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The structure and spatial spread of egocentric leisure networks

M Kowald (IVT, ETH Zurich)
KW Axhausen (IVT, ETH Zurich)

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Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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1. Introduction

The field of transport planning puts much effort on approaching and explaining leisure travel. This travel segment is particularly challenging because it's characteristics are different from other forms of travel: On the one side it is less based on daily routines than e.g. commuting and related peak hour traffic and therefore performed more sporadically. On the other side it is more influenced by social or natural ascendancies like peoples' time and money budgets, plans for joined activities, and weather conditions (see Schlich, 2004).

To investigate social environment's influences on individual leisure behaviour some first studies in transport planning used the methods of social network analysis in recent years (for examples see Larson et al., 2006, 2008; Carrasco, 2006; Frei and Axhausen, 2007). Whilst these projects were fruitful starting points and produced empirical insides they were limited in certain characteristics: The study of Larson *et al.* (2006) was of exploratory character as it is based on a small sample size of only 24 respondents. A more representative study collected information on 350 egocentric networks in the East-York area of Toronto city (Carrasco, 2006). This project was particularly advanced in terms of survey instrument. It collected information on relations between respondents (egos) and their network persons (alter) as well as on alter-alter relations for a 25% sub-sample of the survey population. To report the later relations, respondents were asked to produce a graphical representation of their egocentric network structure with the help of an interviewer (Hogan *et al.*, 2007). The third project surveyed data on 307 egocentric network structures in Zurich city (Frei and Axhausen, 2007). In comparison to the Canadian study this project exclusively focussed on ego-alter relations, the home locations of both, and modes and frequencies used to maintain the contacts. In this way it provided a detailed picture of egocentric networks' geographies and contact strategies (Axhausen and Frei, 2007).

A common characteristic of all three studies is egocentric structures being isolated in terms of missing overlaps between respondents' alters. Such overlaps between egocentric components provide information on the global structure of personal networks. They are of particular interest when aiming to implement social network issues in agent based traffic demand simulations (for e.g. MATSim see Balmer, 2007). In a joint survey project the Institute for Transport Planning and Systems (IVT) of ETH Zurich and the Institute for Land and Sea Transport (ILS) of TU Berlin collect information on both: egocentric networks and their connected global structure by combining the egocentric network approach with snowball sampling. Currently the survey is in the field whereby most fieldwork is finished. This chapter aims to introduce the personal networks' topologies and geographies in descriptive figures and to present first regression models for these two issues.

2. Snowball sampling of connected leisure networks

Snowball sampling belongs to the family of ascending sampling strategies. It uses an initial set of first respondents, called 'seeds' to ask them about their social contacts. Instead of only collecting information on these alters, it aims to also recruit them and again ask them to report their social network. This process is repeated for a number of predetermined iterations (for more detailed discussions on this methodology see Vogt, 2005; Gabler, 1992; Goodman, 1961). In case the snowball approach is combined with a name generator, a technique that usually uses questions and stimuli to focus respondents on that specific part of their entire network, which is of interest for the study, the methodology has the advantage of only needing few seeds to find other members of a given population with similar characteristics (Atkinson and Flint, 2001). Therefore snowball sampling is often used to collect information on hidden or hard-to-reach populations like drug users or persons with sexually transmitted diseases (for examples of studies using snowball sampling or similar approaches see Salentin, 1999; Schweizer, 1998; Jones, 2003; Heckathorn, 1997, 2002; Gabler 1992; Mathews *et al.*, 2008). However, snowball sampling can also be used to survey information on more general networks and investigate their global structures in terms of connectedness (Scott, 2007; Frank, 1979). To do so, several issues have to be considered because snowball sampling is well known for including several sources for bias (for a study with problems resulting from this bias see Silvis *et al.*, 2006).

The present study focuses on leisure contacts. Respondents are asked to fill out a paper-based questionnaire implying questions on four topics: Firstly, information on egos' own characteristics are collected. The second part is a name generator including two questions and providing several stimuli. In summary it asks for leisure contacts and, in addition, for contacts that are of emotional importance for egos' and did not fit in the leisure category. Both kinds of contacts can be considered as 'mile makers' in terms of leisure travel as ego usually meets those persons frequently. In all, egos are allowed to report up to 40 names. The name generator design does unfortunately not allow for multi-relational analysis as both categories of social contacts overlap and respondents were for responds burden's sake not asked to mention alters which fit in both categories twice. The third part of the questionnaire asks egos to report characteristics of each alter mentioned in the name generator and to specify modes and frequencies used to maintain the contact. Fourthly, egos are asked to fill out a highly standardized form of a sociogram by reporting cliques of alters making plans to spend free time together. These structures can be reported by mentioning the context in which a given clique meets, e.g. ‘hiking group’, and identify all alters from the name generator that join this meeting. Egos are allowed to mention up to 20 cliques.

Currently the survey is still in the field. A response rate of around 27.0% is achieved, which is calculated using the COOP4 cooperation rate according the suggestions of the American Association for Public Opinion Research (AAPOR, 2009). The response rate is reliable as data collection is nearly finished. It is satisfying considering the amount of response burden implied in the project, filling out the questionnaire takes in dependence of egos’ network sizes between one and four hours, and considering the survey asking for very confidential information like names and postal addresses of friends and family members (for more details on the questionnaire, arrangements to increase the response rate and strategies to avoid bias see Kowald et al., 2009; also see Kowald and Axhausen, 2010). In all, a lower response rate was expected (see Weis and Axhausen, 2009). To our knowledge the present project uses the snowball approach for the first time in a study of the planned size. Starting with 60 seeds it aims to survey around 500 egos reporting around 10.000 alters. Unlike most other snowball studies which use strict limitations to continue the chain, the only limitation here is that alters have to be mentioned as leisure contacts. The chains are neither limited to specific personal characteristics nor to locations or communication modes.

3. Survey- and target population

One big issue especially in snowball sampling is to define the inference population for which statistical indices are valid. This is related to the issue of defining the target population (Groves, 2004). To start the snowball chain the present study uses seeds from Canton Zurich, which were found by using a stratified random sample in terms of sex, age, and home location, whether it is of rural or urban character. The egos' alters can be located elsewhere and, resulting from that, also egos participating on the later iteration levels of the snowball chain can live elsewhere. However, as most egos, 89.6%, and most alters, 88.2%, are Swiss the Swiss population is our target population. Table 1 compares the survey population to the target population using the Swiss Microcensus (ARE/BfS, 2007).

In all variables the alters' characteristics fit better than the egos' to the Swiss population which is simply due to a larger sample size. An overrepresentation of females can be observed for both: Egos and alters. Focussing on civil status shows married persons being overrepresented, whilst singles are underrepresented. The other attributes fit quite well. Five categories were formed to compare egos' and alters' ages to the Swiss population. For each category its share in terms of the overall population is presented as well as the average age within the category. The first age class is strongly underrepresented in terms of egos because the survey did not use alters under 18 years to continue the snowball chain. In summary persons between 41 and 60 years are overrepresented as well as persons between 61 and 80 years. Younger adults between 21 and 40 are underrepresented. Focussing on the average age per category shows the distribution within each category fitting well. Comparisons for monthly household income and having a drivers license are only available for egos. These characteristics show respondents with lower than average incomes as being strongly underrepresented whilst those with average or higher incomes are overrepresented. In addition the survey includes to many persons with a drivers license. Considering that around 10% of egos and alters are Non-Swiss the overall fit is good and the sample can be interpreted as representing the adult Swiss population which is the population of inference.

Table 1 The characteristics of egos and alters compared to the Swiss population

Character		All egos (n = 468)		All alters (n = 8668)		Microcensus Switzerland	
Sex [%]	Male		39.29		42.59		48.70
	Female		60.71		57.41		51.30
Civil Status [%]	Single		12.84		20.90		29.90
	Married		69.57		64.53		54.50
	Divorced		9.11		8.31		7.60
	Widowed		7.03		5.28		6.60
	Married living seperately		1.45		0.98		1.40
Age [% of people in class | Ø age within the class]	0 – 20	0.62	12.00	2.59	14.13	18.80	13.31
	21 – 40	16.36	33.35	20.11	32.93	28.90	31.41
	41 – 60	49.69	49.77	48.35	49.73	31.00	49.96
	61 – 80	30.64	68.81	26.20	68.40	18.50	69.37
	81 +	2.69	82.46	2.75	84.06	2.80	84.61
Household income [%]	< 8.000		40.77				73.00
	8.001 – 12.000		29.83				19.10
	> 12.000		29.40				7.90
Drivers license [%]	Available		89.89				80.70
	Not available		10.11				19.30

Source: Microcensus data taken from ARE/BfS, (2007).

4. Egocentric leisure networks' topologies

485 egos participated so far. On average they reported 18.9 alters. 27.4% are relatives whilst the others are labelled as friends or acquaintances. An average network includes 31.7% strong relations. Relationship strength is measured by two proxy questions asking which alters are used to discuss important problems and which for help in certain situations like e.g. financial or relationship problems. If an ego considers an alter being important in both manners, this contact is labelled as 'strong'. Comparing egos and alters characteristics shows the networks including high degrees of homophily. The highest shares of alters with egos characteristic can be observed in age (70.5%), defined as egos age +/- 10 years, followed by sex (68.3%), civil status (61.5%) and education (61.1%).

6.6% of the respondents reported one or zero social contacts. Those respondents were not able to report alter-alter relations in the sociogram and are excluded from the analysis of networks' topologies to avoid bias resulting from their network structures. In addition, another 15.1% of all egos are excluded. Although they reported more than one alter they did not report alter-alter relations in the sociogram. Unfortunately does the questionnaire's design not allow to judge whether the missing relations are due to sparse network structures or due to item non-response behaviour, which could be the case as the sociogram is the last part of the questionnaire. However, there are hints on sparse network structures as networks without sociogram often contain less alters than average. Analyses of network topologies are done for 380 egocentric structures, which is still 78.4% of all respondents. Egos' and all ego-alter relations are removed from the networks as by definition an ego would otherwise be the most central actor in the network and all figures would be biased in their direction (Scott, 2007; Wasserman and Faust, 2007). Table 2 provides an overview on the personal networks' topologies.

Personal leisure networks' structures are very heterogeneous and include a high amount of variance in all characteristics. An average personal network has 21.1 alters which are connected to each other by 46.2 relations. 6.7 of these alter are isolates, they only know ego but do not meet with other alters from the particular personal network. Another 14.3 alters join each other in leisure activities. They are organized in 4.0 cliques, leisure contexts in which alters meet to spend free time together, whereby an average clique includes 4.4 members. Usually there is at least one alter which is a member in more than one clique and that combines these cliques to larger components. An average graph includes 2.5 components when isolates are excluded. Whilst the indices for degree- (0.2) and betweenness centralization (0.3), which are calculated following the method offered by Freeman (1979), show that an average network does not include very central actors or central gate keepers, there are few networks in which actors in such powerful positions are present. The average density of 0.2 is not high, showing that more connections between the alters are possible.

Table 2 Egocentric networks' attributes, only egos with filled out sociogram (n = 380)

	Mean	Std.-Deviation	Minimum	Maximum	25 - Percentile	Median	75 - Percentile
Number of alters	21.11	10.07	2.00	40.00	13.00	20.00	29.00
Number of relations	46.17	63.18	1.00	399.00	9.00	23.00	54.00
Cliques	4.00	2.57	1.00	20.00	2.00	3.00	5.00
Number of clique members	4.40	3.16	2.00	28.00	2.00	3.00	5.00
Isolates	6.62	6.15	0.00	33.00	2.00	5.00	9.00
Components (without isolates)	2.52	1.45	1.00	9.00	1.00	2.00	3.00
Density	0.20	0.18	0.01	1.00	0.08	0.15	0.27
Degree centralization	0.22	0.14	0.00	0.80	0.13	0.18	0.29
Betweenness centralization	0.03	0.06	0.00	0.40	0.00	0.00	0.03

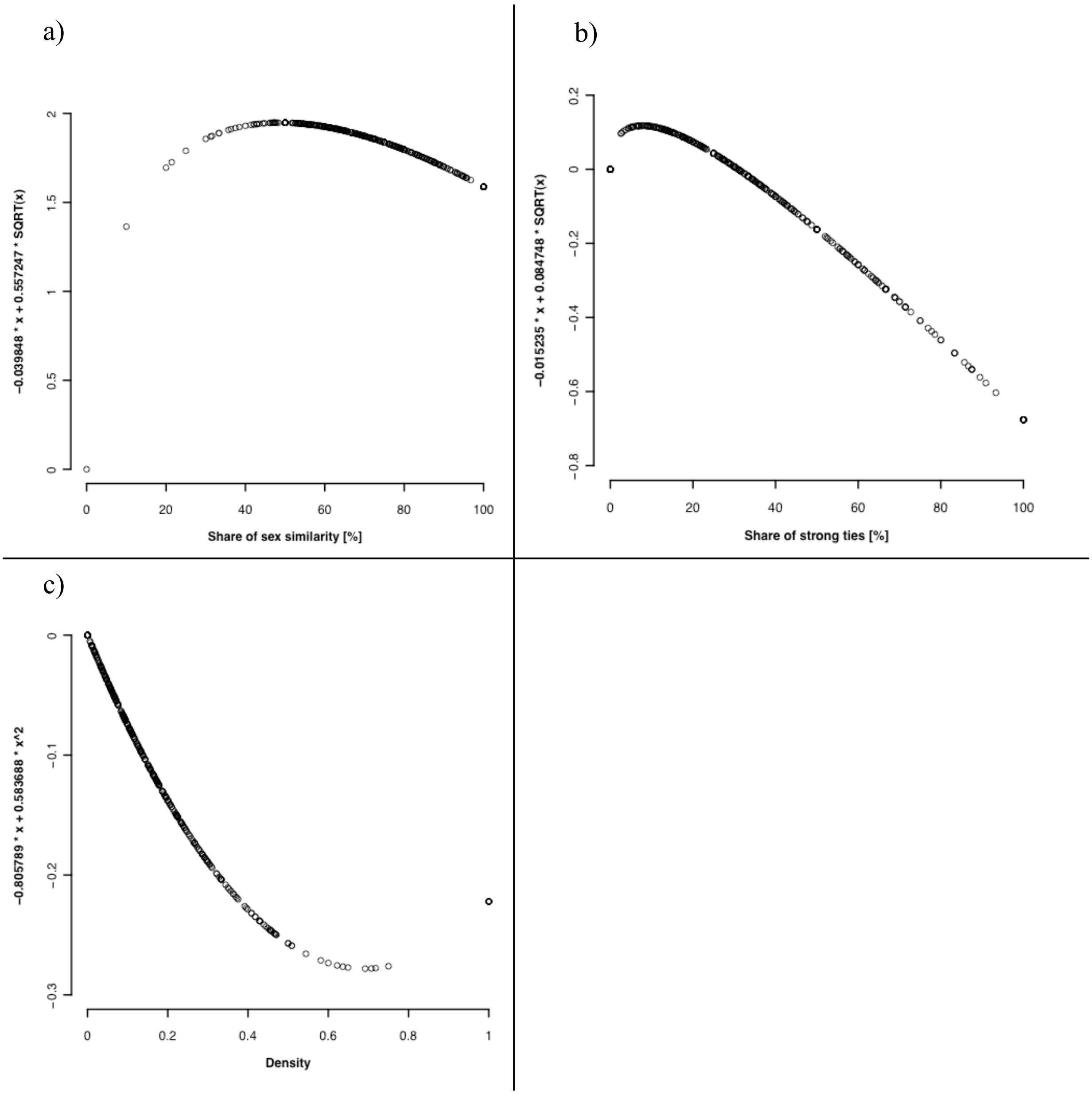
A first model aims to predict network sizes using Egos' characteristics and aspects of the personal networks' topologies. All following models treat leisure networks' characteristics as exogenous variables. Therefore they have to be interpreted carefully by keeping in mind that estimations may include bias. Nevertheless the models provide a good overview of factors influencing the dependent variable. For future work it is planned to treat networks' characteristics as endogenous variables in structural equation models.

The number of alters included in a network results from counts, for which a Poisson regression is the appropriate model form. Employing a likelihood ratio test based on a Poisson and a negative binomial distributions shows the model being overdispersed. Therefore the model design is changed to a negative binomial regression being presented in table 3 (for regressions on count data see Winkelmann, 2008; Washington *et* *al.*, 2003; Dean and Lawless, 1989). It shows egos from households with high incomes, defined as 12.000 CHF or more, tending to have bigger networks. The effect is small but highly significant. If egos' are males and widowers, their networks are smaller than average. The effect is relatively large and a well documented phenomenon in sociological studies (for a general overview see Christakis and Fowler, 2009). Network sizes increase little with an increasing number of persons in egos' households. It also increases with an increasing number of residents in course of an ego's live. The interpretation of these effects is intuitive as all three, spouses, household members and living places provide opportunities for getting known to new people and establish new relationships. Also the number of cliques in egos' networks has a positive effect on the personal network sizes. The interpretation is quite similar: Egos know their alters are meeting in certain contexts and each of these contexts provides the opportunity for egos to join it and with that at least some of them may provide the opportunity of establish relationships to so far unknown persons. Summarizing the parameters for the shares of sex similarity between egos' and their alters and for the square root of these shares results in an effect that shows network sizes increasing when the share of sex similarity is under 40% (figure 1a). On the other side network sizes decrease when the share of sex similarity becomes too high, over 50%. Large networks seem to include a good mixture of males and females, which may result from egos being well embedded in their original 'single' network and the network of their spouses. Also the share of strong ties in a network has some explanatory power. By summarizing the parameters for the share of strong ties and its square root, again an in social network studies often documented phenomenon is confirmed for leisure networks. Egos with low shares of strong relations have larger networks including many relations with weak ties (figure 1b). The higher the share of strong relations, on the other side, the smaller the network is. This is due to the fact that persons can maintain only a limited number of strong ties as each of them needs higher time efforts to be maintained than weak relations (see e.g. Roberts *et al.*, 2009; Dunbar, 2003). In addition, an increasing network density, measured as density and squared density, has a decreasing effect on network sizes (figure 1c). The closer egos network topologies come to a fully connected graph, the more these egos seem to be captured in a shrunken social world in terms of only performing activities with a limited number of alters which are well defined. Also it may be easier for egos with less connected graphs to implement new contacts in their sparse networks.

Table 3 Binomial negative regression model of network size

Variable	Beta	Std. error	Significance
Constant	0.819	0.520	0.1115
Egos characteristics			
High household income (>12.000CHF) [y/n]	0.131	0.042	0.002
Male & widowed [y/n]	-0.658	0.186	0.000
Number persons in household []	0.042	0.015	0.005
Number of first residents in course of live []	0.015	0.007	0.027
Network topology			
Number of cliques in network []	0.072	0.008	0.000
Share of alters with ego's sex []	-0.040	0.008	0.000
Sqrt (Share of alters with ego's sex) []	0.557	0.131	0.000
Share of strong ties []	-0.015	0.002	0.000
Sqrt (Share of strong ties) []	0.084	0.023	0.000
Density []	-0.806	0.278	0.004
$(\text{Density})^2$ []	0.584	0.350	0.094
N	404		
Likelihood ratio	χ = 254.88		0.000

Figure 1 Interaction effects of independent variables from table 3



Some influences are similar to findings from former studies investigating similar networks (see Frei and Axhausen, 2007; van den Berg *et al.*, 2009). That age seems to have no effect despite the male and widowed interaction which is correlated to age, is surprising as it is significant in other investigations. Interesting are the effects resulting from gender similarity and density. Although the model treads these variables as exogenous they seem to have meaningful influences on the network size. We will explore models treating them as endogenous in future.

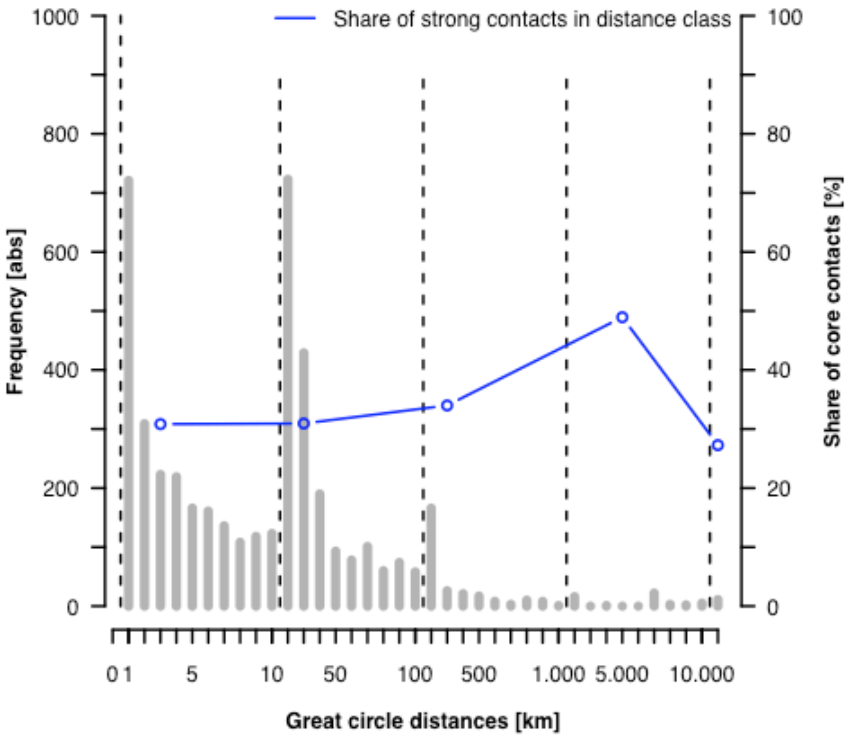
5. Egos' social activity spaces

The second important research issue that the present survey study approaches is the spatial spread of personal networks. This is related to the question by which modes and frequencies egos and alters stay in contact to maintain their relationship. In general, two oppositional trends are often hypnotised when focussing on the link between social networks and their spatial spread. The first hypothesis supposes decreasing network sizes with increasing spatial distances between egos and alters. Reasons are a limited opportunity for getting known to each other, man-made or natural barriers inhibiting information flows and the fact that most persons action spaces are limited (Stutz, 1973). The second hypothesis supposes distance as less meaningful for modern societies and a globalized world. Again there are mainly three arguments: Leisure time budgets have substantially increased over the last decades (Schlich *et al.*, 2004), in the same time travelling got substantially cheaper (Larson *et al.*, 2006; Larson *et al.*, 2008) and finally, various kinds of electronic information and communication technology (ICT) have been developed which allow long distance contacts without the necessity of physical meetings. Particularly the link between ICT and travel patterns is discussed, as ICT can be both, a substitute for face-to-face meetings or a complementary form of personal contacts (see e.g. Mokhtarian and Salomon, 2002; Axhausen and Frei, 2007;

Mok and Wellman, 2007; Larson *et al.*, 2008). However, physical meetings are of particular importance. They are perceived as more intense as interacting agents have to share the same environment. Also their duration is often longer than in case of ICT supported communication (Tilahun and Livinson, 2009).

Figure 2 provides an overview on the spatial distances between egos and alters. It uses fife distance-classes, which are given on a log scale. The first distance class summarizes all alters living in a distance of between 1m and 10 km around egos' home locations and fits for 50.7% of them. The second class contains another 40.2% alters living in a distance between 10 and 100km. 7.0% live in 100 to 1.000km distance, 1.9% in 1.000 to 10.000km and only 0.2% in distances over 10.000km. The overall distribution of distances as well as the distribution within each distance-class follows nearly an exponential decay function. Interesting is the increasing share of strong contacts within the distance classes with an increasing spatial spread.

Figure 2 The geographical distance between egos' and alters' home locations

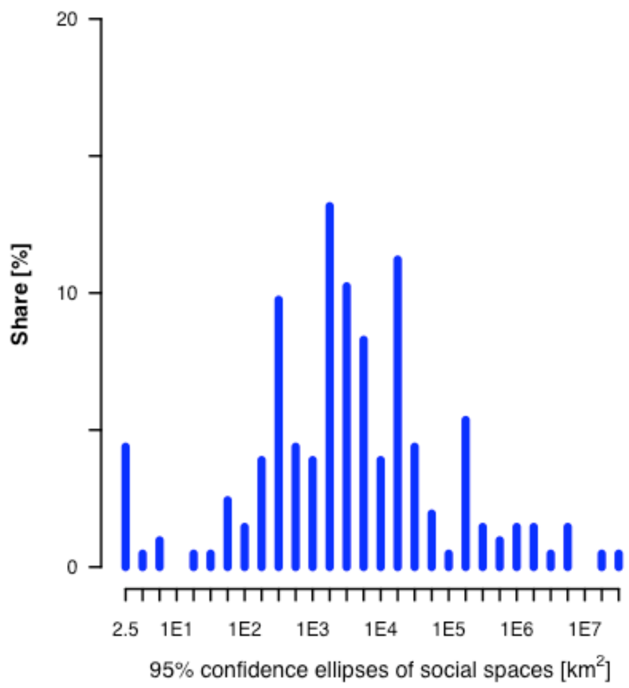


This distance distributions confirms findings from previous studies: Persons have most contacts in their nearer spatial environment but beside this they mix local, regional and international relations (see Larson et al., 2006; Carrasco, 2006; Frei and Axhausen, 2007). They also show that if egos and alters take the efforts of staying in contact over long distances they often are of high emotional importance for each other.

The addresses of egos and alters can, in combination with their communication frequencies, be used to estimate egos' social activity spaces. Whilst the questionnaire asks for physical meetings, contacts per phone, E-Mail, SMS and chat, the activity space is calculated using the summed annual contact frequencies between egos and alters over all these modes. Employing the approach of confidence-ellipses, which can be interpreted as a two dimensional generalization of a given confidence interval, egos' home locations are used as initial points. From here the alters' home locations weighted by the summed annual contact frequencies over all modes are used to adjust the smallest elliptic area in which with a predetermined likelihood, here 95%, all social activities of this ego take place. The approach is often used because it causes only little computation costs. A necessary assumption is a bivariate normal distribution of geographical distances, which the present data match approximately. A disadvantage of the approach it the ellipses' symmetries which often leads to overestimations of their sizes. They often cover areas where no alters or no persons at all live, like mountains or oceans (for a more detailed overview on confidence ellipses see Schönfelder, 2006; Vikrant, 2005).

The distribution of egos' social activity ellipses sizes are presented in figure 3. The x-axis is given on a log-scale. In all ellipses for 220 egos, 45.4% of all respondents, were calculated. These participants mentioning alters with valid postal addresses and reported the contact modes and –frequencies they used to maintain their relationships to the alters. Few ellipses can be labelled as being very small with a size under 2.5km^2. Most social spaces are between 250 and 50.000km^2. A third group of ellipses cover large areas between 250.000 and 2.750.000km^2. Only very few ellipses are larger than that. (For comparisons: Switzerland is about 41.000 km^2)

Figure 3 The size of egos' social space (n = 220)



Estimating a linear regression model aims to detect relevant independent variables and interaction effects. The ellipses sizes are explained by considering egos' characteristics and variables from their network topologies. Implying the logarithm of the dependent variable, the model shows an increasing activity space size with an increasing number of alters in the network, which is intuitive. Increasing similarities between egos and alters in terms of civil status result in a contrary effect: the higher the share of similarity, the smaller the activity space is. A possible explanation is that married persons perform most leisure activities with their spouses, which usually live at the same place as they do. In addition, widowed persons can be assumed as being less active in terms of leisure activities, although this parameter is not of importance here. Other continuous variables only have significant effects when focussing on interactions with dummies. An increasing share of strong relations has an increasing effect on the ellipse sizes when ego comes from a household with high income. A similar effect can be observed for an increasing number of isolates in egos leisure network and a high household income. Both effects indicate egos from financially strong backgrounds being able to maintain relations to persons living at distance whether they are of emotional importance for them, isolates or both. A quite strong influence results from the number of education places an ego has passed when the ego works at home or is retired. Those persons have the opportunity of communication with their alters all day. This opportunity is often smaller for extra-home workers. In addition, at least retirees have more time for physical meetings even if alters are living at larger distances. Egos for which a car is available have larger ellipses as those without an available car. This is an indicator highlighting the importance of physical meetings. The strongest effect is a negative one: Egos between 41 and 60 years old have smaller activity spaces as persons in other ages. Those persons are usually busy with their careers of families. In all the model explains around 40% of the variance in activity ellipses sizes and is highly significant.

Table 4 Linear regression model to estimate social space ellipses' sizes

Variable	Beta	Std. error	Significance
Constant	7.534	0.676	0.000
Continuous variables			
Network size []	0.066	0.020	0.002
Share of alters with ego's civil status []	-0.018	0.008	0.022
Interaction effects			
Share of strong ties [] * High household income (>12.000CHF) [y/n]	0.054	0.011	0.000
Number of isolates in network [] * High household income (>12.000CHF) [y/n]	0.082	0.032	0.011
Number of education places in course of live	* home worker/retiree [y/n]	0.148	0.054	0.007
Dummy variables			
Car sometimes available [y/n]	1.138	0.476	0.018
Ego between 41 and 60 years old [y/n]	-1.170	0.363	0.002
N	142		
Adjusted R^2	0.408		0.000

Again, the effects are similar to estimation from similar data. It is surprising that most continuous variables only result in significant effects under certain conditions, when interacting with dummies. All effects that were found are meaningful. On the other side there are lots of missing values in the data as only 142 ellipses were considered for the model. As the survey is still in the field, we hope obtain a better picture on the geographical distribution in future. To present more details it is planned to model the distances between egos and alters by estimating multilevel models (see e.g. Carrasco *et al.*, 2008).

6. Perspective

The present project aims to approach and explain leisure travel by using the methods of social network analysis. To survey information on both, personal leisure networks as well as their 'global' connected structure it takes a snowball sample. Whilst snowball sampling is known for including several sources of bias and alters as well as egos on the later iteration levels could be located elsewhere, nearly 90% of the survey population lives in Switzerland. Comparing their characteristics to the Swiss population shows the sample being representative by also including some deviations. This paper focuses on the data in terms of descriptive figures and presents first regression models especially for personal leisure networks' topologies and the geographical spread between egos and alters.

The minority of contacts are relatives. Also emotional important 'strong' contacts are a minority when focussing on an average Swiss adult leisure network. Around 21% of the population have networks with no or just one alter. An average network with more than two alters includes 21 persons. Most of them join other alters from this network in leisure activities whilst there are also few that only know ego. Usually there are no central gatekeepers or single alters in powerful positions although some networks have such structures. Modelling network sizes shows several of egos' characteristics and some attributes of their network structures being of explanatory power. This first model treads networks' characteristics as exogenous variables. Because of this the results are only provisional.

Most leisure contacts live within short distances from their egos, 50% within 10km and 91% in 100km distance. The farer away alters live the more often they are of emotional importance for egos. Geo-referenced home locations of egos and alters weighted by their annual contact frequencies were used to estimate egos' activity space ellipses. There are some egos with small ellipses whilst most have middle-sized ellipses of around 20.000km^2 which is e.g. about half of Switzerland. In addition, few egos have large ellipses of around 1.500.000km^2. A linear regression model was estimated to explain ellipses sizes. It showed some of egos characteristics being of influence mostly when interacting with other variables. The largest positive effects result from a high household income, car availability and the number of education places egos have had in the course of their lives. A negative effect is due to be of working age.

Data collection will be finished by the end of 2010. All models presented in this paper are provisional. It is part of future work to improve them by e.g. estimating structural equation models and using multilevel modelling techniques.

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