

# Changes in Swiss Accessibility since 1850

Contribution to "Economic impacts of changing  
accessibilities"

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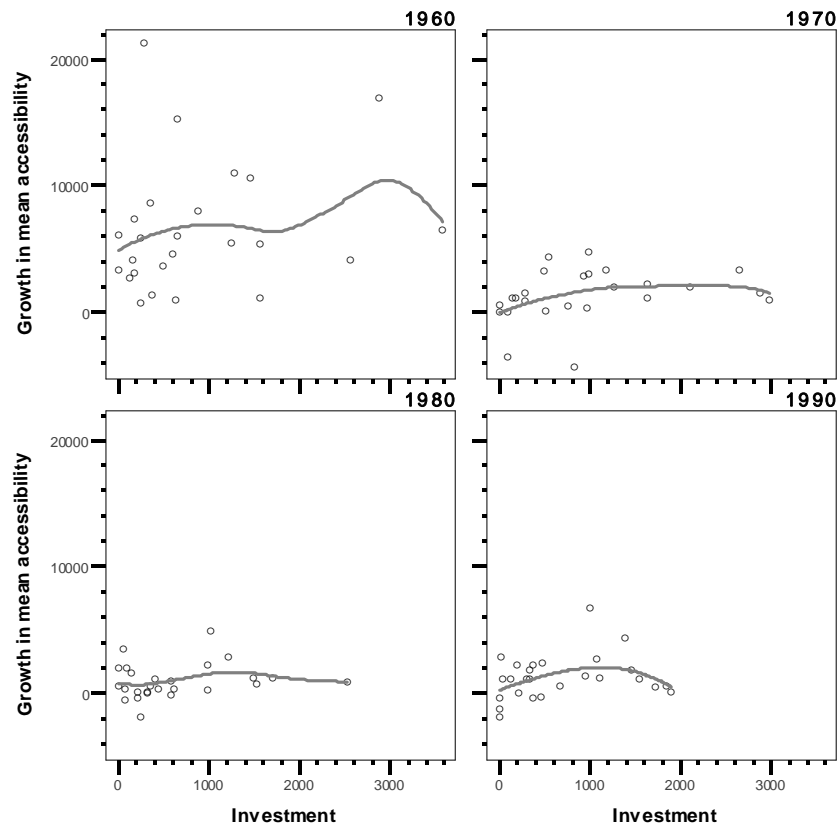
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Contribution to *Economic Impacts of Changing Accessibilities*

**Changes in Swiss accessibility since 1850**

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Arbeitsbericht Verkehrs- und Raumplanung

## Veränderungen der Schweizer Erreichbarkeiten seit 1850

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### Kurzfassung

Der Aufsatz diskutiert die Veränderung der Erreichbarkeit in der Schweiz seit 1850. Solche detaillierten Messungen sind notwendig, wenn man die Wirkungen von Verkehrsinvestitionen auf Wirtschaft und Raumnutzung verstehen will.

Die Erreichbarkeit im Strassenverkehr überholte die Erreichbarkeit im ÖV um 1930 und hat seither die relative Führung ausgebaut. Der relative Vorteil von grossen Städten hat seit 1950 durch den eigenen Bevölkerungsrückgang und Bevölkerungsgewinn im Umland abgenommen. Absolut gesehen sind die Grossstädte noch immer die Standorte mit den höchsten Erreichbarkeitswerten.

### Schlagworte

Investition, Strasse, Schiene, Erreichbarkeit, Schweiz, 1850 bis 2000

### Zitierungsvertrag

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Working paper

## Changes in Swiss accessibility since 1850

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### Abstract

This paper discusses the changes in Swiss accessibility since 1850 after arguing that such spatially detailed measures are needed, if one wants to understand the impact of transport investment on the economy and land use patterns.

The road-based accessibility overtook that offered by the railways around 1930 and has kept a steady relative lead since then. The relative advantage of the large cities has been eroded since 1950 through their population loss and the massive population gain of the metropolitan fringe. In absolute terms, though, they are still locations with the highest accessibilities.

### Keywords

Public investment, accessibility, roads, rail, Switzerland, 1850 to 2000

### Preferred citation style

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## 1 Current assumptions

In their current elegant paper Shirley and Winston (2004) expand the literature on the impact of public road investment on national productivity by using detailed industrial inventory data. In this paper, as in most others following Aschauer's original work (1989)<sup>1</sup>, the services provided by the road network are equated with the level of the capital stock in the road system. This assumes that the ratio of these services to the capital stock is constant for the time period studied. If this assumption is violated, the estimated changes in capital stock elasticities are confounded with the elasticities due to technological, regulatory and population changes.

This paper presents evidence that this assumption is indeed erroneous, in particular over long time periods. It will suggest that in future work the services provided should be measured directly and demonstrates that this indeed possible for long time periods at high spatial resolution using the example of Switzerland since 1850, and in more detail since 1950.

The link between capital investment in roads and productivity is mediated through multiple transformations, each step having its own technology and logic:

- Investment builds lane miles on new alignments or adds them to existing ones. It builds new junctions.
- Investment improves alignments in terms of gradients, radii or intersection design
- The new lane miles and new or improved junctions add capacity
- Added capacities and improved alignments allow more travel and/or higher speeds
- The higher speeds and volumes permit firms to exploit the available economies of scale, scope or density in their enlarged market areas. These changes are measured as improved productivity
- The larger catchment areas allow individuals to match their desires and needs better against the available supply of goods and services; in particular, they should be able improve their earnings by finding a closer approximation to their most productive employment.

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<sup>1</sup> See references in Shirley and Winston (2004), but also Banister and Berechman (2000); Kesselring, Halbherr and Maggi (1982); Lutter (1980); Seimetz (1987); Vickerman (1991)

Looked at it this way, it is rather unlikely that the strict proportionality assumed before can occur in practise. The paper will proceed in its first part by providing Swiss evidence for the lack of such proportionality. In the second part it will present spatially and temporally disaggregated estimates of the accessibility for the 184 Swiss districts since 1850 and the about 3'000 Swiss municipalities since 1950. The focus will be on the discussion of the changes over time. The technical aspects of the underlying network models have been discussed in Fröhlich, Tschopp and Axhausen, 2006 and Fröhlich and Axhausen, 2004. It concludes with a dynamic model integrating investment, generalised cost of travel, market size and productivity, which allows for a more detailed description of the factors underlying the economic impacts of accessibility change.

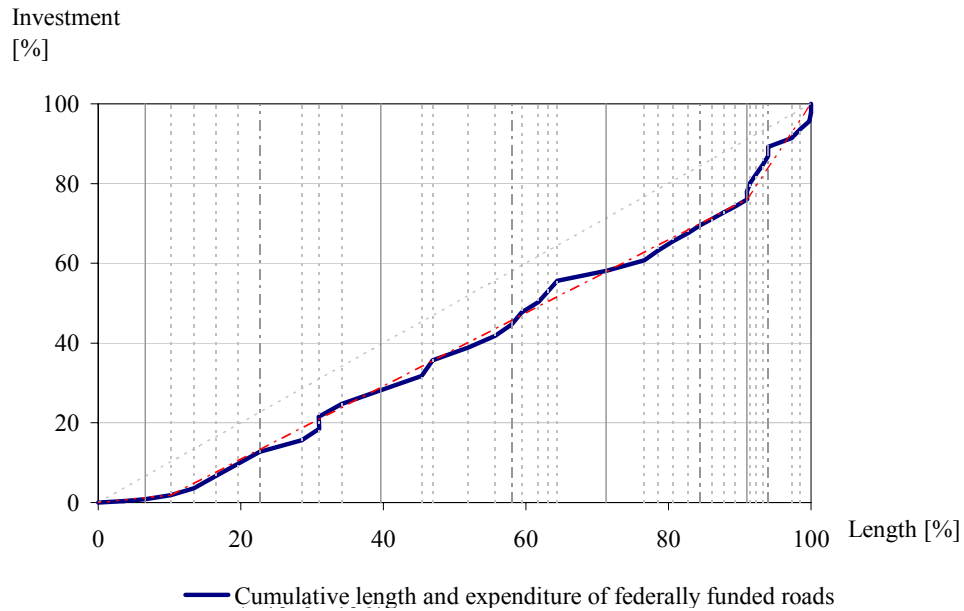
## 2 Observed trend breaks

Based on the evidence presented in Axhausen and Fröhlich, 2004; Axhausen, Tschopp, Fröhlich und Keller (2004) and Gätzi (2004), which in turn are based on a joint research project between the Institute for Transport Planning and Systems (ETH Zürich), Inventory of Historical Transport Infrastructures (Berne) and the Institute d'Histoire (Universite de Neuchatel), it is possible to demonstrate trend breaks, which drastically reduce the value of (public) road capital as a proxy for the service provided by the road system.

Figure 1 shows the cumulative investment into the Swiss national road system – roughly equivalent to the US interstate system – and the number of miles of Nationalstrassen built. After the very cheap first miles, the costs per mile were stable until about 90% of the current system had been built. They then trebled due to higher specifications, as well as the fact that the long term plan underlying the built-out of the system had delayed the expensive and less necessary parts of the network until the end.

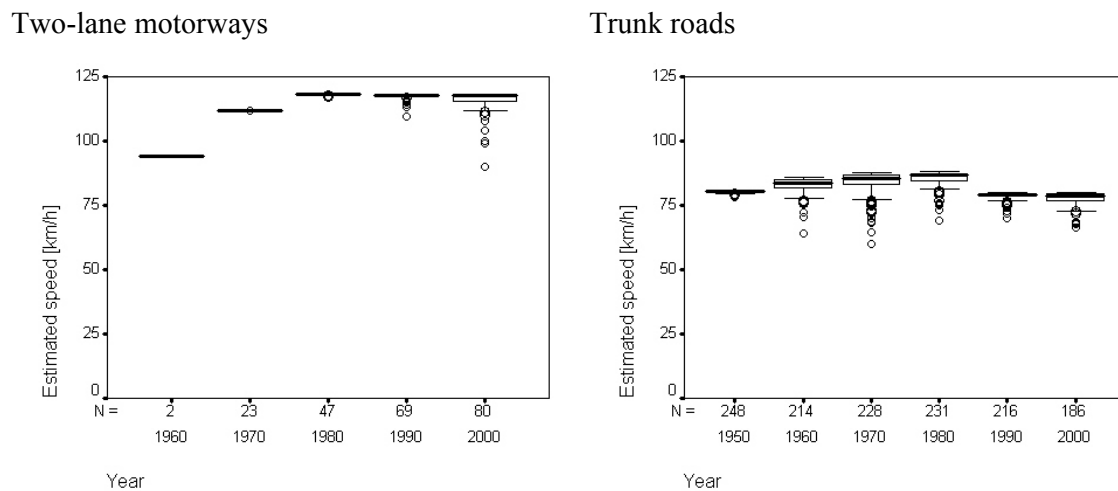
Continued investment, as visible above, should translate into higher average speeds. In the period before speed regulation, this trend could be observed in Switzerland (Figure 2) on both motorways and trunk-roads due to more highly powered cars and the availability of sufficient capacity. The combination of speed limits and decreasing capacity reserves has lowered average speeds during the last two decades, including an increasing speed variance.

Figure 1 Network length and cumulative inflation-corrected costs of the Swiss federal road network



Source: Gätzi (2004)

Figure 2 Distribution of estimated daily average link speeds by type of link on Swiss roads and by year



The estimates are based on the relevant traffic counts and consistent assumptions about capacities and speed-volume-relationships (Erath and Fröhlich, 2003).

The preferred localized measure of road network service is accessibility (Rietveld and Bruinsma, 1998 or Geurs, and Ritsema van Eck, 2001) (See also below):

$$A_i = \ln \sum_{\forall j} X_j f(c_{ij}) \quad [\text{Equation 1}]$$

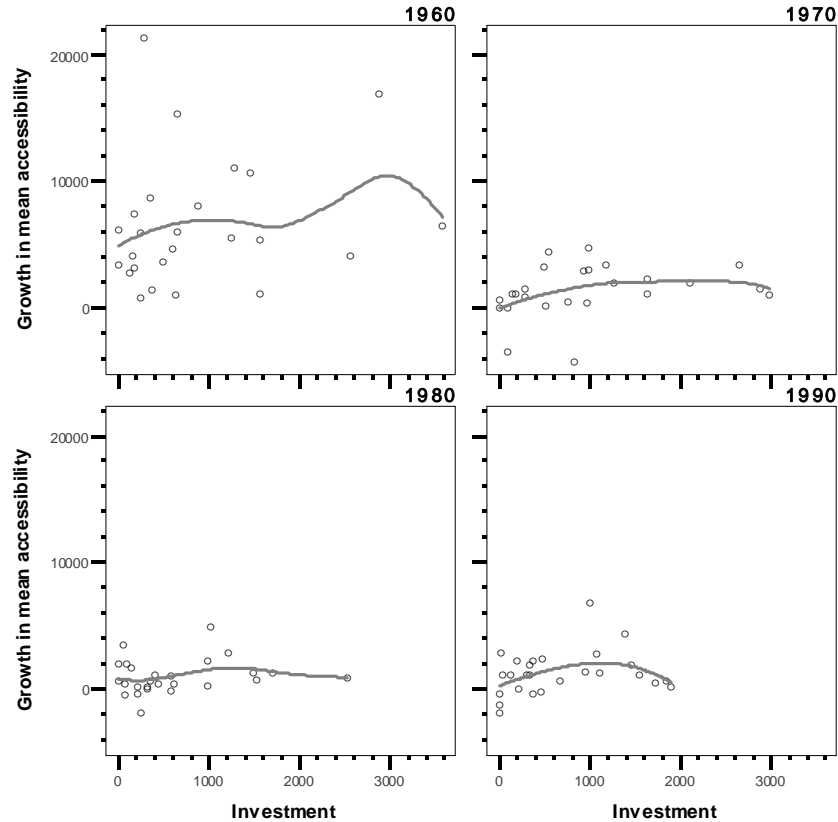
with:

- $A_i$  : Accessibility of location i
- $X_j$  : Number of opportunities at location j, such as residents, work places, customers, consumers, purchasing power, etc; but here chosen to be population
- $c_{ij}$  : Generalised cost of travel between locations i and j, here travel time.
- $f()$  : Weighting function for the generalised costs of travel, here:  $e^{-\lambda c_{ij}}$
- $\lambda$  : Parameter set to 0.2 in line with Schilling's 1973 estimate.

This formulation can be shown to be an exact measure of the consumer surplus (rent) in a destination and mode/route choice context (Williams, 1977; Ben-Akiva and Lerman, 1985) and therefore of the service offered by the road or public transport system. This formulation already highlights that the distribution of spatial opportunities and markets is essential to the service of the road network. Independent change in this dimension undermines the assumptions mentioned above and the on-going suburbanisation process is in parts independent of road and public transport system development.

Based on detailed road network models for each decade and a matching population database (Tschopp, Sieber, Keller and Axhausen, 2003; Axhausen, Dolci, Fröhlich, Scherer and Carosio, 2006) the accessibility values of each of the 3000 Swiss municipalities were calculated for each decade since 1950 using travel times as the only indicator of the generalised costs of travel. The municipal values were averaged by canton (For details see Axhausen and Fröhlich, 2004) to match the time series of investments. Figure 3 shows the scatterplots of the first differences of these variables by decade. An analysis of the partial correlation confirms the first impression: there is no discernable link between investment and accessibility change, especially after accounting for population changes.

Figure 3 Change in mean cantonal accessibility versus investment into federally funded roads by decade starting with the year indicated



Source: Axhausen and Fröhlich (2004);

The evidence presented above has shown that the assumption of a strict proportionality between road investment and road services is not warranted in the case of Switzerland between 1950 and 2000. It has demonstrated how policy change with regards to road standards, regulatory change with regards to speed limits and population growth and shifts confound the direct impacts of road investment. Any model linking productivity growth and investment has to account for these variables, which implies a treatment at a spatial change much smaller than usual in this literature (mostly US states or NUTS1 or NUTS2 regions in Europe). It is clear, that the analysis presented in Figure 3 is unsophisticated, but it seems unlikely that the general conclusion will be changed by a more sophisticated analysis.

If the contention of the argument holds in other contexts, then the literature on the interaction between road investment and growth is to a large extent back to the drawing board. Certainly,

it needs to employ better measures of the road system services and do so at a high level of spatial disaggregation. The next section of the paper will discuss such results, already mentioned in the discussion above.

### **3 Swiss accessibility since 1850**

#### **3.1 Calculating the travel times and the accessibilities**

The calculation of accessibilities requires information about the activity opportunities, here as usual in the literature population, and information about the generalised cost of travel between any two points, here as usual in the literature approximated by travel times. Tschopp, Keller and Axhausen (2003) describe the population database for Switzerland since 1850, which has been assembled from census data, but made spatially uniform by tracing all changes in the administrative boundaries over this period. Before 1950 the spatial resolution was the district, which is an administrative unit of the Kantone of relative uniform size. After 1950 municipalities were used, which are much more numerous (about 3'000 in 2000) and much varied with regards to physical and population size. A substantial number of changes had to be considered (mergers of municipalities, creation of a new canton, districts switching between cantons). The data is available for 1850, 1888, 1910, 1930 and every decade since 1950.

The travel times employed are shortest-path travel times based on detailed assumptions of mean speeds by link type (See Erath and Fröhlich, 2003). The historical road networks are reconstructed by removing links from a detailed current year 2000 using all available sources (administrative records, maps, newspaper and professional magazine articles). In addition, for the year 2000 it was possible to calculate the travel times using a user equilibrium assignment approach involving the best current estimate of the road transport demands between the municipalities. For details see Fröhlich, Tschopp and Axhausen, 2005 or Axhausen, Dolci, Fröhlich, Scherer and Carosio, 2006. The public transport travel times are derived from detailed timetables for all years considered, which consider all regular services on the main lines, plus important bus services. This includes the scheduled coach services running before the arrival of the railways. All calculations were performed with the assignment software VISUM 8.0 (PTV AG, 2002).

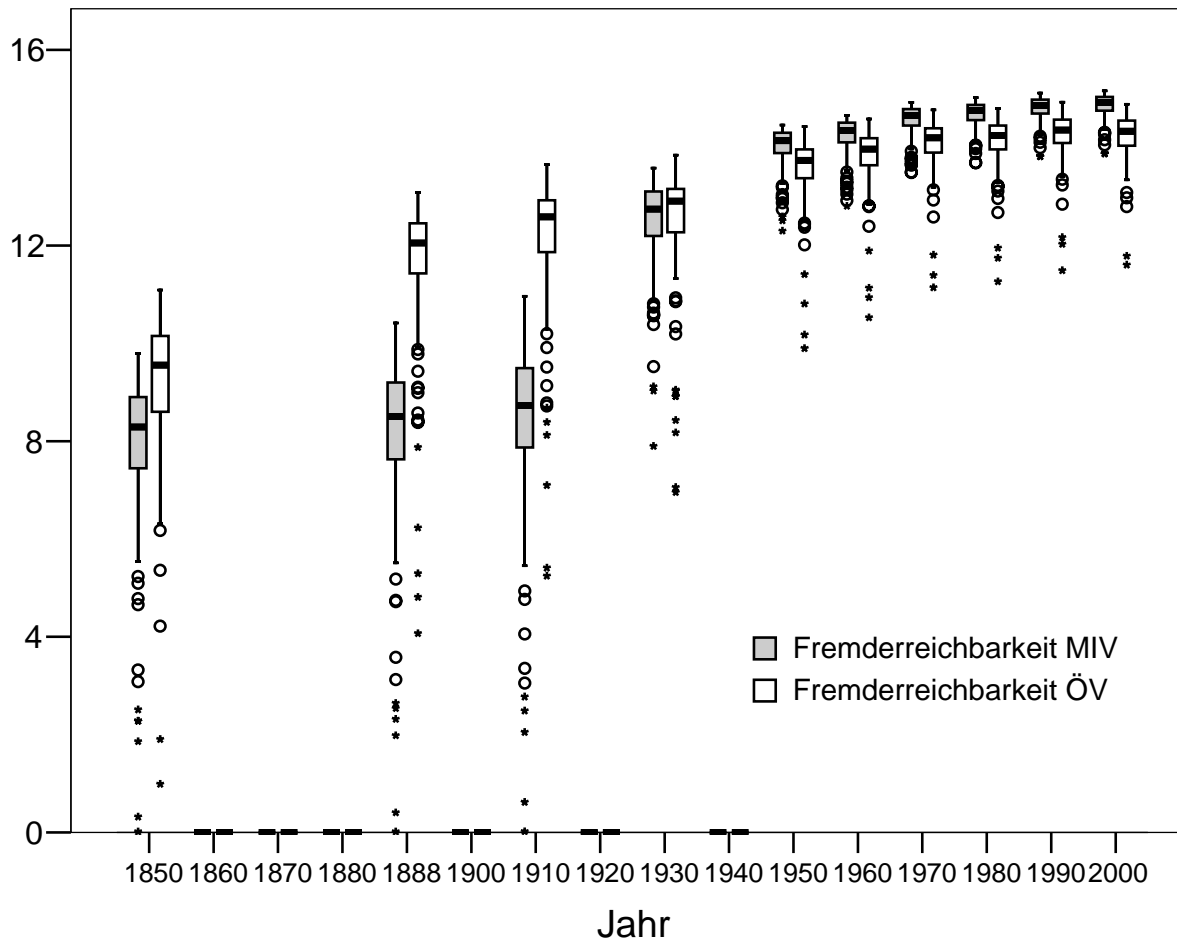
### 3.2 Accessibility change since 1850

The first time series is based on the administrative centres of the districts, which cover the country reasonably regularly. Although more detailed data is available for the period since 1950, for consistency only the districts will be considered here. The size of the districts is too large to estimate their own contribution to their accessibility. This component is therefore omitted below. Figure 4 presents the development of the medians of the road- and railway based accessibilities of the districts since 1850. The isochrones for Lausanne, Zürich and Chur (Figure 5 to Figure 7) illustrate the differences between the systems directly. The historical trend is clear: the low speeds on often very bad roads made the road system uncompetitive until around 1930, when both the quality of the roads and of the vehicles permitted the speeds to catch up (Merki, 2002; Schiedt, 2004, Schiedt and Bretschart 2004; Raff and Traijtenberg, 1995). Until that point the services offered by the railway and coach services were vastly superior (Remember the log scale of the accessibility). The exact point of the switch over is open to discussion, because it depends on the assumptions about the mean speeds possible on the roads. The relatively slow adoption of the car and the long low quality of the roads points to the 1940s for Switzerland. In the US and French case one would assume it to happen a decade earlier. Nevertheless, the speed of the catchup is impressive. While the log scale hides the sizes of the advantage of the road system, the railway system is never far behind, especially if one considers that the benefits of higher frequencies are only captured through the better timetabling and lower transfer times. Both profit from the population increase. Both are able to reduce the variance between the districts, but the railways less so than the road system. These regional differences can be seen clearer, when turning to the municipal values calculated for the period since 1950.

### 3.3 Accessibility change since 1950

As explained above, the finer networks constructed for the period after 1950 allow the calculation of population based accessibilities for each of the about 3'000 Swiss municipalities. Figure 8 shows them using road-based travel times, Figure 9 does so for the public transport travel times. The log was not taken to allow the differences to emerge. Still, one should keep in mind that welfare differences are not as large as the linear scale suggests.

Figure 4 Boxplots of the Swiss district accessibilities since 1850



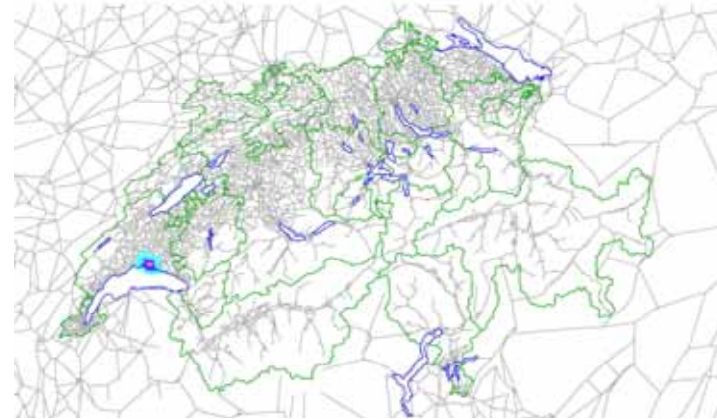
The accessibilities only considered the contributions of other districts. Given the larger spatial resolution the generalised cost (travel time) parameter was chosen to be 0.01. Please note, that the accessibilities are logarithmic.

Figure 5 Isochrones originating from Lausanne (1850 and 1910)

Road transport, 1850



Road transport, 1910



Public transport, 1850



Public transport, 1910



Figure 6 Isochrones originating from Zürich (1850 and 1910)

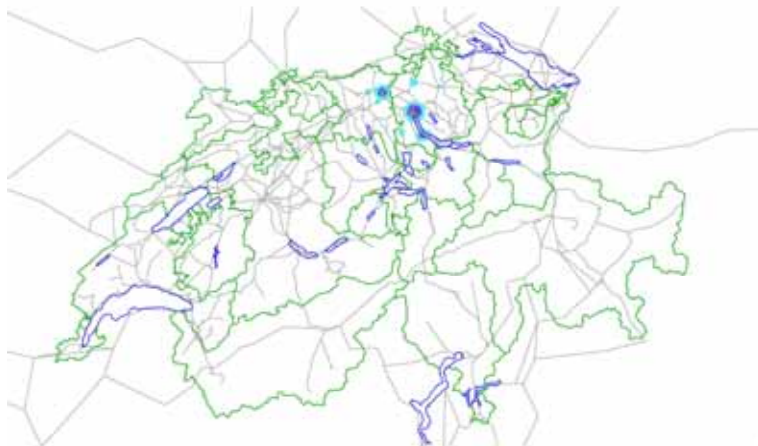
Road transport, 1850



Road transport, 1910



Public transport, 1850



Public transport, 1910

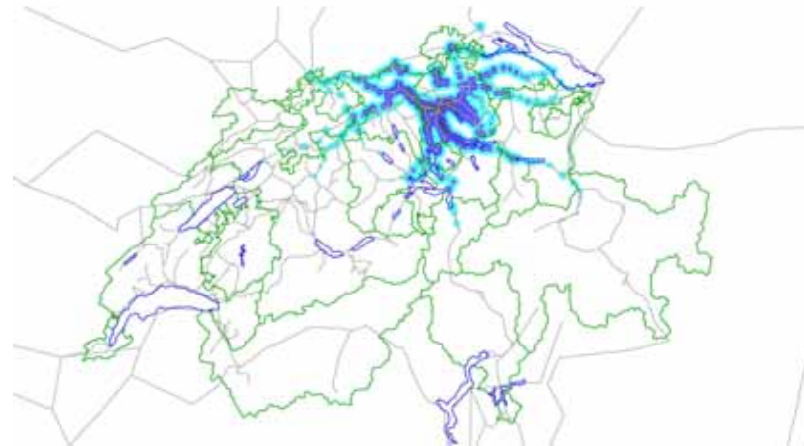
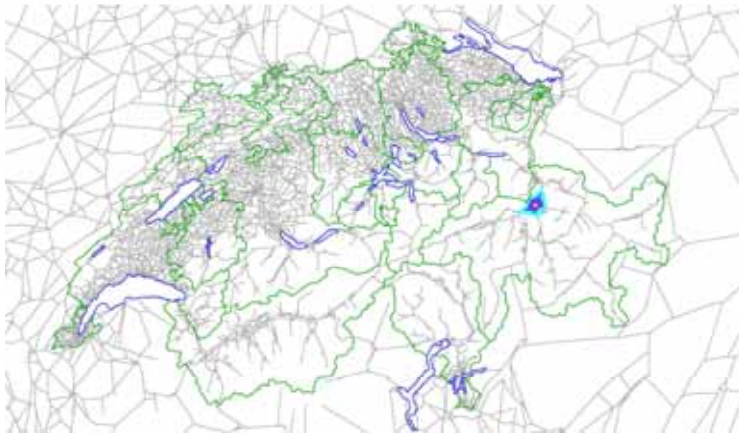
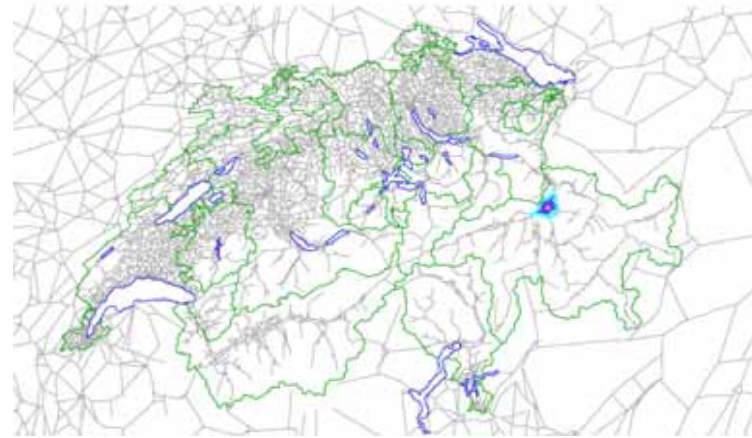


Figure 7 Isochrones originating from Chur (1850 and 1910)

Road transport, 1850



Road transport, 1910



Public transport, 1850



Public transport, 1910



Figure 8 Road-based municipal accessibilities 1950 to 2000 (without taking logarithms)

1950



1960



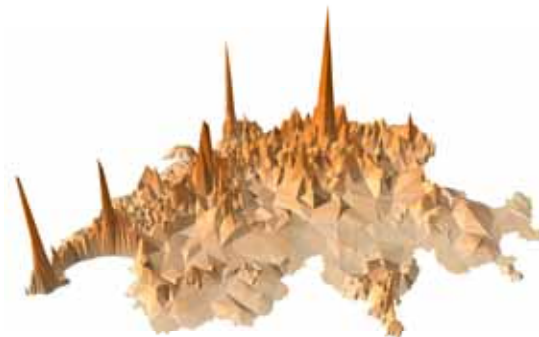
1970



1980



1990



2000

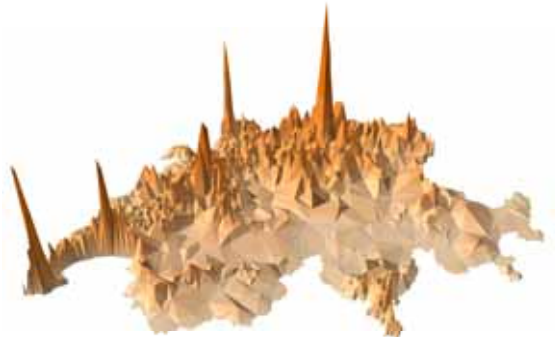


Figure 9 Public transport-based municipal accessibilities 1950 to 2000 (without taking logarithms)

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1950



1960



1970



1980



1990



2000



The big cities of Switzerland are easy to identify in either case: Geneva, Lausanne, Berne, Zürich, Basel, but also, if less clearly Lucerne, Lugano and St. Gall. They have been able to maintain their accessibilities, as the losses due to their shrinking own population since 1960 were balanced by the higher speeds to metropolitan rings around them, where population growth was strongest in the wake of suburbanisation of first population and later employment. The gains in accessibility were strongest in the areas between the major cities, in the case of the railways concentrated around the main lines, while more spread out for road-based values. Figure 10 underlines this point by presenting the distributions of the accessibilities over time. The changes since 1950 have the same spatial patterns for the road and public transport – based accessibilities (See Figure 11). The relative loss of the centres and the rural peripheries is accompanied by the increases in the metropolitan areas and the major tourist centres in the Alps, such as Zermatt or St. Moritz, which have gained population.

The mean ratio of the road to public transport – based accessibility is nearly unchanged over the period (see Table 1), but the median is increasing slightly. Investment in both systems was systematic enough to keep them in balance. It was also spatially comparable, as the standard deviation of the ratios is essentially unchanged. Only the variance in the public transport accessibilities grows, indicating a mixture of service reduction and population losses in certain parts of the country. The calculations were repeated for employment in the second and third sector. They correlate highly with the population values and surprisingly more so for the second than the third sector in the case of the road-based accessibilities (Second sector: road – based 0.945-0.972; public transport – based 0.907-0.932; third sector: road-based 0.915-0.978; public-transport – based 0.911-0.951). One should recall though, that a large part of Swiss industry is traditionally located in rural areas and small towns.

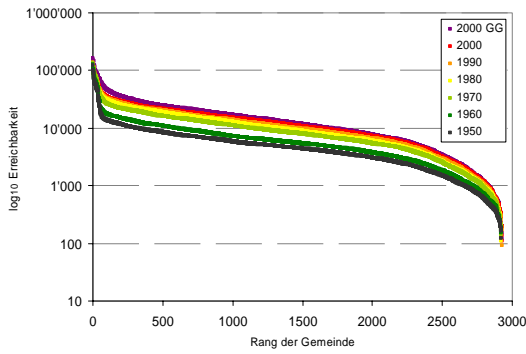
The advantage of the road-based accessibilities over the public transport–based values is also visible in Figure 12. It is particularly obvious where motorways are not paralleled by railway lines, as along the southern half of the A13 (Chur - Bellinzona), the A1 west of Bern and along the A12 (Bern - Vevey). The quality along the railway depends on the existence of a local station. Large variability results of their specific presence or absence. Public transport is relatively better in peripheral areas, where there are no motorways, such as the Engadin or parts of the Jura Mountains towards France.

Table 1 Road- and public transport based accessibilities since 1950

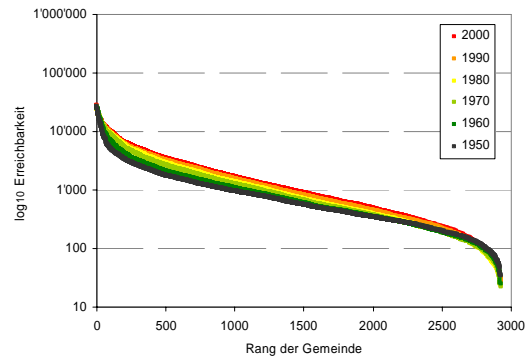
	1950	1960	1970	1980	1990	2000
Road-based accessibilities						
Mean	8.272	8.488	8.859	8.957	9.034	9.120
Median	8.409	8.617	9.006	9.111	9.200	9.302
Std. deviation	0.917	0.935	0.971	0.994	0.995	0.993
25% Percentile	7.827	8.038	8.426	8.498	8.576	8.659
75% Percentile	8.867	9.102	9.513	9.653	9.710	9.798
Public transport – based accessibilities						
Mean	6.446	6.516	6.611	6.665	6.775	6.849
Median	6.360	6.438	6.539	6.603	6.742	6.828
Std. deviation	1.102	1.193	1.288	1.308	1.301	1.304
25% Percentile	5.666	5.659	5.659	5.717	5.820	5.921
75% Percentile	7.166	7.320	7.522	7.616	7.745	7.800
Ratio of road to public transport-based accessibilities						
Mean	1.307	1.332	1.376	1.381	1.368	1.365
Median	1.277	1.299	1.335	1.334	1.324	1.324
Std. deviation	0.191	0.209	0.232	0.237	0.226	0.222
25% Percentile	1.158	1.167	1.192	1.192	1.189	1.188
75% Percentile	1.428	1.462	1.532	1.532	1.506	1.499

Figure 10 Distributions of accessibilities sorted by rank over time

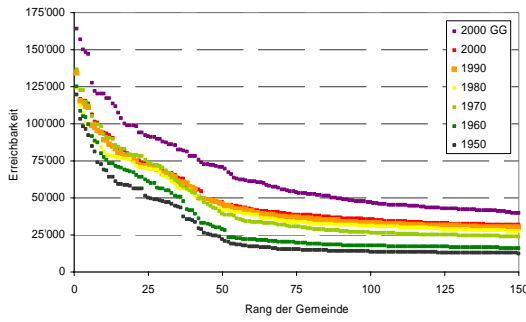
Road-based (All)



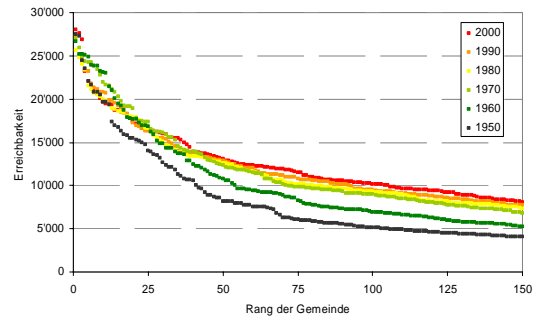
Public transport based (All)



Road-based (top 150 municipalities)



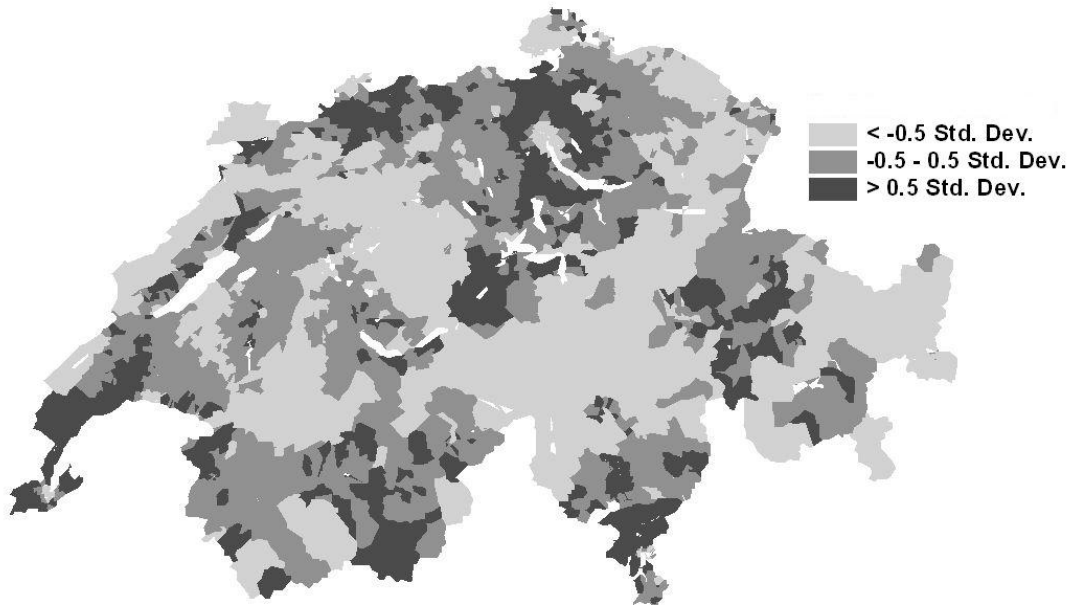
Public transport based (top 150 municipalities)



Please note the different scale for the two lower graphs

Figure 11 Ratio of 2000 to 1950 accessibilities

Road-based accessibility - Statistics: Min = 0.884; - 0.5 Std. dev. = 1.079; Median = 1.099; Mean = 1.103; + 0.5 Std. dev. = 1.127; Max = 1.376



Public transport based accessibility: Statistics: Min = 0.682; - 0.5 Std. dev. = 1.020; Median = 1.056; Mean = 1.061; + 0.5 Std. dev. = 1.102; Max = 1.515

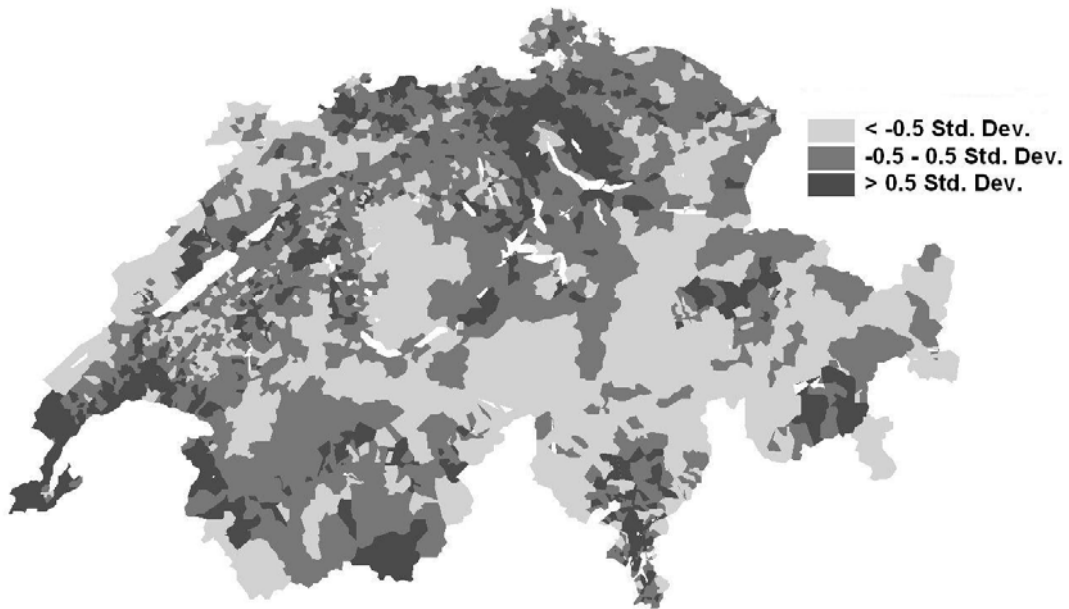
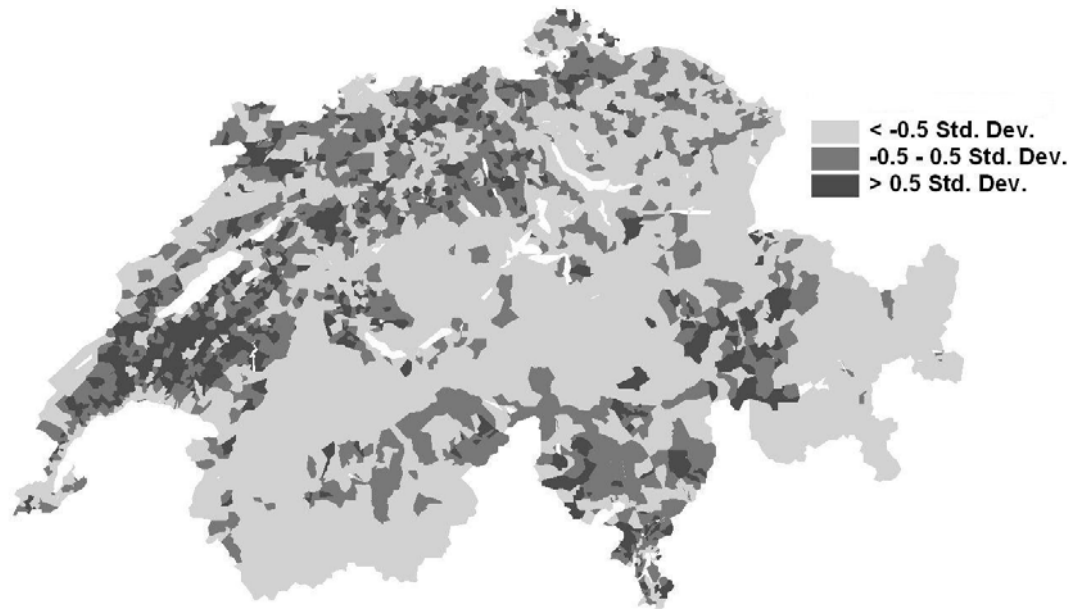


Figure 12 Ratio of road to public transport based accessibilities (2000)

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Statistics: Min = 0.954; - 0.5 Std. dev. = 1.254; Median = 1.324; Mean = 1.365;  
+ 0.5 Std. dev. = 1.477; Max = 2.446

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## 4 Methods comparison

As mentioned above, the travel times were calculated using a set of assumptions about the mean speeds driven in different decades on different road types. For the year 2000 it was possible to compare these travel times with those calculated with a complete user equilibrium assignment based on fully validated and calibrated demand matrix for the country (Vrtic *et al.*, 2004). Table 2 provides the comparative results, which show that the accessibilities obtained are slightly to low with a median of the ratios of 1.007, which is not worrying. Figure 13 shows that these differences are noticeable in the agglomerations, where they are due to the some changes in link classification in Vrtic *et al.*, 2005 and the non-modelled within-zone traffic. Both differences increase speeds and enlarge accessibilities.

Table 2 Methods comparison for road-based accessibility (2000)

	2000 Simplified assumptions	2000 User equilibrium (National model)	Ratio UE versus Simplified model
Mean	9.120	9.223	1.011
Median	9.302	9.387	1.007
Standard deviation	0.993	1.043	1.050
25% - Percentile	8.659	8.733	1.001
75% - Percentile	9.798	9.932	1.017

Figure 13 Ratio of the UE derived results to the accessibilities calculated using simplified speed assumptions (2000)



Statistics: Min = 0.969; - 0.5 Std. dev. = 1.001; Median = 1.007; Mean = 1.011;  
+ 0.5 Std. dev. = 1.021; Max = 1.202

## 5 Conclusions and outlook

The paper has shown in this first part that one cannot measure the service of the road or rail system by using the public capital stock as a proxy. Too many of the necessary assumptions do not hold for the Swiss case, and by extension for other countries and regions. The best available measure of that service, accessibility obtained as the logsum of a (simplified) destination choice model, requires zone-to-zone travel times. A companion paper showed that these can be obtained with reasonable effort by tracing the road system changes backwards from a current network model. The quality of such a simplified approach was compared with a user equilibrium assignment and found very high. The same can be done for public transport services, if one is able to code the relevant time-tables in a suitable public transport assignment model.

The paper presents the results of such calculations for Switzerland. For the period since 1850 the changes were traced at the level of districts, which cover the country reasonably uniformly. The accessibilities have grown enormously as a result of population and system speed increases. The advantage of the railway plus bus system was spent by 1930 when reliable fast cars in combination with roads with hard surfaces allowed the necessary speeds. The road system has retained a steady relative advantage since. The detailed spatial changes since 1950 show how suburbanisation and motorway construction has shifted the relative advantage away from the central cities to the suburban areas. In the periphery, the major tourist centres have been able to gain, but those areas suffering population losses have lost accessibility on top.

While accessibility change is a policy relevant result in its own right, it is only the first step for the more comprehensive analysis of the economic effects of transport system investment. The necessary modelling work is now under way and the authors hope to present it in the near future.

## 6 Acknowledgements

This paper draws on Axhausen, 2004 and Axhausen, Fröhlich, Tschopp and Keller, 2005, expanding them as appropriate.

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