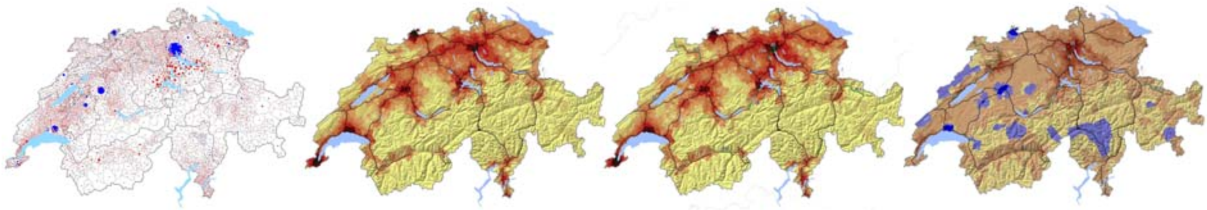

Development of accessibility in Switzerland between 2000 and 2020: first results

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Abstract

The evolution of transport infrastructure and changes in transport provision affect accessibility both within Switzerland and between Switzerland and its neighbours. Along with other factors, this has implications for the country's spatial development. This study sets out to compare the accessibility indicators predicted for Switzerland in 2020 with those of 2000 for both private motorized and public transport.

The study employs a model based on the situation in 2000 and factoring in the programmed improvements to the national road network and changes in the rail service up to 2020. Travel time matrices between municipalities were calculated for both private motorized and public transport for 2000 and 2020. In calculating potential accessibility, the population and number of jobs in the municipality of destination in 2000 and the population forecast for 2020 were taken as activity opportunities. Accessibility was then calculated as the sum of these opportunities weighted by travel time.

The findings suggest significant regional changes in accessibility near the newly built motorway sections. The changes in accessibility determined by the calculations appear plausible. As the data on public transport accessibility are still being computed, the relevant results are only provisional.

Keywords

2020 –Accessibility – 4th Swiss Transport Research Conference – STRC 2004 – Monte Verità

1. Introduction

Changes in transport provision most immediately affect the physical environment by triggering shifts in accessibility distribution. Accessibility is generally defined as a measure of how easily people can participate in activities such as work or leisure. Good accessibility is thus a prime locational asset for a region. Yet, while a uniformly high level of accessibility for whole areas may seem to make sense from a regional planning perspective, it remains both impracticable and undesirable in terms of resource consumption. A transport system inevitably comprises a set of primary nodes in whose vicinity accessibility is particularly good. Moreover, to ensure adequate capacity utilization and the consequent optimization of resource consumption, the provision of transport infrastructure must also be geared to demand. The fundamental challenge for planners is therefore to decide what degree of accessibility to provide where and how best to achieve this.

After providing a brief outline of the key methods of quantifying accessibility, the adopted system – which uses potential accessibility – is examined in greater detail. The following chapter describes the two components of the model, the land-use and transport systems. The major part of the study then presents the initial findings and details the next steps.

2. Accessibility measurement

2.1 Summary

In the absence of any universal definition of accessibility, the applied concept should be geared to the stated research goals. Common measures of accessibility may be roughly divided into three groups (Geurs, Ritsema van Eck, 2001):

- **Infrastructure-based accessibility measures**: founded on the performance of the transport system (e.g. travel speed)
- **Activity-based accessibility measures:** founded on the distribution of activities in space and time
    - Geographical measures: representing accessibility at a location to all other destinations
        - Contour measures: indicate the number of activity points accessible within a certain period (e.g. number of jobs within 30 minutes). Contour measures may thus be viewed as a specific instance of potential accessibility.
        - Potential accessibility: activity points are weighted by the necessary travel time to these points using, e.g. a negative exponential function.
    - Space-time measures: representing the potential of activities in which individuals can participate given (predefined) time constraints.
- **Utility-based accessibility measures**: founded on the benefits people derive from access to the spatially distributed activities.

2.2 Selection of accessibility measure

This study aims to create a basis for measuring changes in accessibility achieved by additional transport provision. Use of the potential accessibility concept appears particularly appropriate because it permits quantification of the interaction opportunities arising from land-use and transport systems.

2.3 Potential accessibility

2.3.1 Calculation

Potential accessibility is an activity-based measure using two components: a transport component, essentially the travel time between zones, and a land-use component determined by the activity opportunities per zone.

Potential accessibility (A_i) may be defined by the following formula:

$$A_i = \sum_{j=1}^{j} D_j \cdot F(c_{ij})$$

where D_j is the number of activity points in zone j, c_{ij} is the generalized travel cost between zone i and zone j and $F(c_{ij})$ is the impedance function.

This study will use a negative exponential function[1] as the impedance function:

$$F(c_{ij}) = e^{-\beta \cdot c_{ij}}$$

The parameter β determines the weighting of activity opportunities. The higher the value of β, the more heavily the readily accessible (nearby) activity opportunities are weighted. The relevant literature adopts values for β ranging from 0.5 at regional (Simma et al., 2001) and 0.2 at nationwide level (Axhausen and Fröhlich, 2002) to 0.01 for Europe (Schürmann et al., 1997). As this study calculates accessibility at a national level, the value of 0.2 adopted by Axhausen and Fröhlich (2002) will be used for β.

The smaller the number of zones considered – or, hence, the larger the individual zone – and the bigger β the greater is the significance of the intrazonal potential. The intrazonal potential, or internal accessibility, is defined as the number of activity opportunities within a zone weighted by the average travel time within this zone.

[1] See Geurs and Riitsema van Eck (2002) for a discussion of the different impedance and decay functions.

2.3.2 Advantages and disadvantages of potential accessibility

Advantages

- The concept of potential accessibility may be grasped intuitively.
- The demands placed on the required data are compared to e.g. utility based measures relatively modest, even though both land-use and transport systems are considered.

Disadvantages

- Intrazonal potential has a substantial impact on accessibility. The problem is that the applied internal travel time is only an estimate.
- The indicators characterize the accessibility of one zone in relation to all others. The assumption is that all inhabitants within a zone enjoy the same quality of accessibility despite their varying needs and different perceptions of travel time and travel inconveniences.
- While potential accessibility indicators reflect the spatial distribution of the available activity opportunities, they make no allowance for the distribution of demand. Yet, this competitive element does play a role, e.g. in cities where the ready supply of jobs is matched by a similarly high demand. The fiercer competition effectively serves to lower job accessibility.
- The impedance function has a major impact on the accessibility calculations for a particular area. The selection of impedance function and the parameters used in this function therefore requires particular care if helpful indicators are to be obtained. This calls for sensitivity analyses.

3. Background

3.1 Land-use system

This study determines accessibility at municipal level using the boundary definitions as per 5 December 2000 (reporting date for 2000 census). However, as the largest cities were broken down into sub-zones (See Table 1), a total of 2,936 zones are featured in the calculations.

Table 1 Municipalities with sub-zones

Municipality	No. of sub-zones
Basel	6
Berne	5
Biel/Bienne	2
Geneva	6
Lausanne	4
Lucerne	2
St. Gallen	2
Winterthur	3
Zurich	10

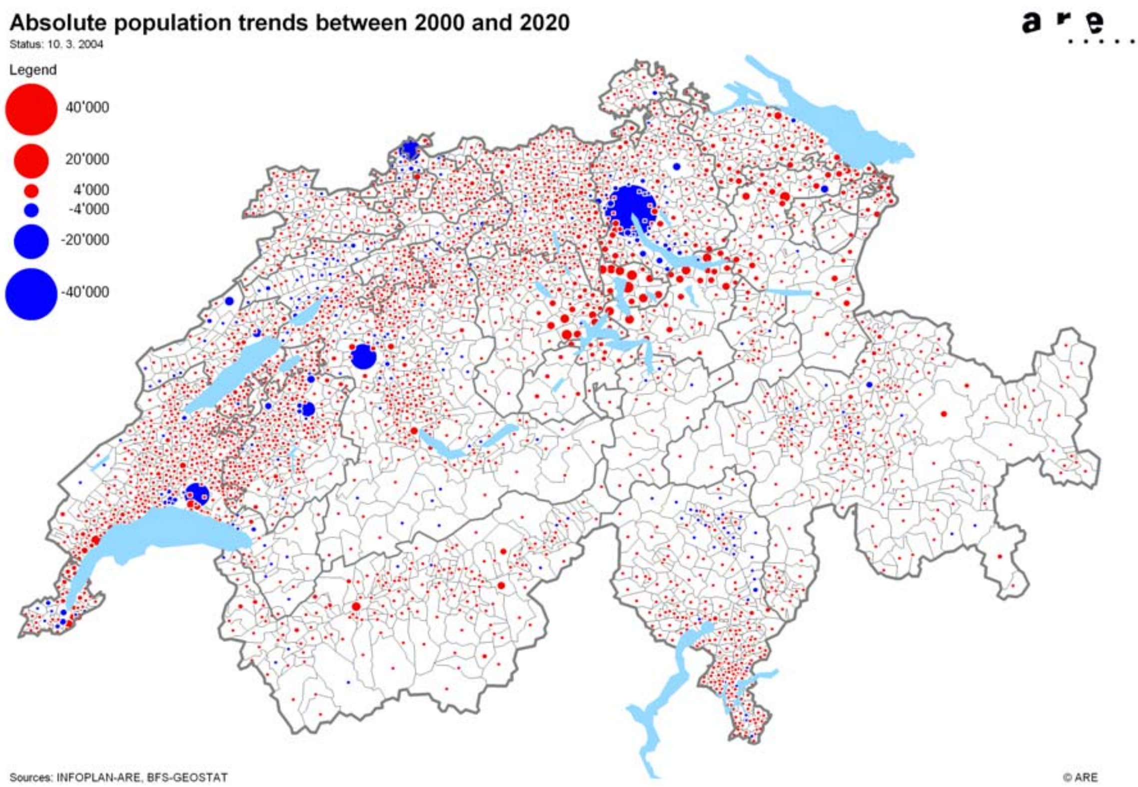
As accessibility is influenced by the spread of activity opportunities, the number of opportunities must be known for each zone[2]. To consider accessibility trends in this first step from as general a perspective as possible, both inhabitants and jobs are viewed as activity opportunities. Accessibility data are calculated for the population in 2000 and employment in 1998 as well as for the population and jobs predicted in a trend scenario[3] for 2020.

The adopted scenario envisages a fairly sharp fall in population in the centres of the major cities over the next 20 years, coupled with a strong increase in the municipalities around the cities.

[2] Where the competitive element is also taken into account, allowance has to be made for both the distribution of activity opportunities and the spread of demand for activities (see, for example, Geurs, Ritsema van Eck, 2001).

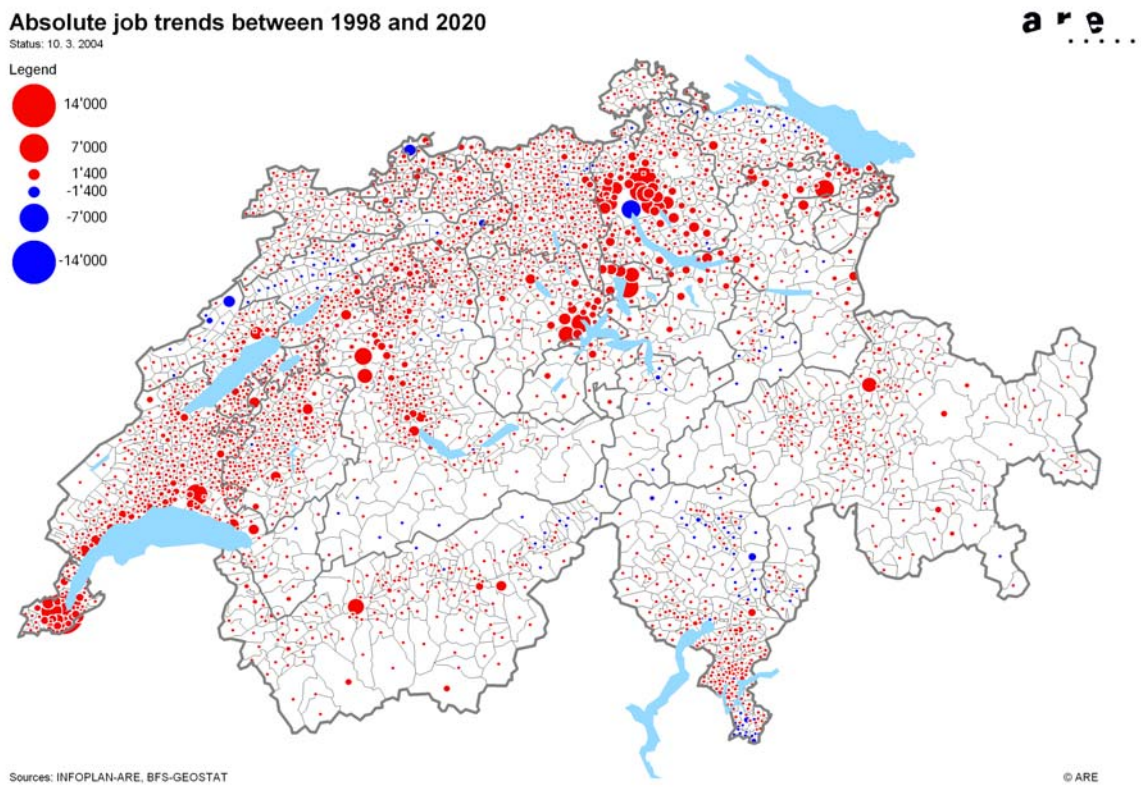
[3] See Bundesamt für Raumentwicklung, 2002

Figure 1 Absolute population trends between 2000 and 2020



Declining employment is predicted for the cities of Zurich and Basel and for certain rural areas, while job levels in the cities of Geneva, Lausanne, Berne, St. Gallen, Lucerne and Zug are expected to rise. A particularly steep increase in job numbers is forecast for the outlying municipalities next to Zurich (primarily Zurich North).

Figure 2 Absolute job trends between 1998 and 2020



3.2 Transport system

3.2.1 Travel time matrix for private motorized transport

The car-based travel time matrix between municipalities was calculated using the ARE road network, embracing 8,000 nodes and 20,000 links. The calculation of travel time was based on the speed indicated in the model for each link. Traffic loads were ignored in the selection of speed, both because loads on the network in 2020 are as yet unknown and because the analyses were intended to reflect the improvements in accessibility achieved by new transport infrastructure.

The calculation of car-based travel time in the model is based on the shortest possible journey time from that node in the road network closest to the centroid[4] of the municipality of origin to that node closest to the centroid of the municipality of destination.

The travel time matrix for 2020 is based on the existing road network plus the planned improvements set out in the seventh long-term development programme of the Swiss Federal Roads Authority (ASTRA)[5].

3.2.2 Travel time matrix for public transport

Public transport provision is defined by the relevant timetables. For the year 2020 only the timetable for the railways is known. Therefore the same level of detail is adopted for 2000 (timetable period 99/00) and the travel time matrix is calculated for both year 2020 and 2000 on the basis of the rail connections. A fixed allowance is made for the public road transport links to railway stations. The model encompasses some 700 different public transport routes.

The model breaks down the public transport travel time into the following components:

- Travel time by road from that node in the road network closest to the population centroid of the municipality of origin (node of origin) to the nearest station (station of origin).
- Shortest possible travel time by rail indicated by the timetable (including time allowed for changing trains and waiting) from the station of origin to that node in the station closest to the population centroid of the municipality of destination (node of destination).
- Shortest possible travel time by road network from station of destination to node of destination

3.2.3 Intrazonal travel time

The approach adopted in determining intrazonal travel times is that used by Fröhlich and Axhausen (2002). Municipalities are classed by population in four groups, the same internal

[4] The population centroid weighted by population density (hectare grid from 1990 census) was used.

[5] See Bundesamt für Strassen, ASTRA (2003)

travel times being allocated to each group (See Table 2 Internal travel times). The only difference from the method used by Fröhlich and Axhausen (2002) relates to the division of some municipalities, i.e. the larger cities, into several sub-zones.

Table 2 Internal travel times

Name	Inhabitants	Internal travel times: public transport	Internal travel times: individual transport
Cities	> 100,000	15 min	15 min
Towns	30,000 to 100,000	12 min	10 min
Villages	5,000 to 30,000	10 min	7 min
Small villages	< 5,000	8 min	4 min

Source: Fröhlich and Axhausen (2002)

4. Results

4.1 Preliminary remarks

Changes in accessibility may result from either changes in the land-use system (increase or decrease in activity opportunities) or developments in the transport system (timetable or infrastructure). For this reason, both the accessibility to activity opportunities in 2000 and to those in 2020 were calculated for 2020. This allows analysis both of the change in accessibility solely attributable to developments in the transport system and of that resulting from the combination of changes in activity opportunities and transport system.

4.2 Private motorized transport

4.2.1 Population accessibility

Car-based population accessibility (Figure 3 for 2000 and Figure 4 for 2020) is especially high in and around Switzerland's five major cities (Zurich, Geneva, Basel, Lausanne and Berne). This high accessibility stretches far into the surrounding conurbations, the corridor west of Zurich towards Aargau being a prime example. The Lower Valais region aside, all parts of the rural cantons suffer from relatively poor accessibility. This, however, is not solely due to the transport system, but equally reflects the significantly lower population densities in the rural areas and their geographical location.

Figure 3 Private motorized transport: population accessibility in 2000

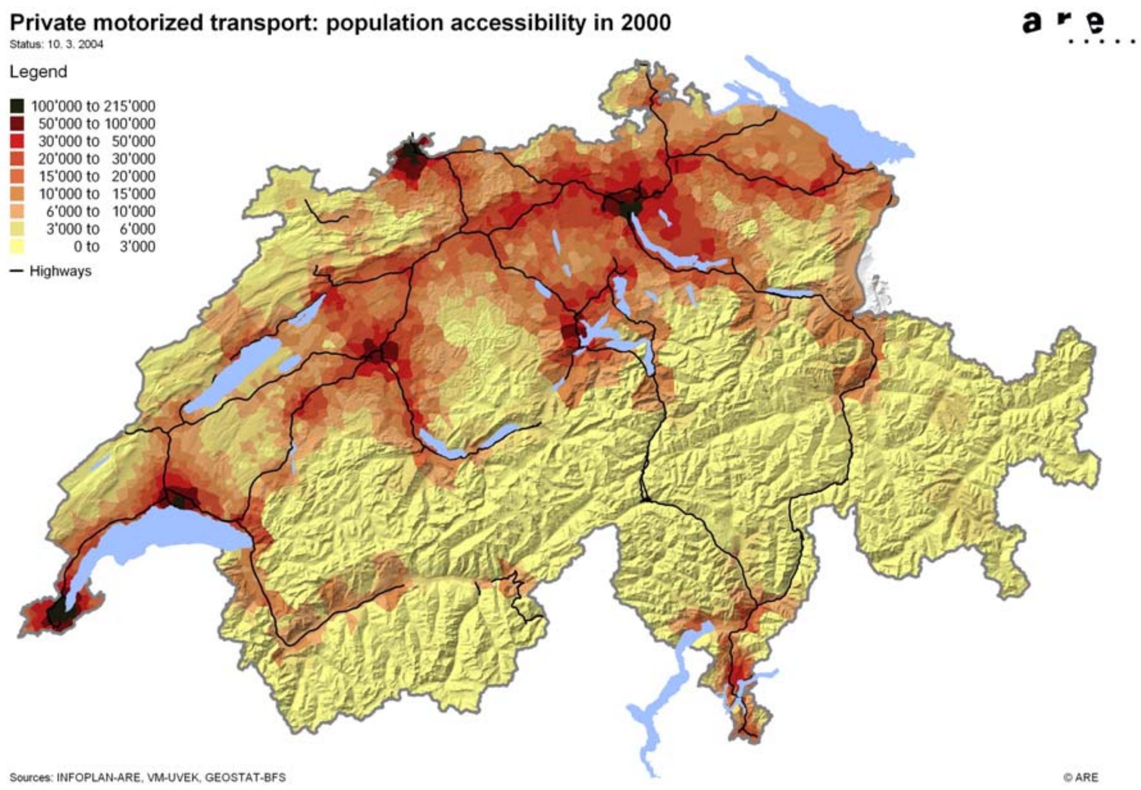


Figure 4 Private motorized transport: population accessibility in 2020

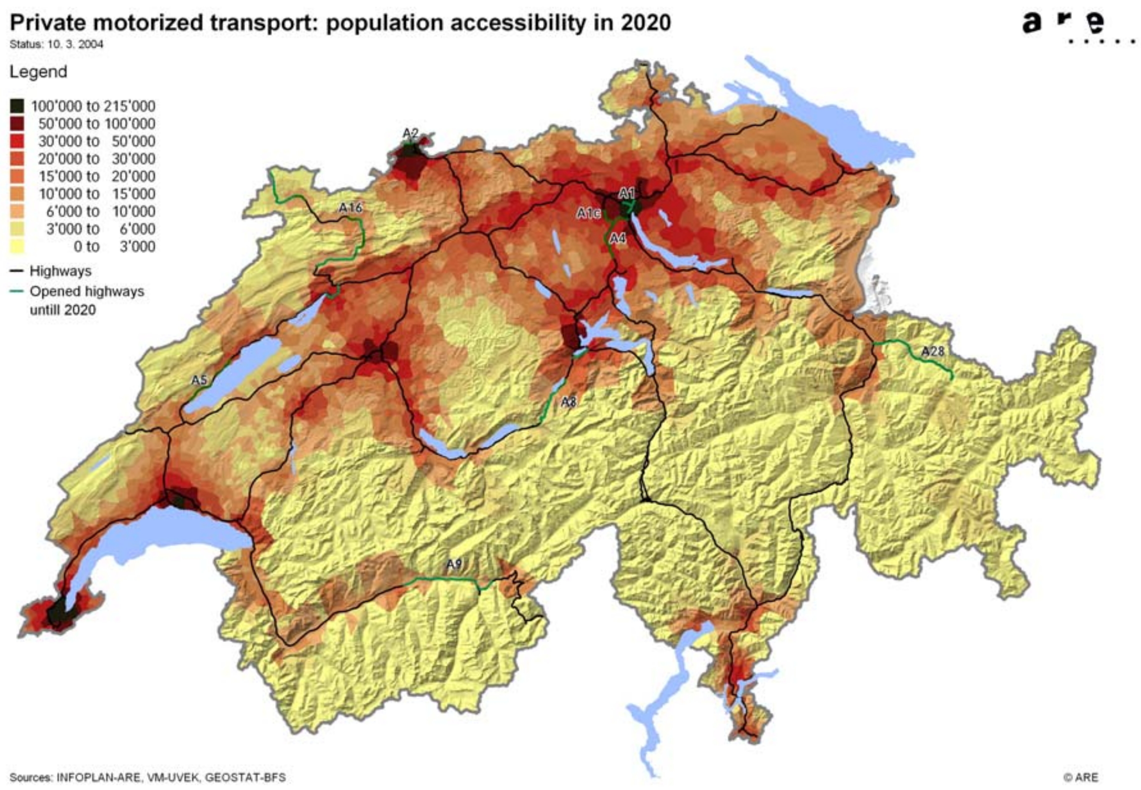


Figure 5 Private motorized transport: change in population accessibility between 2000 and 2020 achieved by transport system

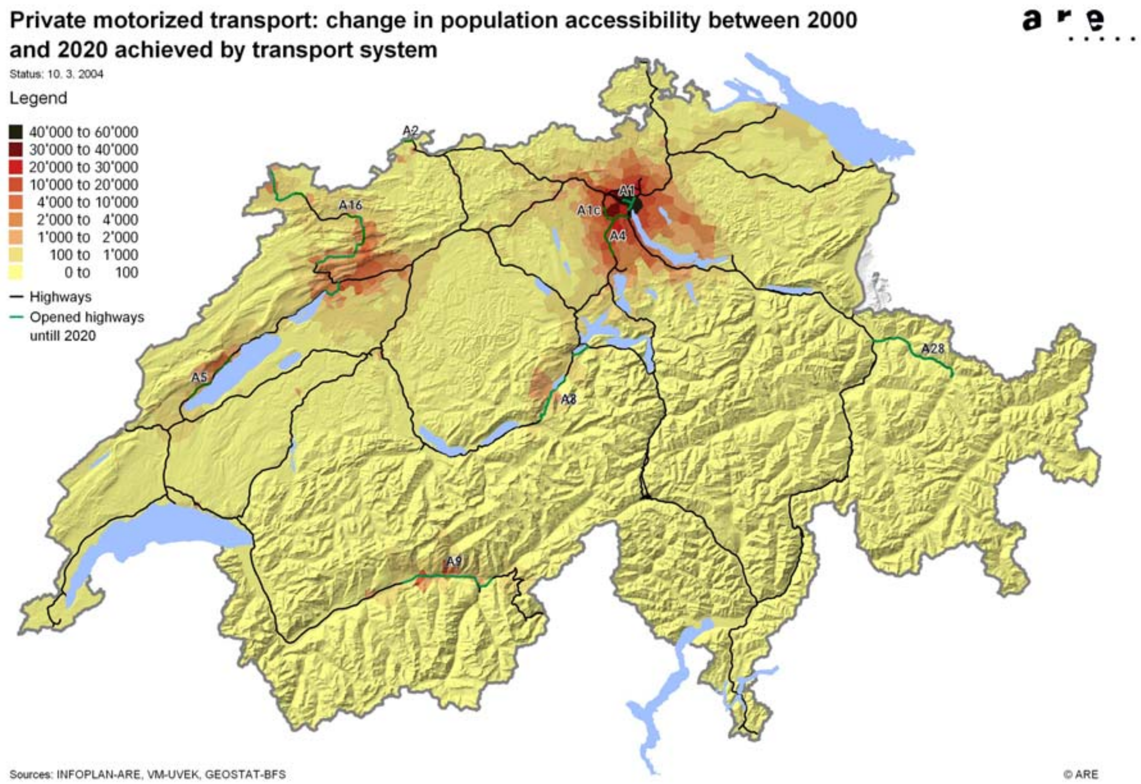
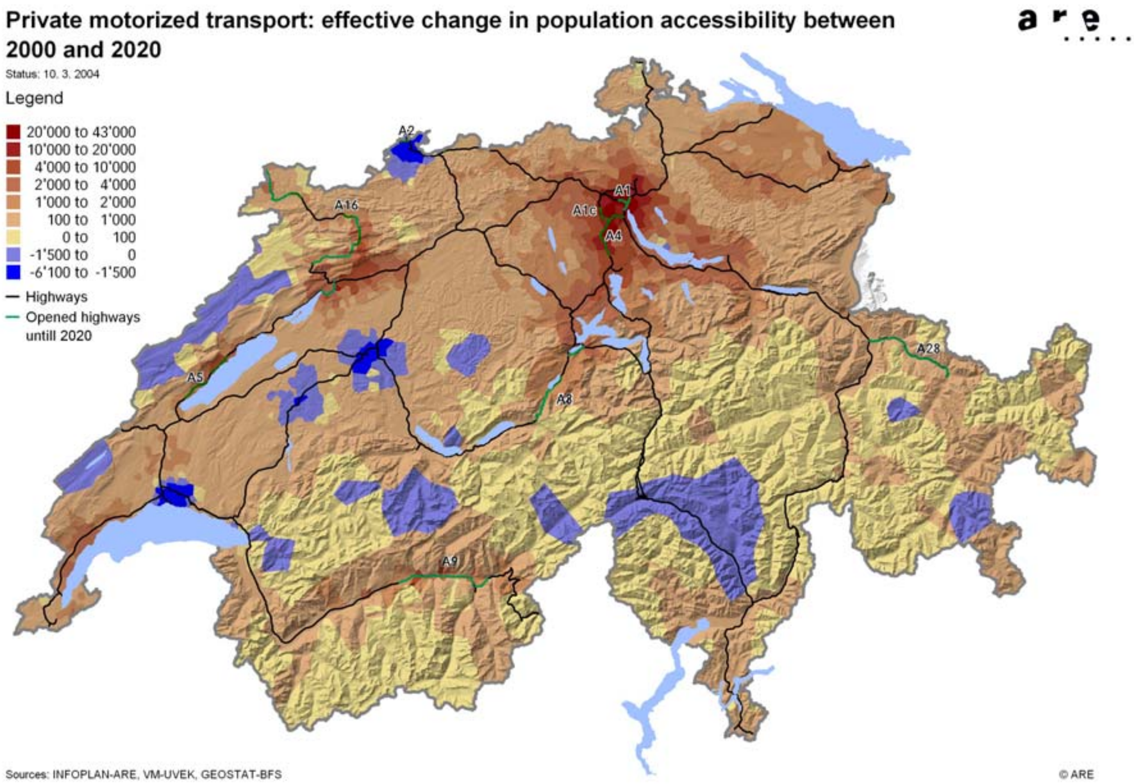


Figure 5 shows the change in population accessibility achieved by developments in the transport system. The differences show that the new motorways between Zug and Zurich (A4) and in the city of Zurich (A1), both of which pass through heavily populated areas, yield the greatest benefits in absolute terms. These two projects – in conjunction with the new A8 motorway section between Sachseln and Lungern – also have the greatest impact in terms of geographical area, improving accessibility well into central Switzerland. Construction of the A16 and A5 motorways will particularly benefit Solothurn and Biel; while the changes here are not overly significant in absolute terms, their impact is felt over a surprisingly wide geographical area. At the same time the impact on accessibility of the new-build schemes by Lac de Neuchâtel (A5), in Valais (A9) and near Porrentruy is comparatively small. Their chief merit resides in the fact that they serve to complete the national network.

Figure 6 Private motorized transport: effective change in population accessibility between 2000 and 2020



The effective change in population accessibility by 2020 (Figure 6) reflects both demographic trends and developments in the transport system. Population accessibility consequently falls in those regions where the trend scenario predicts a decline in population and the transport system undergoes no improvement (e.g. in the city of Lausanne or the Sopraceneri region of Ticino). In some cases, though, palpable improvements to the transport system may – as with Zurich – outweigh a fall in the regional population and still secure net gains in accessibility.

4.2.2 Job accessibility

Job accessibility, like population accessibility, is particularly high in the five major Swiss cities, while failing to extend as far into the outlying areas of the conurbation. In the case of jobs, the high accessibility figures are much more clearly focused on city centres and areas near key motorways.

Figure 7 Private motorized transport: job accessibility in 1998

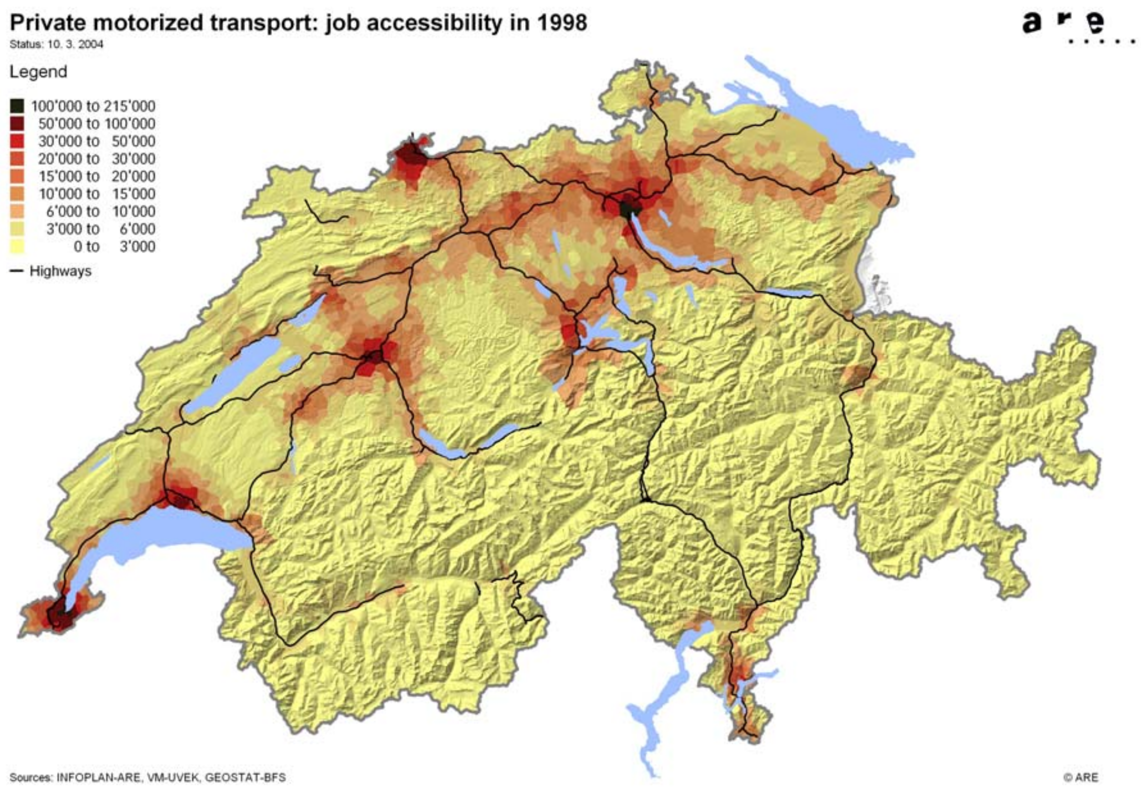


Figure 8 Private motorized transport: job accessibility in 2020

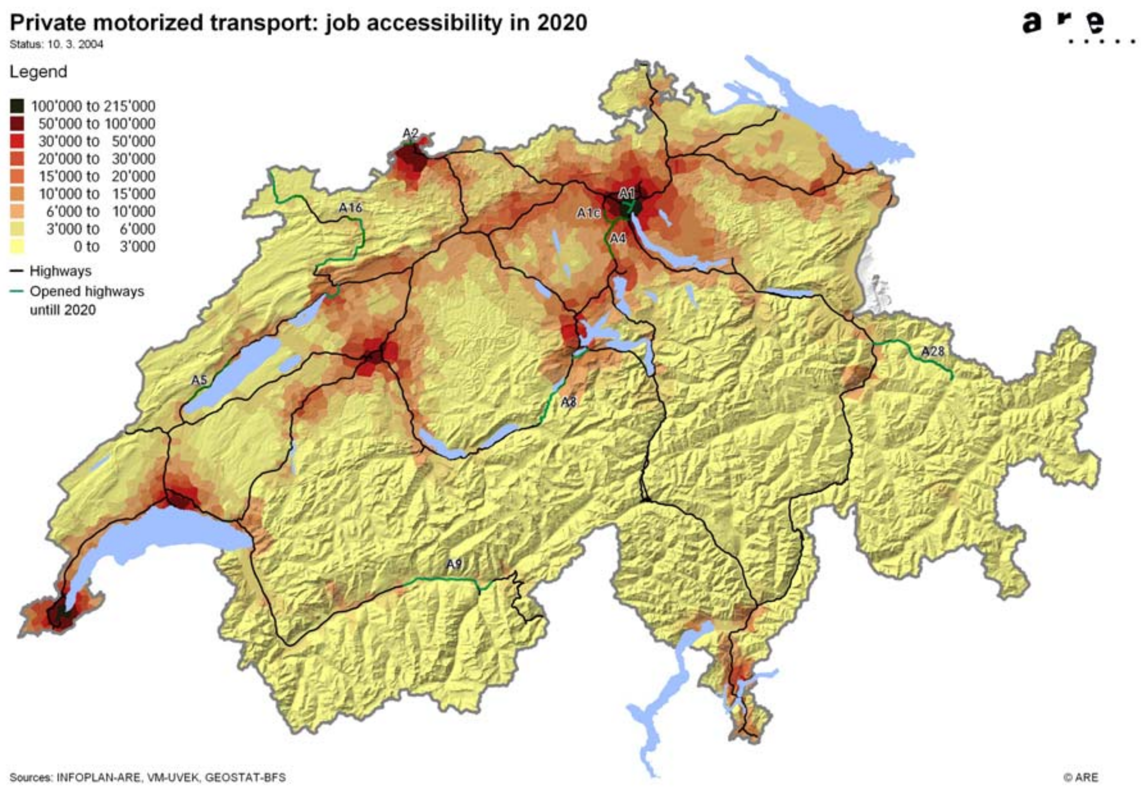
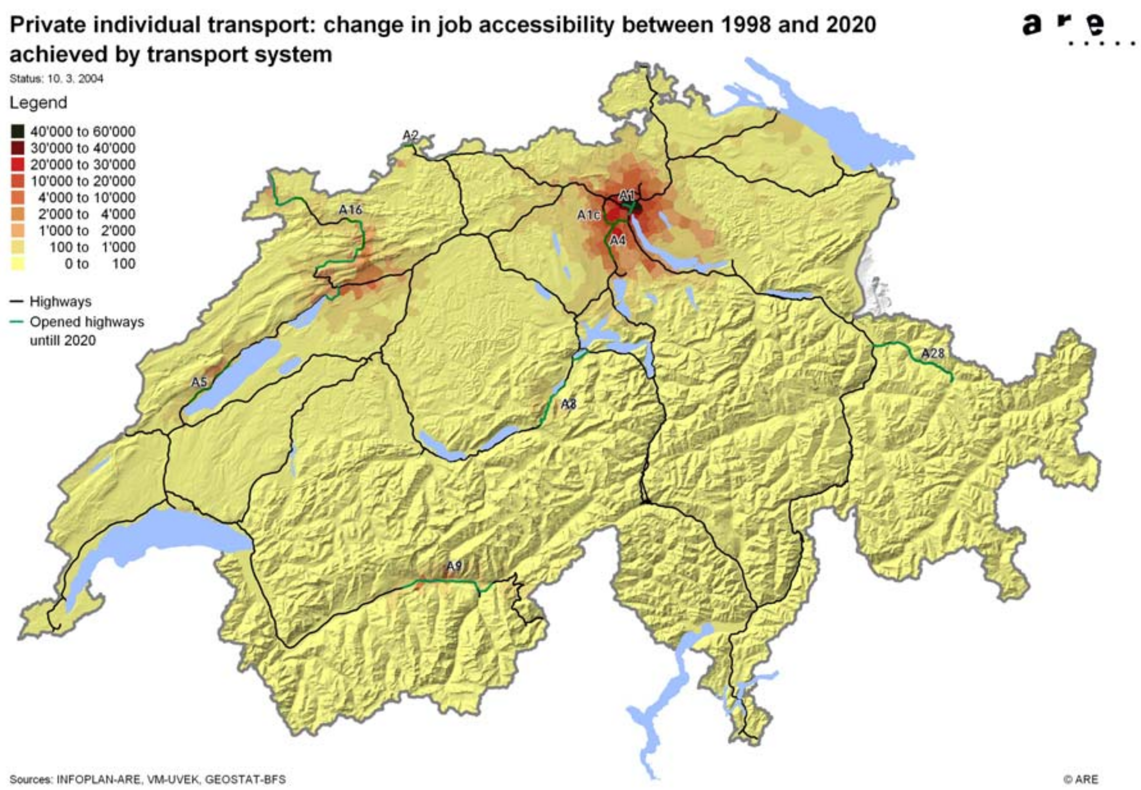
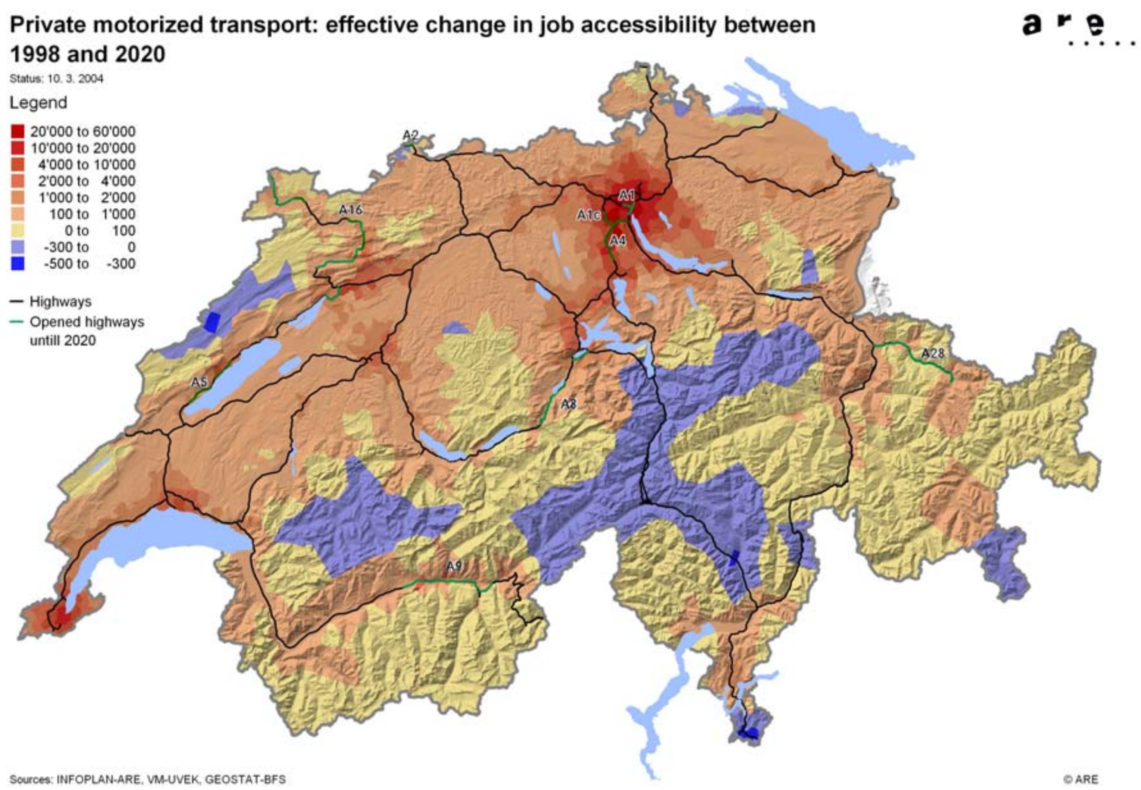


Figure 9 Private motorized transport: change in job accessibility between 1998 and 2020 achieved by transport system



The improvements in accessibility between 1998 and 2020 achieved by new transport infrastructure are shown in Figure 9. Once again, the A4 motorway between Zug and Zurich and the A1 motorway in the city of Zurich have a major impact, while that of the other new schemes is relatively small. At the same time, given the heavy concentration of employment in urban centres, the impact of these improvements on job accessibility is limited to a smaller geographical area than for population accessibility.

Figure 10 Private motorized transport: effective change in job accessibility between 1998 and 2020

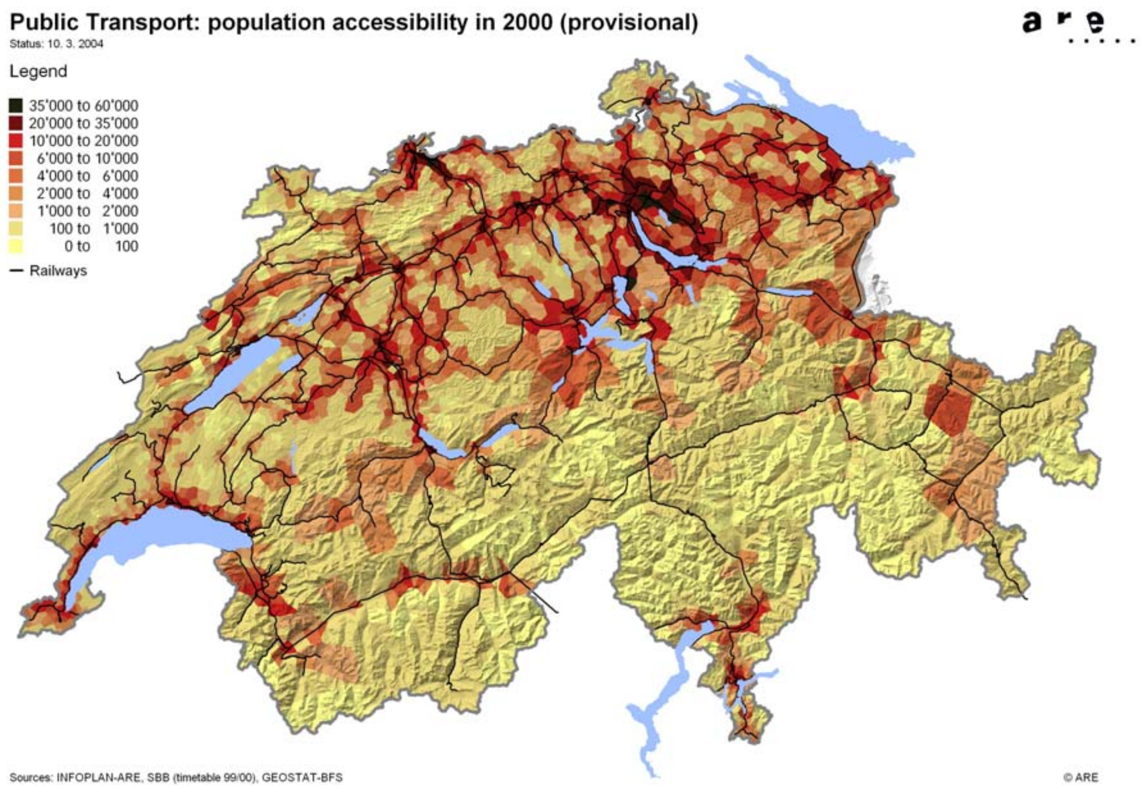


The effective differences shown in Figure 10 reflect the predicted regional economic trends in conjunction with developments in the transport system. A decline in job accessibility appears particularly likely in areas already exhibiting low values. This chiefly applies to a large geographical area stretching in three directions from the Gotthard, to Ticino, Valais and Uri/Glarus. A similar fall seems on the cards on the boundary between Valais and the Bernese Oberland and in the Neuchâtel Jura region.

4.3 Public transport

The calculation of public transport accessibility is somewhat more complex than for private motorized transport. As trips may comprise several stages plus the times for accessing or changing the means of transport, more assumptions have to be made in calculating the travel time matrix than are required for car-based travel. Indeed, the minor gaps in the timetable that may still exist in the model for 2020 could well have a significant impact on the accessibility indicators. Given the uncertainties in the model, the analysis for public transport is confined to population accessibility. As the results for public transport remain provisional and require further checking only population accessibility for 2000 is shown.

Figure 11 Public transport: population accessibility in 2000 (provisional)



Not surprisingly, the population accessibility by public transport in 2000 is highest around Zurich. Indeed, the situation is favourable in most parts of the Zurich conurbation by virtue of the efficient suburban railway system and high population density. The cities of Basel and Berne fare equally well, though accessibility declines quite rapidly with increasing distance from the city centre due to the lower level of transport provision and dwindling population density.

The Swiss Federal Railways' "Bahn 2000" programme and the "NEAT" Projects lead to service improvements in public transport (better connections, higher frequencies and shorter travel times). To be able to show these improvements until 2020 with an accessibility model, further work has to be done.

The model has to weight service frequency more heavily, instead of concentrating solely on journey times. Instead of the shortest journey time, the calculation needs to be based on perceived travelling time, factoring in waiting periods when changing from one service to another and the density of the service network.

5. Discussion of results

For private motorized transport, the calculations deliver good and plausible results that may be used for further analyses. However, the trip chains that are an inevitable feature of public transport make the associated accessibility calculations more complex. The findings for public transport are still incomplete and thus require further validation.

Moreover, the following components offer scope for improvements to the transport model and accessibility calculations:

- **Travel time matrix for public transport:** Use of the fastest daily connection in the public transport travel time matrix is not strictly correct. An efficient means of integrating timetable information (waiting periods, density of service) needs to be found (perceived travelling time).
- **Spatial resolution:** A finer mapping of the road network is required, especially in the cities. The public transport model needs finer resolution nationwide, coupled with a greater degree of precision in specifying access times to the network. In particular, the catchment areas of stops and road network nodes may prove a useful alternative to municipalities in analysing current situations.
- **Traffic loads in road network:** Particularly in towns and cities, the speed adopted in the model fails to reflect actual speeds. If feasible, the use of load-dependent speeds for the road network in 2000 and 2020 would enable the model to factor in the problem of traffic congestion in urban areas.
- **Intrazonal potential:** The intrazonal potential, in particular the internal travel time within a zone, requires more accurate determination. Furthermore, zone sizes should be kept as small as possible to minimize the impact of the intrazonal potential.
- **Impedance function:** A precise sensitivity analysis needs to be conducted to determine the optimum value for parameter β. Parameter β requires adjustment to both the geographical extension of the investigated area and the resolution of the transport model. Further tests are also necessary to determine whether an alternative function should be adopted as the impedance function.
- **Investigated area:** To guarantee the realistic evaluation of accessibility near Switzerland's borders, the investigated area should include the border regions of neighbouring countries.
- **Unpopulated areas** (e.g. areas over 2,000 m above sea level) should be excluded from the analysis or separately identified in the maps.
- **Calculation method:** The calculation method should be amended to eliminate the drawbacks of potential accessibility listed under 2.3.2.

Apart from improvements to the model and calculation method, the scope of analyses may also be expanded. Of particular interest are comparisons between car-based and public transport accessibility or the calculation of a general indicator as the weighted mean of the accessibility indicators for population, jobs and other activity opportunities.

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