mobil.TUM2024
Thursday, April 11 2024: Session G1: Reducing Car Usage

Generating car dependence

Exploration of factors from a multidimensional perspective in Lombardy, Italy

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POLITECNICO MILANO 1863 | DIPARTIMENTO DI ARCHITETTURA E STUDI URBANI

European Commission

The present work has been carried out in the framework of the Collaborative Doctoral Partnership Agreement No. 35455 between the European Commission Joint Research Centre and Politecnico di Milano.

Car Dependence?

(still an open question…)

combination of personal and contextual factors that prioritise car-based mobility over alternative transport and access options.

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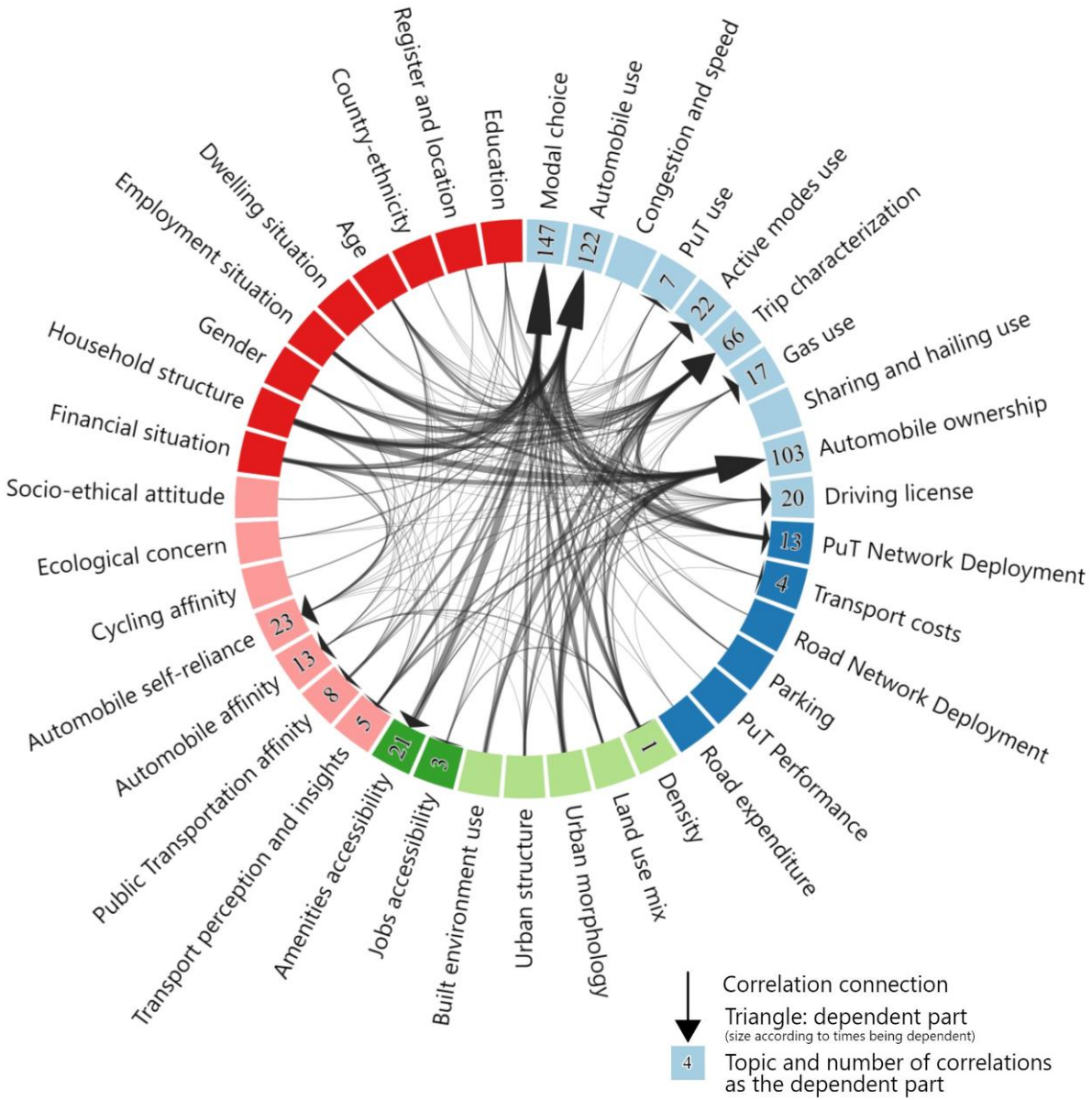
Goal: to assess CD

Generated with AI (Bing Copilot)

Literature review ▶▶▶ CD dimensions



Car dependence sources

- Transport Supply
- Accessibility
- Land use and form
- Sociodemographic factors

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Car dependence effects

- Transport demand
- Opinions and experiences

Lombardy Case Study

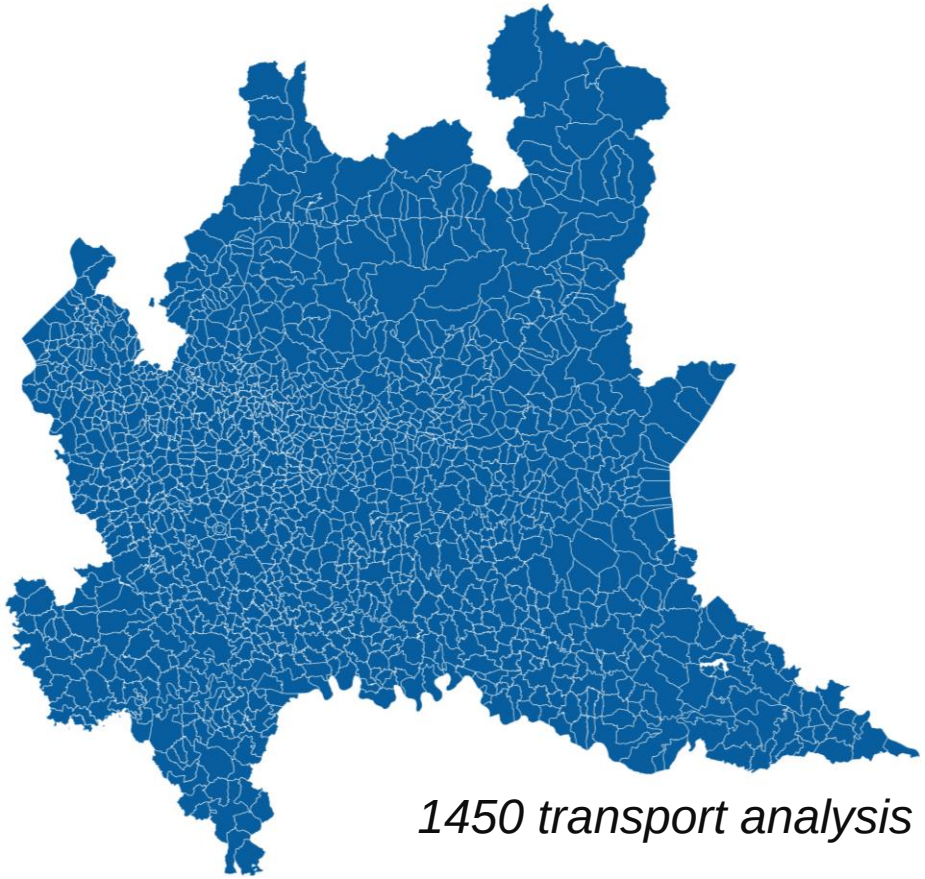
- Main Italian region by size and population
- Different contexts and spatial settings: **hetereogenity**
- 64,5% car modal share, 624 cars / 1000 inhabs

0 50 100 km

Source: ESRI World Imaginery

car dependence regional dataset

- Based on the regional OD survey structure
- Covering dimensions from different sources
- Method: SQL (PostgreSQL), QGIS.



1450 transport analysis zones

Quantifying every feasible and potential element relatet to our context's car dependence…

CD sources

173 variables

CD effects

313 variables

Complexity
Applicability
Synthesis?

1. Which sources of car dependence are more crucial to explain their effects?

2. Which are the more car-dependent contexts within the regional setting?

Methodology

PEARSON CORRELATION MATRIX

Least correlated source variables combinations

SENSITIVITY ANALYSIS (SA)

- Dimensionality **reduction**
- Identification of **main inputs** governing the model outcome
  many sources → Effect

– but… –

SA assumes
independent inputs

Main CD source variables

Background source: AI-generated image with Copilot

dataset management

CD effects

dataset filtering

9 main variables selected, representative of diverse indicators related to CD in literature

1. Commuting average distance
2. Private motorized trips average distance
3. Non-commuting average distance
4. Motorisation rate
5. Commuting, private motorized modal share
6. Non commuting, private motorized modal share
7. Self-containment index (workers at home TAZ)
8. Drivers rate
9. First-license average age

CD sources

dataset sorting

173 main variables grouped into 23 topics

each topic has multiple variable subsets, resulting in different **variables combinations** to be modelled (*up to 3 millions*)

1. Public transport service
2. Railway accessibility
3. Road density
4. Highway distance
5. Cycling infra density
6. Cycling quality
7. Urban compactness (m2 constructed/m2 urbanized)
8. Urban density
9. Population at 1.5km radius
10. Urbnz. surf. at 1.5km r
11. Built surface at 1.5km r
12. Land use mix
13. Residential type mix
14. Dense residential share
15. Sprawl Index measures
16. Services accessibility
17. Children rate
18. Elderly rate
19. Foreigners rate
20. Employment rate
21. Average age
22. Household size
23. Income

Pearson correlation matrix

- Over the 3 million options, selection of **least correlated combinations:**

Lower average variables correlation index

Higher number of significant (99%) correlated var couples

Lower sum of average subset correlation index

Lower product of average subset correlation index

+ 1 additional informed combination (for calibration)

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to be assessed on **Global Sensitivity Analysis**

5 source variables combinations x 9 effect variables: **45 SA models**

Sensitivity Analysis

theory

variance

- **decomposed** into partial variances
- Normalizing, then "**Sobol indices**"
- **Importance of each variable**? ST_{i_1} $[0, 1]$

contribution of indep var i_1 to y

mutual contribution of indep vars i_1 and i_2 to y

$$V_y = \sum_{i_1=1}^{N_i} V_{i_1} + \sum_{i_2>i_1}^{N_i} V_{i_1 i_2} + \cdots + V_{1\ldots N_i}$$

$/V_y$

$$1 = \sum_{i_1=1}^{N_i} S_{i_1} + \sum_{i_2>i_1}^{N_i} S_{i_1 i_2} + \cdots + S_{1\ldots N_i}$$

$$ST_{i_1} = S_{i_1} + \sum_{i_2 \neq i_1}^{N_i} S_{i_1 i_2} + \sum_{i_3 \neq i_1, i_2}^{N_i} S_{i_1 i_2 i_3} + \cdots + S_{1\ldots N_i}$$

model quality

- V_y: Variance from dataset
- V_y^{PCE}: Variance from decomposed orthogonal set
  (PCE: Polynomial Chaos Expansion)
- $\varepsilon_{training}$: amount of variance unexplained

should have same order to be reliable

VOR
(variance order ratio)
V_y/V_y^{PCE}

Sensitivity Analysis

results

model acceptance

Condition: Variances must have same order → $VOR_m \in (0.5 , 5)$

Var Subset \ \CD Effect Var [ε_m]	1	2	3	4	5	6	7	8	9
Low avg. var CorrInd	0.51	~~0.66~~	~~0.76~~	0.67	0.39	0.56	0.58	0.32	0.36
Sign. non corr vars	0.52	0.58	0.54	~~0.68~~	~~0.38~~	0.55	0.55	0.36	0.39
Lower sum avg	0.48	0.48	0.44	~~0.69~~	0.37	~~0.57~~	~~0.57~~	0.32	0.37
Lower product avg	0.52	0.51	0.54	~~0.71~~	~~0.40~~	~~0.58~~	0.53	0.32	0.37
Informed comb	0.62	0.50	~~0.56~~	~~0.68~~	~~0.40~~	~~0.60~~	0.51	0.35	0.41

31/45 models accepted for consideration

weighted variables comparison

Each source variable (i) obtains an overall score (SC_i) acording to its ST_i values and the model (m) unexplained variance (ε_m)

$$SM_{i,m} = ST_{i,m} \cdot \frac{1 - \varepsilon_m}{\varepsilon_m}$$

Variables with highest complessive score (SC_i) are selected as **main source variables**:

$$SC_i = \sum_m SM_{i,m}$$

SA & Principal Component Analysis

results

selecting vars with $SC_i > 1$

Variable	Description	SC_i
pop_around	Population sum on grid 500 m cell and the eight adjacent cells *	5.50
forgn_rate	Rate of foreigners per inhabitants	4.76
elder_rate	Rate of over 65 y.o. people per inhabitants	3.61
ucsr_all	Constructed to urbanized surface ratio, measured at whole transport zone	3.21
altri_all	Number of weekly available non-metropolitan bus trips at 550m distance *	3.08
builtsurfs_around	Built surface sum on grid 500 m cell and the eight adjacent cells *	2.73
tlurb_around	Urbanized surface sum on grid 500 m cell and the eight adjacent cells *	2.52
atm_all	Number of weekly available metropolitan bus, tram and metro trips at 550m distance *	2.35
perc_o4pc_av	Length percentage of cycling routes (connecting to other towns at a 6km radius) with more than 4% slopes	2.21
avg_hh_size	Average quantity of people per household	1.47
hwdist_avgpop	Distance to closest motorway access	1.40
emplo_rate	Rate of employed people per inhabitants	1.26
log_cir_1500_2000	Log Circuicity of points at 1.5-2km: ratio between straight line and network distance	1.13
trips_all	Number of every weekly available public transport trip (including also railway) at 550m distance *	1.12

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14 main variables selected

Main CD source variables

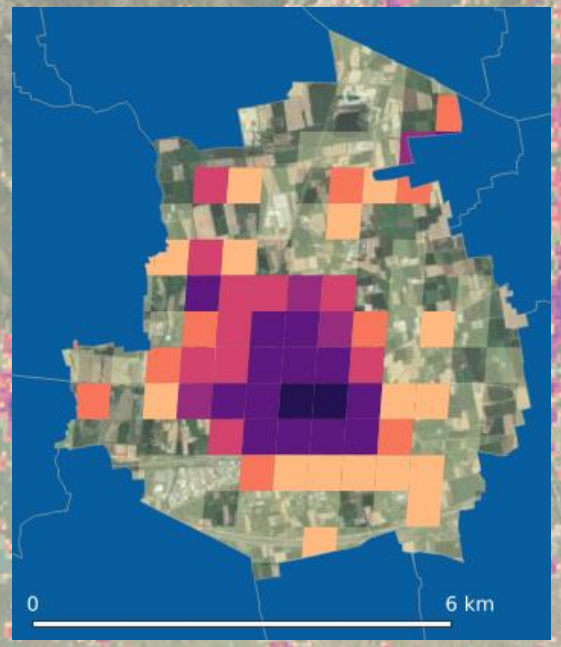
Dimension	
Land use and form	• **Population sum around** (grid 500m cell plus eight adjacent cells) • **Compactness**: Constructed to urbanized surface ratio, measured at whole transport zone • **Built surface sum around** (grid 500m cell plus eight adjacent cells) • **Urbanized surface around** (grid 500m cell plus eight adjacent cells) • **1.5-2km Circuicity** (Ratio between straight line and network distance)
Transport Supply	• Number of weekly available **non-metropolitan bus trips** at 550m distance • Number of weekly available **metropolitan bus, tram and metro trips** at 550m distance • Length ratio of cycling routes (to other towns at a 6km radius) with **more than 4% slopes** • Distance to **closest motorway access**
Socio-demographic factors	• **Foreigners** rate • **Over-65** rate • Average **household** members quantity • **Employed** population rate

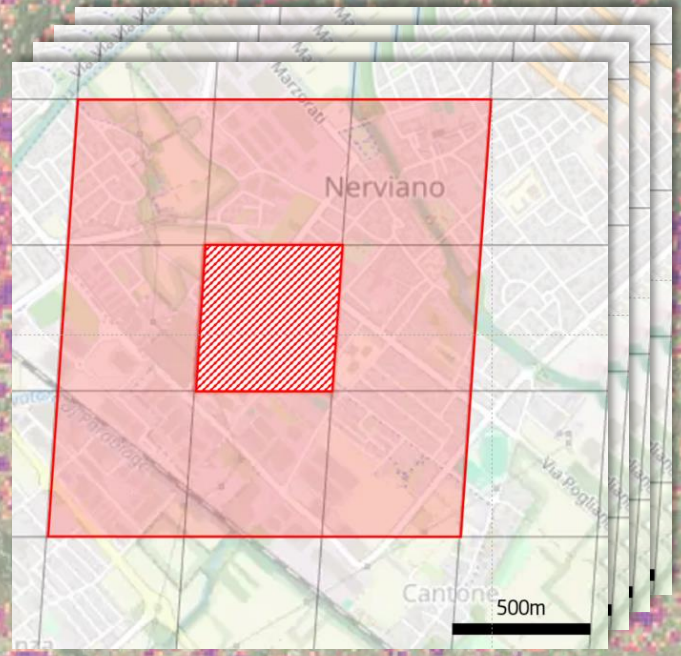
- Accessibility, residential typology outperformed? Multicolinear?

Background source: AI-generated image with Copilot

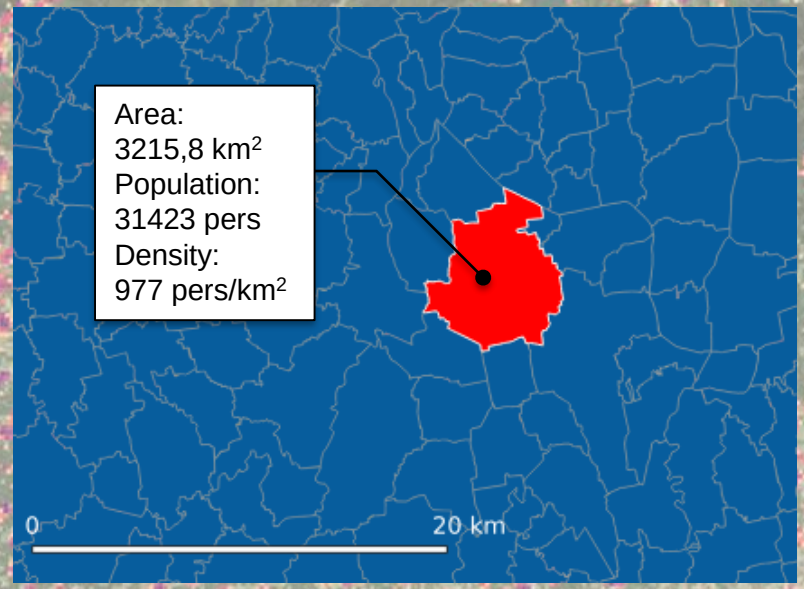
- What about **density**?

Weighted proximity scale…





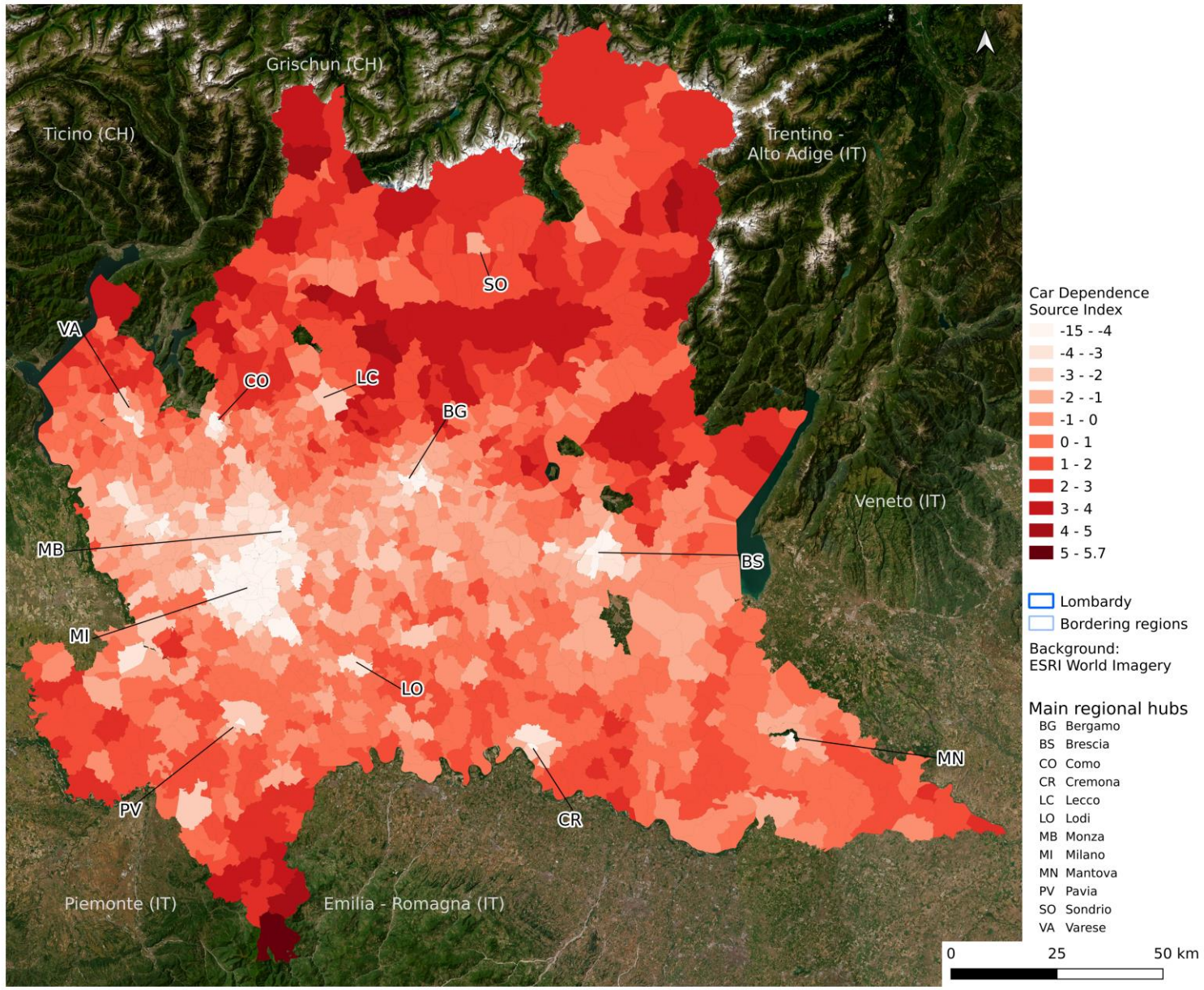
…over full-aggregation?



$$PopAround_k = \sum_c \left(PopAround_{c,k} * \frac{Pop_{c,k}}{\sum_c Pop_{c,k}} \right)$$

Background source: AI-generated image with Copilot

car dependence composite index



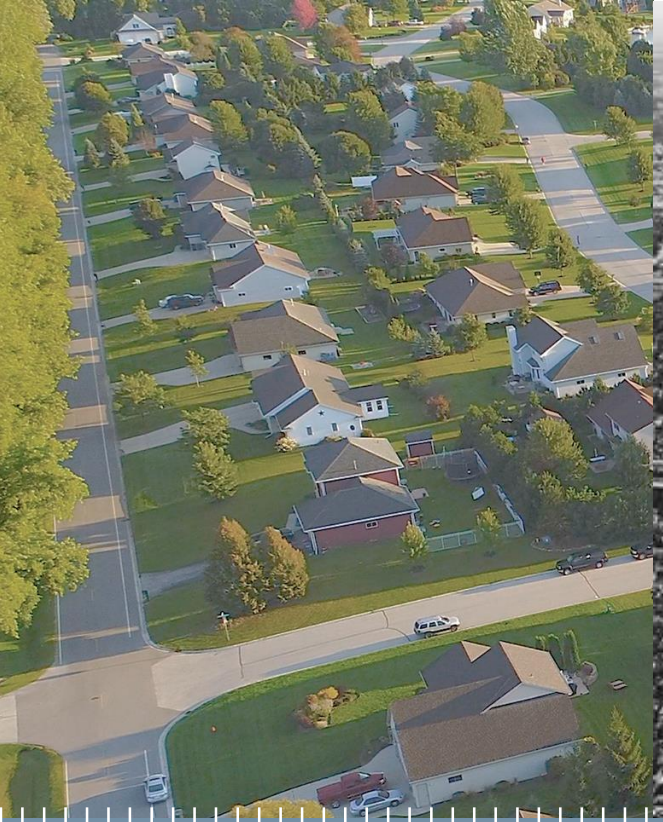
Variable	pop_around	builtsurfs_around	tlurb_around	trips_all	atm_all	forgn_rate	altri_all
PCA coef.	**-0.43**	**-0.42**	**-0.40**	-0.35	-0.27	-0.23	-0.22

Variable	Emplo_rate	avg_hh_size	ucsr_all	log_cir_1500_2000	Elder_rate	perc_o4pc_av	hwdist_avgpop
PCA coef.	-0.16	0.00	0.04	0.10	0.14	0.24	0.26

- Main cities, as expected, have less car-dependent sources, contrary to more remote places
- Still, some extent of variability appears within suburban areas
- The index can be a source for more place-based research and action, highlighting relevant CD hotspots.

Conclusions

- The process not only highlights main variables, but also more efficient ways of assessing some topics
- Land use and form and transport supply are main drivers of *measurable* car dependence.
- Cautions: the unexplained variance is not negligible (SA: 32%-67%).
- So what's not explained? More attention to *qualitative* CD: practises, attitudes. How to integrate it into this framework?



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Speaker: Jaime SIERRA MUÑOZ | jaime.sierra@polimi.it

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SA & Principal Component Analysis

results

Variable	SC_i	Variable	SC_i	Variable	SC_i
pop_around	5.50	rmedhholds	0.37	perc_roads_av	0.03
forgn_rate	4.76	all_2	0.30	cdist_at8	0.03
elder_rate	3.61	net_all	0.28	frc_noncycle	0.03
ucsr_all	3.21	sumtpu_altriatm	0.24	log_cir_2000_2500	0.02
altri_all	3.08	frc_noncycle_l	0.23	cdist_at11	0.02
builtsurfs_around	2.73	statdist	0.20	log_cir_500_1000	0.02
tlurb_around	2.52	all_3	0.20	cyclquality	0.01
atm_all	2.35	all_1	0.19	sumsc_acc	0.01
perc_o4pc_av	2.21	ReTy_Mix	0.19	cdist_at6	0.01
avg_hh_size	1.47	all_0	0.18	trenord_all	0.00
hwdist_avgpop	1.40	ucsr_urb	0.14	all_4	0.00
emplo_rate	1.26	LUM_ULAll	0.14	all_6	0.00
log_cir_1500_2000	1.13	cdist_at3	0.12	rdens_tazall	0.00
trips_all	1.12	log_cir_2500_3000	0.09	taz_cycledens	0.00
hhover2px	0.69	sndi_rem	0.09	popavg_grid_cycledens	0.00
child_rate	0.62	cycldetour_f_av	0.09	popavg_road_cycledens	0.00
rdens_bturb	0.55	trainscore_tazavgpop	0.08	taz_cycledens_urb	0.00
perc_densresid_resid	0.47	rdens_gridpopav	0.07	tazroad_cycledensurb	0.00
log_cir_1000_1500	0.44	LUM_ULUrb	0.07	numcycleroutes	0.00
dPOPBuiltS	0.44	cdist_at10	0.06	perc_cyclelane_av	0.00
elev_perc_av	0.41	tazroad_cycledens	0.05	perc_street_av	0.00
avg_age	0.39	rmedcont	0.05	dPOPTAZ	0.00