Prediction of AADT on a nationwide network based on an accessibility-weighted centrality measure

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1 Introduction - Objective

Many studies in the field of transport modelling have dealt with the issue of annual average daily traffic (AADT) prediction, developing different methodologies to tackle the problem. In general, two main streams of literature can be found:

- exploiting different modelling techniques varying from aspatial regression to spatial models
- testing the construction and the inclusion of more variables describing the demand patterns in the model

However, the vast majority is tailored to **small, or medium, scale analysis levels**, and they serve mainly the purpose of interpolation, making them **not appropriate for prediction and forecasting** purposes.

The **objective** of the current research is to develop a **direct demand modelling approach** for prediction of AADT on a nationwide network. The particularity of the nationwide statistical models stems from their inherent **incapability** to capture the **interregional demand patterns** that occur on the links.

2 Methodology

We utilize and expand a graph theoretical concept to align with travel demand modelling requirements. A new variable called **accessibility-weighted centrality measure** is constructed by associating the **network structure** with the **travel accessibility** concept.

Stress centrality index is defined as the number of shortest paths connecting all pairs of nodes of the network that pass through a link.

$$Stress\ centrality_e = \sum_{i,j \in V} \sigma_{ij}(e) \quad (1)$$

Where e is any link of the network, V the set of all nodes, σ_{ij} the shortest path from node i to node j, and $\sigma_{ij}(e)$ is equal to one if the link e is part of the shortest path connecting i and j nodes.

A set of **modifications** is required since

- nodes **produce and attract** different number of trips
- **interaction** between nodes **diminishes** by distance

$$Accessibility-weighted\ centrality_e = \sum_{i,j \in V} \sigma_{ij}(e) \quad (2)$$

$$\sigma_{ij}(e) = \sum_{i,j \in V} Popul_i \frac{Employm_j * \frac{f(cost_{ij}^{car})}{f(cost_{ij}^{car}) + f(cost_{ij}^{PuT})}}{Travel\ Accessibility_i} \quad (3)$$

$$Travel\ Accessibility_i = \sum_i^j Employm_j * max\{f(cost_{ij}^{car}), f(cost_{ij}^{PuT})\} \quad (4)$$

$$f(cost_{ij}^{mode}) = \begin{cases} e^{-0.018 * cost_{ij}^{1.52}}; car \\ e^{-0.004 * cost_{ij}^{1.47}}; PuT \end{cases} \quad (5)$$

In addition to the already tested models in the literature, the family of **spatial simultaneous autoregressive (SAR) models** is tested and its out-of-sample predictive accuracy is assessed. A comparison with the output of a traditional 4-step model (Swiss national model) is conducted to highlight the strengths and weaknesses of the other models.

- Spatial error model: $Y = \beta X + u$ (6) with $u = \lambda W u + \varepsilon$

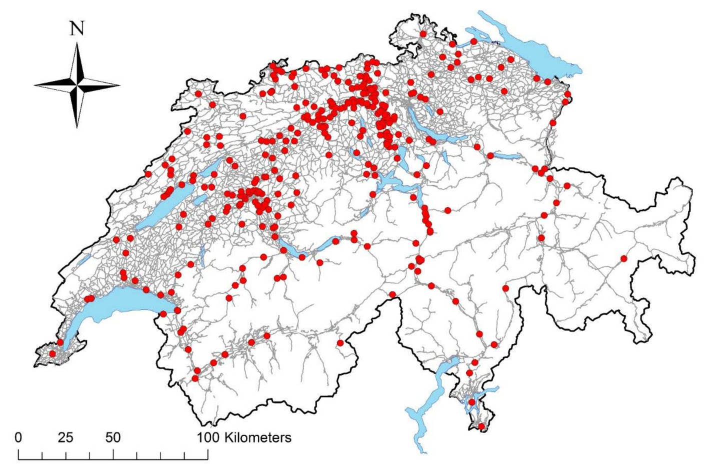
where λ is the spatial autoregressive coefficient and W an adjacency matrix

- Spatial lag model: $Y = \rho W Y + \beta X + \varepsilon$ (7)

where ρ is the spatial autocorrelation parameter, and WY is the term for the lagged variable

3 Case study

Swiss national network including 416 AADT observation for year 2010



- AADT values are Box-Cox transformed (Box-Cox parameter=0.1812)
- A municipal zonal system is employed
- Spatial neighbourhood definition and extent is tested thoroughly (W)

4 Results and conclusions

Model results (full-sample)

	OLS		OLS acc. weighted centr.		Spatial Error Model	
Dependent variable: AADT (box-cox)	**Estimate**	**Sign.**	**Estimate**	**Sign.**	**Estimate**	**Sign.**
Intercept	21.21	***	16.27	***	16.03	***
Major road	-7.20	***	-4.59	***	-3.90	***
Rural major road	-8.42	***	-5.55	***	-5.04	***
Urban main road	-7.84	***	-4.46	***	-4.09	***
Three-lane road; dummy	3.56	***	2.00	***	1.90	***
Freeway with one lane; dummy	-3.90	***	-2.54	***	-2.05	***
ln Population dens.: R=10 km	-		1.22	***	1.11	***
ln Population dens.: R=20 km	1.22	***				
ln Public transp. density: 5km	0.86	***	0.31	**	0.33	**
Acc.weighted centrality (Box-Cox)	-		0.22	***	0.26	***
Acc.weighted centr./ Stress centr. (Box-Cox)	-		-8.09	***	-9.55	***
lambda	-		-		0.49	***
# of obs.	416					
adj. R-squared	0.833		0.87			-
AIC	1902		1803		1765	
Moran's I measure	0.09	***	0.17	***	0	
Signif. codes: 0 '***' 1%'**' 5% '*' 10%						

Out-of-sample predictive accuracy (20% validation set; 100 replications)

Model	MdAPE	MPE	MAPE	MSE
National model (4-step)	4.95	3.54	14.4	3.57E+06
Universal Kriging: Gaussian variogram	21.97	11.61	35.07	2.85E+07
Geographically Weighted Regression	23.22	8.06	34.3	3.28E+07
Sp. error: Netw. distance	23.91	13.24	37.35	3.35E+07
OLS acc.-weighted centr.	24.14	12.28	36.96	3.41E+07
Sp. lag Netw. distance	23.91	12.47	37.04	3.46E+07
OLS	27.55	15.9	43.31	4.61E+07
Negative binomial	27.14	23.52	44.69	6.67E+07

MdAPE=median absolute percent error, MPE=mean percent error,
MAPE=mean absolute percent error, MSE=mean squared error

Conclusions

- The newly-constructed variable enhances substantially the goodness-of-fit and the predictive accuracy of models
- SAR models yield slightly worse results than the remaining spatial models (GWR and kriging) but their coefficients estimates are **unbiased and consistent**, which is important for **prediction and forecasting** purposes
- Overall, statistical models constitute a **trustworthy alternative**, given their **simplicity** and **low-associated efforts**, and they can provide **valuable insights**
- 4-step model **outperforms** the rest considerably. However it is much more **data- and effort-intensive**. Also, it has been calibrated against the AADT values

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