directly measured as cost per hour or aggregated in the cost position of any civil works required for the deployment of antenna sites.

Constructing, operating and maintaining mobile networks gives rise to labour and service costs. Cost per working hour varies from country to country.

For every country, we assume the same number of working hours, except for activities in which we can identify significant differences in working hours between countries (e.g. construction permits).

Civil works carried out by external providers are not differentiated in terms of material and labour cost. In this case, cost differences are evaluated based on specific benchmarking indices for construction work.

Cost differences are identified based on data published by the Swiss Federal Statistical Office (BFS). To accommodate the cost differences between the countries in our comparison, we applied the following correction factors:

Table 13: Correction factors[15]

Country	Labour Cost Correction Factor
Switzerland	1.00
Germany	0.71
Austria	0.69
France	0.81
Italy	0.59

Table 14: Correction factors[16]

Country	Index Construction works
Switzerland	1.00
Germany	0.87
Austria	0.91
France	0.92
Italy	0.65

5.8.2 Key findings

The impact of this cost driver was determined by the difference in labour costs and civil works compared with the other countries in our study.

The relative impact of the cost driver as a percentage of the entire difference in mobile costs is listed below (for each country).

Table 15: Relative shares

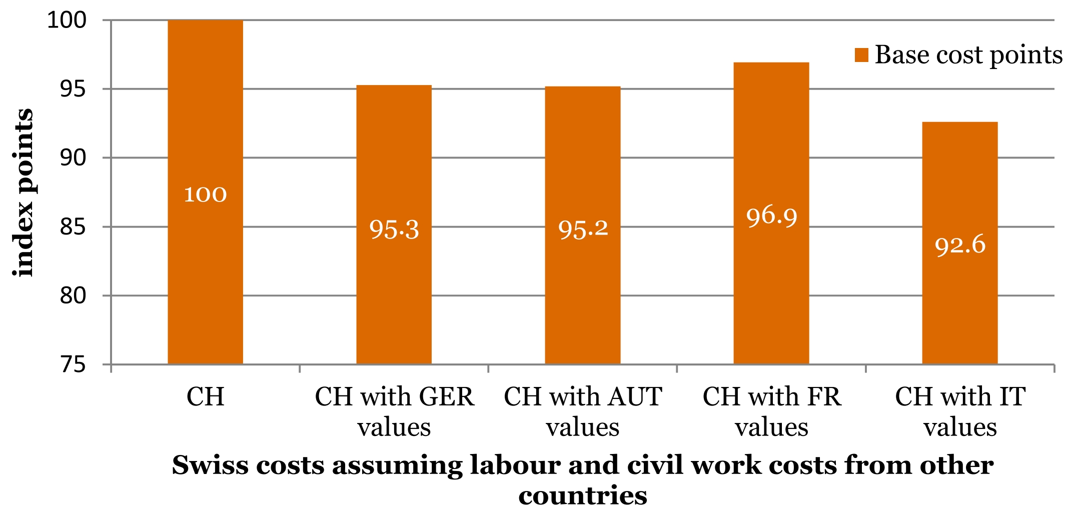
Cost driver	GER/CH	AUT/CH	FR/CH	IT/CH
Relative share of the whole cost difference due to different labour and civil work cost	8.8%	10.6%	6.3%	12.9%

[15] http://www.bfs.admin.ch/bfs/portal/de/index/themen/06/04/blank/data.html

[16] http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Comparative_price_levels_for_investment

As illustrated above, 8.8 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of lower labour cost and civil work cost in Germany.

Figure 26: Impact on cost in Switzerland due to different labour and civil work costs



In the figure above, the cost in Switzerland is indexed at 100 points. The chart shows by how many points the costs would fall if Switzerland had labour and civil work costs equal to the neighbouring countries.

As illustrated above, if the cost of labour and civil works in Switzerland were the same as in Germany, for instance, mobile network costs in Switzerland would fall from 100 to 95.3 index points.

5.9 Cost driver: Energy cost

5.9.1 Background

Energy cost is a cost component in the operation of mobile networks. For our calculations, we assume that energy consumption is equal in the countries in our study, but the costs for energy differ from country to country.

In Switzerland, micro sites consume in average energy worth CHF 1,500 per year. Macro sites consume in average two times more energy (i.e. CHF 3,000 each year).

Energy costs have been adjusted based on benchmark indices from Eurostat and the Swiss Federal Statistical Office (BFS). Energy consumption has been considered in average equal in all countries, thus making it possible to identify the cost differences between countries.

To determine the cost differences between the countries compared, we applied the following correction factors:

Table 16: Correction factors[17]

Country	Energy cost per kWh – industrial companies (in EUR)	Energy Cost Correction Factor
Switzerland	0.1560	1.00
Germany	0.0900	0.58
Austria	0.0917	0.59
France	0.0722	0.46
Italy	0.1145	0.73

5.9.2 Key findings

The impact of this cost driver is determined by the difference in the cost of energy compared with the other countries.

The relative impact as a percentage of the entire difference in mobile costs is listed below (for each country).

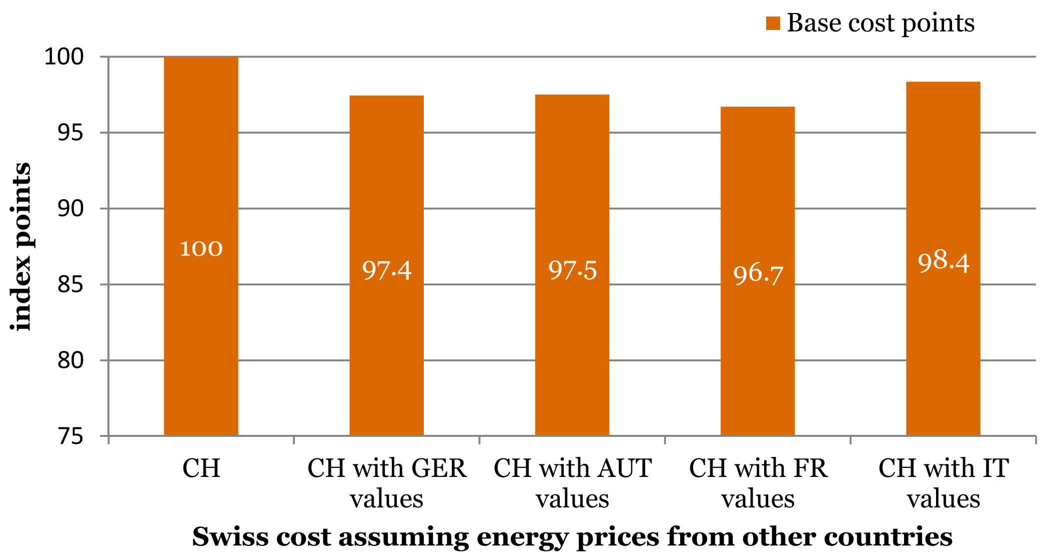
[17] eurostat. (n.d.). *electricity price by type of users*. Retrieved 12 31, 2012, from http://epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=ten00117&language=en and http://www.news.admin.ch/message/index.html?lang=de&msg-id=40988;

Table 17: Relative shares

Cost driver	*GER/CH*	*AUT/CH*	*FR/CH*	*IT/CH*
Relative share of the whole cost difference due to lower energy costs in the countries compared	4.8%	5.5%	6.7%	2.9%

As illustrated above, 4.8 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of lower energy costs in Germany.

Figure 27: Impact on cost in Switzerland due to differences in energy costs



In the figure above, the cost in Switzerland is indexed at 100 points. The chart shows by how many points the costs would fall if Switzerland had energy costs equal to its neighbours.

As illustrated above, if the mobile network in Switzerland were to have the same energy costs as in Germany, for instance, mobile network costs in Switzerland would fall from 100 to 97.4 index points.

5.10 Cost driver: Tunnels

5.10.1 Background

Another relatively small driver of mobile network costs is the coverage of tunnels. Tunnels longer than 1.4 kilometres (a value that we set for this study in agreement with the Swiss operators) cannot be covered with external antenna sites and require additional antennas inside the tunnels. Consequently, the number of tunnels covered in a country influences the mobile network costs. In our model, we assume the same percentage of tunnel coverage as in Switzerland for all countries.

Figure 28: Kilometres of tunnels per 1 million inhabitants

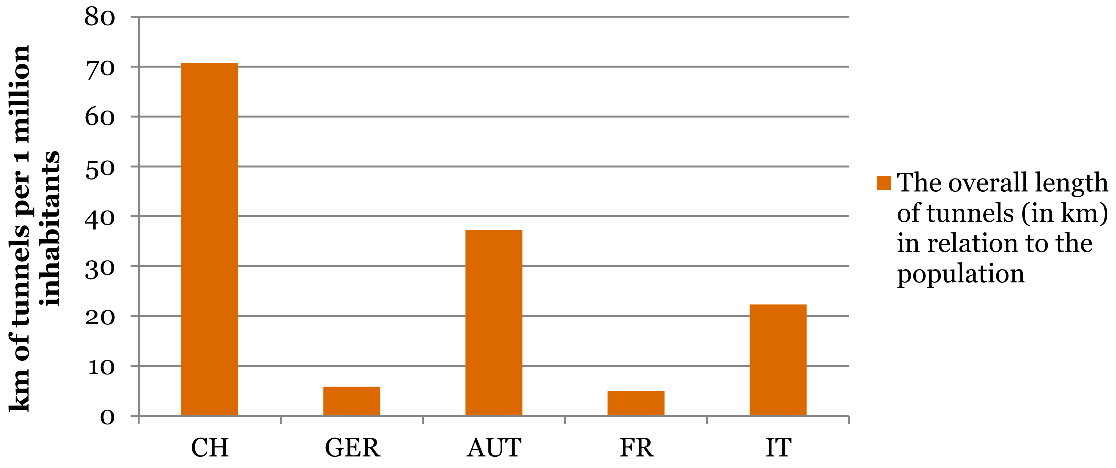


Figure 29: Length of tunnels in relation to land territory

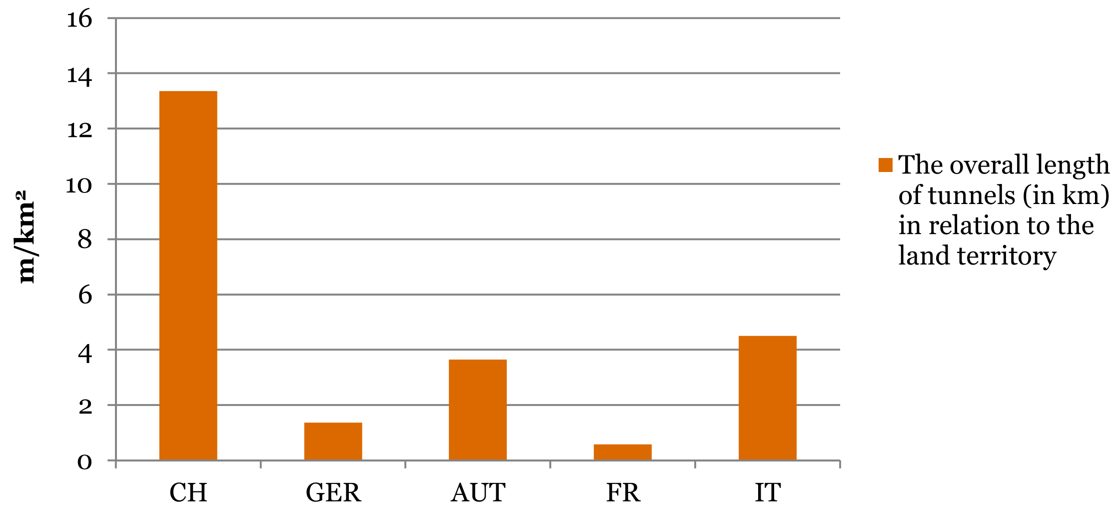


Table 18: Length and number of tunnels

Tunnel (over 1.4 km) / Country	*CH*	*GER*	*AUT*	*FR*	*IT*
Number of rail & road tunnels	155	154	90	102	451
Rail & road tunnel in km	550	477	303	315	1353

5.10.2 Key findings Switzerland

In Switzerland, there are more roads and rail tunnels than in the neighbouring countries, when compared on a per capita basis or in relation to its whole land territory. Furthermore, in Switzerland, costs are higher on average for constructing, operating and maintaining the mobile network compared with the surrounding countries. As a result, the additional calculated cost per capita to provide mobile coverage in tunnels in Switzerland is higher than elsewhere.

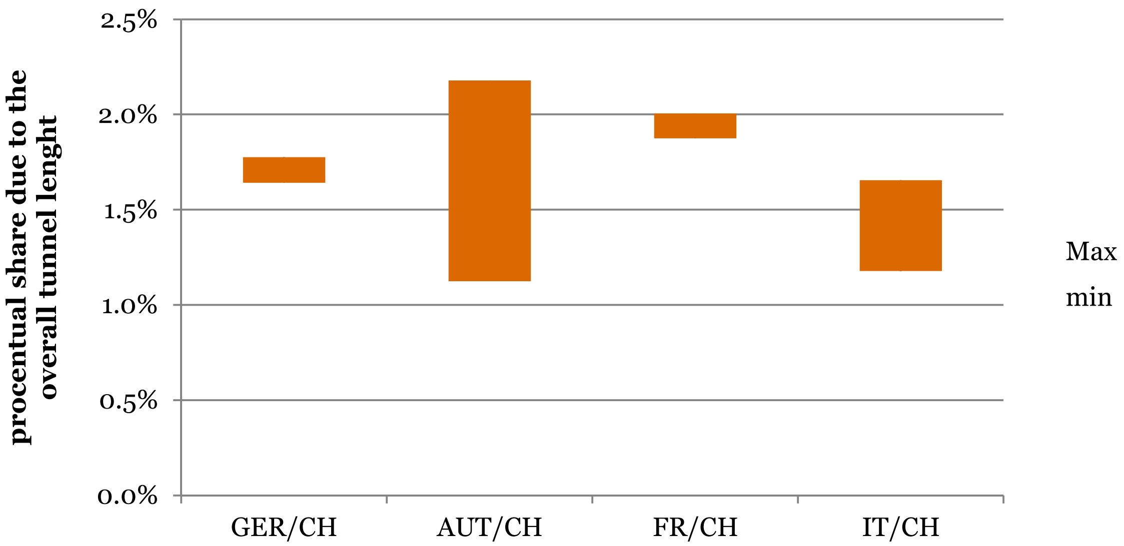
5.10.3 Results of the international comparison of the cost drivers

We assume in our model that the same effective coverage in all countries as in Switzerland in order to analyse the cost differences between them. However, it may be assumed that coverage in the other countries in our study is not as high as in Switzerland.

Our analysis reveals that a share of about 1 to 2 per cent of the entire cost difference between Switzerland and the surrounding countries is due to the coverage of tunnels.

Assuming that the other countries do not provide coverage in tunnels would have a further impact on the cost differences. The biggest impact is quantified for Austria, although it is still small. The share of the entire cost difference due to the overall length of tunnels would rise from 1.1 per cent up to 2.2 per cent (as illustrated in the figure below). In the other countries in our study, the difference between the minimum and maximum value is negligible.

Figure 30: Cost driver coverage of tunnel



The cost difference between Switzerland and its neighbouring countries is (to a relatively small extent) a result of differences in the overall tunnel length within the countries compared. The relative impact as a percentage of the entire difference in mobile costs is listed below (for each country).

Table 19: Relative shares

Cost driver	*GER/CH*	*AUT/CH*	*FR/CH*	*IT/CH*
Relative share of the whole cost difference due to different relative tunnel lengths	1.5%	1.0%	1.7%	1.1%

As illustrated above, 1.5 per cent of the entire cost difference between Switzerland and Germany, for instance, is the result of different overall lengths of tunnels in those countries.

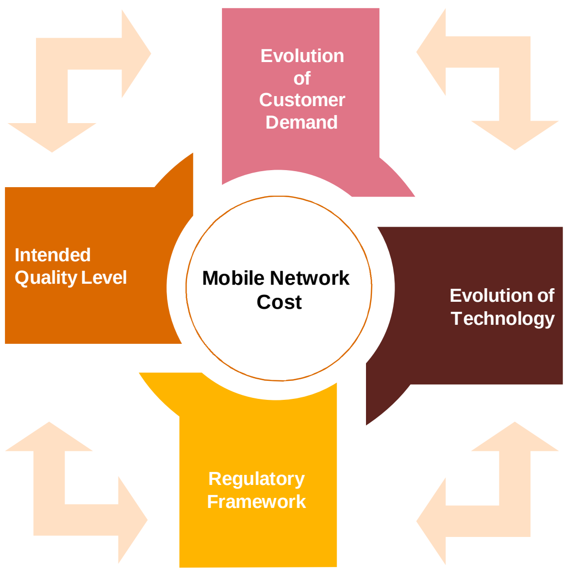
6. Key findings

Our study demonstrates that differences in the NIR regulations and in the topographical and geographical characteristics of the countries have a significant impact on network costs. Indeed, the topographical and geographical characteristics as well as the regulations of each country have a larger impact on mobile costs than the classical cost factors like labour cost, energy cost and rental cost. In particular, the difference in the population density in border regions together with topography drives a significant share of the cost difference between Switzerland and its neighbouring countries.

The current NIR regulations have the largest impact on the network cost differences between Switzerland and each of the other countries in the study and they influence also several of the other cost drivers due to the increased number of required sites to overcome limitation in capacity.

The coverage of railway tracks and roads is a significant cost factor; however, the proportionally lower number of railway tracks in Switzerland in rural areas compared with the other countries reduces the impact of this cost driver on the total cost differences between Switzerland and the other countries in our study.

We designed our study to reduce the complexity of the interdependencies of cost factors in producing quantitative outcomes; therefore, some relevant qualitative factors are not explicitly reflected in the results. Besides the cost drivers considered in the calculation model, the cost structure of mobile networks is influenced by a complex ecosystem of different highly interdependent and dynamic factors. These include the evolution of customer demand in terms of the availability and the capacity of mobile data services. Such demand growth is not always linear, but also occurs in bursts and waves driven largely by external factors (new services, different pricing models). In addition, there is the ability of technology to meet demand, the regulatory framework, which directly or indirectly accelerates or slows site deployment and the adoption of new technologies, and, finally, the level of quality at which mobile operators are able and willing to serve the existing demand in a specific time range.



Any future discussions regarding cost developments relating to the building, operating and maintenance of mobile networks will therefore need to consider these qualitative elements.

For example, customers' demand for data capacity is rising due to the availability of new mobile devices and services (besides other aspects of consumer behaviour). To meet the desired level of data capacity, operators will need to deploy more sites and/or new technologies that can manage more data traffic. Implementing new technologies means new investments and thus additional costs. There are other considerations, too: the timing of such investments influences the cost; new technologies might not absorb the full extent of the rising demand; and new sites might not be deployed as quickly as expected due to legal procedures or other regulatory constraints. Consequently, there may even be a fall in the perceived quality of the mobile network despite the higher mobile network costs.

7. Glossary

GSM: Global System for Mobile Communications (originally, Groupe Spécial Mobile). GSM is a standard used to describe 2G (second generation) protocols used by mobile phones on digital cellular networks.

HSPA: High Speed Packet Access. HSPA are standards extending the data speed for UMTS. HSPA requires additional equipment to basic UMTS.

ICNIRP: International Commission on Non-ionizing Radiation Protection. ICNIRP is an international commission specializing in non-ionizing radiation protection. The organization's activities include determining the exposure limits for electromagnetic fields used by devices such as cellular phones (source: Wikipedia).

LTE: Long Term Evolution. LTE is a standard to describe 4G (fourth generation) protocols for mobile communication of high-speed data.

NIR: Non-ionizing radiation. The electromagnetic radiation from and to antennas related to the operation of mobile devices.

UMTS: Universal Mobile Telecommunications System. UMTS is the third generation mobile cellular system for network, also referred to as 3G. UMTS supports maximum theoretical data transfer rates of 42 Mbit/s when HSPA is used.

Editorial staff

This report was written and produced by:

- Angelo Mathis, Director, PwC
- Bogdan Sutter, Director, PwC
- Peter Kartscher, Partner, PwC

© 2013 PwC. All rights reserved. In this document, "PwC" refers to PricewaterhouseCoopers AG which is a member firm of PricewaterhouseCoopers International Limited, each member firm of which is a separate legal entity.