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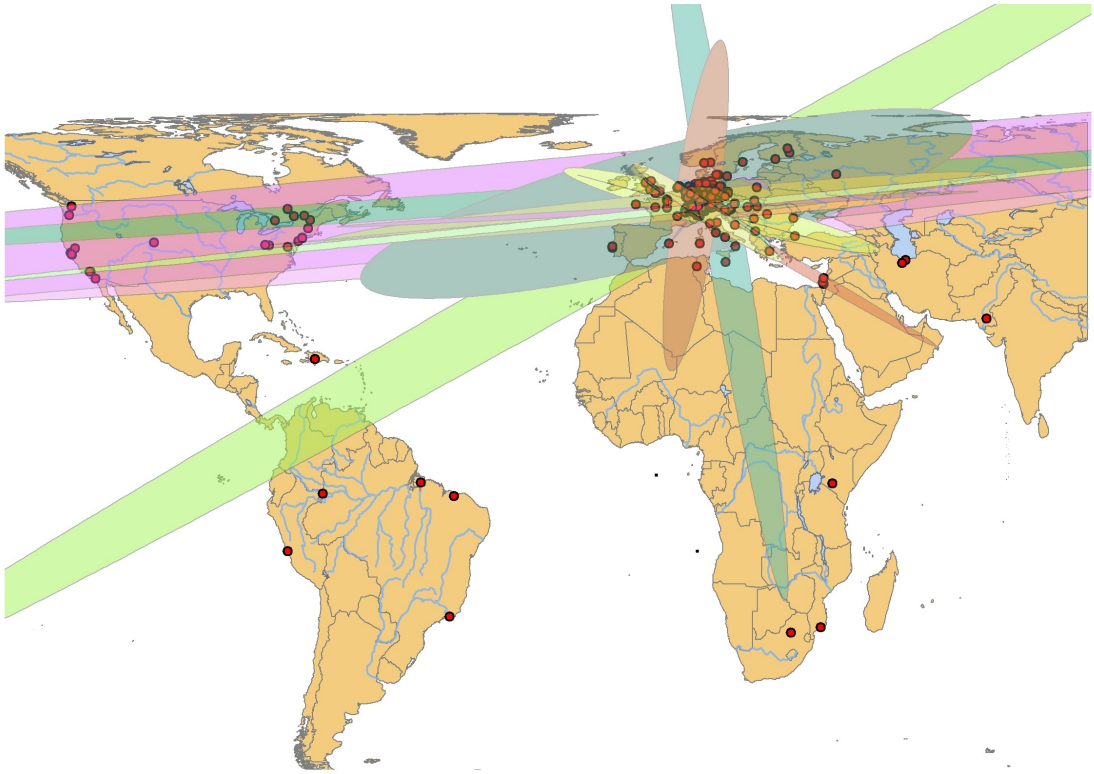

Size and structure of social network geographies

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Working paper 439

Size and structure of social network geographies

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Kurzfassung

Reisen ist der Preis, den wir bezahlen, um mit Anderen zusammen zu sein. Zumindest ist es ein substantieller Teil der generalisierten Kosten, um jemanden zu treffen. Wenn man diesen Standpunkt einnimmt und zusätzlich mit einbezieht, dass der überwiegende Teil des Verkehrs Aktivitäten mit anderen Personen dient, wundert man sich, wieso dem sozialen Inhalt von Aktivitäten und den Einschränkungen aus der Koordination mit anderen in der Verkehrsforschung bisher so wenig Beachtung geschenkt wurde. Dieser Aufsatz erweitert die bisher vorwiegend qualitative soziale Netzwerkforschung mit der Analyse einer grossen quantitativen Erhebung von egozentrischen Zürcher sozialen Netzen. Die exakte Geokodierung der Wohnorte der Egos und deren Kontakte (alteri) bilden die Grundlage für die Untersuchung der Grösse und Struktur ihrer sozialer Netzwerkgeographien. Diese wird durch statistische Konfidenzellipsen der räumlichen Verteilung der Alter in den egozentrischen Netzwerken gemessen. Es zeigt sich, dass junge, gut ausgebildete Personen mit tiefen und mittleren Einkommen, die eine ereignisreiche Arbeits- und Ausbildungsbiographie haben, dazu tendieren, grössere soziale Netzwerkgeographien zu unterhalten. Diese Parameter sowie ein kleines Verhältnis zwischen der Neben- und Hauptachse und einer starker Ausprägung in west-östlicher Richtung sind die bestimmenden Faktoren für extensive soziale Netzwerkgeographien.

Schlagworte

Social network, network geography, number of contacts, distance between contacts, negative binominal model, Tobit model

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Working Paper 439

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Abstract

Travel is the price we pay to be with others, at least it is a very substantial part of the generalised cost of meeting them. If we accept this proposition, and consider that the vast majority of travel serves activities with others, then one has to wonder, why the social content of activities and the constraints arising from coordination with others has received so little attention so far in transport research. This paper supplements the previous extensive qualitative research by the analysis of a large quantitative survey of ego-centric social networks in Zurich. The exact geocoding of the ego's and alteri's home location builds the basis for this paper's analysis of the size and structure of social network geographies and the distances involved. The size and structure of social network geographies is measured by the confidence ellipse of the spatial distribution of the members in egocentric social networks. Young, well educated people with a low and middle income and an eventful work- and education-biography tend to maintain bigger social network geographies. These parameters as well as a low ratio between the minor and the main axis and a strong east-west direction are the main determinants for big social network geographies

Keywords

Social network, network geography, number of contacts, distance between contacts, negative binominal model, Tobit model

Preferred citation style

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1 Transport planning and social networks

Transport planning aims to describe, understand and model the choices people make during the execution of their daily lives, including the more or less frequent journeys outside their daily activity space (Schönfelder and Axhausen, 2003; Ortuzar and Willumsen, 2001). The models are in turn used to evaluate and optimise changes to the transport system undertaken by the owners of its various components, e.g. airline connections offered, railroad time tables, frequency, size and comfort of busses run, reductions or expansions of road capacity, or the development of cycling networks. The dominant paradigm for its work is the individual satisfying its needs while maximising the utility derived from the activities undertaken. That this undersocialised understanding limits the scope of its work severely has been understood since the mid-1970's, but it has taken until now to provide a set of methods and models, which can replace the previous generation in practical application (Jones, Dix, Clarke and Heggie, 1983). As part of these developments it has become clear, that it is crucial to understand the geography of the social networks to which the travellers belong, if one wants to understand the destination choices of the travellers. This is particularly true for leisure travel, which dominates the travel market in terms of the miles travelled and journey undertaken, as it is largely about being with others or meeting them (Axhausen, Löchl, Schlich, Buhl and Widmer, 2007; Larsen, Urry and Axhausen, 2006). If travel is generally about meeting others, then it is obviously important to know from where these others start their trip to the meeting point, to know what they know about the opportunities offered by a destination, to know which constraints limit their choices or availability and therefore the choices of the full group meeting.

Unfortunately, sociology has had so far no reason to characterise and measure the geographies of the social networks. Its focus has been on the structure of the social networks and their impact on the social processes in need of explanation (See Wasserman and Faust, 1994). The information obtained about the locations of the members in complete or ego-centric networks is spatially rough, if available at all. Geographers have generally ignored this issue. Transport planners have therefore recently begun to undertake new survey work satisfying their needs, while drawing on the extensive sociological experience in the capturing of ego-centric networks (See for example Marsden, 1990, 2005). Transport planners bring their particular experiences to this enterprise, especially the ability to geo-reference addresses exactly and their familiarity with the calculation of transport network-based distances, travel times and costs for the movement (communication) between any two locations.

This paper and its companion paper (Axhausen and Frei, 2007) report on the – to our knowledge - largest of these new quantitative surveys. Its closest comparison was undertaken independently at about the same time in Toronto by a team involving sociologists and transport planners (Carasco, Hogan, Miller and Wellman, forthcoming). The scope of our survey was derived from an a-priori set of hypotheses sketched for the first time in Axhausen, 2002 (See Axhausen, 2007 for their current formulation), which found its final form reflecting discussion (Axhausen, forthcoming), initial qualitative work (Ohnmacht and Axhausen, 2005; Larsen, Urry and Axhausen, 2006), related quantitative work on mobility biographies (Beige and Axhausen, 2006) and an substantial pre-test (Frei, 2007). The survey instruments address:

- The basic socio-demographics of the respondent today
- The mobility biography of residential and employment moves over the lifetime, including information about income levels, mobility tool ownership, main mode of transport to work
- Four name-generators (see below) and a name interpreter, which includes among others the exact home location of the contacts (alteri) of the respondents and the frequency of their interactions by four modes: face-to-face, phone, email and texting (short-message-service – SMS).

This unique combination reflects the conviction that the social networks reflect the life course of the respondent, as the interactions with friends, relatives and others do not depend as much as previously on their physical vicinity. The social network accumulates over the places the respondents have lived and worked in. The survey permits a range of analyses, which have not been undertaken so far, which in turn shed new light on current social practises in building and maintaining social networks and implicitly social capital. The survey overcomes the limitations of other previous sources about the spatial patterns of social interactions, which were by definition partial to a particular mode: travel and activity diaries (face-to-face contacts), telecommunication diaries (phone plus a subset of the electronic channels: email, SMS, chat) and more comprehensive then the small number of previous surveys covering multiple modes, but not identifying the social network members involved (combined travel and (tele)-communication surveys). The key questions are:

- What is the form of the precisely measured distance distribution between the home locations of the respondents and the members of their ego-centric network?
- Can we explain the differences of the key parameters of the distributions between the respondents?

- What size and orientation do the geographies of the social network have?
- What are the patterns of the frequencies of the interactions by mode?
- Do the market shares of the modes of interaction vary systematically with physical distance?

This paper will address the first three questions, while its companion paper addressed the last two. The papers also cover different aspects of the background to the papers. This paper describes the survey in detail and compares its respondents against a different, much larger sample drawn for an official representative survey in the same study area. The companion paper addresses the theoretical background to our work. The papers review supplementary parts of the relevant literature.

The remainder of this paper has the following structure. The survey, its conduct and the representativeness of the sampled obtained are discussed next. As it is a key indicator of the survey quality, the number of the contacts obtained are analysed in detail and compared with the results of the literature. The distribution of the distances between the respondents and their alteri are the focus of the following section, including a presentation of the modelling of the distribution parameters. The final empirical section describes the approach taken to capture the size and orientation of the social network geographies, presents the population and respondent statistics and models the differences between the respondents. The conclusions look ahead to the next steps necessary to integrate these results into the new generation of agent-based micro-simulation of travel mentioned above.

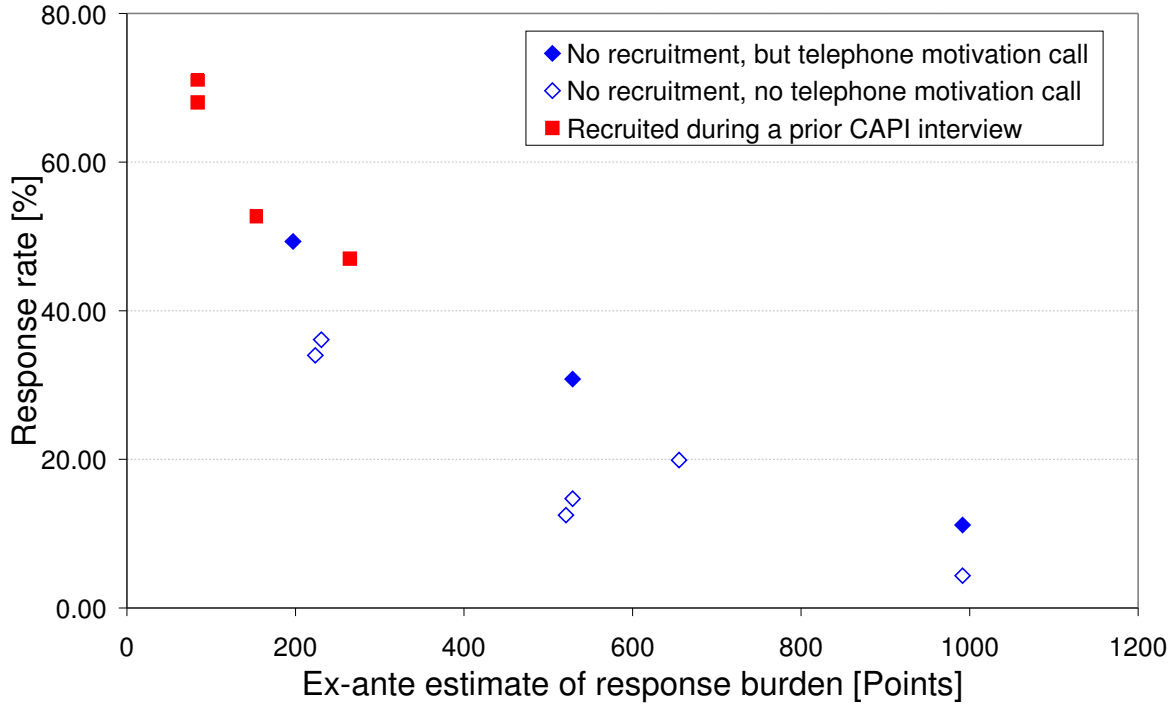
2 Dataset

The data collection which covers jointly travel, social networks and mobility biographies was conducted by December 2005 and December 2006. During a pretest (Axhausen, Frei and Ohnmacht, 2006 and Frei, 2007) three different survey methodologies (only self-completion; only face-to-face, mixed face-to-face and self-completion) were tested to identify a survey format which minimised missing values due to fatigue effects of the interviewees and reduced the recall problems of the retrospective survey items. The mixed methods was the best approach with an acceptable cost per response (110 CHF/usable response[1]). For the survey 4'200 Zürich residents persons were randomly among those for which the addresses and telephone numbers were available. Following an announcement letter the sample was contacted on different days of the week and times of day and then recruited during this telephone interview, including arranging the appointment for the face-to-face interview. With the reminder notice for the interview the respondents received the written form to give them the possibility to raise questions during the upcoming interview. The written part consists of a person form and a form with mobility biographical questions about moves, former and current job locations, the usage of mobility tools, important live events and memberships in groups that meet periodically (see Beige and Axhausen, 2005 and 2006) for detailed information about mobility biographies). The one hour face-to-face interview covered the social contact questionnaire but was also used to detect and address respondent difficulties and to establish rapport with the respondent.

It was possible to reach 2'714 (64.4%) by phone within five attempts. From those it was possible to recruit 332 persons of which 307 (10.7%) were interviewed and completed the questionnaire. (For further details see Frei, 2007) The interviewees received no incentive. Due to the high response burden the response rate is acceptable and is within expectations. Figure 1 shows a clear, nearly linear correlation between the response burden and the response rate in a recent set of surveys at the Institute. The ex-ante estimated response burden of the written format of this survey can be found in lower right corner of Figure 1. The comparable survey in Toronto Canada mentioned above was able to reach a respondent rate of about 50 % with an incentive of 50 CAN$ (Carrasco, Hogan, Wellman and Miller, forthcoming), but drawing on known responders from the first wave of the overall study.

[1] About US$ 90 or € 70 in August 2007.

Figure 1 Response rate and ex-ante assessment of response burden



Source: Axhausen (2007), Figure 1.

Table 1 shows the socio demographic characteristics of the respondents in comparison with the Zurich population, as observed in the Swiss Microcensus Travel 2005, its representative national travel diary survey (Swiss Federal Statistical Office and Swiss Federal Office for Spatial Development, 2007). The income information is not directly comparable because the Microcensus measures the household income while this study is person-based. The comparison shows that the Zurich population is a little bit older, slightly better educated and has a higher share of public transport season tickets. The mean age for the respondents with a university degree is with 43.61 years below the population mean and for those with an obligatory schooling higher with 56.77 years respectively 59.66 years for those with a vocational training. Respondents with no public transport season tickets are overrepresented in the group of people with vocational training and a university degree. Still, overall a reweighting of the data seems not necessary given the relatively small deviations.

Table 1 Socio-demographic comparison between the characteristics of the Zürich respondents and the Zürich population[1]

Variable	Survey Mean	Population Mean	Difference

Age	50.76	46.90	+8.2%

Variable	Survey Share	Population Share	Difference
Males	43.6%	46.4%	-2.80%
Education			
N.A.	5.2%	2.6%	2.60%
Obligatory schooling	8.0%	12.5%	-4.50%
Vocational training	31.8%	42.3%	-10.50%
Highschool diploma	8.3%	9.2%	-0.90%
Further technical training	20.8%	15.6%	5.20%
University degree	26.0%	17.8%	8.20%
Car available			
Always	44.6%	42.8%	1.80%
Frequently and rarely	17.0%	18.4%	-1.40%
Public transport season tickets			
50% discount card (Halbtax)	49.5%	37.9%	11.60%
National season (GA)	24.6%	14.2%	10.40%
Regional season	13.8%	18.7%	-4.90%
Personal income			
NA	12.8%		
0-1999	13.8%		
2000-5999	46.4%		
6000+	27.0%		

[1] As observed in the Microcensus Travel 2005 (Bundesamt für Statistik und Bundesamt für Raumentwicklung, 2007)

3 Number of relationships

Before discussing the respondents' reported number of relationships and interactions, it is necessary to review the methods of obtaining such information from respondents. Name-generators and name-interpreters are used to survey ego-centric networks. The name generator specifies the type of relationship the survey wants the respondent, the ego, to list. They often impose an arbitrary maximum number of contacts to be listed (see for example Diaz-Bone, 1997). The name-generator defines the ego-centric network and is therefore central for further analysis. The name-interpreters are then further questions to detail the description of the contact, alter, e.g. sociodemographic data or characteristics of the relationship.

Generators can be differentiated in "interpersonal name-generators" and "global name-generators" (see Pfenning, 1995). In contrast to interpersonal name-generators, global generators do not survey single alteri. Instead they concentrate on establishing the global structure of social relationships e.g. if the most of the friends have the same political position. The group of interpersonal name-generators can be differentiated again in two subgroups, in "name-generators appropriate to context" and "name-generators appropriated to a stimulus". Name-generators appropriate to context survey relationships in different social contexts. The social context therefore can be the family, general friends, neighbours, work mates etc. Problematic is the interpretation of the single context e.g. "what is a friend?" or "what is a work mate?". In different cultures but within one culture there can be different understandings of these terms. Therefore most surveys today use name-generators appropriate to a stimulus. With a stimulus a certain kind of activity is given, e.g. discussing important matters, for which the interviewee names alteri. With this approach the possible lack of clarity in the understand of specific social contexts such as friendship can be avoided.

Name-generators and name-interpreters together are the network-instrument. The best known and used instruments are Burt's instruments (Burt, 1984), Fischer's instrument (Fischer, 1982) and Wellmann's instrument (Wellmann, 1979). Burt's instrument was used for the first time 1985 in the General Social Survey (GSS). A random sample of 1534 persons was interviewed with the following name-generator: "From time to time, most people discuss important personal matters with other people. Looking back the last six month – that would be back to last August – who are the people with whom you discuss an important personal matter?" (Burt, 1984, 331). Fischer's instrument was designed for Northern California Community Study (NCCS). 1050 persons were asked with Fischer's instrument which uses ten questions appro-

priated to stimulus.[2] Coates and Wellmann obtained ego-centric social networks 1968 in East York, Toronto. As Burt they used only one name-generator: "I'd like to ask you a few questions about the people outside your home that you feel closest to; these could be friends, neighbours or relatives" (Wellmann, 1979, 1209). Only the first six of the named alteri were recorded and described in detail.

For our research goal of measuring the size and structure of social network geographies influencing travel behaviour, destination choice or residential choice, it is not so important to survey alters from all different social context spheres but to get the ego's most important alteri, the core-ties. Therefore we used an adapted and appropriate set of name-generator as stimuli. The respondents were handed two lists with two different name-generators. The first name generator is adapted from Burt's and Fischer's instrument where we asked for persons with whom the respondents "discuss important problems, with whom you stay in regular contact or which you can ask for help". These questions cover the ten stimuli from Fischer in an abstract way as Burt's generator does and should cover the "very close" or "most important" contacts. The second name generator asked for persons with whom the respondents spend leisure time. This generator targets weaker ties against the background that leisure travel makes up the largest share of long distance travel. The name-interpreter asked for all of the named contacts how they got to know each other, how long the relationship exists, the frequency of contacts by different modes (face-to-face, telephone, email and sms – short message service via mobile phone), where they met the last time and the contact's place of residence. The origin of the acquaintance was categorized as family, subdivided in first degree, relatives or partner, from/of the work, education or partner or others. The frequency of contacts should be specified as ac-

[2] Fischer's name generator asks for the first names of those who:

(l) respondents would ask to look after their homes when they go out of town:

(2) had helped with tasks around the house in the previous three months:

(3) they talk with about how they do their jobs (asked only of employed respondents):

(4) they do various social activities with - sharing a meal, visiting. going out socially,

etc.;

(5) they get together with to talk about hobbies;

(6) they date seriously or consider B fiancé(e) (asked only of unmarried respondents);

(7) they talk with about personal matters of concern;

(8) they rely on for advice about important decisions; and

(9) they would or would ask for ;1 sizable loan.

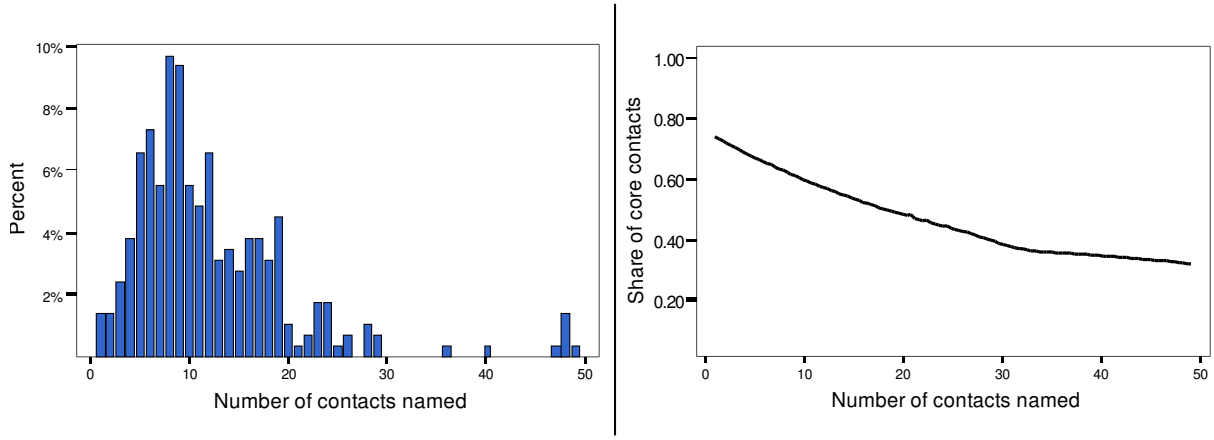
(10) Is there anyone who is important to you who doesn't show up on this list'?

(Fischer, 1982, 290)

curately as possible e.g. every week, 2 times per year. The contact's place of residence should be indicated as much as possible with post code, municipality, street and house number.

A first point of discussion is the validation of the answers. The respondents were able to name 17 relationships with the first name-generator and 32 with the second. Therefore a total of 49 alteri could be named. In fact the lists could have been extended if it would have been necessary. The range of named relationships is 1 to 49. The maximum number of reported relationship was reached once and the mean was 12.35 relationships. Related to the possible number of relationships of 49 the exhaustion rate is 25.2%. This indicates that the respondents were given an adequate possibility to name relationships. Figure 2 a shows the distribution of the number of relationships. The distribution is left skewed and has a variance of 73.0. The share of important relationships is 52% and drops, as expected, with an increasing number of reported relationships (Figure 2 b).

Figure 2 Distribution of the number of relationships



A comparison of the instrument used with the best established instruments to survey social networks is given in Table 2. A single name-generator causes small ego-centric social networks. The sizes of the networks surveyed with the Fisher-instrument are remarkably higher then those with the two other instruments. The IVT-instrument which uses two name-generator – questions with four prompts is in between the Fischer and the two single prompt name-generators. The other instruments report a high share of relatives and proportionally higher share of strong ties. The share of relatives seems to be a indicator for the social network density as the share of weak ties decreases with them. As shown in Figure 2b the share of strong ties drops with the numbers of relationships reported, which is as well visible the other surveys, except that the IVT-instrument seems to be biased against reporting family relationships, which is probably caused by the generic formulation "persons with whom the respondents

spend leisure time" for weak ties. The duration of the relationships cannot be compared across all instruments because of different measurement approaches. It seems that if this question is asked in classes, the classes should have a wider range than just 10 years, especially if we expect a high share of relatives. The mean of the contact frequency per year is strongly dependent on the share of relationships which meet daily. The small share of weak ties in the small networks causes the big differences between the two single name generators and the IVT-instrument.

Table 2 Comparison of the instruments

Variable	East York	NCCS	GSS	IVT
Instrument				
Name-generator	I'd like to ask you a few questions about the people outside your home that you feel closest to.	11 prompts	Looking back the last six month, who are the people with whom you discuss an important personal matter?	4 prompts
Generator limitation	6	No limitation	5	No limitation
Ego-centric network				
Size (Ø)	4.70	18.48	3.01	12.35
Share of relatives (Ø)	0.50	0.44	0.61	0.31
Share of weak ties (Ø)	0.18	0.32	0.23	0.48
Duration of the relation in years (Ø)	>10 for 57% of the ties	16	(6 years and more, was the highest class)	20.6
Contact frequency per year (Ø)	150.4	-	194.6	59.0

Source: adapted from Diaz-Bone (1997, 78) and own data

The number of social relationships reported and socio-demographic attributes of the respondents is compared in Table 3. Age seems to makes a rather large difference, with the younger people cultivating more relationships than the older ones. The share of the important relation-

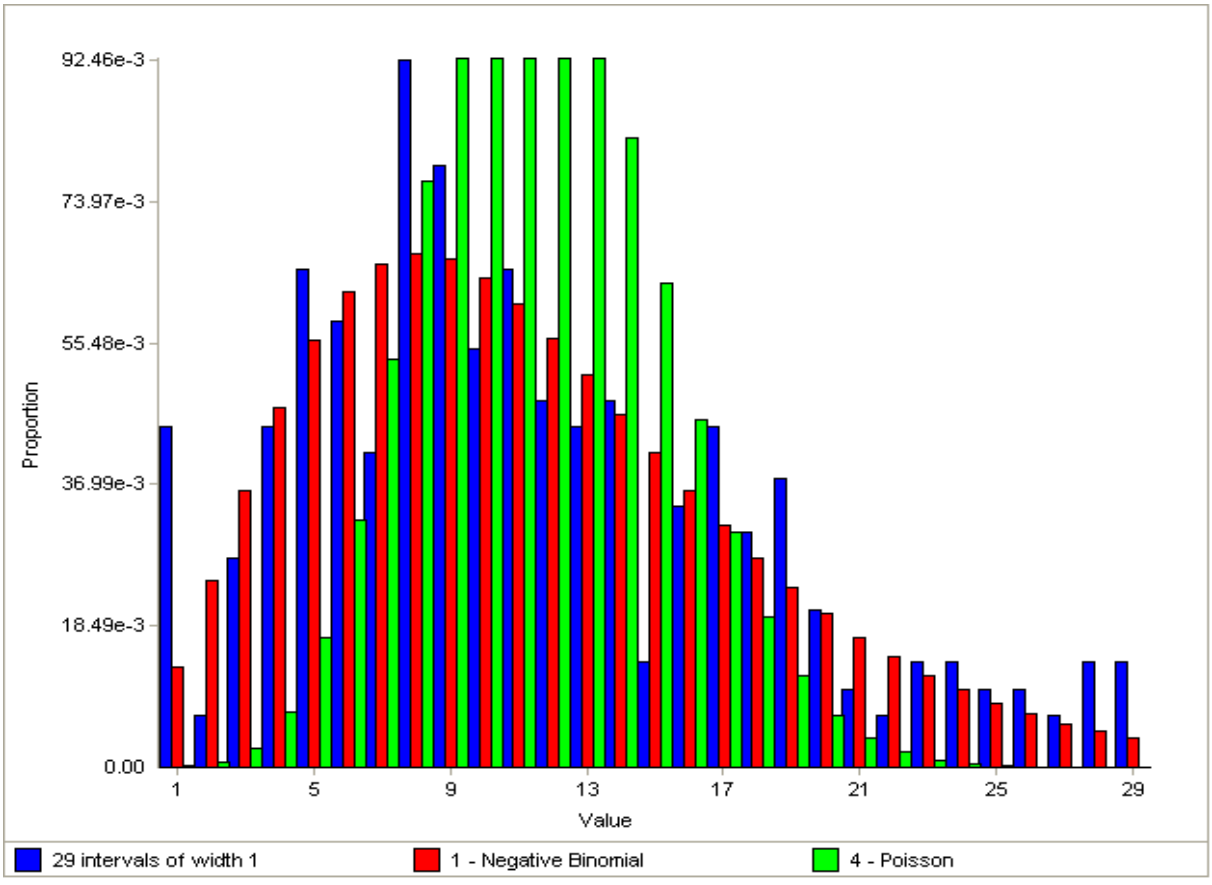
ships seems to growth with the age but has a small drop in the oldest age class. Gender seems to have no influence on the numbers of relationships. The education level indicates that a higher level of education increases the number of relationships, but there is no clear trend visible as the differences are rather small. The share of important relationships is slightly higher for persons with higher levels of education. There seems to be no income dependence.

Table 3 Number of social relationships by socio-demographic characteristics

Variable	Median		Mean		St. dev.	
Category	Important	All	Important	All	Important	All
Age						
Up to 30	6	12.5	7.1	15.1	3.6	9.4
30 to 40	5	14	6.8	14.0	3.3	5.4
40 to 60	5	10	6.7	12.4	4.4	9.2
60 and older	5	9	5.6	10.6	3.6	8.0
Sex						
Female	5	11	6.4	12.6	4.0	7.8
Male	5	11	6.2	12.3	3.6	8.7
Education						
N.A.	5	11	4.9	10.8	1.6	4.4
Obligatory schooling	5	8	5.5	12.5	2.7	11.9
Vocational training	5	11	6.1	11.6	3.9	8.0
Highschool diploma	5	12	6.5	14.1	4.0	9.0
Further technical training	5	8.5	6.1	10.6	3.9	6.4
University degree	5	13	7.2	14.5	3.4	8.2
Income [sFr/month]						
N.A.	5	10	6.0	11.3	3.3	6.6
0-1999	5	12.5	5.9	12.5	3.1	6.1
2000-5999	5	11	6.6	13.1	3.9	8.7
6000+	5	11	6.3	12.1	4.3	9.4
All	5	11	6	12	4	8

To capture the wide range in the number of social relationships in further analysis it necessary to determine the probability distribution which represents the data set. Figure 2 shows that the data follows a left skewed bell shaped curve. A possibility to represent this shape is the discrete Poisson distribution. The variance for the number of relationships is with 73.0 much bigger than the mean of 12.3. This is an indicator for over-dispersion. As the Poisson distribution is described only by one parameter, it is symmetric. To deal with the skew of the number of relationships a negative binomial distribution can be used instead of a Poisson distribution. To obtain a distribution that fits the six persons reporting very high numbers (above 30 relationships) were removed as potential outliers. Figure 3 compares the number of relationships reported, and best-fit negative binomial distribution and the Poisson distributions.

Figure 3 Frequency- comparison plot



Best-fit parameters of the negative binominal distribution: 4, Probability: 0.26, Chi-Square Test: 13.53 (Interval width:2; 14 df) (Estimated with ExpertFit – Version 7.00 - Averill M. Law & Associates, 2006).

Socio-demographic, travel related, biographical and survey-specific dummy variables are employed to explain the number of social contacts using a negative binominal regression. After removing variables which correlate highly with each other (limit = 0.5; e.g. working status and place of work), variables with a significance level lower then 0.05 were removed stepwise. The parameter estimates are reported in Table 4.

The goodness-of-fit is, as expected from the descriptive statistics, rather low (R^2=0.13), but the F-Statistic is significant.

Table 4 Parameter estimates for the negative binominal regression of the number of contacts

Variable	Mean	St.dev.	Beta	b/St. err	Sign.
Constant			3.092	10.169	0.000
Age [years]	53.283	19.163	-0.040	-3.113	0.002
Age^2/1000 [years^2/1000]	3.208	2.081	0.352	2.806	0.005
Annual or monthly public transport ticket [y/n]	0.853	0.893	0.242	2.036	0.042
Number of relocations []	5.963	3.116	0.038	3.023	0.003
University degree [y/n]	0.247	0.430	0.178	1.921	0.055
Part time employed [y/n]	0.170	0.382	-0.256	-2.321	0.020
Retiree [y/n]	0.327	0.469	-0.302	-2.003	0.045
Children < 18 y [y/n]	0.250	0.434	0.177	2.307	0.021
N	300				
Adjusted R^2	0.13				

The age of the respondents shows a U-shaped influence. Younger people maintain many contacts and then the number declines with increasing age, whereas every additional year causes a lower decrease of the number of social relationships. The ownership of public annual or monthly transport ticket has a positive influence on the number of social relationships. Maintaining a bigger social network seems to be influenced by the ownership of mobility tools, but only the annual or monthly subscription to public transport tickets was highly significant. The number of relocations influences the number of relationships. The positive influence of the number of relocations indicates that people keep their important friendships after relocation even at a certain distance. By building up a social network at the new location and keeping in

touch with "old" friends, numbers of social contacts increase. A higher education, at least a university degree, leads to a larger number of social contacts. But there is no clear trend visible between the number of relationships and education. A rather high influence on the numbers of social relationships has the working status. In 27.3% the original context of the acquaintance is work (41.0% friends, 25.9% family, 4.9% partner and 0.9% others) and therefore is the second most frequent original context. The big influence of the work status is therefore not surprising. Part time employees and retired people have fewer social relationships than fulltime employees and equivalents e.g. students. It is surprising, that children have a positive influence on the amount of social contacts, because it would be expected that the additional workload for parents would decrease the number of social relationship, but children open up the possibility to meet new possible contacts e.g. other parents with small children, parent-teacher conferences etc., which here outweighs the first effect.

4 Social network distance

The mapping of the social acquaintances' home locations shows that the respondents' reach is very varied: from the local to the global (see Figure 4).

Figure 4 Mapping of the acquaintances' residences in Google Earth

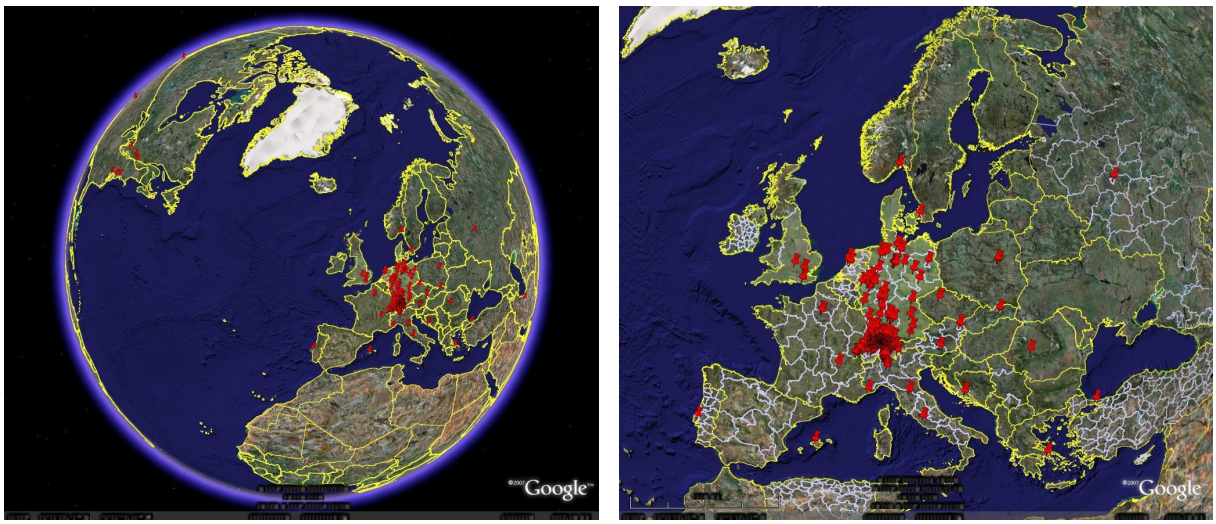
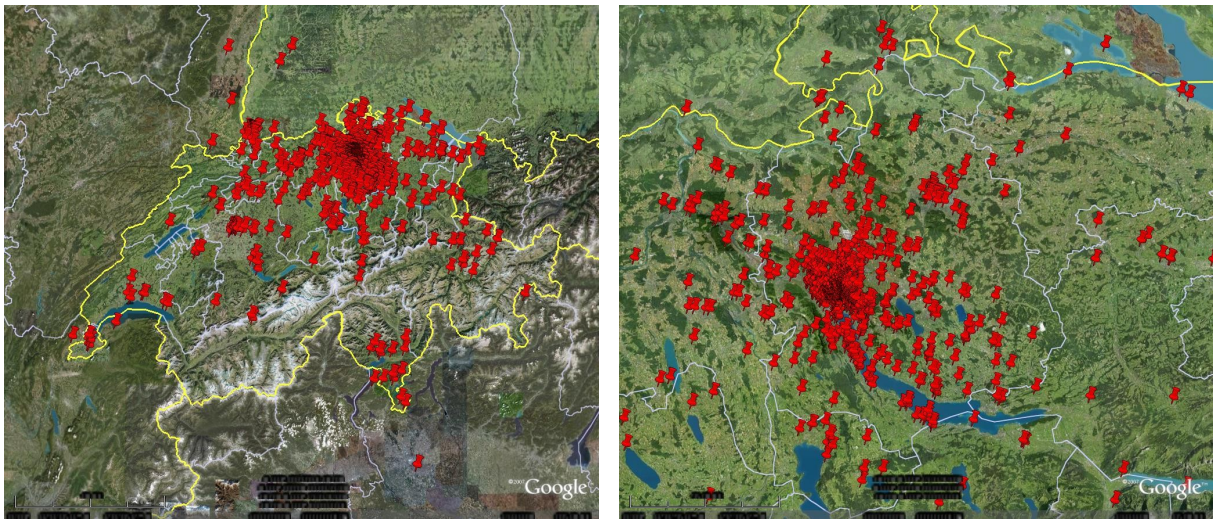


Figure 4 Mapping of the acquaintances' residences in Google Earth

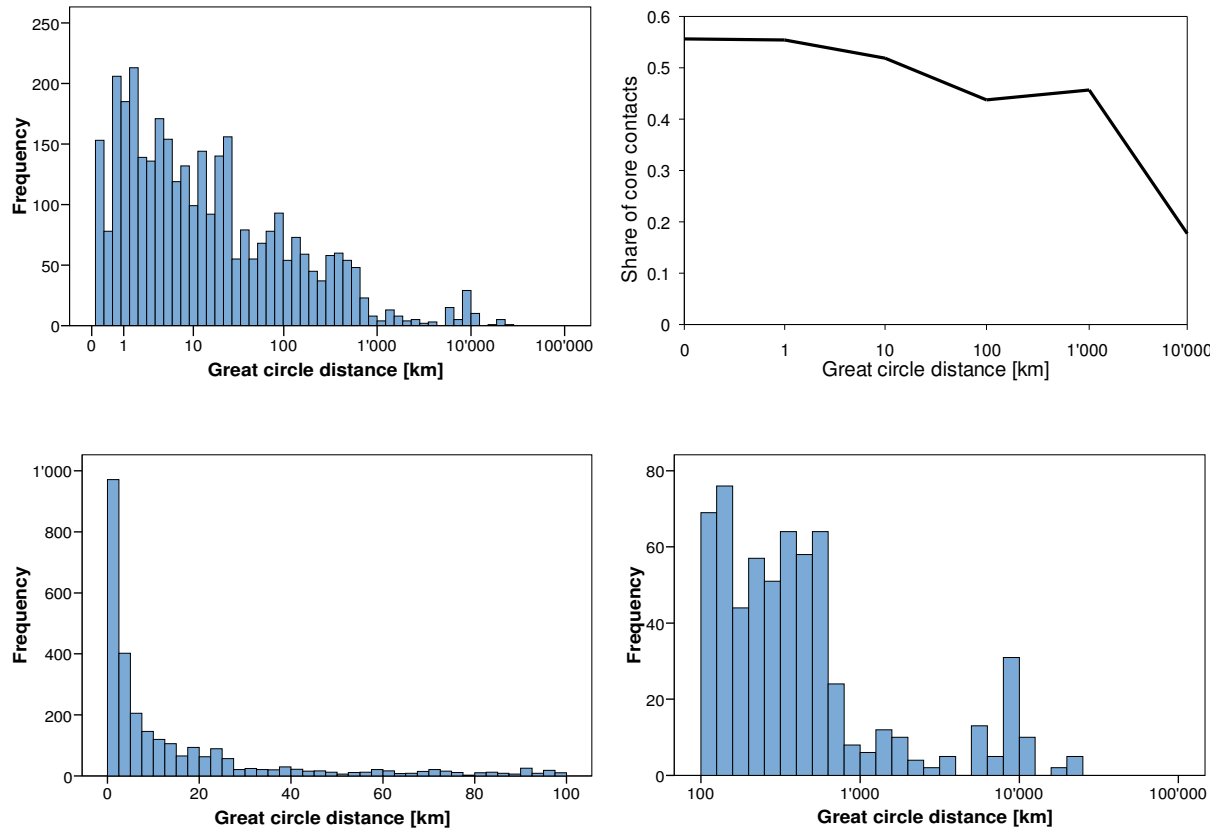


Geocoded home locations of the respondents' alteri in Google Earth

The simplest way to measure the spatial dispersion of the egos relationships is to measure the distance between their home locations. The distribution of the great circle distances (Figure 5) between the respondents' residence and their relationships has three elements. Nearly two-thirds of the alteri live locally within 25 km. The bulk of the remaining distances are divided into regional and national relationships (within 26-100 km 13%) and international relationships in Europe (within 101-1000 km, 155). A noticeable share of intercontinental links makes up the rest of 3% (Figure 5). The peak at about 10'000 km marks the intercontinental distance between Zurich and the USA. The respondents mix local contacts of daily life with a multitude of non-local and often long distance contacts. The socio-demographic differences (Table 5) are driven by age, education and their origin of acquaintance plus the attachment to personally more important contacts (Figure 5).

Figure 5 Distribution of the great circle distances between respondents and their contacts (note the different scaling of the x-axis)

Figure 5 Distribution of the great circle distances between respondents and their contacts (note the different scaling of the x-axis)

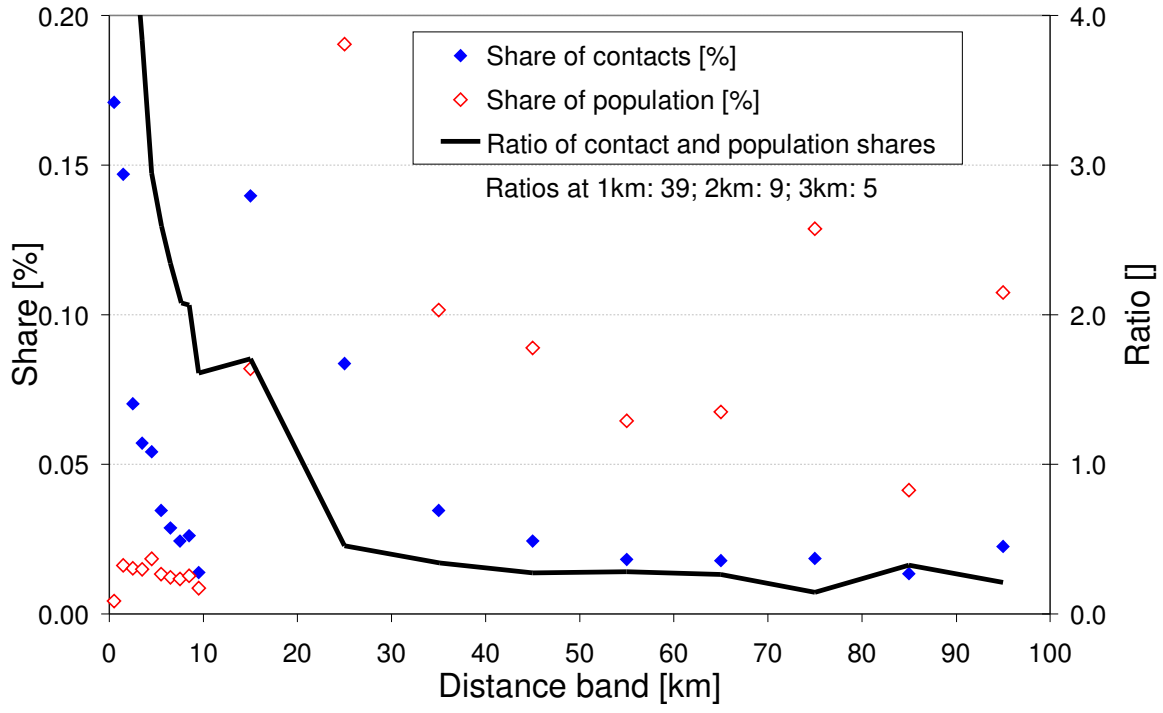


The distance shows a strong exponential decay which is clearly visible in the histogram (Figure 5c), but the distribution does not follow a simple parametric distribution, which seems reasonable because people are not equal distributed over space because of places which are not habitable e.g. mountains or the sea and because people tend cluster in cities. To approximate the distance decay a Weibull distribution seems to be appropriate and better then a log-normal distribution because of the zeros in the data. Best-fit parameters for the Weibull distribution are: a scale parameter of 33.27 and a shape parameter of 0.35. Nevertheless the goodness of fit statistics rejects the null hypothesis (Chi-Square, Kolmogorov-Smirnov and Anderson-Darling Test) even at the 0.25-level. (Estimated with ExpertFit – Version 7.00 (Averill M. Law & Associates, 2006).

Figure 6 shows a comparison between the shares of the population around the centroid of the respondents' residences near the main station of Zürich and the share of relationships in the same distance bands. The population shares were calculated using the Swiss census hectare

raster data of the Federal Bureau of Statistics (BfS). This comparison is limited to Switzerland, because of missing comparable data for the surrounding countries, but this is not so critical as the population in Southern Germany, the nearest neighbour, which is at least 30 km away, is rather sparse. The decay of the relationships shares in the close-up range is remarkable in contrast to the population shares. Still, the share of contacts is overproportional as visible in the very high ratios.. The population share would be expected to grow with square of the distance at an equal distribution. But it decreases in the close-up range slightly with the distance to the inner city of Zurich. From the distance band of 10 km on, the bigger cities of Switzerland and their agglomerations are clearly visible with the peak of Winterthur and Rapperswil and then Basle and Bern. The last two peaks are also slightly visible at the share of relationships. The ratio of these shares is independent of the distance bands and shows first a steep and then steady decrease with the distance from home. While people still select more then proportionally from those close-by, the range is today well beyond the distance of 30 min walk.

Figure 6 Contacts and population shares by distance band around Zürich



Note the change in the width of the distances classes at 10km; due to lack of data the contribution of the populations in southern Germany had to be omitted

Table 5 Descriptive statistics of the great circle distances between home locations of contact and respondents [km] (with and without contacts within 25 km from the respondent)

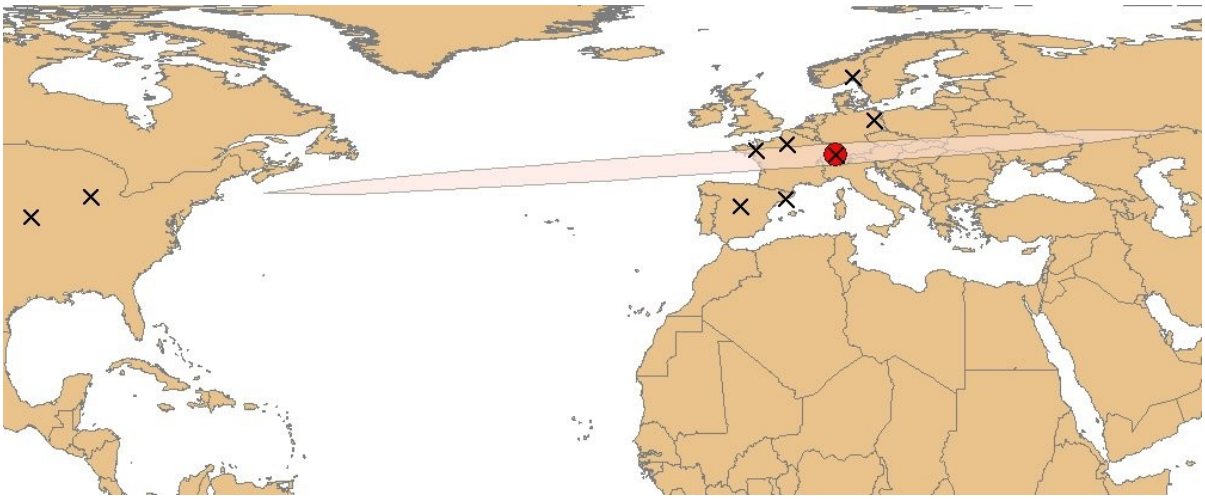
Variable	Median		Mean		S.E. of the mean		Number of cases	
Category	with	w/o	with	w/o	with	w/o	with	w/o
Age								
Up to 30	13.3	92.8	316.2	707.0	65.9	165.4	675	239
30 to 40	9.5	166.5	580.8	1489.5	89.6	233.5	576	191
40 to 60	8.9	95.7	138.0	440.1	22.9	95.6	973	206
60 and older	8.4	121.9	219.5	773.9	43.9	169.0	1287	313
Sex								
Female	7.6	96.0	246.1	784.5	32.8	114.3	2045	523
Male	12.4	124.3	318.7	893.2	42.9	135.0	1466	426
Education								
N.A.	6.6	92.8	574.2	2751.3	243.4	1106.6	179	36
Obligatory schooling	4.3	75.8	210.6	826.3	113.8	458.8	254	62
Vocational training	8.4	86.5	130.4	523.0	32.4	140.9	1050	234
Highschool diploma	7.3	128.6	256.6	714.9	98.5	272.7	280	99
Further technical training	15.0	151.1	322.2	817.9	58.1	159.8	661	215
University degree	10.3	124.6	364.3	920.5	47.5	138.7	1087	303
Income [sFr/month]								
n.a.	13.3	156.6	264.8	733.2	83.1	236.6	375	117
0-1999	4.9	123.9	355.8	1341.8	81.2	295.2	462	121
2000-5999	8.5	108.7	233.3	679.8	31.2	99.1	1680	492
6000+	11.7	96.4	317.1	952.0	58.2	224.4	994	219
Type of contact								
Others	26.2	60.9	242.2	452.8	116.5	208.8	32	17
Friends	7.1	127.6	277.3	1030.1	43.6	172.8	1439	338
Partner	2.2	112.1	150.6	910.6	71.4	440.8	172	26
Family	21.0	96.6	304.7	637.6	45.8	106.8	911	357
Work mates	8.7	123.8	272.1	877.1	53.7	207.2	957	211

All	9.0	108.7	276.4	833.2	26.2	87.4	3511	949

5 Social network geographies

The analysis above focussed on the distance between the respondents' and their contacts' residence, but the distance alone ignores the pattern of the contact, e.g. the agglomeration of contacts, which can not be measured just by distance and its distribution parameters. Biologists and more recently transport planners had to address the identical question of how to measure spatial distributions in their analysis of the daily activity spaces. They proposed parametric, semi-parametric and non-parametric approaches to measure the size of the activity spaces (See Schönfelder, 2006 for a review). The most popular, but also problematic approach is to calculate the size of the confidence ellipse, i.e. the two-dimensional generalization of the confidence interval (see Figure 7 for an example). It is a parametric approach, as the form of the approximation is fixed and the normal distribution of the locations is assumed, which is not true as shown above. The symmetry of the confidence ellipse leads often to cases where half of the area covered by the ellipse is empty of locations and therefore to too big. Rai, Balmer, Rieser, Vaze, Schönfelder and Axhausen (forthcoming) suggest other geometries which overcome this problem, but at the expense of substantial computational costs.

Figure 7 Example social geography

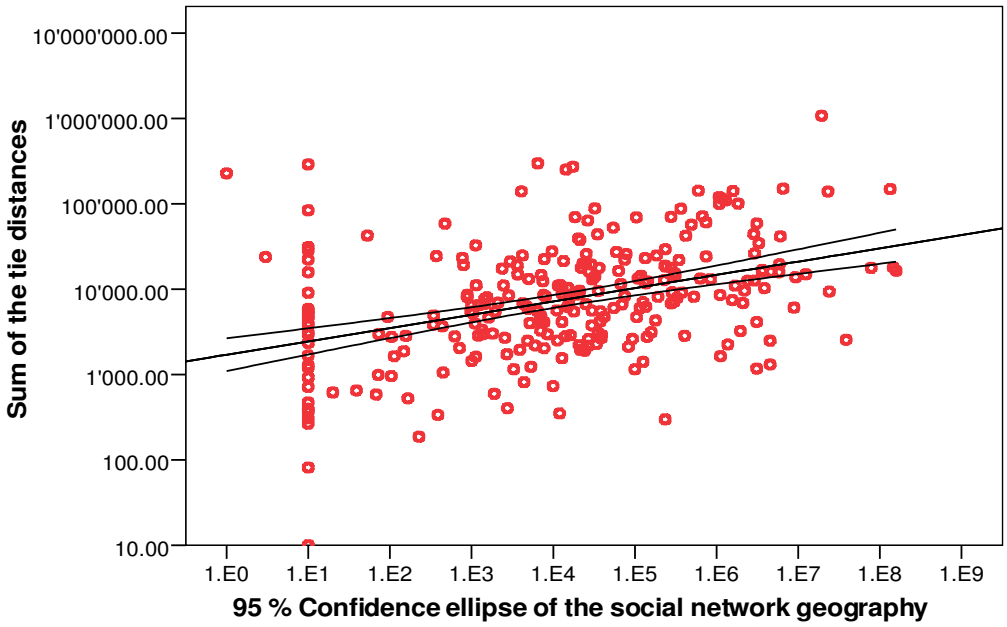


The respondent is female, 35 years old, full time employed and has moved 8 times in the last 22 years. The red circle tags the current home location and the black crosses are the home locations of the acquaintances.

The confidence ellipses calculated and used in this paper, are the two dimensional 95% confidence interval around the relationships' home locations weighted by the frequency of face-to-face visits. The areas are calculated using the Behrmann-projection[3], which is a cylindrical map projection and equal-area, which is important as the calculated geographies are very varied and therefore prone to distortions.

How ever, the easiest way to capture the geography would by the sum of the distances of the egocentric social network ties. Unfortunately, this fails mainly due the clusters of people and the members of their social networks tend and it especially matters to transport planning if e.g. a social network consists only of two geographical agglomerations or if the members are evenly spatially distributed, because the expected distances travelled for meeting these contacts would be completely different. The frequency weighted sum of the contact distances correlates very weekly with the size of the 95% confidence ellipses (Figure 8).

Figure 8 Sum of contact distances [km] against size of network geography [km^2]



R-square = 0.163;

The confidence ellipse measures geographical patterns with just three parameters (length of the main axis, ratio between the two axes and angle of the main axis). This makes it an easy to

[3] http://www.mathworks.com/access/helpdesk/help/toolbox/map/index.html?/access/helpdesk/help/toolbox/map/behrmanncylindricalprojection.html&http

use instrument for the analysis of the spatial distribution of social relationships. For analyzing the patterns of social geographies we use the following measures:

- The area measures the spatial expanse and incorporates the frequency of contacts as well as the spatial density as a confidence interval in two dimensions around the regression line of the residences. A disadvantage of the confidence ellipse as a measurement of size is that it covers the relative frequency and not the absolute frequency, which can lead to bigger areas for social networks which could be maintained with lesser effort (measured by great circle distance) as others under certain circumstances. The positive correlation of the number of relationships with the size leads to the assumption that this happens rather rarely.

- The ratio of the axes measures how geographically directed the relationships are. In the case of egocentric social networks this can be interpreted as how spatially divers a social network is. E.g. a low ratio represents clusters of social contacts in just two regions or along an axis.

- The angle of the main axis represents the geographical orientation of the ellipses. At a certain length of the main axis it could be interpreted as a cultural diversity of the social network. E.g. it could be assumed that in Zürich the German language and the fact that the biggest share of immigrants to Zurich are Germans (17.4% of all immigrants (Statistik Stadt Zürich, 2006)) will lead to south – north directions of the ellipses, whereas in the intercontinental group an east – west direction should prevail.

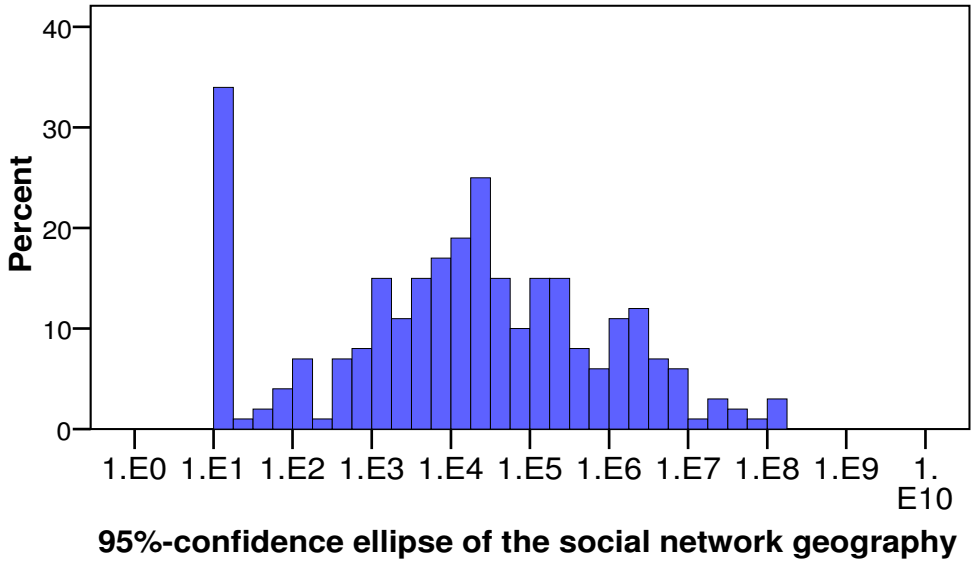
The distribution of the size of the 95% confidence ellipses seems to follow a log-normal distribution (Figure 9), if we ignore the third of the respondents who have a local set of contacts. The fit statistics for a lognormal distribution are good and do not reject this distribution at the 0.05-level (Chi-Square, Kolmogorov-Smirnov and Anderson-Darling Test) (Estimated with ExpertFit – Version 7.00 (Averill M. Law & Associates, 2006). Other distributions, such as the Weibull, Gamma, log-Logistic and many more performed less well.

The patterns of the socio-demographic differences follow generally the patterns of the distances to the contacts' home location above (Table 6). An analysis of variance shows that none of these differences are statistically significant. Only if one takes the logs of the sizes of the geographies, then the age differences are significant. A model of the logarithm of the size of the 95% confidence ellipses as a dependent variable has to be consider that the values are all nonnegative, with 33 zero values in a total of 276 observations[4]. Conventional regression-

[4] The smaller sample is due to the respondents with three or fewer distinct geocodes for their contacts for which no ellipses can be calculated.

methods, as the ordinary least square method, are not adequate for such censored values (Greene, 2000).

Figure 9 Distribution of the social network geometries measured as 95% confidence ellipses [km^2]



Social network geographies of less then 10 km^2 were coded as zero.

Table 6 Descriptive statistics of 95% confidence ellipses of the social network geographies [10^5 km^2] (with and without contacts within 25 km from the respondent)

Variable	Median		Mean		S.E. of the mean		Number of cases	
Category	with	w/o	with	w/o	with	w/o	with	w/o
Age								
Up to 30	0.27	0.27	66.73	68.29	40.37	41.29	44	43
30 to 40	0.12	0.18	36.19	41.76	29.71	34.25	49	39
40 to 60	0.14	0.25	17.74	20.80	8.38	9.78	78	58

60 and older	0.16	0.29	17.75	20.68	12.24	14.25	131	103
Sex								
Female	0.15	0.21	20.54	23.57	9.86	11.29	160	129
Male	0.21	0.31	37.68	42.64	17.83	20.14	142	114
Education								
N.A.	0.33	0.33	6.62	6.62	5.14	5.14	9	9
Obligatory schooling	0.04	0.14	1.71	2.14	1.18	1.46	28	20
Vocational training	0.06	0.15	5.74	7.03	2.56	3.12	101	71
Highschool diploma	0.16	0.19	51.37	55.65	35.09	37.94	27	24
Further technical training	0.21	0.34	35.51	39.39	25.97	28.78	64	55
University degree	0.38	0.40	55.04	59.34	28.93	31.14	73	64
Income [sFr/month]								
N.A.	0.54	0.93	4.86	5.46	1.63	1.82	50	40
0-1999	0.14	0.18	52.74	57.39	25.56	27.70	41	34
2000-5999	0.15	0.20	22.34	24.55	13.38	14.69	132	111
6000+	0.09	0.22	41.18	51.83	26.89	33.76	79	58
All	0.16	0.25	28.53	32.52	9.83	11.18	302	243

A model which is able to differentiate between limit-observations and non-limit-observations is the Tobit Model. The Tobit model assumes that the limit outcome is determined by the level of the nonlimit outcome. To test this assumption, a different model which is also appropriate for the data can be compared to the Tobit model. This is Cragg's Model for Censored Data (Cragg, 1971). It is used, when the assumption of the Tobit model, that the nonlimit outcome is determined apart from the level of the nonlimit outcome, is not true. Cragg's Model is a combination of the Probit model (for y=0) and the truncated regression (for y>0). The zeroes in our data have their origin in two different problems, the first problem is, that only 44% of the geocodes have street address accuracy, while the rest has only zip-level accuracy, which leads to just one geocode for several contacts and the second problem is, that the confidence

ellipse needs at least three spatially distinct locations to be calculated. The origin of the zeros in the data leads to the assumption, that the non-limit outcome is determined by the same level as the limit outcome, which is shown through the Probit and Tobit results (Table 7).

The Tobit model was calculated after removing variables which correlate highly with each other (limit=0.5), and variables with a significance level lower then 0.05 were removed stepwise. The parameter estimates are reported in Table 7.

Table 7 Parameter estimates for the Tobit regression of the logarithm of the size of the 95% confidence ellipses and the associated Probit model of the Cragg approach

			Tobit model		Probit model	
Variable	Mean	St .dev.	Beta	Sign.	Beta	Sign.
Constant	-	-	9.929	0.00	2.487	0.03
Age [years]	53.430	19.305	-0.296	0.00	-0.114	0.01
$Age^2/1000$ [$years^2/1000$]	3.226	2.099	2.946	0.00	1.091	0.01
Car ownership [y/n]	0.472	0.500	1.609	0.01	0.187	0.37
Number of relationships []	12.406	8.454	0.201	0.00	0.084	0.00
Education/workplace changes []	3.336	2.475	0.289	0.02	0.053	0.28
Further technical training [y/n]	0.213	0.410	2.485	0.00	0.581	0.04
University degree [y/n]	0.245	0.431	2.617	0.00	0.397	0.16
Income >6000 sFr./month [y/n]	0.262	0.441	-1.643	0.028	-0.279	0.24
N			286			241
Goodness-of-fit			Adjusted $R^{2=}0.25$		Chi^2 (8 df) = 47.31	

The analysis of the Tobit results shows that there are different factors which influence the social network geographies. The first group consists of socio-demographic variables. The model results indicate that young people with a high education and with a low- or a middle income tend to maintain a more spatially distributed social network. The influence of the age and the education is similar to their influence on the numbers of relationships. The influence of the income seems to be unexpected as a spatially more distributed social network is expensive to maintain. An interpretation of the negative influence could be that a higher income is often linked to a higher workload and more responsibility which leads to a higher

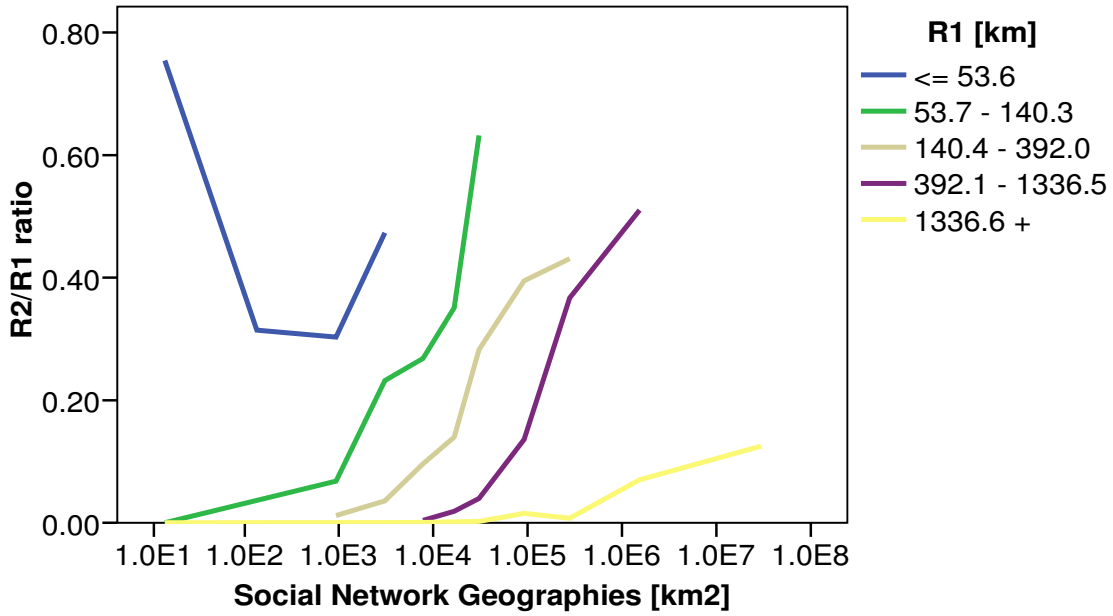
value of time for these persons. As travel costs have decreased over the decades (See for example Fröhlich, Tschopp and Axhausen, 2006 for Switzerland or Bruegmann, 2005 for the USA), the time costs seem to exceed the financial costs of travelling. The ownership of a car has a positive influence on the size of the social network geographies, even if the ownership of a car does not contribute to he maintenance of contacts over the distance (see above), it is an indicator of mobile people. The number of relationships has an influence as mentioned above, as it is correlated with the share of non-core contacts, as it is now possible to maintain spatially more widely distributed network of weaker ties (see Figure 5) with less frequent face-to-face contacts in combination with telecommunication contacts (see Axhausen, 2007 for details). The number of education or workplace moves is a biographical influence on the social network geographies. It seems that being less anchored in space and being professionally flexible have a positive influence on the size of the social network geographies, while surprisingly, the spatial distribution of the education and workplace changes, measured by their confidence ellipses, has no significant influence on them. Overall the model explains 25% of the variance of the social network geographies.

The parameters of the Probit model follow exactly the parameters of the Tobit model (See Table 7). The resulting predictions are 100% correct for the 1s (y>0) and 22.5% correct for the 0s, which results in overall 89.2% correct values. As the parameters of the Probit model show, that the limit outcome is determined by the level of the non-limit outcome, the estimates of the truncated model for the non-limit observations are omitted.

The shown results of the Tobit and Probit models explain the size of the egocentric social network. However, the area of the ellipse is one out of three measurable parameters describing an ellipse. For example, a circle (which would be an ellipse with a ratio of one between the minor axis (R2) and the main axis (R1)) with the same area as a narrow ellipse (which is a ellipse with a low R2/R1 ratio) are not the same and therefore barely comparable in substantive terms. This could be one of many reasons for the relatively low explanatory power of the Tobit model. To analyze the influence of the ratio of the two axis on the area, the relation of the size of the ellipses and the ratio between the minor axis (R2) and the main axis (R1) are illustrated in Figure 10. The x-axis represents the logarithm of the size of the confidence ellipses (km^2), the values of the R1/R2-ratios are their means of each deciles of the area and the ratios are subdivided in quintiles of the main axis (km). Three trends are visible: Regional contact geographies with a main axis shorter than 54 km have no small R2/R1 ratios and do not show a strong spatial orientation. For large geographies only small ratios are observed and the longer

the main axis (R1) is, the smaller the maximum of the observed ratios are. This means that as social network geographies become larger, the more spatially concentrated in a certain direction the contacts are. It seems to be necessary for the maintenance of large social network geographies, to make it possible to visit a substantial part of the contacts with one longer trip, e.g. overseas journey, and some shorter trips from the new base location.

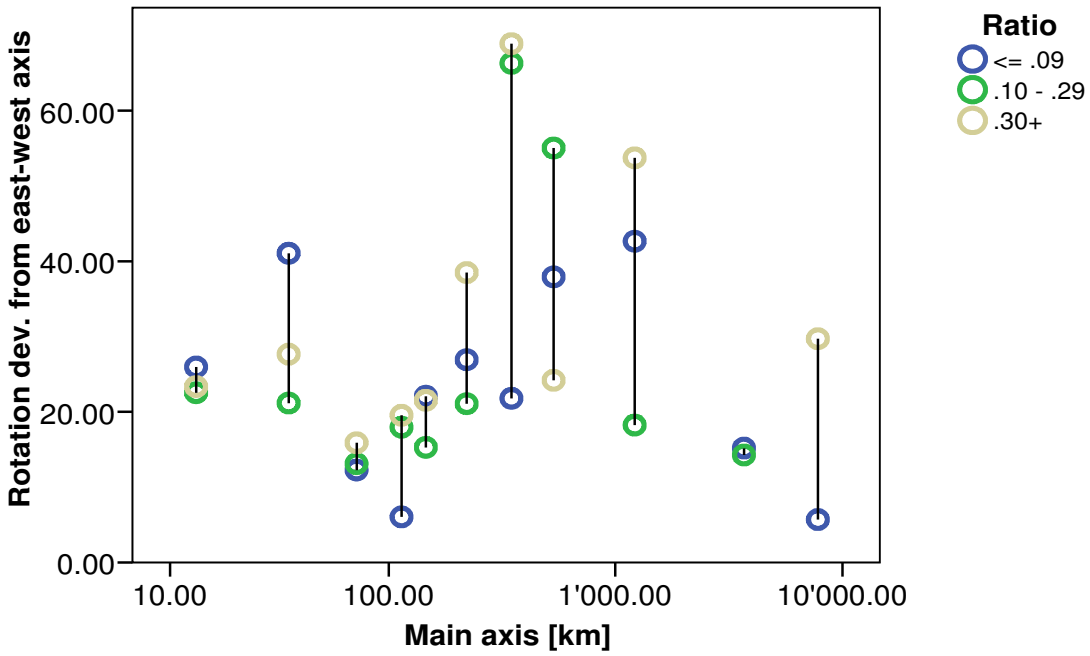
Figure 10 Size vs. main/minor axis (R1/R2) ratio



The third parameter of the confidence ellipse is the orientation of the main axis measured as the rotation deviation from the east-west direction in degrees. Figure 11 shows the mean of the rotation by deciles of the main axis length. As the ratio between the axes is important for analysing the rotation, the values are subdivided by the terciles of the ratios. As mentioned above, the rotation represents the geographical orientation of the ellipse. The rotation is stronger, when the ratio between the main axes is small. Therefore the analysis concentrates on the blue and green points in Figure 11. Overall the deviations from the east-west axis are not as large as expected and have their maximum in these categories at 67 degrees. However, there are two remarkable breaks around 100 km and 1'000 km which divide the figure in three sections. The first section between 10 km and 100 km shows a drop of the rotation. The very local and regional geometries tend to have a higher ratio than the geometries at national level. The deviation from east-west on the regional level around Zurich (~40km) is similar to the catchment area of the commuters to Zurich, which is concentrated along the Lake Zurich (Botte, 2003). On the national level, around 100 km, the orientation follows a clear east-west direction which

is determined by the larger Swiss cities, Basel and Bern in western- and St. Gallen in the eastern direction. From 100 km till 1'000 km the rotation–degree increases till 42 degrees which indicates a dominant share of contacts in Germany at this level of the main axis length. As expected the rotation decreases for intercontinental social networks, which is caused mainly by the ties to the USA.

Figure 11 Orientation of the social geographies



6 Conclusions and research questions

Social network geographies give an idea of the geographical patterns of personal relationships and especially how spatially distributed they are. The analysis has shown that the distribution of the network geographies is very wide from just local ties to international ties and a remarkable share of intercontinental ties. Long distance ties are a part of more than the half of the egocentric networks which is reflected in the statistics of long distance travel, where the highest share for the main purpose is visiting friends and relatives (e.g. Bundesamt für Raumentwicklung, 2000 or Bureau of Transportation Statistics, 1995). It should be taken in account during further research and modelling that social network geographies have a certain structure at a certain size. These first results of analysing the patterns of social network geographies show, that the ego's characteristics, mainly its socio-demographics and life course,

can explain them to a certain extent, but a big part remains unexplained. The analysis of the ratio between the two axes of the confidence ellipse showed, that the larger social network geographies are mainly driven by the length of the main axis accompanied by short minor axis, which shows that the observed large social network geographies can only be maintained by having strong clusters of long distance ties. This and the fact that the geographical size of the social network geographies is dependent on their geographical orientation should be taken in account in further modelling of the social network geographies. To improve the explanation of the social network geographies future surveys should add characteristics of the alters, e.g. their gender, their age, their educational level etc. to obtain a richer picture. The results also indicate that the basic willingness of the respondents to adopt the new and to travel plays a role beyond their socio-demographics, this indicates a need to add appropriate items or scales to capture the propensity for curiosity, variety seeking, risk taking and innovation.

Political decision makers should also be aware of the large size of social network geographies and how geographically wide the social capital of the population is distributed today. Next to the costs that travel causes, environmental aspects, travel time etc., also the social capital aspects should be taken in account in decision making (see Axhausen, 2006 for a more extensive discussion). This link requires transport policy making to be linked with social policy making to make sure that citizens, especially vulnerable ones, get support in the reconstruction and creation of their social capital, as and when needed. See for example Putnam, Feldstein and Cohen (2003) for a selection of such initiatives.

7 Acknowledgments

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