Geographic, socio-cultural and attitudinal determinants of activity space: a case study of EU Institutions in Luxembourg and Strasbourg

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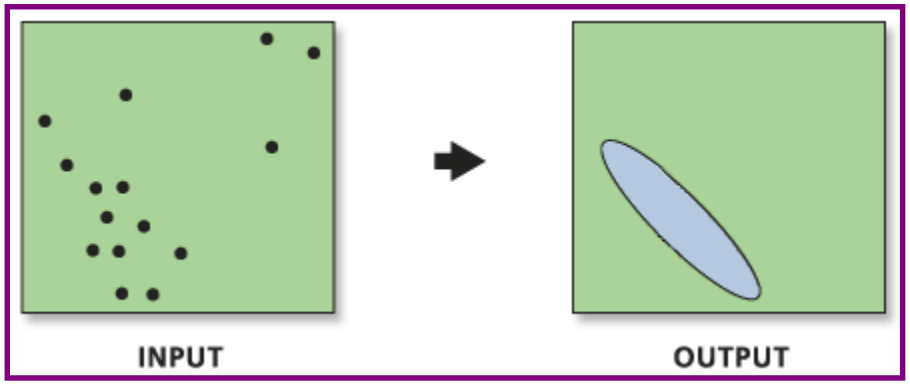
Outline of the presentation

- Introduction
- Key determinants of a person's activity space
- Structural equation model
- Data collection and geocoding of activity addresses
- Empirical result
- Conclusions

Activity space

- Activity space study allows to determine to which degree the activity space of individuals are influenced. Activity space modelling can be used to identify the mobility effects on an area.
- Definition: Areas or places that an individual has already visited during a period of time
- Measurement: Directional Distribution (Standard Deviational Ellipse)

The Standard Deviational Ellipse tool creates a new **Output Feature Class** containing elliptical polygons. The attribute values for these ellipse polygons include X and Y coordinates for the mean center, two standard distances (long and short axes), and the orientation of the ellipse.

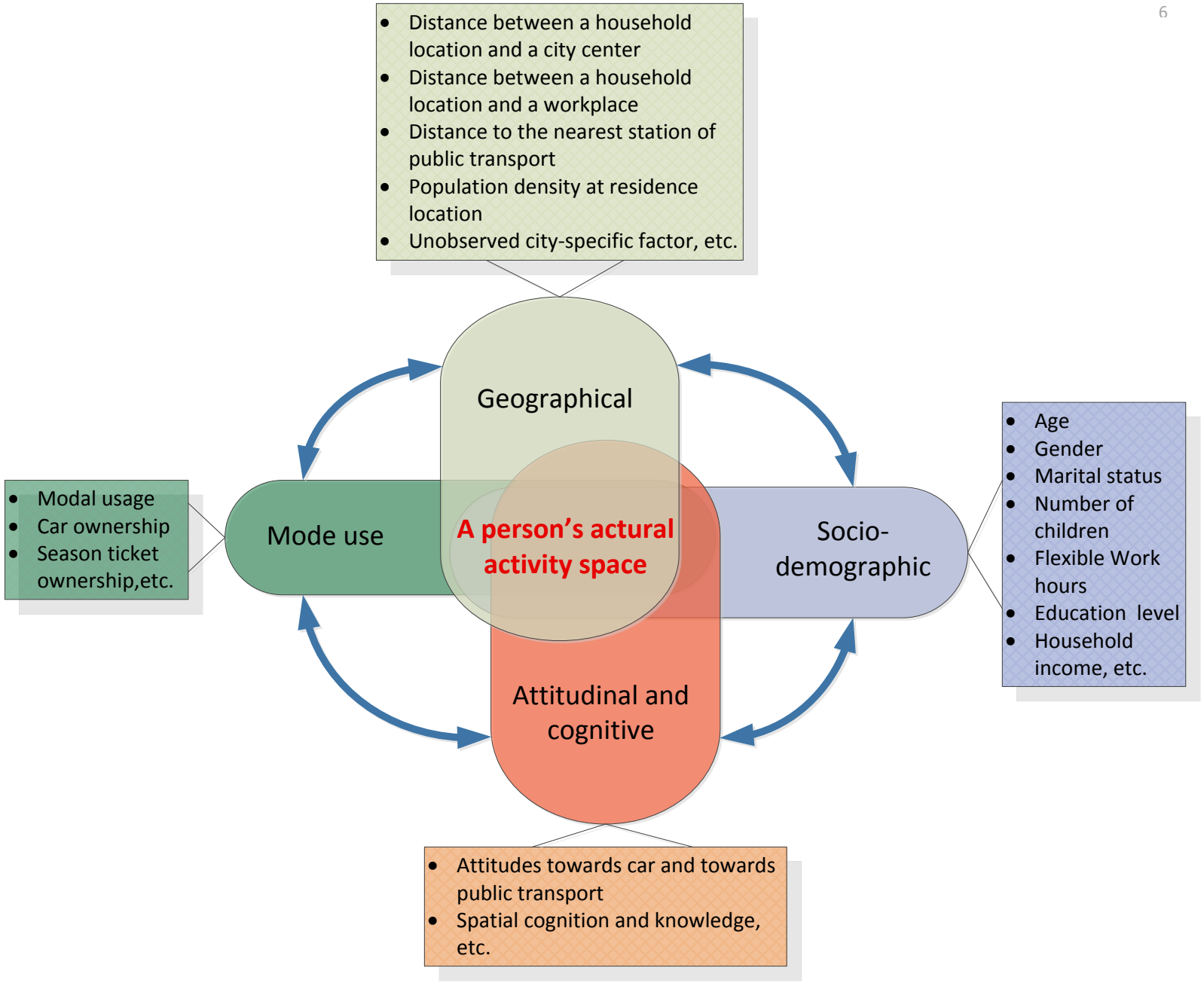


Literature review on activity space study

- Hagerstrand (1970): A person's space-time prism shapes his potentional activity space
- Dijst (1999) : Four determinants are proposed to explain an individual's activity space: distance between the bases of the activity space, available time interval, travel time ratio and the speed of travel (transport modes)
- Schönfelder and Axhausen (2003): the size of a person's activity space is mainly determined by the overall number of unique locations visited by an individual

Conceptual framework to explain the size of a person's activity space

- Geographical: density of build environment, distance between a person's residential location and his workplace, degree of urbanization and amenities in the neighbourhood
- Socio-demographic: a person's lifecycle stage, gender, household income and marital status, presence of children
- Modal usage: built environment is related to a person's mode choice. Mode choice is related also to its trip destination.
- Attitudinal and cognitive: spatial knowledge about activity locations (spatial cognition space) (Schönfelder, 2001). Attitudinal preference influences a person's location choices of activity (Ory and Mokhtarian 2009).


Distance between a household location and a city center
Distance between a household location and a workplace
Distance to the nearest station of public transport
Population density at residence location
Unobserved city-specific factor, etc.
Geographical
Modal usage
Car ownership
Season ticket ownership,etc.
Mode use
A person's actural activity space
Socio-demographic
Age
Gender
Marital status
Number of children
Flexible Work hours
Education level
Household income, etc.
Attitudinal and cognitive
Attitudes towards car and towards public transport
Spatial cognition and knowledge, etc.

Preliminary analysis by multiple regression model

Multiple regression analysis of size of individual's activity space

	Size of activity space (including home and work places)				Size of activity space (without home and work places)			
	Luxembourg		Strasbourg		Luxembourg		Strasbourg	
	Coef.	S.D.	Coef.	S.D.	Coef.	S.D.	Coef.	S.D.
Intercept	5.35	1.23	5.6	1.98	5.34	1.67	3.2	3.61
male	0.05	0.21	0.38	0.33	0.33	0.27	0.28	0.6
age_30_40	0.003	0.63	0.56	0.78	0.02	0.85	1.12	1.66
age_40_50	0.18	0.64	0.76	0.75	0.24	0.86	1.06	1.58
age_50_60	-0.17	0.65	0.5	0.74	-0.5	0.88	0.09	1.56
Couple	0.09	0.29	-0.46	0.4	0.08	0.37	0.06	0.72
N_children	-0.06	0.11	-0.19	0.17	-0.23*	0.14	-0.77****	0.28
Flex_time	-0.14	0.27	-0.69*	0.44	-0.38	0.35	0.21	0.82
N_car	0.03	0.16	0.18	0.24	0.16	0.21	0.3	0.41
Season_ticket	0.27	0.23	0.55	0.41	0.4	0.3	1.2**	0.72
mode_w_car	0.02	0.44	0.28	0.42	0.07	0.55	0.74	0.73
mode_w_pt	-0.04	0.43	0.24	0.46	-0.09	0.53	0.16	0.87
Dist_home_work	0.04****	0.01	0.03***	0.01	0.04****	0.01	0.01	0.02
Dist_station	-0.01	0.03	-0.09	0.08	-0.02	0.06	-0.17	0.16
log(Density)	-0.37****	0.12	-0.37***	0.17	-0.38***	0.16	-0.26	0.28
N	282		106		282		106	

Remark: 1 **** p-value ≤ 0.01, *** 0.01<p-value ≤ 0.05, **0.05<p-value ≤ 0.1,* .10<p-value ≤ 0.15

2 dependent variable is the logarithm of size of individual activity space

Structural equation modelling approach (1)

- Modelling the interrelationship between these variables and their influences on the activity space of individuals
- The SEM is composed of a system of equations which represent the relationships between endogenous and exogenous variables
- The general SEM comprises of two components (Kaplan, 2001):

1) a *path model* which captures the casual relationships of endogenous and exogenous variables

2) a *measurement model* which links latent variables with a set of observable measurements (Baumgartner and Homburg,1996)

$$\boldsymbol{\eta} = \mathbf{B}\boldsymbol{\eta} + \boldsymbol{\Gamma}\boldsymbol{\xi} + \boldsymbol{\zeta} \quad (1)$$

Structural model which expresses the hypothesized relationships

$$\mathbf{y} = \boldsymbol{\Lambda}_{\mathbf{y}}\boldsymbol{\eta} + \boldsymbol{\varepsilon} \quad (2)$$

$$\mathbf{x} = \boldsymbol{\Lambda}_{\mathbf{x}}\boldsymbol{\xi} + \boldsymbol{\delta} \quad (3)$$

Measurement models which tie the latent variables to observable indicators

Structural equation modelling approach (2)

- The estimation of the SEM model is based on minimization of the differences between the observed and estimated variance-covariance matrices.
- A most commonly used estimation method is the Maximum Likelihood (ML) method
- This method requires a multivariate normal distribution of the endogenous variables

Data collection and geocoding of activity addresses

- Data : Employees of three EU Institutions : European Investment Bank and Court of Justice of the European Union (Luxembourg) and the Council of Europe (Strasbourg)
- After data cleaning, the obtained samples are 299 and 114 persons for Luxembourg and Strasbourg, respectively.
- The survey was conducted during November-December 2012
- The survey collected the geographical information at a level of street or quarter about an individual's residence, workplace and visiting places of activities in the month before the date of the survey
- 74.5% and 55.3% of the reported non-work activity addresses with a resolution at address/quarter/street levels for the samples in Luxembourg and Strasbourg, respectively
- Measurement of a person's activity space: standard deviational ellipse

ACROSS mobility survey

-Mobility surveys results for the three European Institutions in Strasbourg and Luxembourg

Mobility survey in:

-Geographical location : home, work & daily activities locations
-Sociological position: age, gender, household composition, grade
-Personal attitudes : attitudes towards transport modes & cities of work

Results:

-Council of Europe (Strasbourg, 145 samples)
-European Investment Bank (Luxembourg, 131 samples)
-Court of Justice of the European Union (Luxembourg, 239 samples)

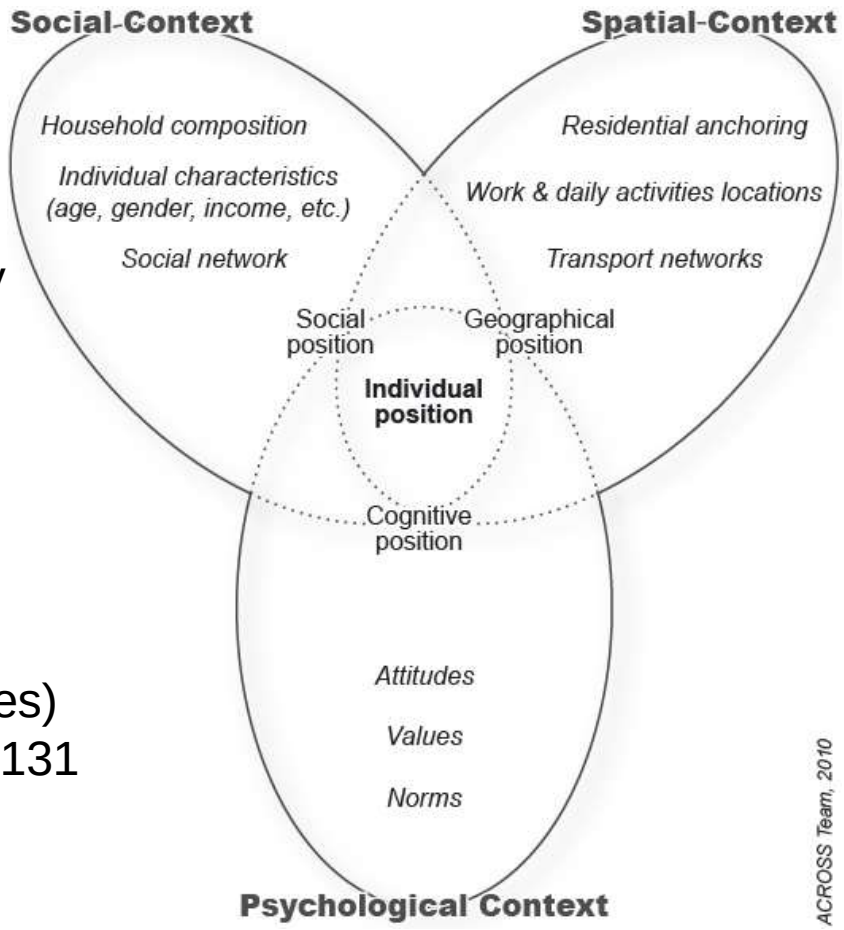
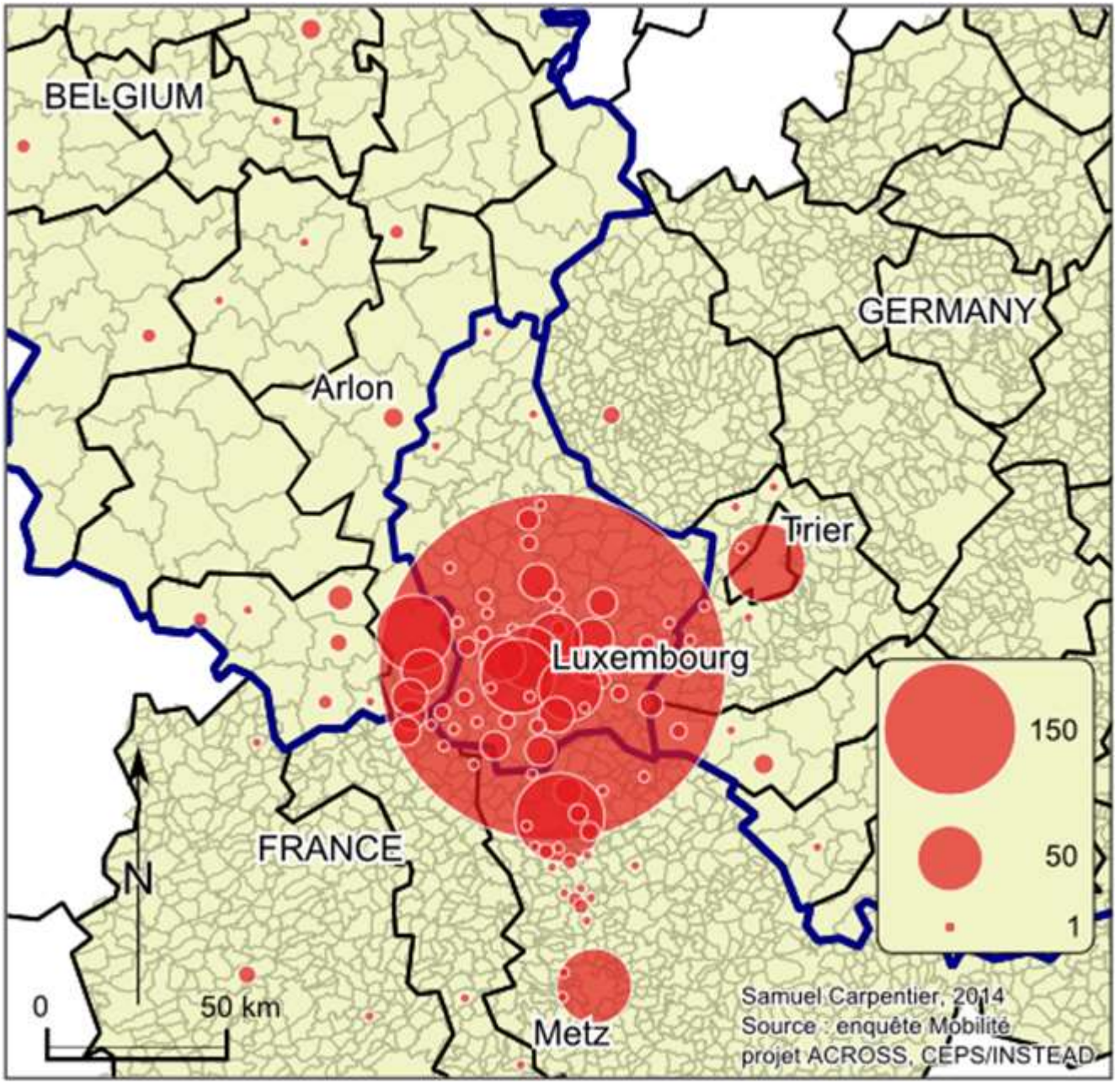


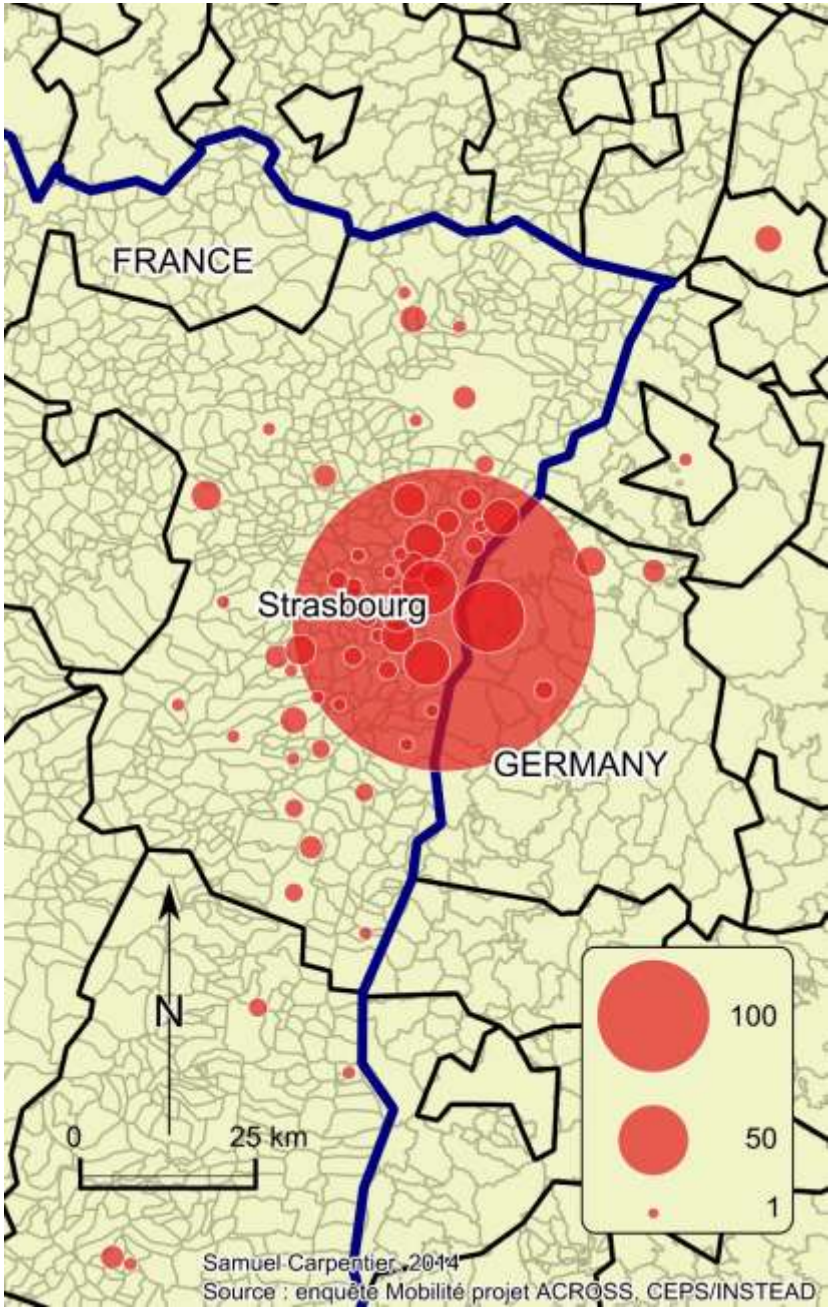
Table 1. Summary statistics of socio-demographic, built environment and modal commitment variables

Variable	Description	Luxembourg Mean (S.D.)	Strasbourg Mean (S.D)
Sample size (N)		282	106
Size of activity space (km2)	Size of a person's activity space, measured by a standard deviational ellipse (km^2)	153.9 (281.8)	77.1 (160.4)
Socio-demographic variables			
Male	1 if male, 0 female (% of 1)	0.45	0.23
Age		42.12 (8.5)	44.21 (8.0)
N_children	Number of young children less than 15 years of age in the household	0.92 (1.1)	0.90 (1.0)
Couple	1 if the individual lives in couple, 0 otherwise (% of 1)	0.78	0.80
Flex_time	1 if individual has flexible work hours, 0 otherwise (% of 1)	0.83	0.90
Working_spouse	1 if the spouse of household head has a job, 0 otherwise	0.59	0.69
Built environment			
Dist_station	Distance from a person's home to nearest railway station (km)	2.38 (3.3)	1.95 (1.7)
Dist_home_work	Distance between a person's household location and his workplace (km)	10.85 (12.8)	9.74 (13.6)
Dist_citycenter	Distance from a person's home to nearest city center (km)		
Density	Population density by commune (hab./km^2)	1039.0 (748.0)	2214.2 (1524.1)
Modal commitments characteristics			
Car_ownership	1 if there is at least one car in the household, 0 otherwise (% of 1)	0.93	0.93
Season_ticket	1 if the individual has a season ticket for public transport, 0 otherwise (% of 1)	0.67	0.21
Average commuting travel time	Respondent's declared commuting travel time (minute)	33.87 (21.48)	30.00 (21.44)

Table Median of size of individual activity space (km2)

	Luxembourg	Strasbourg	All
Sex			
Male	33.3	14.6	28.5
Female	27.1	23.0	24.8
Household type			
Single	22.8	26.5	23.0
Couple	34.9	20.0	27.9
Children of less than 15 years			
No	24.5	17.6	24.0
Yes	34.3	22.1	30.3
Age			
<30 yeas	7.8	14.6	8.6
30-40 years	27.1	14.8	24.5
40-50 years	46.7	22.0	32.1
50-60 years	23.8	21.9	23.3
>60 years	17.4	39.2	17.4
Mode of commuting trip			
by car	31.5	23.5	23.1
by PT	44.2	29.6	38.0
Season ticket for public transport			
yes	33.7	38.8	33.7
no	26.4	17.8	22.0
Number of car			
0	11.9	5.6	11.0
1	23.3	14.6	20.6
more than 1	45.8	24.2	32.8


BELGIUM
GERMANY
Arlon
Trier
Luxembourg
FRANCE
Metz
N
0
50 km
150
50
1
Samuel Carpentier, 2014
Source : enquête Mobilité
projet ACROSS, CEPS/INSTEAD


FRANCE
Strasbourg
GERMANY
N
0
25 km
100
50
1
Samuel Carpentier, 2014
Source : enquête Mobilité projet ACROSS, CEPS/INSTEAD

SEM model estimation and model fit statistics

- The SEM model is estimated by the SAS CALIS procedure
- The model estimation process is guided by a two-step estimation procedure (Kline, 2005)
- First step: identifying an acceptable measurement model based on a conceptual relationship
- Second step: improving the acceptable model at the first step by fitting some alternative models with different structures and association assumptions
- Our endogenous variable (size of a person's activity space) indicates a moderate non-normality. After a log-transformation, it follows a normal distribution.
- *Model fit statistics:* χ^2 statistic is not robust. Several model-fit statistics are needed.

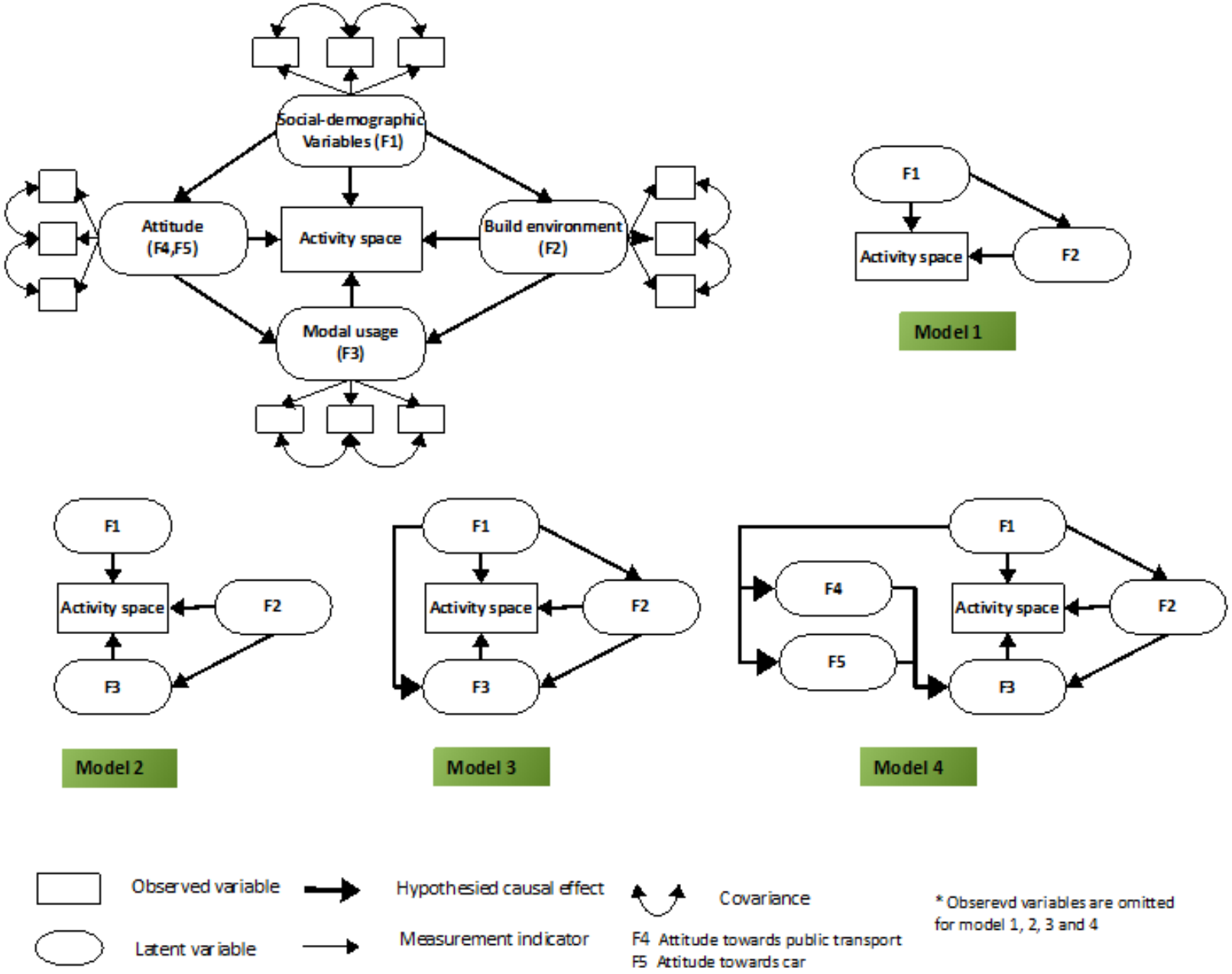


Fig. 1. Structural relations among exogenous, endogenous variables and a person's activity space

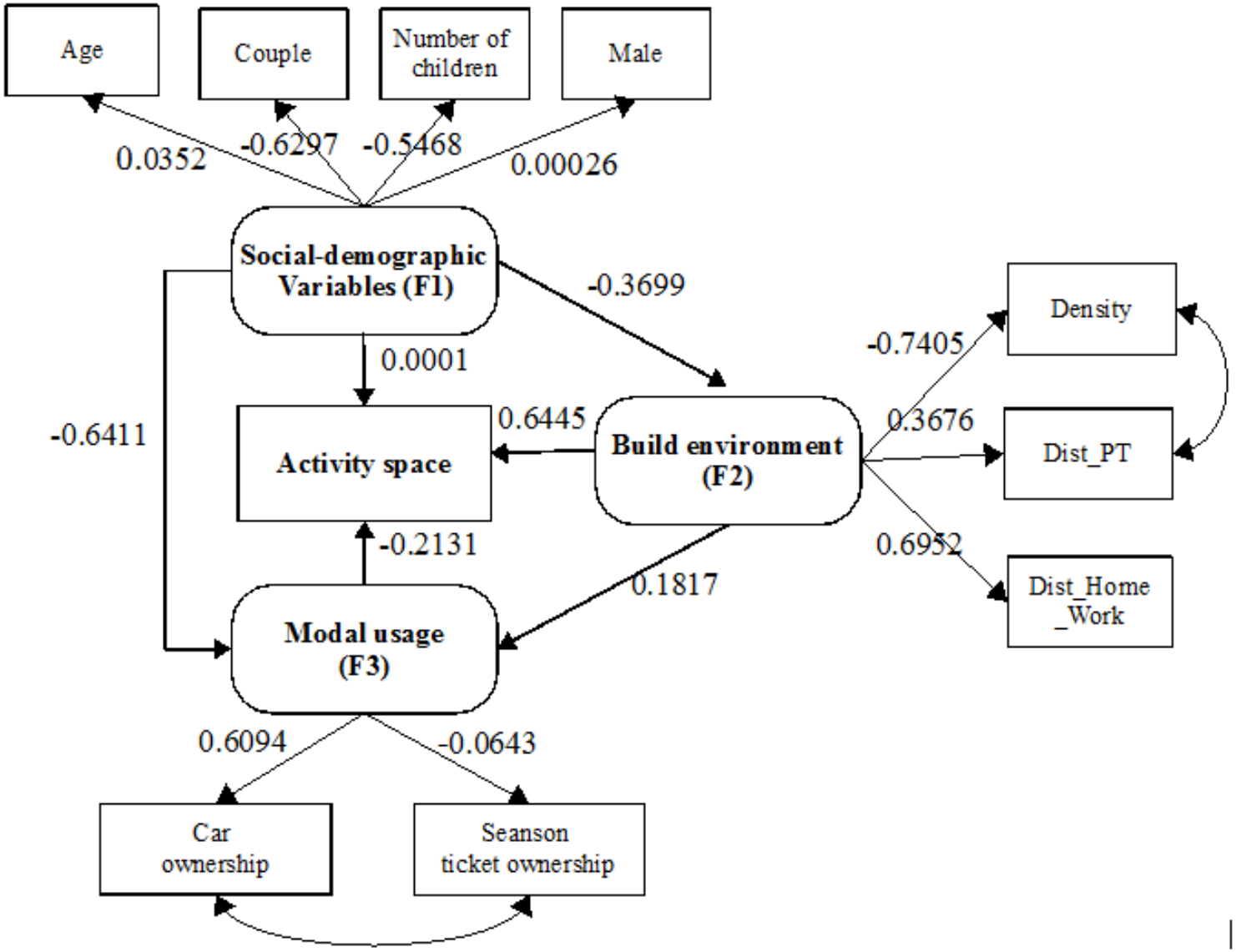
Model fit statistics and the criteria for goodness-of-fit

Table 2 Model fit statistics and the criteria for goodness-of-fit

Model-fit statistics	Critical value of goodness-of-fit[1]	Model 1	Model 2	**Model 3**	Model 4
N		388	388	**388**	388
Df		31	28	**28**	219
χ^2	Better fit for smaller values	97.451	88.941	**71.392**	588.488
χ^2 /df	<=3.0	3.14	3.176	**2.549**	2.68716
Pr > Chi-Square	<=0.05	<.0001	<.0001	**<.0001**	<.0001
Jöreskog-Sörbom Goodness of Fit Index (GFI)	>=0.95	0.9535	0.9569	**0.9656**	0.8796
RMSEA (root mean square error of approximation)	<=0.06	0.0774	0.0750	**0.0633**	0.0660
Standardized root mean square residual (SRMR)	<=0.09	0.0766	0.0626	**0.0494**	0.0789

Remark: the critical values of goodness-of-fit statistics are drawn from Lei and Wu (2007), Kline (2005) and Iacobucci (2010).

Estimation results (1)



Estimation results (2)

Table 4 Direct, indirect and total effects of latent factors on the size of activity space

Latent variable	Direct effect	Indirect effect	Total effect
Socio-demographic variables (F1)	0.000099	F1 → F2 → AS = -0.2384 F1 → F3 → AS = 0.1366 F1 → F2 → F3 → AS = 0.0143	-0.0874
Built environment (F2)	0.6445	F2 → F3 → AS = -0.0387	0.6058
Modal usage (F3)	-0.2131		-0.2313

Remark: 1.AS means activity space; 2. An indirect effect is computed as the multiplication of path coefficients. For example, F1 → F2 → AS = -0.3699*0.6445 = -0.2384; 3. Total effect is the summation of the direct and indirect effects on AS.

Estimation results (3)

- Coefficients in the measurement model as well as those in the path model are explained as regression coefficients on its dependent variable
- A square multiple correlation (R^2) represents the percentage of variance explained by a predictor (covariate)
- For socio-demographic measurements (F1), couple and number of children in the household are two main determinants of the socio-demographic latent variable (F1)
- For the latent variable of build environment (F2), home-work distance and population density are two main determinants
- For the latent variable of modal usage (F3), car ownership is the main determinant

Conclusion and future extensions

- The SEM approach provides a flexible framework to investigate direct and indirect effects of the covariates on the activity space of individuals
- The results suggest that build environment related to home-work distance and population density of household location is most relevant determinants of the size of the activity space when a person's workplace is controlled.
- The socio-demographic characteristics have relatively low effects on the size of activity space
- Possible directions for future analysis include the incorporation of :

  -Measurements related to the modal usage of a person's activity space and/or a relevant accessibility measurement.

Reference

Ma, T-Y, Gerber P, Carpentier S, Klien S. (2014) Geographic, socio-cultural and modal usage determinants of activity space: a case study of EU Institutions in Luxembourg and Strasbourg. *Transportation Research Procedia,* 3, 109-118

Thank you for your attention

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