

## **Part 2: Freeways Model**

## 1. INTRODUCTION

### 1.1 Facts about Switzerland

Switzerland is bounded on the north by France and Germany, on the east by Austria and Liechtenstein, on the south by Italy, and on the west by France as it is showed in figure 8.

**Figure 8. Situation of Switzerland**



It is one of the most mountainous countries of Europe, with more than 70 percent of its area covered by the Alps, in the central and southern sections, and the Jura, in the northwest. The Swiss Alps are part of the largest mountain system in Europe and are famous for their jagged peaks and steep gorges.

There are several ranges within the Alps, including the Pennine range, which has Switzerland's highest peak, 4,634 meter. Dufourspitze of Monte Rosa. The Jura (Celtic for 145 forest') are much lower and smaller than the Alps and are popular for cross-country skiing. The renowned Swiss watchmaking industry began in the Jura Mountains.

Between these two mountain systems lies the Swiss plateau, an average of 400 meters above sea level and some 50 kilometers; it extends from Lake Geneva (Lac Léman) in the extreme southwest to the Lake of Constance (Bodensee) in the extreme northeast.

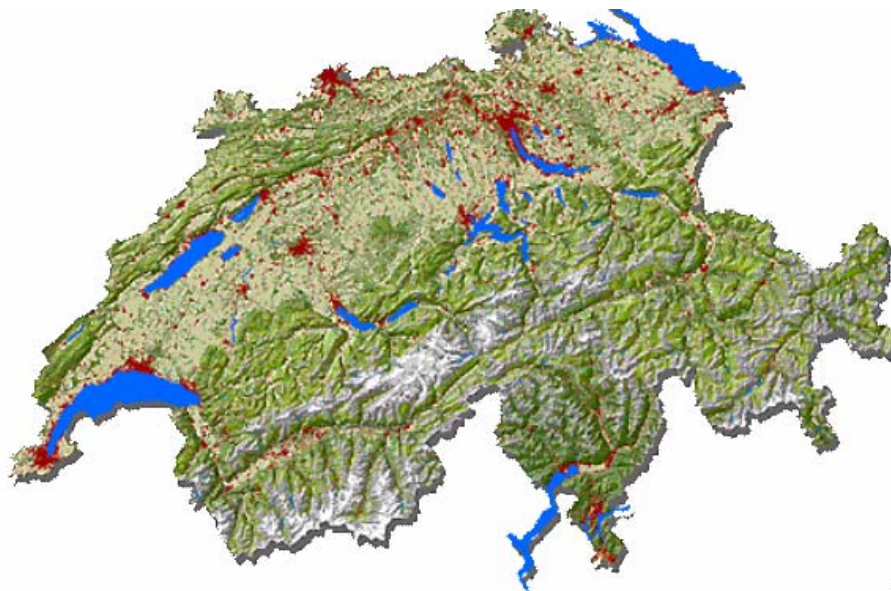
The plateau is thickly studded with hills. Between the ranges of the Alps and Jura also stretch long valleys connected by transverse gorges; one such valley is the Engadine along the Inn River in the southeast. Nearly every Swiss valley is traversed by streams, often interrupted by picturesque waterfalls, including the Staubbach Falls (about 290 meters / 950 feet) in the canton of Bern.

The principal river system is formed by the Rhine and its tributaries. Other important rivers are the Rhone, Ticino, and Inn. However, Swiss rivers are not navigable for any appreciable extent. Switzerland is famous for its many lakes, particularly those of the Alpine region, known for their scenic beauty.

The most important include Lake Geneva, Lake of Constance, Lake of Lugano, and Lake Maggiore (at which lies Switzerland's lowest point, 194 meters / 636 feet above sea level), which are not wholly within Swiss borders; and Lake of Neuchâtel, Lake of Lucerne and Zürichsee, Brienzersee, and Thunersee, which are entirely within Switzerland.

As it can be seen in figure 8, the population in Switzerland stacks mainly between the Alps in the south and the Jura mountains in the north. The largest urban areas are around the Zurich lake, Basel and spread out in the Plateau or Mittelland (like Bern. Another important centre of the country is the area around the Lake Lemman (Geneve, Lausanne).

**Figure 9. Geography of Switzerland**



Some other relevant settlements are the Rhone Valley, the south of canton Ticino and the territory behind the Lake Constanza.

The big mountain systems exposed before force people to live in the areas above aforementioned.

## **1.2 Major highways**

The major highways are shown in the map of the appendix 6. The future openings are also included.

The highways in Switzerland used to be named Nx, whereas N stood for "*Nationalstrasse*" (National road) and x was a number, but they have recently been renamed to follow the common European naming schema. These names start with the letter "A" for "*Autobahn*" (German) or "*Autoroute*" (French). Highways of international importance also have names starting with the letter "E", therefore some highways have two names.

In Switzerland, names of towns are used for navigation on the roads, rather than highway numbers. Signs show the names of the major cities, road numbers are rarely seen. Signs on or for highways use white letters on green background. Signs for major roads use white letters on blue background, signs for local roads use black letters on white background.

Highways in Switzerland are often congested, particularly in summertime. Weekends are especially bad. The most busy highway is the highway A1 between Zurich and Bern, but also the Gotthard tunnel between Göschenen and Airolo is often very crowded. Cars may build up for as long as 20 km and it needs a lot of patience to get to the other side of the Alps. An alternative is to use the San Bernardino pass but congestions are there very likely too.

In order to use the highways in Switzerland, a toll has to be paid. But there are no toll booth, instead a special sticker - known as the "*Autobahn Vignette*" - is required. The sticker is valid for one calendar year (January until December), there is nothing like a one day or one week pass. It costs CHF 50.00 and is available at the customs at the borders and at all gas stations and post offices throughout the country. The sticker must be fixed to the windshield on cars and trucks, there are particular rules for where it has to be placed on motorbikes.

## 2. MODEL

Transport systems have been built primarily to expand the reach of both people and industry. One measure of the resulting change in the spatial system is the change in *accessibility*. For this, two components must be considered. First, what can be reached, and second, how much effort is necessary to get there? Accessibility is both the primary product of transport infrastructure and the link between transport infrastructure and land use.

During the last fifty years, private vehicle traffic has changed dramatically; the private car is no longer a luxury in Western Europe. The interregional infrastructure for private vehicles has been changing from an ill-fitting, multipurpose, slow road network into a fast, single-purpose, strong, hierarchical motorway and road network. In recent years, many studies of European changes in accessibility (Schürmann *et al.*, 1997; Bruinsma and Rietveld, 1993) have sought to determine the impact of major infrastructure developments, primarily railroads and motorways, on the accessibility distribution in Europe and their future effects.

The approach of the present work is to look backwards in order to trace changes in accessibility for private vehicle traffic over the period from 1950 through 2000, in 10 years steps like can be seen in the appendix 1. The population size at the municipal level is used as a first approximation of the number of activity opportunities.

In the following, the measurement of accessibility as implemented here is explained, followed by a description of the data sources used in the analysis. The main goal is the discussion of changes in accessibility in Switzerland. The results are then summarised and interpreted in the discussion.

The starting point for the present model is the road network of Switzerland in the year 2000. It consists of approximately 20,000 links, 15,000 nodes and 3,000 districts. From this, different road networks are built for the years of interest (that is, 1990, 1980, 1970, 1960 and 1950). This data are contained in Vissum (PTV 2000), a GIS and transportation software that enables the handling of large network databases in order to make traffic calculations. The different sizes of the network through the time are available in the appendix 1.

The year of opening of the links in the motorway network was taken from ASTRA (2001).

An "all-or-nothing" traffic assignment is used to calculate the travel time from each municipality to every other municipality in Switzerland. This yields a 2903 x 2903 matrix, applying nearly 9 millions trips on the Swiss road network (i.e., one trip between each zone). The large size of this matrix made the treatment of the data pretty difficult.

## 2.1 Speed

By removing the motorways from the model and adjusting the mean speed for the different road types in each year accomplish. The speed values for the links are obtained from old editions of the HCM (1985) as well as Dietrich *et al.* (1998), and are shown in Table 1.

The rise in the mean speed for every kind of link trough the time act in response to the improvement in the level of service. That applies mainly to aspects like the width, steepness and percentage of turns.

**Table 1. Mean speed of the link types for different years [km/h]**

Kind of link	Year				
	1960	1970	1980	1990	2000
Motorway-120	85	95	110	112	114
Motorway-100	85	95	90	92	94
Motorway-80	85	95	75	77	79
Motorway-access	30	30	30	30	30
Main road	40	45	55	65	70
Connection road	25	40	50	60	60
Collection road	30	35	45	50	50
Access road	25	25	35	40	40
Alpine transit road	35	40	50	60	60
Alpine main Road	30	35	45	50	50
Alpine collection road	25	25	35	40	40
Alpine access road	15	20	25	30	30
Urban main road	22	22	22	22	22
Urban collection road	17	17	17	17	17

Source: own calculation with data from HCM (1985) and Dietrich et al.  
(1998)

## 2.2 Capacity

For some links, this method suggests unrealistically high traffic volumes. Thus, it is necessary to set the capacity restraint function as a constant; in other words, there is no increase in travel time for a link, irrespective of the load.

In the table 2 are shown the capacities trough the time.

**Table 2. Mean capacity of the link types for different years [vehicles/h]**

CAPACITY TROUGH THE TIME					
Kind of link	1960	1970	1980	1990	2000
Motorway-120 *	48000	48000	48000	48000	48000
Motorway-100 *	48000	48000	48000	48000	48000
Motorway-80 *	48000	48000	48000	48000	48000
Motorway-access	15600	15600	15600	15600	15600
Alpine access road	5400	7200	9000	10800	12600
Alpine main road	9000	12000	15000	18000	21000
Alpine collection road	5400	7200	9000	10800	12600
Alpine transit road	9000	12000	15000	18000	21000
Access road	5400	7200	9000	10800	12600
Main road	12600	16800	21000	25200	28800
Collection road	7500	10000	12500	15000	17500
Urban main road	9000	12000	15000	18000	21000
Urban collection road	5400	7200	9000	10800	12600
Connection road	9000	12000	15000	18000	21000

\* Values for a two lane motorway

Source:own calculation from Brilon and Weiser (1998) and Die Autostrasse (1966)

This concern implies that the congestion is not considered in the calculation of the travel times. The problem about considering the traffic jams in the network lies in the impossibility of getting the data for the first decades of this study.

Nowadays the capacity of the Swiss network is overloaded. Concerning to the Hauptstrassennetz the main problem appears in the Gotthard (N2) in the Friday

evenings. Moreover two daily peaks about 7 a.m. and 5 p.m. affect the biggest urban areas jamming the motorways around them (Axhausen, 2001).

The calculation of the travel times is performed with help of the transport model VISUM (PTV , 2000). The connection between the centroid of a municipality and the road network is established by choosing the closest node of the minor road network (all roads excluding motorways: the connection to the network must be done through the minor road). No access or egress times are considered; this means that travel time reflects the path between the nearest minor node by the origin and the destination.

## **2.3 Population**

The implementation of the population database at the community level was necessary in order to calculate accessibility.

The population of Switzerland is estimated at just over seven million. Twenty per cent of the population are foreign nationals. With much of the land area mountainous and one fifth of the country covered by lakes, glaciers, rocks and permanent snow, Switzerland is densely populated. Switzerland's history and position in Central Europe has led to three major distinct national identities evolving: German, French and Italian. A very small, 0.7% of the population, are Romansch and are mainly in the eastern mountains of Grisons, in the Canton Graubunden.

In the 19th century Switzerland was the poorest country in continental Europe which inspired a tradition of emigration, still part of the culture today. The number of Swiss citizens resident in Switzerland has decreased since 1996 with about 10,000 leaving every year. Asylum seekers and refugees have traditionally been welcomed in Switzerland since the 1957 Hungarian revolution. Immigrant groups include Hungarians, Tibetans, Tamils and most recently Kosovars. Switzerland accepted the second highest numbers of Kosovan asylum seekers after Germany in 1998.

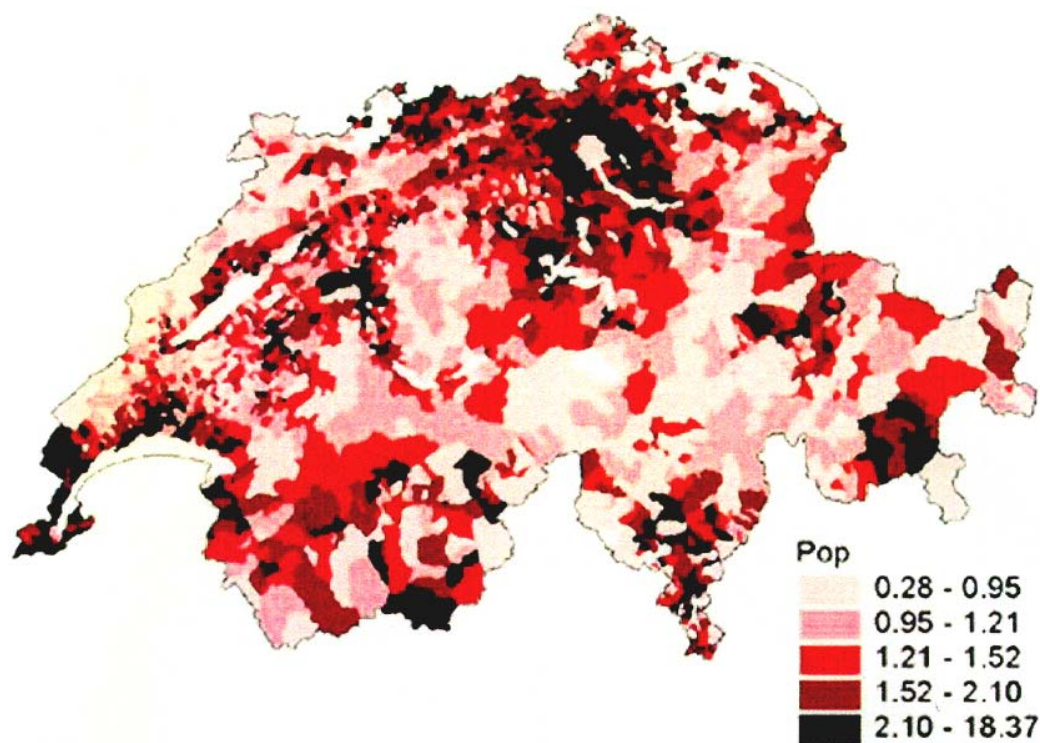
The population data come from the censuses of 1950, 1960, 1970, 1980 and 1990. In the case of 2000, population data of the Bundesamt für Statistik (Swiss Department of Statistic) from the beginning of 1999 is employed, (see Figure 10). The extended time frame leads to some minor problems regarding the analyses and the mapping of the results. In some cantons, for example Thurgau or Basel-Landschaft, municipalities have been divided or merged; these changes are not considered within this data set. Additionally, the Arch View files containing the municipality borders uses 1998 as the reference year and thus leaves some small gaps in the map. However, the aforementioned problems affect only smaller municipalities; thus, the calculation of accessibility is still precise enough given the extended time frame and the broad scope of the study.



Looking at either of the maps, population or accessibility change, one should keep in mind that municipalities with a large physical area may appear more important than smaller areas, such as suburban areas. Figure 10 shows the change in population from 1950 to 1999 on a municipal level. It shows an overall relative growth, due to an increase in the Swiss population in absolute terms from 4.715 to 7.123 million (BFS, 1999).

In the report of the Bundesamt für Statistik (1992), the changes in population for different periods are discussed. The period between 1941 and 1970 showed a significant increase in population, which came about in conjunction with a strong economy. The peripheral areas, the rural parts, and especially the non-tourist, alpine valleys lost population. On the other hand, the cities, and particularly their surroundings, gained population due to the rise in the industry. From 1970 to 1990, cities lost population to their surrounding municipalities because of the flow of families looking for a quieter environment. This led to an increasing agglomeration effect around the larger centres. Additionally, the Rhone Valley and the urban areas of Tessin saw population increases. In rural areas, only regions with economically inferior situations lost further people, (i.e., the Gotthard area, Jura, Canton Uri).

**Figure 10. Population change at the municipality level from 1950 to 1999, by quintile (1.0 means the same number of residents in 1999 as 1950)**



### **3. ACCESSIBILITY MEASURES**

Accessibility is a term often used in transport and land-use studies and the main aim of this master thesis is to survey the range of measures of accessibility that have been proposed in the Part 1 and decide which are the suitable ones to be applied.

Accessibility is seen as being concerned with the opportunity available to an individual or type of person at a given location to take part in a particular activity or set of activities. However various other interpretations of the term accessibility have been made and in order to survey the range of indices to which the term accessibility measure has been applied it is necessary to consider also the range of definitions that have been given to the term accessibility. No single 'best' measure is identified; rather the choice depends on the type of problem being studied and the resources available. Some consideration is given also to the areas of study in which accessibility may be a useful concept.

In the present work, accessibility is defined as (Geurs and Ritsema van Eck, 2001):

...the extent to which the land-use transport system enables [groups of] individuals or goods to reach activities or destinations by means of a [combination of] transport mode[s].

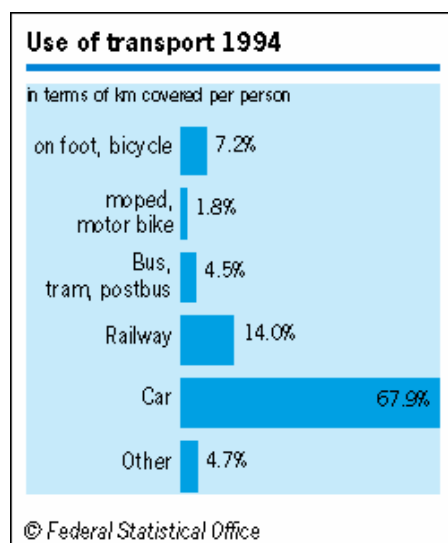
Though several different approaches have been developed since the fifties to measure accessibility, only the two major concepts in use are discussed below. Both of these approaches reveal the different levels of infrastructure in a region and areas relevant to the region, as well as what activity opportunities are present for the regional inhabitants.

The resources available to study the improvement in accessibility in Switzerland in the period 1950-2000 are limited. On the other side, the broad scope of this master thesis makes the size of the problem considered to be pretty large. These two topics will influence decisively in the election of the accessibility measure.

There are many reasons that account for the use of the freeway network to study the accessibility in Switzerland in the period 1950 – 2000. Next some of them are exposed.

The modal split for the use of the different means of transport shows that 2/3 parts of the kilometres covered by a person are made by car (1994) as it can be seen in figure 11. That shows that the most relevant percentage of travels is made by car.

**Figure 11 . Use of transport in Switzerland in 1994.**



In the last 4 decades the amount of private cars has increased 7 times. The possession of a car is no longer a luxury in Switzerland. Altogether there are currently 4,7 million cars for a population of 7,1 millions, which means that the families have as an average, two cars. The consequence is the ease of travelling by car, although Switzerland has a modern and dense public transport network.

**Table 3 .Vehicles in Switzerland 1960 - 2001.**

	1960	1970	1980	1990	2000	2001
<b>Passenger cars</b>	509000	1383000	2246000	2985000	3545000	3629000
<b>Motorcycles</b>	...	142000	137000	299000	493000	521000
<b>Goods vehicles</b>	55100	107000	169000	252000	279000	285000
<b>of which delivery vehicles</b>	...	...	...	196000	227000	234000

In comparison with other transport modes, the national highways network has experienced a quick growth. While road and rail had little or no growth, the national highways become the more and more important. That change in the different mode networks is showed in the table 4.

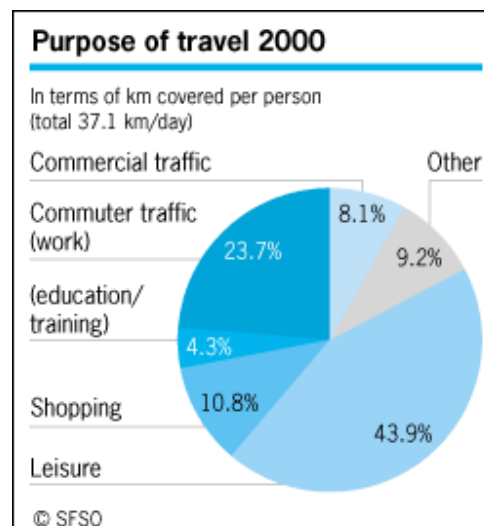
**Table 4 .Network in kilometres 1960 - 2000.**

	Rail	Road <sup>1</sup>	national highways
<b>1960</b>		5,155,934	112
<b>1970</b>		4,996,013	651
<b>1980</b>		4,986,544	1,171
<b>1990</b>		5,047,097	1,495
<b>2000</b>		5,047,128	1,638

<sup>1</sup> Local roads: Position 1984

As it is shown in the figure 12 the main purpose of travel is the leisure (44%), like it is usual in Western Europe. If the goal is to analyse the accessibility, no conclusions can be determined from that: it is a hard work to know where the travellers are willing to go. Therefore no main possibility (or kind of activity point) can be determined for this study with such a broad scope of analysing the accessibility in a whole country. Besides, the objective of the master thesis is the study of the network and not the accessibility to a given activity.

**Figure 12. Purpose of travel in Switzerland**



All these reasons show that that the freeway network is the best way to analyse the development in accessibility in Switzerland in the period 1950-2000.

The next step is decide which accessibility measurements are suitable to analyse this problem.

### **3.1 Contour measures**

These measures are discussed in the section 7.5.2 and they can be summarised as follows:

the number of opportunities for a given activity reachable within a given travel cost or the travel cost required to reach a given number of opportunities for a given activity.

This type of measure aims to describe the transport and land-use system from the user's point of view. The contour levels need to be chosen realistically (for example, the number of grocery shops within three hours is not very useful) and consideration should be given to the different types of access required to different types of facility (for example, it is possible that a person is not interested in access to more than one hospital or post office but wants some choice of grocery shops and a wide choice of jobs).

**3.1.1 Isochronal approach.** The isochronal approach to accessibility measurement focuses on the number of activity points that can be reached in a given time. This yields the number of activity points (i.e., people, places of work, shopping opportunities) accessible in a given amount of time. This is a transparent method but also disregards activity points that are just outside the set travel time and the differential impact of the travel times between the reference point and the opportunity.

The calculation is made with the software PTV Vissum. The centroid from where the calculation is made is Zurich. It is the biggest city and conglomeration in Switzerland. Therefore the more travels are generated from or to Zurich. Various intervals are set in order to track the development in the time. These times are 10, 20, 30, 40, 50, 60, 75, 90 and 105 minutes as it can be seen in the appendix 2.

**3.1.2 Travel time.** Alternatively the measure of the travel time from Zurich is set. The measures are taken to six relevant Swiss cities: Basel, Bern, Chur, Luzern, St. Gallen and Winterthur. Their situation can be seen in the figure 8.

These urban areas represent all the directions from Zurich. They also vary in distance to Zurich and number of inhabitants.

Therefore their travel times are a good measure to analyse the decay of the cost of travelling from or to Zurich. The goal here is to analyse the curve of the travel time trough the decades with aim of detecting a trend.

### 3.2 Potential accessibility

When calculating the potential accessibility some considerations should be taken in account. In this case some limitations are present. Due to the broad scope of the study not many resources are available.

Concerning to the activity points to study the population is taken. No matter the age, profession, social group or sex. All the inhabitants of every municipality count as a unity for this study. It is supposed that all of them origin the same amount of travels.

The travel time is taken as the deterrent function. Like it has been showed in the part 1, some other deterrent functions could have been taken (i.e. the sum of distances of the links between two given nodes). But travel time is better when available.

The next step is the decision of the accessibility measure. The profits and the disadvantages of the different kinds of measure are discussed in the section 7 of the Part 1.

With these resources some measures are not suitable to be applied:

- Firstly, it must be said that there are no traffic inventories available for the period 1950-2000 in the Swiss network for all the decades. Thus it is not possible to pose a demand model.
- Secondly, time-space geography focuses on individuals and their daily activities. That is out of the scope of this study.
- The revealed value measures try to reflect how the changes in either or both of the transport and land-use systems (and hence in accessibility) affect to the cost of a given trip.

Thus, these two last measures are not convenient to the study that is being carried. On the other side, the Hansen measures (also called gravity or potential measures) appear to be suitable in this case. They express the accessibility of a zone in terms of the accessibility of all the other zones.

That is to say, the way to measure accessibility is to weight attractiveness of the activity points with the necessary travel time to these points by means of a negative potential function (See Kwan, 1998, for a discussion of other possible weighting functions).

**3.2.1 Municipality accessibility.** This measure is defined as:

$$PopAcc_i = \sum_{j=1}^{j=n} P_j * e^{-\alpha * c_{ij}} \quad [14]$$

where  $PopAcc_i$  = accessibility to people living in municipality,  $i$

$P_j$  = the number of residents of municipality,  $j$

$c_{ij}$  = travel time by private vehicle between the municipality  $i$  and municipality  $j$

$\alpha$  = exponent

The main challenge here is to find the appropriate exponent,  $\alpha$ , that determines the destination choice of the people, which can vary over time. In the past, the  $\alpha$  factor should have been larger than today, but these values would have to be derived from old traffic surveys, which are not available yet. In the literature, the range for the  $\alpha$  factor reaches from 0.5 at a regional level (Simma *et al.*, 2001) to 0.01 for Europe (Schürmann *et al.*, 1997). In the present study, the  $\alpha$  factor is taken as 0.1 and kept constant across periods.

That is a generalised Hansen measure like the one described in the section 5.4.1 of the Part 1. For this case of study, the opportunities at zone  $j$  match with the whole of the population, and the travel cost is considered like the travel time between two given municipalities.

The deterrent effect of the travel cost correspond with the negative exponential, like the one showed in the Figure 7 of the Part 1, but with the correction exponent above aforementioned.

**3.2.2 Cantonal accessibility.** Alternatively to the municipality accessibility this measure is defined as the mean accessibility of all the communities that belong to every canton.

$$C.A_i = \frac{\sum_j PopAcc_j}{n_i} \quad [15]$$

Where  $C.A_i$  = cantonal accessibility of the canton  $i$

$PopAcc_j$  = accessibility to population in the municipality  $j$

$n_i$  = number of municipalities in the canton  $i$

This measure is more convenient in order to picture the results. The maps with the results of accessibility will show the accessibility of each one of 26 Swiss cantons.

#### **4. PROGRAM**

This program was written with the help of the statistical program SAS. The capacity of SAS for managing large files made this software pack the only option to calculate the accessibility. Although the formula looks quite simple, the difficulty lays in the number of municipalities (more than 2900) that origin a travel matrix of almost 9 million times.

The number of activity points in the origin itself, here defined by population, must also be considered. For this, four different classes of municipalities were considered and average internal travel times determined. The first is for cities (> 100,000 inhabitants) with an average travel time of 15 minutes, the second for towns (30,000- 100,000 inhabitants) with a travel time of 10 minutes, the third for villages (5,000- 30,000 inhabitants) with a travel time of 7 minutes, and the last for small villages (< 5,000 inhabitants) with a travel time of 4 minutes. That program is showed in the appendix 1.

Alternatively some other runs are made with another program (appendix 2) that does not account for the activity points in the origin itself. That is, the population living in the own city or village. That way of calculating accessibility is more reasonable. If the purpose is to study the motorway network, it is logical to assume that little travels have like origin and destination the same node. Some exceptions can be made to that assumption (e g the motorways around the big urban areas).

On the other side the visualization of the results is better with the results of the first draft of the program, so both are used in this master thesis.



## 5.RESULTS

### 5.1 Isochronal approach.

The results are shown in the appendix 2.

It is plane to see that the main change in the area reached with the same time happens between 1970 and 1980.

In 1970 one could reach the boundaries of canton Zurich in one hour while in 1980 within the same time this boundary broadens as far as canton Bern and the Lake Constanza.

In year 2000 the one hour isochrone is much bigger getting as far as Bern city and canton Graubunden.

### 5.2 Travel time

The results are shown in the appendix 5. An overview of these reductions in the travel times is shown in the next table 5.

**Table 5. Travel time reductions**

	<i>TRAVEL TIMES REDUCTIONS</i>					
	<i>Basel</i>	<i>Bern</i>	<i>St. Gallen</i>	<i>Winterthur</i>	<i>Chur</i>	<i>Luzern</i>
1950-2000	56%	56%	58%	60%	64%	48%

Source: own calculation

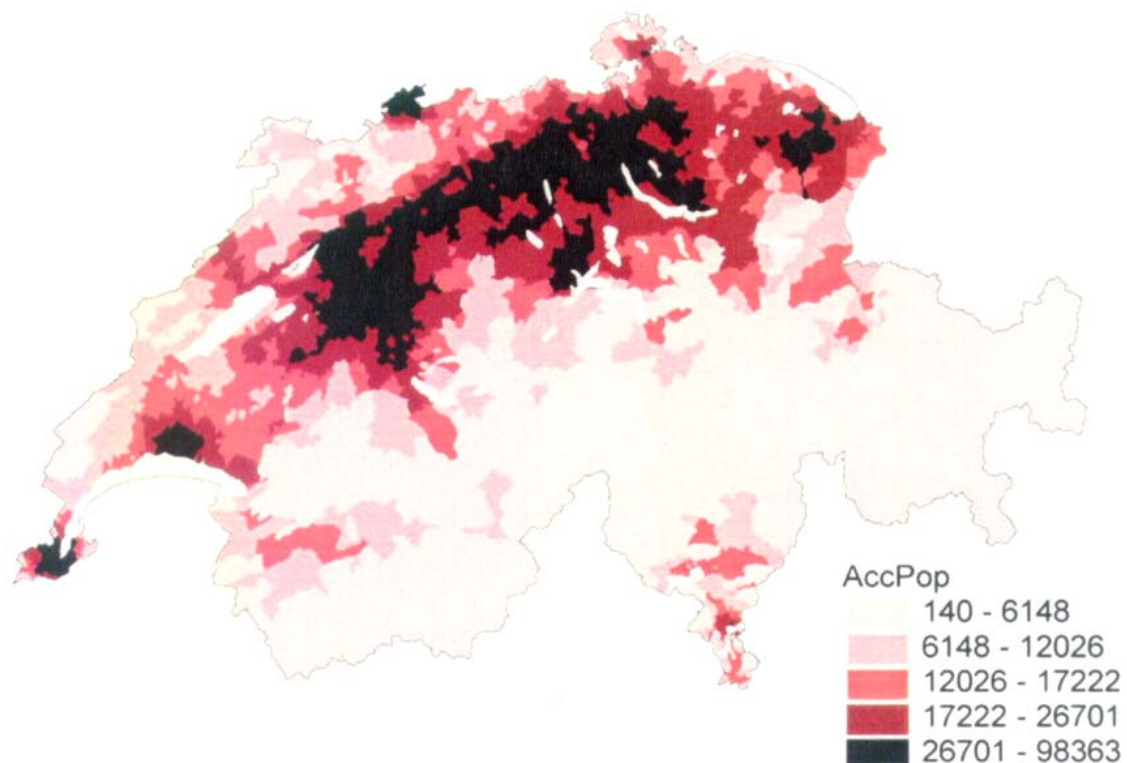
These numbers show that the travel times nowadays is at least the half it used to be. That represents a much lower travel cost for the individuals and in consequence the easiness of travelling by car

### 5.3 Potential accessibility

In 1950, the major urban areas (see Figure 13), Zurich, Bern, Basle, Geneva, Lausanne, St. Gallen and Lucerne, had a clear absolute accessibility advantage over the other parts of Switzerland. The only band of high accessibility is in the Mittelland, spreading between Bern and Zurich. With the exception of the Rhone valley, large parts of the mountain regions have low accessibility values. The bottlenecks of the Swiss major road network between regions are also visible, for example in the area around the Urner and Walen Lakes.

A second calculation of accessibilities is done with the road network of 1950 but with the population data of 2000. This shows little change overall. However, the loss of population in some areas (e.g., Glarus) and the gain around others (Zuger and Vierwaldstätter Lakes) are apparent.

**Figure 13. Absolute accessibility for the year 1950, by quintile (1950 network and population)**

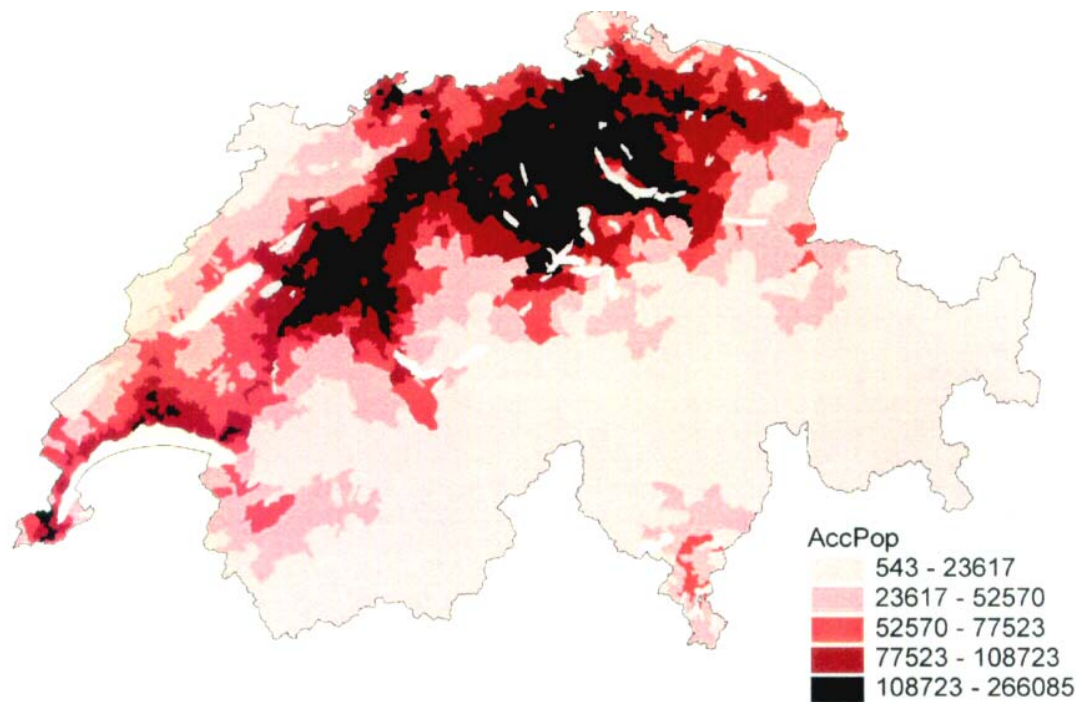


In 2000 (see Figure 3) the locations in the highest quintile of accessibility are concentrated in a circular area around Zurich including the Bülach, Olten and the northern part of the Vierwaldstätter Lake. Around Bern, a cross-shaped area with municipalities of high accessibility can be seen, leading from Biel to Thun and from Solothurn to Fribourg. Around Lake Geneva, the distribution has changed from two main peaks, Geneva and Lausanne, to a more homogeneous appearance, with two additional peaks at Vevey and Nyon.

As in 1960 the areas with lower accessibility coincide with the southern part of Switzerland except from southern Ticino and the Rhone Valley following the national highway.

**Figure 14. Absolute accessibility for the year 2000 by quintile (2000 network and population)**

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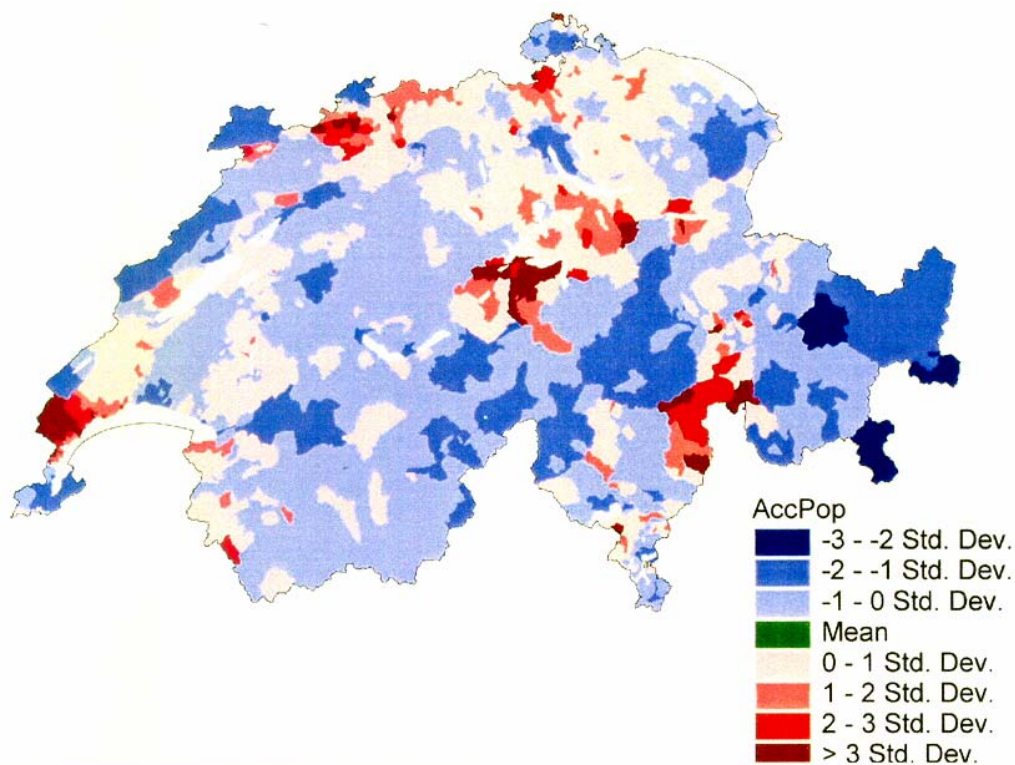


If the accessibility changes between 2000 and 1950 are considered (see Figure 15), the removal of some bottlenecks, like Walen Lake (N 3), Gotthard (N 2) and San Bernadino (N 13) brought major changes to areas now reached by motorways. Additionally, some border areas have improved considerably, such as Glattfelden -Eglisan (N 51, N 50), Mohlin - Rheinfelden (N 3), South of Basel, West of Yverdon-Les-Bains (N 5, N 9), and the Nyon area (N 1).

The changes within urban areas are small, as there was already a high level of accessibility in the fifties. The alpine areas without motorway access, such as the Engadin, Appenzell, and the Vorderrhein areas, have stayed on a low level. However, none of the municipalities have in 2000 a lower accessibility than 1950.

**Figure 15. Relative change from 1950 to 2000 in accessibility in standard deviation.**

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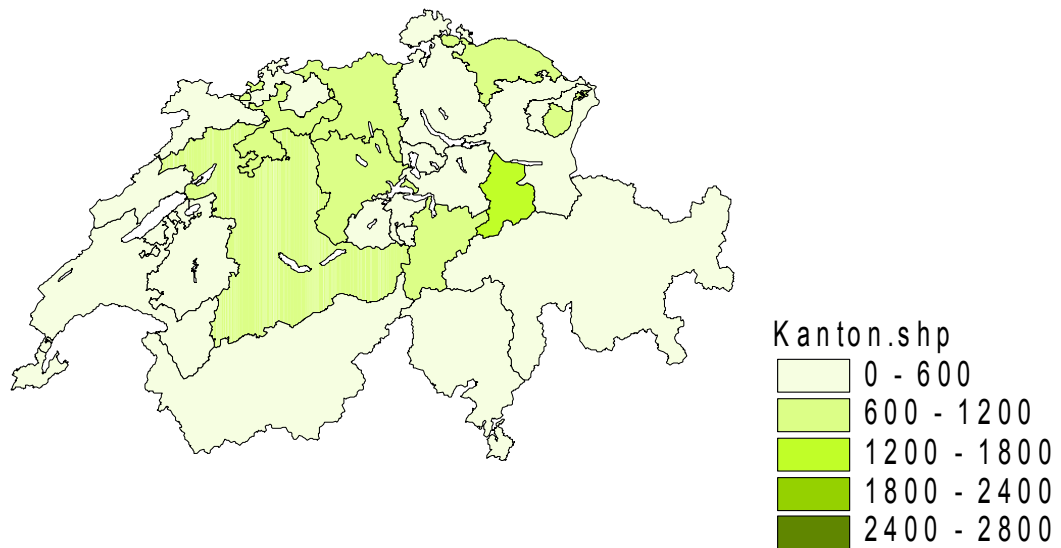
The figures showed by now are a result of running the program where four different classes of municipalities were considered and average internal travel times determined. That program is shown in the appendix 1. Alternatively some other runs were made with another program (appendix 2) that does not account for the activity points in the origin itself. That is, the population living in the own city or village. The results for every decade are shown in the appendix 11. The same range in the fields of accessibility is used to make easier the comparison among them.

Then again accessibility is calculated for the cantons with the goal of visualizing better the results. Also here the same range in the fields of accessibility is used in order to compare now just the results of 1960 and 2000.

In first place it can be seen that the cantons with a higher accessibility are the ones in the left Middleland (Bern, Argau, Solothurn; Luzern).

**Figure16. Accessibility in the cantons (1960)**

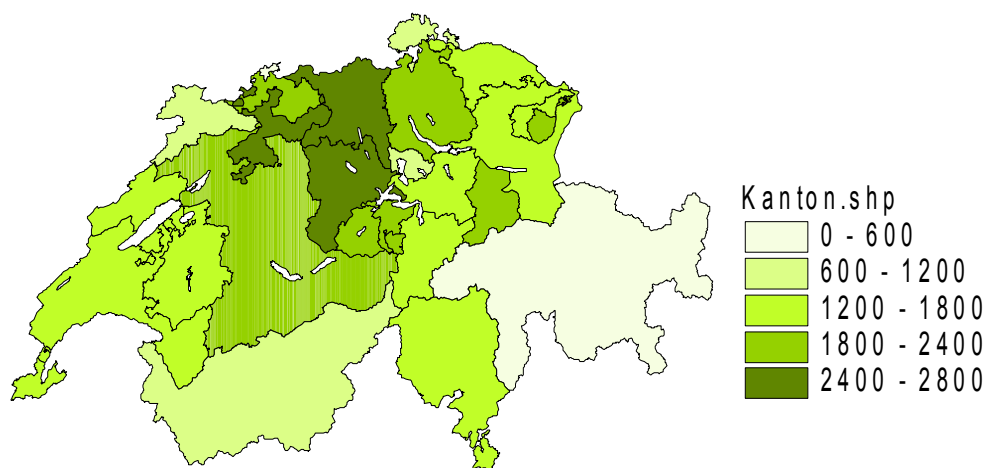
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In figure 17 the accessibility for year 2000 is represented. At the first glance sticks out the low accessibility in the bigger and southern cantons (Graubünden and Valais) and Jura. These cantons correspond to the ones with a higher ratio of mountains.

**Figure17. Accessibility in the cantons (2000)**

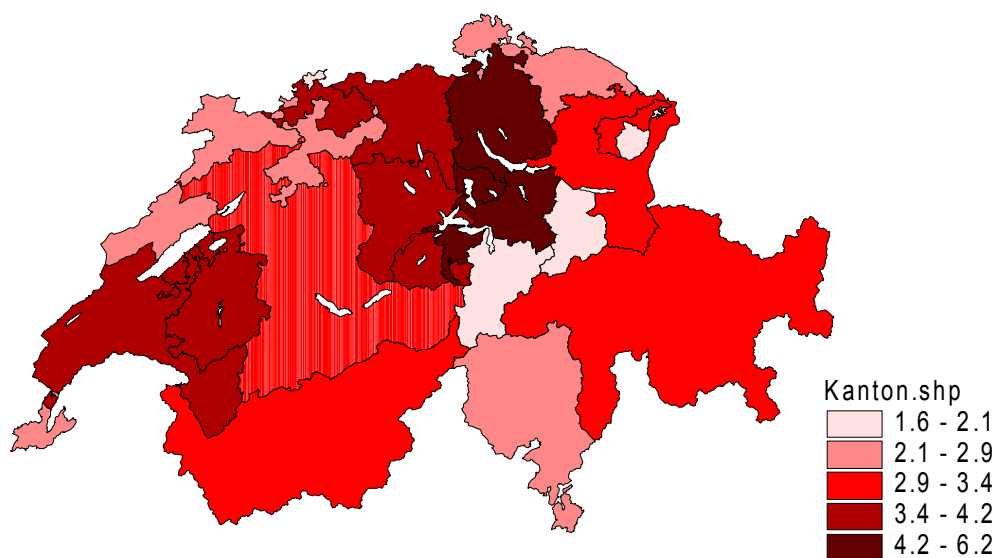
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It is also remarkable the evolution in the cantons situated in the centre of the country (Obwalden, Nidwalden, Zurich, Argau, Basel-Land, Zurich, Zug and Schwyz). The western cantons have experienced also a relevant progress (Vaud and Fribourg). These progresses are represented in the figure 18.

**Figure18. Gain in accessibility in the cantons (1960)**

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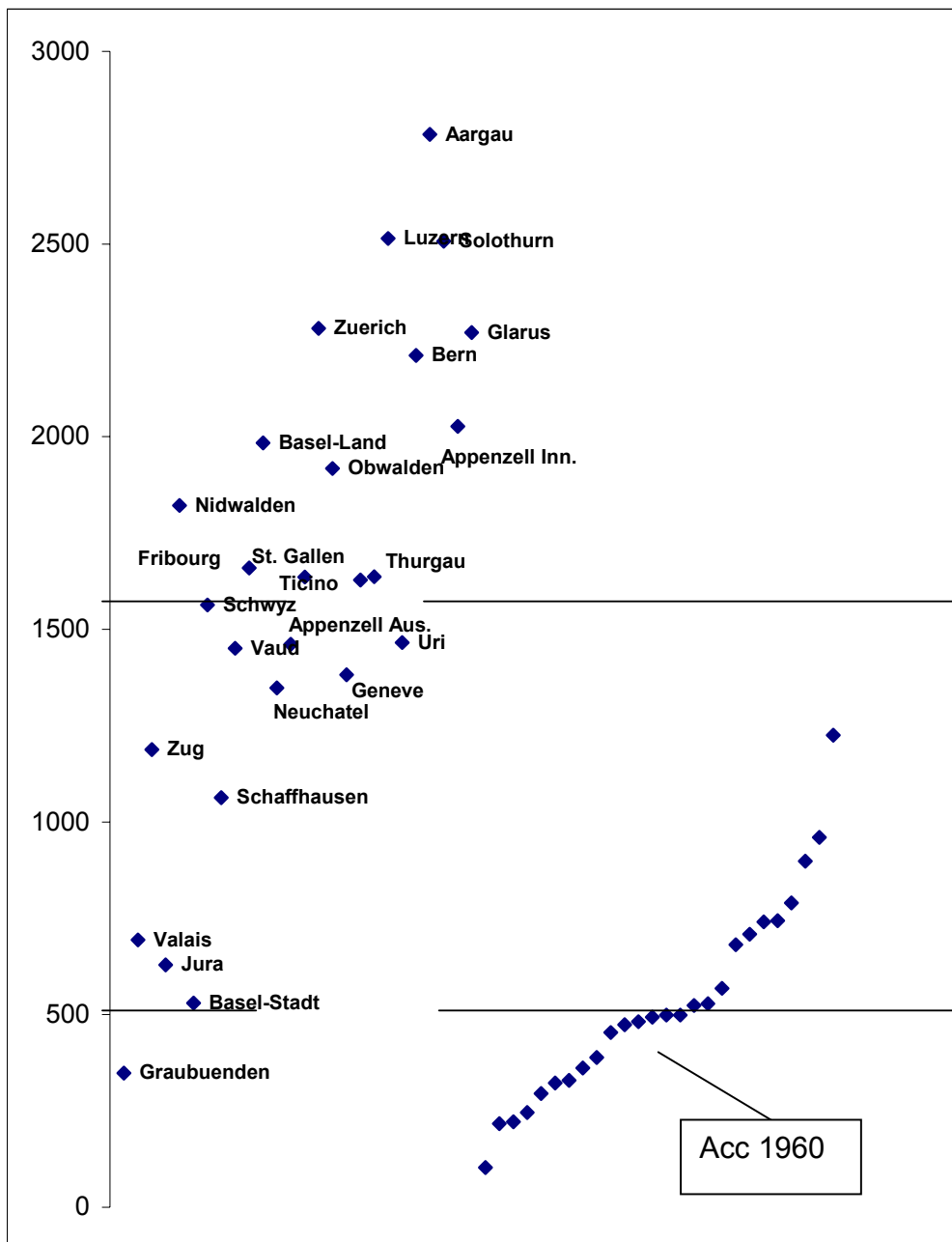


These data could be summarised in some trends. Like it is showed in the figure 19 the mean of the measure of accessibility has experienced a improvement of approximately 3 times (from 529 to 1615). It is remarkable that the minimum measure has increased more quickly than the maximum measure.

In the figure two lines representing the mean measure for each of the two years is represented. Also remark that as the break of the trend shows not all the cantons have developed with the same velocity and that the differences nowadays are lager than they used to be (about 1500 units in year 2000 and less than 250 in year 1960)

**Figure19. Gain in accessibility in the cantons (1960)**

Descriptive Statistics				
	N	Minimum	Maximum	Mean
Acc 1960	26	102,9062671	1225,563417	528,8841127
Acc 2000	26	348,2179089	2784,34992	1615,325765





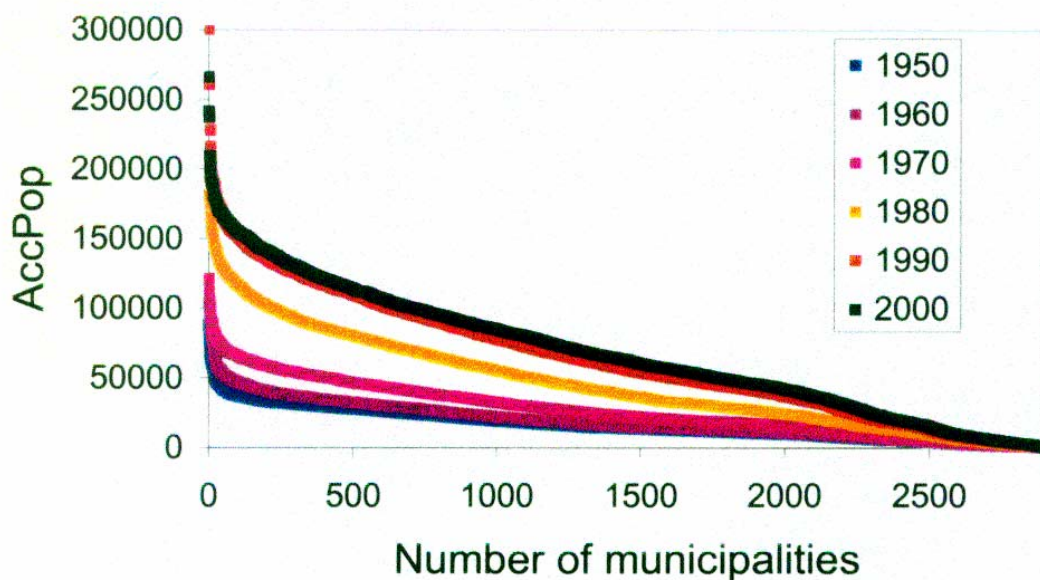
## 6.DISCUSSION

In the present work, the change of accessibility for population over time, from 1950 to 2000, is calculated. The relationship between spatial development and the effects of infrastructure is a very complex one. Thus, it is not simple to find the causal connections (Metron, 2000). Many theories have been developed (Hansen, 1959; Wilson, 1967; Kesselring et al., 1982) and empirical studies have found various interesting results. However, many questions remain open.

One problem is that most studies examine only a short period, and thus the conclusions reached or hypotheses discussed can only be generalised to examined time frame. It would be interesting to use these theories with data sets from other periods as well. However, data over longer time frames is not always available.

The problems with such short time periods are obvious from the distribution of accessibilities shown here for the different years, (see Figure 20). In the fifties as well as in the sixties, cities had a significant accessibility advantage over the countryside. In the seventies, all areas profit, and the distribution curve for accessibility became steeper .

**Figure19. distribution of municipal accessibility (1950 - 2000)**



The most important changes occurring between 1970 and 1980 are in the distribution between municipalities and the decrease in the difference between cities and the rural areas. In addition, in the next period (1980 to 1990), this trend

continued, with some municipalities overtaking the major urban areas, with respect to their accessibilities.

The analysis held here is a first step in a challenging research project. Some considerations must be taken into account.

The development of the road network should also include the Hauptstrassen network (National Highways). In the present model, only opportunities within Switzerland are considered, but some areas with high populations (Geneva, Basel, etc.) are close to the border. This means that the model must be enlarged to the border areas in neighbouring countries in order to be more realistic

The accessibility calculations should also be repeated considering other relevant data, such as places of work and shopping opportunities.

As a final but interesting step, the weighting function needs further considerations. On one hand, the  $\alpha$  factor for the potential function should be calibrated for different periods and perhaps for different regions as well, and on the other hand the use of a potential function as such has to be checked.