Promoting active mobility: Evidence-based decision-making using statistical models

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Abstract

Shifting traffic to active transport modes (eg. walking/cycling) poses one of the most promising ways of tackling the persisting challenges that arise from motorized traffic. However, planning and policy making in walking and cycling domains is frequently impeded by a small-scaled and heterogeneous political landscape that rarely acts based on evidence thus limiting cost-effectiveness and target achievement. This paper proposes a largely data-driven planning approach that builds upon aggregated statistical models explaining walking and cycling modal shares. In addition to investigating a comprehensive set of influencing factors in relevant fields such as environment, climate, infrastructure or demographics, we bring attention to the role of political and administrative commitment in aggregated modal share modeling. Results suggest that our holistic approach is feasible both methodologically and in terms of its applicability in planning practice. As a first step towards evidence-based decision making the incremental effects of individual planning measures can be simulated and thus be used to rank options according to their effectiveness. Another outcome lies in the data-driven identification of spatial target areas for specific agenda setting in terms of awareness, mobility behavior, infrastructure, settlement structure and other planning-relevant domains.

Keywords: active mobility; walking/cycling determinants; political commitment to set actions; statistical modeling; GIS; regional policies; transport policy; transport planning; evidence-based planning; settlement structure; accessibility; social milieus; operationalization.

Disclaimer: This paper combines the work presented at REAL CORP Conference 2017 (see Hackl et al. 2017) and the content submitted to Transport Research Arena 2018 (see Hackl et al. 2018). It extends the previous work through additional analyses on political and administrative commitment and provides a combined presentation of both pedestrian and cycling statistical models.

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1. Introduction

1.1. Active mobility planning in Austria – a story of great plans and small steps

Since the beginning of mass motorization, the growing shares in motorized traffic pose a serious challenge in Austrian as well as international transport planning. Problems that arise from the negative external effects generated along the development path of today's transport system (Merki 2008) present themselves as air-, noise and other environmental pollution, negative health effects and high accident rates as well as specific urban challenges pertaining to a lack of space (Perschon 2012). The numerous downsides of motorized traffic have been often discussed, see Buchwald and et al. (1993), Banister (2008), Knoflacher (2013) or Cervero (2013) and highlight the importance of a change in transport planning paradigms.

In contrast to ongoing motorization, the international focus of traffic planning has gradually shifted towards active modes which are often labelled as a sustainable basis for modern transport systems (see Vandenbulcke et al. 2008; Rietveld and Daniel 2004; Lovelace et al. 2017). They feature a set of desirable ecological (resource neutrality, zero-emission, downsize of land consumption), economical (reflecting an indirect net product for Austria of up to 882.5 Mio.€, equivalent to 18.328 full-time jobs) (BMLFUW 2009) and socially (positive impact on health) sustainable properties (Meschik and Traub 2008).

In quantitative terms the current challenges for the Austrian transport system regarding mode-choice become apparent when looking at the recent mobility surveys. Comparing 2013/2014 'Österreich Unterwegs' (BMVIT 2016) total shares in motorized traffic with the preceding survey in 1995 reveals that private car shares (as a driver and co-driver) increased by 6.6% during this 19 year period. This amounts to 57.1% of total motorized traffic in 2013/2014 whereas pedestrian traffic shares dropped substantially from 26.9% to 17.4%. Cycling, featuring the lowest shares with 5.3% and 6.5%, more or less stagnated[1].

In order to mitigate the above negative external effects a number of policy papers with respect to active travel have been drafted in Austria. In general it can be stated that on both national and federal levels there is a policy emphasis on cycling traffic. The masterplans for cycling (BMLFUW 2011; BMLFUW 2015b) aim at increasing bicycle shares to 10% in 2015 and 13% until 2025. In contrast to the quantitative goals in cycling, the current pedestrian masterplan (BMLFUW 2015a) doesn't feature a target pedestrian share. Instead its focus lies on suggesting dedicated actions including the prioritization of pedestrian needs in newly planned settlements, better infrastructure, awareness raising, coordination between planning and administrative bodies, monitoring of modal shares, safety measures and in-depth mobility research. A recent momentum regarding political commitment to walking originates from the international Charter for walking (walk21 2017). However, the strategic documents on national and federal levels don't bear legal obligations for local planning agencies to actually enhance walking or cycling quality. While it is popular amongst local decision makers to commit themselves to the improvement of walkability in cities and villages, there is yet no quantitative evidence that this commitment actually results in increased pedestrian shares (rather, pedestrian share dropped significantly in the last two decades). Nonetheless some federal plans set even higher goals such as increasing active modal shares to 40% by 2035 in Carinthia (Carinthian government 2016).

One of the key drivers of engaging in developing evidence-based planning approaches in this research project is a general lack of quantitative information on the effectiveness of different (infrastructure) measures in Austria. There is no systemically collected data that allows for determining the quantitative impact of planning measures on walking or cycling shares. Hence there are no hard and fast rules for identifying the most effective measures. This is a major drawback when it comes to agenda-setting and decision-making in active mobility planning, particularly under difficult general conditions (e.g. restricted budgets, conflicts of interest with other transport modes, etc.).

On top of that, the decentralized structure of the Austrian planning system somewhat impedes coordinated action and the implementation of the federal strategies and funding programs (see fig. 1). Since most of the legal competence for infrastructure planning is in the hands of the 2100 Austrian municipalities, high level masterplans cannot impose actions at municipality levels where responsibility to build infrastructure for active modes resides for the most part. Due to a fragmented local political landscape and the sheer number of decision making bodies, the political commitment and/or willingness to invest into active mobility measures can be characterized as rather heterogeneous. While there are generally accepted technical planning guidelines and recommendations (Meschik and Traub 2008) or the generic RVS guidelines for non-motorized traffic suggesting minimum technical standards they are not legally binding (FSV 2019). Hence it is difficult to identify an Austrian-wide political common sense relating to cycling and walking planning.

[1] For comparability those figures refer to workdays in autumn. The 2013/14 values for an average day of the week amount to 60.5% (motorized transport), 17.8% (walking) and 6,4% (cycling), respectively.

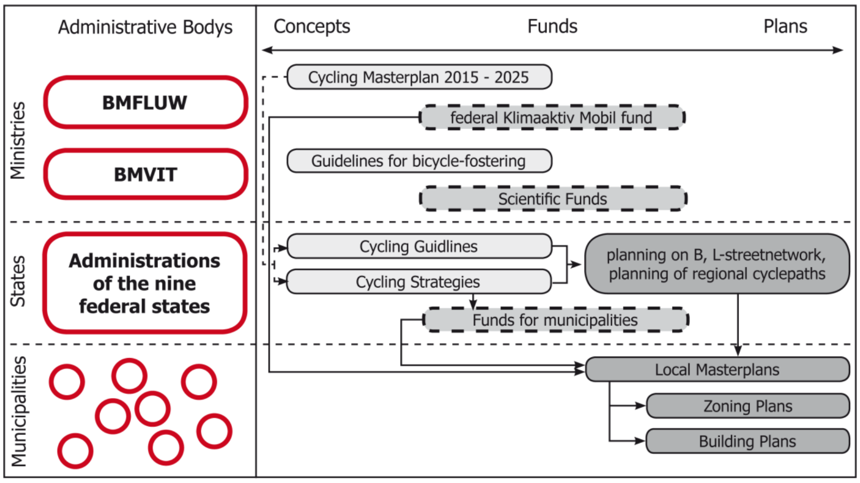

Fig. 1 Structure of the Austrian bicycle planning System (Raffler 2016)

Planners are confronted with increasingly difficult general conditions: to achieve the best outcome in terms of increasing pedestrian and cycling shares, i.e. modal shift effects while at the same time being quite limited financially. The main problem to be addressed is "that investments in cycling promotion are currently not always put into action where they may be most expedient, but there, where local political will is the highest" (Raffler et al. 2019) which is even more true for walking. This is exemplified looking at the federal state of Upper-Austria and comparing planning actions (measured as number of cycling projects funded by the Austrian federal ministry of environment – BMLFUW – *klimaaktiv* program) and respective cycling shares at municipality level: By looking at Figure 2 it becomes clear that current agenda setting and investment into cycling promoting measures does not reflect actual performance in terms of cycling shares. In addition to the different levels of political commitment, the weak relationship shows that the simple rationale of investing into any projects in order to boost non-motorized modal shares does not duly account for the complexity behind active mode choice and its driving forces.

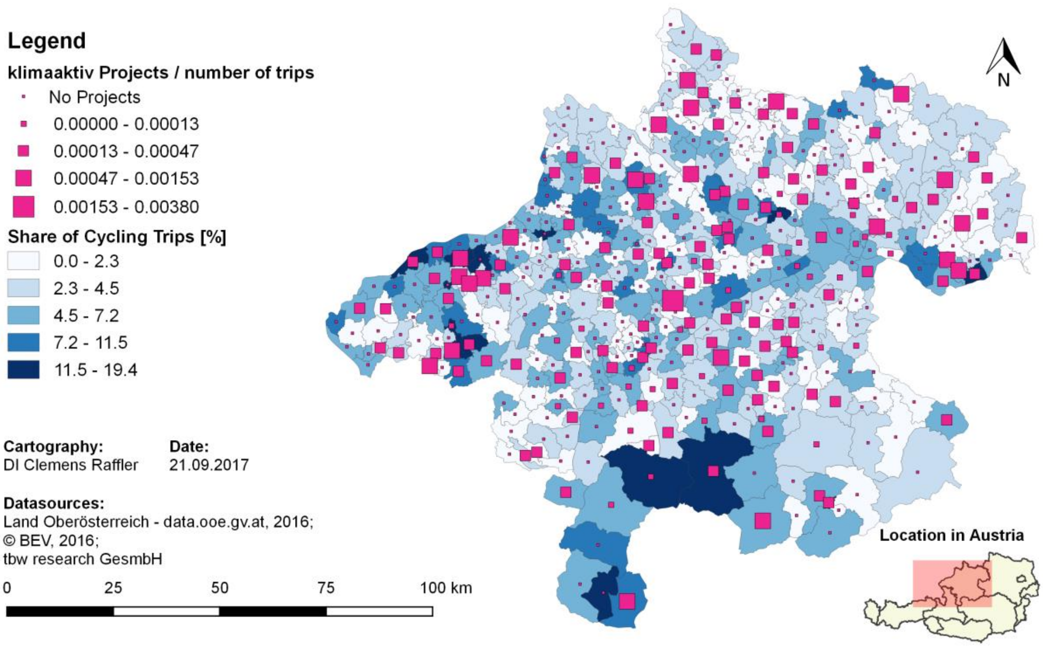

Fig. 2 Comparison between the number of number of klimaaktiv projects for the promotion of cycling shares

In a nutshell, a general lack of knowledge about cause and effect patterns between active modes and their drivers in the respective contexts of user groups and local settings is currently impeding agenda setting and planning actions aiming at creating a substantial modal shift towards active travel.

1.2. Research as evidence based-role models: Concepts, methods, findings and their application

International research on active mobility planning includes a broad spectrum of papers aiming at remedying the above planning problems by suggesting decision support to planners and political stakeholders. This builds upon the concept of evidence-based planning which represents the main rationale for planners and policy makers (Faludi 2006). This approach originates from Western-European planning culture (Davoudi 2006) and its influence can be found in papers from the UK and the Benelux-States (see Parkin et al. 2007b, Vandenbulcke et al. 2008, Rietveld and Daniel 2004). The paradigm is to better understand the factors that influence the respective mode-choice which then can be used as scientific evidence in the planning process. This is particularly true for research in the cycling domain and was best reflected by Heinen et al. (2010): *"In order to be able to develop sound policies that encourage cycling, it is essential to understand what determines bicycle use."* The main rationale behind investigating the determining factors of active travel is to reveal the relevant mechanisms planners may need to address in order to positively influence the development of active modal shares (Parkin et al. 2007b). Another key advantage of a solid evidence base on active mobility is that funding activities can be focused on where they will provide the biggest return in terms of modal split increases, hence tackling the problem of uncoordinated (or even ineffective) initiatives (Raffler et al. 2019).

When looking at latest research, a great number of hypotheses have been proven in order to assess the direction and influence of determinants on active modal choice. Those can be roughly categorized into three groups of influencing factors (Heinen et al. 2010):

1. *determinants that can directly be influenced by planners*: urban form, density, landuse mix and infrastructure for active mobility (infrastructure type such as on- or off road cycling infrastructure, existing infrastructure for motorized traffic and overall traffic organization)
2. *determinants that can indirectly be influenced by planners*: socioeconomic/sociodemographic mix in a city or neighborhood depicting age, gender and income structures, predominant social and environmental psychology such as social norms towards or against active mobility as well as social milieu mix which largely constitutes on basis of the former factors
3. *determinants that cannot be influenced by planners*: Those are mostly geographical preconditions such as climate, weather, topography which either limit or encourage walking and cycling (Raffler et al. 2019)

There have been intensive discussions on assumptions about the influence of compact and dense urban structures, its landuse mix (Pucher and Buehler 2006) as well as microscale design of urban form (Rybarczyk and Wu 2014). Although most research confirms the hypothesis that compact urban form (Saelens et al. 2003, Pucher and Buehler 2006, Parkin et al. 2007b) and a heterogeneous landuse mix (Cervero and Duncan 2003) encourages bicycle usage due to better accessibility and shorter trip length, there are also studies showing insignificant results regarding density (Cervero and Duncan 2003, Winters et al. 2007).
Another core topic discussed by transport researchers and traffic planners concerns the best type of infrastructure for active mobility, especially regarding the choice between different cycling infrastructures (off- on-road cycleways and cyclepaths) (Garrard et al. 2008, Akar and Clifton 2009, Winters and Teschke 2010, Caulfield et al. 2012). From a user perspective, infrastructure preferences vary among different groups of cyclists: For example, Garrard et al. (2008) showed empirically that off-road cycling infrastructure is preferred by female cyclists. Unlike for example Irish policy (Caulfield et al. 2012), Austrian cycling policy does not impose any legally binding regulations regarding the type of infrastructure (BMLFUW 2015b). Yet Austrian planning guidelines suggest using driving speeds and traffic volumes as parameters when deciding on cycling infrastructure type (FSV 2019). However, in in real world planning processes the discussion frequently doesn't revolve around the type of infrastructure but whether to build any cycling infrastructure at all.
International research on the influence of social and environmental behavior comprises small-scale detailed surveys on the relation between individual social background and attitudinal characteristics towards cycling (eg. Guell et al. 2012, Souza et al. 2014). Another set of studies uses quantitative data at a larger scale in order to investigate lifestyle types and their respective mobility behavior (van Acker 2015). In the Austrian context, the latter approach has been complemented by the concept of SINUS social milieus which originated form market research (Sinus Markt- und Sozialforschung GmbH 2019). As a theory-based construct, this approach clusters society into different milieus according to personal attributes, attitudes, personal aims and the rejection of certain goals in life (Dangschat et al. 2012). A German study investigated into the likelihood of riding a bicycle from the perspective of 10 social milieus in 2017 (Sinus Markt- und Sozialforschung GmbH 2017a): The results show that open-minded and financially well-off groups have a higher propensity to use the bicycle as traditional groups and/or financially weak social milieus. In addition to that, the individual drivers for bicycle use differ among groups. While open minded people use the bicycle for daily trips, the social milieu 'performers' cycle as outdoor and leisure activity. Summing up, datasets on social milieus pose a new and promising way of incorporating meaningful determinants for walking and cycling that previously have been neglected.

In contrast to cycling, papers on pedestrian traffic generally do not focus on planning support, rather they tend to have a health science perspective (eg. Leslie et al. 2005; Cerin et al. 2009; Verhoeven et al. 2016). Hence they do not explicitly propose results that are designed for the use in active planning processes; nevertheless they have an indirect implication for planning activities.

From a methodological point of view, influencing factors can generally be identified by performing simple, mono-causal correlational analyses (Leslie et al. 2005) or by setting up more sophisticated models using regression techniques. There are two main approaches (Aoun et al. 2015; Parkin et al. 2007a):

1. *Aggregated models* estimate walking or cycling modal shares from census or survey data at the administrative level of municipalities or origin-destination flows. Those models don't reflect individual behavior but investigate the impact of a local administrative area's properties (infrastructural, socioeconomic or social) on active mode shares. Most approaches achieve this by estimating the impact of the respective municipal configurations applying slightly adapted OLS regression techniques as shown by Rietveld and Daniel (2004) (2004), Parkin et al. (2007b), Vandenbulcke et al. (2008), Pucher and Buehler (2006) and Cerin et al. (2009). Due to the aggregated perspective, those models are sometimes used in strategic planning contexts. The models can then be used by planners and decision makers to assess the impact of certain planning actions by consulting the raw model equation.
2. The second approach comprises *disaggregate models* which reflects the probability of choice to participate in active mobility at the individual level. The individual's preferences to walk or cycle are obtained by the collection of data on stated- or revealed individual preference. For statistical modeling, mostly binary logistic regression approaches are used. The practical application of these models is to explore and identify individual properties (e.g. socioeconomic status) that influence active mode choice and therefore encourage bicycle promotion among specific groups. For examples, see Wardman et al. (2007) or Heinen et al. (2013).

1.3. Knowledge gaps and practical problems

Regarding national and international research, our literature review revealed that there still exist three major knowledge gaps relating to the application and extension of aggregated mode share models:

(1) As described above, a large amount of research focuses on decision support for bicycle planning and therefore narrowing the view on active mobility which naturally includes pedestrian traffic. Hence existing research should be extended beyond health science into transport research and planning in order to identify possible countermeasures remedying declining pedestrian shares based on solid evidence (see 1.1: drop of 9.5% in Austrian pedestrian shares between 1995 and 2013/14).

(2) General critique on active mode share modelling approaches focuses on the lacking representation of so-called 'soft' factors (in contrast to 'hard' factors, such as topography, infrastructure or accessibility). As Heinen et al. (2010) point out with regard to poorly reflected psychological factors (eg. personal attitudes towards active modes) we suggest to extend this critique to the omission of *political/administrative commitment* factors as those are frequently cited as being crucial for a successful promotion of non-motorized modes. This assumption is backed up by oral evidence sourced from local planning stakeholders – and therefore considered a relevant point of critique. Despite the efforts of preceding models to investigate into the effects of "policy" (Rietveld and Daniel 2004; Pucher and Buehler 2006) with the help of proxy-variables such as *gasoline prices per litre*, *cycling fatality rate* (Pucher and Buehler 2006), *parking costs*, *network speed* or *voter-proportion of certain political parties* (Rietveld, 2004), research on comprehensive proxy variables that reflect political will in a more realistic way is missing. While there is a great number research investigating British, Dutch, Belgian or American contexts of active travel, there are no such comprehensive models for Austria which potentially lowers the success rate of national planning activities. In addition to that we intend shedding new light on the discussion of social attitudes as an determinant of active mobility, as new datasets describing social milieus became available in Austria.

(3) Austrian national decision support approaches are currently somewhat limited both in their thematic and spatial views on active mobility as there exist only two approaches in federal states Vorarlberg and Tirol building upon accessibility analyses (Verracon GmbH 2016; Tyrolian Government 2014). Accessibility may be one of the most important determinants (largely reflecting neighbourhood form and settlement density) but it is safe to say that it doesn't amount to the only relevant factor of cycling and walking. Moreover, such mono-causal approaches may neglect other important (nested) co-influencing factors that need to be addressed by evidence-based policy-making. This issue calls for novel approaches aiming at supporting the national active mobility planning in a systematic and holistic manner. Precisely, there is a lack of scientific evidence to prioritize investments for walking and cycling at the municipal level. A first approach for investment prioritization has recently been presented for bicycle measures by Raffler et al.(2019): Built on the hypothesis that investment in cycling is most expedient in areas where cycling is least physically exhausting, a prioritization technique for investment into bicycle traffic based on regression residuals has been presented. However, the fact that this approach only considers the physical determinants

of cycling (hilliness and/or distance) constitutes a research gap in Austrian decision support. Put differently, mono-causal approaches need to be extended by including other determinants of active mobility.

1.4. Aim of this research: a deeper understanding of spatial variation of active travel

In face of the various challenges limiting success for active mobility planning in Austria (heterogeneous political commitment, lack of knowledge about cause and effect patterns, uncoordinated actions), this paper aims at providing the scientific basis in order to tackle some of these problems. At the same time we aim to shed light on the internationally existing knowledge gaps (lacking consideration of walking, measurement and inclusion of political/administrative commitment in aggregated mode choice models as well as their application in real-world planning).

We build a comprehensive aggregated modeling framework for active travel modes (one each for walking and cycling) with a spatial focus on Upper-Austrian municipalities. The models examine the cause and effect patterns behind the regional variation of active travel shares by investigating the quantitative links between active mobility and spatial, infrastructural and social influences. Based on a dedicated pool of hypotheses we devote special attention to the transparent operationalization of influencing factors including new variables reflecting local social milieus and political commitment to promote active mobility. As a complementary analysis we correlate the proxy variables on political commitment with an index on self-assessed local commitment (sourced from municipal administrations through an accompanying online-survey) in order to quantitatively assess the relationship between subjective and objective willingness to support active travel.

With this we aim at answering questions such as whether or not there are widely applicable generic concepts for increasing active modal shares or whether plans rather need to be custom-made for each municipality. In the latter case we aim at guiding planning by identifying the most promising fields of action and target population groups as well as estimating the potential effects of the planned measures in the respective contexts. Summing up, this paper aims at (1) providing the first holistic evidence-based approach to aid active-mobility planners in achieving the best outcome considering their somewhat limited budget, (2) contributing to the internationally scarce research on the determinants of walking and (3) shedding light on the operationalization and use of proxy variables operationalizing political commitment in aggregated models.

2. Data and Methods

2.1. Data

A crucial step predating the model building process is the choice and collection of appropriate data for the aggregate mode choice models. The current section describes the details behind data collection and refinement which includes the preparation of traffic survey data, conduction of a supplementary survey on self-evaluated importance of active modes by municipal representatives (eg. mayors, administrative staff) and acquisition of quantitative data describing influencing factors on active mode shares.

Traffic survey data:

In order to operationalize active modal shares at the local level of municipalities we first acquired data from the traffic survey of the state of Upper Austria which was conducted in October 2012 (Government of Upper Austria 2014). Although this decision narrows the spatial focus of our research through the exclusion of the other eight federal states from the analysis, Upper Austria is one of the few states that features nearly every element of the heterogeneous Austrian spatial structure (eg. alpine regions as well as rural forests, hills, urban and semi-urban zones) and provides a reasonable sample-size of municipalities. Also Upper Austria currently holds a unique position as it is the only Austrian federal state to provide complete data on modal shares on the municipality level.

Modal shares for a total N of 444 municipalities are based on person-specific trips (specified by mode and trip purpose): numbers of trips were projected and statistically weighted in order to correct for sample bias. Active mode shares were calculated as the respective proportions of walking and cycling trips and the total number of reported trips per municipality. In order to secure a sound 95% confidence interval of the modal shares, we excluded municipalities where the number of interviewed persons was less than 200. (see Table 1, filtered). Also, we used the unweighted number of reported trips to weight cases (municipalities) when calibrating the regression models so to give relatively more weight to more robust values in the outcome variable. Those actions do not harm the models' representativeness but rather remove modal share values based on a weak empirical foundation. Related issues pertaining to the confidence levels of the non-motorized modal shares impeded a further differentiation of the models in terms of trip-purposes. Though initially planned this would have asked for substantially larger sample sizes of the mobility survey and was therefore skipped. The descriptive statistics presented in table 1 show that Upper Austrian walking shares at the municipality level are considerably larger than cycling shares.

Table 1. Descriptive variables of the Upper-Austrian active mode shares by municipality

mode	model-type	N [municipalities]	mean [%]	min [%]	max [%]	SD [%]
walking	unfiltered	444	11.46	0.71	32.48	4.8
	filtered	338	12.21	3.32	32.48	4.83
cycling	unfiltered	444	3.55	0	21.4	2.70
	filtered	338	3.88	0.25	17.47	2.6

Walking and cycling shares range between 0.7% and 32% and 0% and 21%, respectively. They exhibit a substantial right skew resulting from a far from normal distribution[2]. Removing municipalities with less than 200 surveyed persons reduces N by 106 while slightly increasing the mean values for both modes. Also, some of the extreme values on the outer limits of the distribution have been excluded due to the filtering. Following the trend in the national travel survey, walking shares in Upper Austria are generally higher than cycling shares (no zero-share municipalities, higher maximum and mean values) but feature a similar statistical distribution.

Datasets on active travel determinants:
Alongside these traffic and survey data, numerous additional data sources have been tapped in order to form model covariates describing local spatial, infrastructural and socioeconomic properties. Datasets range from spatial information from the national Graph-Integration-Platform (GIP) and OpenStreetMap (OSM), digital elevation models and population density rasters, demographic and socioeconomic data by Statistics Austria as well as data on social milieus from INTEGRAL Markt- und Meinungsforschung. Weather and climate-related information was sourced from ZAMG (Zentralanstalt für Meteorologie und Geodynamik). Some data was directly obtained from the thriving Austrian OpenData initiative (data.gv.at) or representatives of the Upper Austrian state administration.

Supplementary survey on political will:
Pertaining to defining proxy variables reflecting political commitment towards active mobility within a model framework we conducted an online survey among Upper Austrian administration representatives on the municipal level. The survey aimed at collecting the local importance of bicycle traffic by self-assessing questions like 'How important is bicycle traffic for your municipality?', or 'Is there a dedicated budget for bicycle infrastructure?' following a simple grading system. Owing to the thematic focus of the Upper Austrian provincial government the survey had a focus on cycling. The collected data resemble an empirical picture of the perceived preconditions and self-assessed efforts related to actions to promote cycling. In order to increase the response rate the web link for participating in the survey was distributed by a well-known sender (Government of Upper Austria) to all 444 municipalities shortly after the *Summit for Cycling* event in Linz, Upper Austria. The relatively high response rate of 54 percent (242 cases) proves that this approach has been successful. However, it was not possible to directly include the survey results in the statistical models due to the missing municipalities.

2.2. Methods

Our research approach was guided by structuring the model building procedure in five major steps (see fig. 2). Driven by literature, we first (1) specified three groups of influences that are known to have an effect on non-motorized modal choice: *spatial, environmental and climate, infrastructural and demographic/socioeconomic (including commitment of the communal decision-makers)* influences, hence to manage and structure a potentially vast amount of covariates. In a second step (2), we formulated hypotheses on the expected impact direction and strength of theoretical indicators that could be assigned to one of the three factor groups. The third working step (3) was focused on the operationalization (data acquisition, geospatial and mathematical modelling, econometric techniques) of the variables that built upon the data sources in the previous section. Figure 3 lists the main highlights of the third working steps output variables. The fourth and last step of analysis (4) constituted the statistical inference process and the formulation of multivariate regression models to predict non-motorized modal shares as the outcome variable on the municipality scale.
While building the statistical models (see figure 3), we conducted a supplementary work-step (5) measuring the correlational relationship between the proxy variables reflecting political and administrative commitment and an affinity index (affinity to promote cycling) constructed from various items included in the above self-assessment

[2] The mean modal shares among Upper Austrian municipalities should not be mixed up with the overall Upper Austrian shares which amount to 14.6% for walking and 5.1% for cycling, respectively.

municipality survey. This was done in order to safeguard the relevance and adequacy of the selected proxy variables.
The following section gives a brief overview by determinant category over the 700+ variables that were gathered and computed. We will describe variables listed in figure 3 in more detail as those were built devoting advanced methodological attention in ways not yet presented by international research on active mode share modeling. The main tools that were applied in the variable-forming process include GIS (ArcGIS, QGIS and PostGIS) as well as the statistical software package SPSS for the data management, processing, testing and inferencing model formulations.

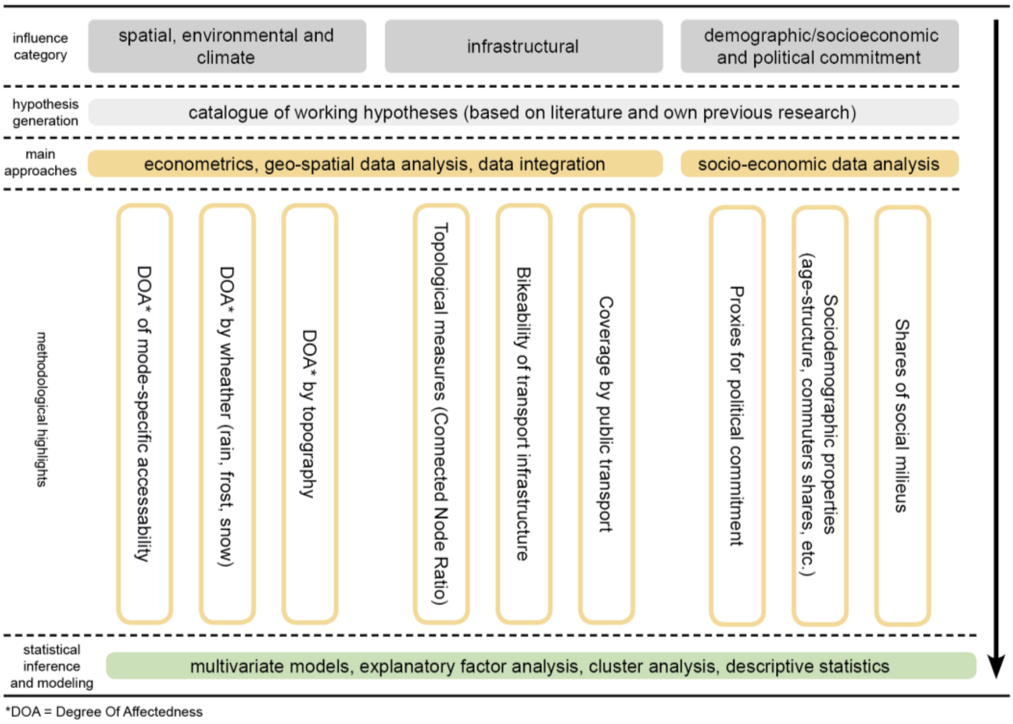

Fig. 3 Overview of model building workflow

Spatial and environmental determinants:
When looking at the variable configurations of existing research, spatial and environmental determinants have always been a core element when investigating active mode choice (eg. Parkin et al. 2007b; Vandenbulcke et al. 2008). This group of factors includes determinants that can be characterized as slow-changing factors: settlement structure and various ‘static’ environmental characteristics that cannot directly be influence by planners (relief, climate). Secondly, a broad set of accessibility indicators resembling determinants that can be (directly or indirectly) influenced by planning decisions:

(1) The calculation concept for the accessibility covariates follows an extended version of the *density-based intra-zonal and external distance estimation* approach by Kordi et al. (2012): Local/regional walking, cycling and driving distances and times from the cells of a 250m population density grid to different categories of trip destinations (e.g. health services, social infrastructure, shopping) were computed using network analysis. In order to obtain a single aggregated accessibility value per municipality we used the population of the origin raster for the calculation of a weighted mean of all possible route configurations in a municipality. The population density raster provides the necessary information for the calculation of a so called degree of affectedness (DOA) of municipal population by mode specific accessibilities (see fig. 2) and was also utilized for other environmental variables.

(2) The second focus of the accessibility analysis was the reflection of *mode specific characteristics of accessibility*. Our approach integrates attributes from different data sources (number of lanes, lane-speed, cycling-infrastructure from GIP and OSM). To further reflect realistic impedance for both active modes in an alpine country like Austria, we considered street-slopes according to a 10m digital elevation model that was geographically matched to the street network. We calculated the arithmetic ratios between non-motorized travel time and its motorized counterpart in order to realistically capture the rationale behind travel-time acceptance for motorized households. Due to limited degree of data completion in the Austrian road graph at the time of writing this paper, it was not possible to include detailed information about different types of cycling infrastructures, such as off- or on-road cycling infrastructures and cyclepaths.

Instead, a classification of graph edges was conducted in order to distinguish between edges that are especially suitable for cycling (low velocity, declared as bicycle infrastructure in either OSM or GIP) and edges where motorized traffic is dominating. By calculating the proportion of suitable cycling infrastructure along the shortest paths in the accessibility analysis, it was possible to account for the local infrastructural situation despite being limited from the data perspective. Access to public transport was operationalized by calculating the mean *distances to stations* by using raster based cost-path analysis. This type of routing algorithm works with traversable raster surfaces rather than road graphs. The choice for this approach was specifically related to the fact that a traversable raster surface is more suitable to model the walking or biking accessibility to public transport: They better reflect the nature of a pedestrian's pathfinding to stations as routing is not bound to discrete graph-edges.

(3) Weights were attached to the trip-destinations of routes in order to take into account the *relative importance* of a destination (visiting frequencies for doctors, hospitals, pharmacies, schools, grocery stores, supermarkets, administrative facilities) and size of their target groups. This was accomplished by adding a literature-based list of demand factors and empirical findings on target groups.

(4) Approaches related to the above step (1) of the accessibility analysis were applied for the operationalization of environmental variables. Examples are determinants that reflect climate (e.g. number of snow cover days, frost, etc.) or topography as a *DOA* of local population. Although topography is considered as a negative impedance in active travel – especially in cycling (Raffler et al. 2019) – it can also be interpreted as scenically valuable. We therefore included measures by applying state-of-the-art slope- and ruggedness-index analysis through the use of GDAL algorithms.

Infrastructural determinants:

Determinants reflecting infrastructural conditions play a crucial role in this research, as they can be directly addressed by planning actions and local/regional development plans. We calculated measures describing the local topology of the road network following the approach of Tresidder (2005): Those are represented by municipal *Intersection Density* (arithmetic ratio between connecting nodes and the total municipal network length/settlement area) as well as the *Connected Node Ratio* (arithmetic ratio between the number of connecting nodes and all network-nodes in a municipality). Those variables describe the permeability of the municipal road network as these can influence the enjoyment and comfort of local active trips through more direct routes. Walkability and bikeability reflect mode-specific time advantages as well as the convenience and scenic quality of cycling routes. In order to operationalize these features we included the density of cycle tracks, the share of traffic-calmed streets or the density of traffic accident hotspots at the road graph level. This was particularly challenging as the data sources GIP and OSM comprised unstable and incomplete information on cycling and walking infrastructure at the time of the data acquisition.

Demographic and socioeconomic factors and political/administrative commitment:

Demographic and socioeconomic factors have frequently been a major point of discussion in the context of research on non-motorized traffic (Goodman 2013; Heinen et al, 2010). Therefore we extracted several variables from census-based surveys which include aggregate measures on demographic structures, household structure (eg. mean household size), age groups, education, car ownership or purchase power per person/household. A more sophisticated view on local mind sets was provided by variables on social milieus (local shares of *SINUS-milieu* groups) that cluster population according to lifestyles and attitudes (milieus include *conservatives*, *hedonists*, or *performers*, etc.). In the specific context of this research, we aimed at extending the existing efforts of operationalization of the local active travel mode culture and the local commitment to support active modes among decision-makers. One approach consisted of collecting information on the municipality's membership in federal or state-level initiatives such as at the Upper Austrian cycling promotion programme (*fahrradberatung.at*, bicycle coaching initiative for municipalities), *Klimabündnis Austria* (an organisation promoting climate protection) or the number of projects realized in the *Klima-aktiv* programme (climate protection initiative of the Austrian BMLFUW). This information was used to calculate workable variables such as number of years since first assignment or simple 0/1 dummy variables. A second approach was based on including election results on municipal and state level elections. In this context it shall be noted that past political commitment may have implicitly manifested itself in kind of actually realized infrastructure projects or awareness-raising projects in favour of active travel modes whereas the above variables describe the current local 'climate' for active travel modes and potential for its promotion in the near future.

Regression model

We derived multivariate regression models aiming at identifying the relative importance of the determinants on the spatial variation of both active travel modes at the scale of Upper Austrian municipalities. The outcome variable (share of walking/cycling trips in all trips in a municipality) and the regression coefficients comprise the matrix of the municipalities' characteristics in the independent variables or covariates. The final set of independent variables was derived iteratively from a pool of 700+ candidate variables adopting a hierarchical scheme of model selection and a set of complementary tests and procedures. As sample size is relatively small (338 municipalities after applying the filter) the possible number of predictor variables is somewhat limited. However, with up to 17 variables in the pedestrian model and up to 22 predictor variables in the bicycle model, the upper value following Green (1991) in minimum sample size is 234, which is well exceeded. As a guiding principle we were aiming at combining several individual variables to form combined indicators (eg. the composite accessibility or landscape scenic quality variables) wherever feasible in order to reduce the number of covariates while increasing their explanatory power. Starting off by testing the inclusion of a basic set determinants (largely based on previous research) which were force-entered into the regression model we continued to include thematic sets of additional variables in stepwise modes (both backward and forward) in order to check for incremental improvements by adding new predictors to the equation. Each step was checked in terms of theoretical plausibility and accompanied by applying statistical tests (e.g. checking for multicollinearity or suppressor effects) so not to leave crucial modelling decisions to purely statistical criteria or let them be unduly influenced by random sampling variation. To quote and example some variables on adverse weather conditions (eg. number of frost days or rain days) had to be removed from the models as they exhibited considerable correlation with each other. For each model variant we tested for autocorrelation (independent errors) and heteroscedasticity – both tests signalized their absence.

3. Results

Table 2 and 3 show the main statistical results for the pedestrian and cycling models. The outcome variable is the respective modal share in Upper Austrian municipalities. The determinant variables are labelled according to their respective factor group (see 2.2) by prefixes ENV, INF or POP, respectively. It shall be noted that while from a planner's viewpoint the focus is clearly on variables that can actually be influenced by planning actions (e.g. relating to infrastructure, behaviour, awareness) it is nonetheless crucial to include other variables in order to cover all relevant determinants as comprehensive as possible and to control for the respective effects while explaining the corresponding variance proportions in the regression outcome variable. Omitting these controlling covariates one would run the risk of falsely attributing non-related parts of variance in outcome *y* to planning-relevant variables while they are in fact due to other factors (potentially non-controllable by planners such as weather or topology). In order to duly compare the effects of individual determinants on active mobility shares one should consult column β containing the standardized coefficients.

Pedestrian Model

Overall, the model on walking shares explains 77.5% of the variance in pedestrian shares among Upper Austrian communities (R^2=0.775). The large positive value for the composite variable on walking accessibility to various POIs confirms the hypothesis that compact settlement structures and relative proximity to basic amenities is a key requisite for walking (ENV_composite_acc_pot_walking). This is also partially reflected by the effect of 'INF_share_urban_environment' expressing the share of land use category 'urban' along the municipal road network indicating that denser environments are in general more pedestrian-friendly. In a similar vein the share of out-commuters in the local workforce exhibits a negative effect of walking shares. The positive sign of the climate variable 'ENV_no_snow_cover_days' indicates a potential swap of modal choice during the snowy season as the same variable shows a negative sign in the cycling model. A part of regular cyclists is switching to walking mode in case weather conditions appear unsafe or discomforting for cycling. With respect to policy relevant factors the weighted (according to type of PT) distance to public transport access points is an important predictor suggesting that the availability of adequate public transport is encouraging walking when controlling for other relevant factors.

Table 2. Pedestrian model coefficients, standardized coefficients, t-statistic, significance and correlation with pedestrian share (**p<.001, *p<.005)

Variable	b	ß	t-statistic	p	correlation with y
Constant	-0.338	-	-248.841	0.000	-
ENV_composite_acc_pot_walking	0.0022	0.594	316.332	0.000	0.730
ENV_no_snow_cover_days	0.0008	0.272	308.277	0.000	0.032
ENV_landscape_scenic score	0.0089	0.054	72.098	0.000	0.177
INF_distance_PT_weighted	-2.02E-05	-0.127	-172.589	0.000	-0.210
INF_share_connected_nodes	2.5619	0.066	55.570	0.000	0.523
INF_share_urban_environment	0.0758	0.313	181.514	0.000	0.680
INF_relative_prob_accidents	-0.2328	-0.008	-11.471	0.000	0.016

POP_no_klimaaktiv_pop	0.0082	0.082	124.273	0.000	0.108
POP_share_pop_o_65y	0.0016	0.072	49.474	0.000	0.490
POP_share_pop_u_15y	0.0028	0.076	72.223	0.000	-0.398
POP_share_educ_university_lvl	-0.0012	-0.085	-44.637	0.000	0.379
POP_dummy_klimabuendnis	0.0037	0.027	37.668	0.000	0.256
POP_part_time_rate_men	0.0017	0.080	105.880	0.000	0.305
POP_share_milieu_adaptive_pragmatic	0.0047	0.212	169.723	0.000	-0.411
POP_share_milieu_post_material	0.0114	0.421	234.423	0.000	0.279
POP_share_milieu_traditional	0.0043	0.261	138.970	0.000	-0.269
POP_share_out-commute	-0.0005	-0.124	-89.936	0.000	-0.609
R	0.880				
R^2	0.775				
R^2_{adj}	0.775				

With respect to population and political/administrative commitment it can be concluded that certain features of the local population (such as relatively high shares of both older and young people; 'POP_share_pop_o_65y' and 'POP_share_pop_u_15y') as well as relative high shares of specific social milieus (adaptive pragmatic, post-materialistic or traditional) contribute to walking. In general terms milieu variables tend to have a substantial explanatory power for walking shares. To a slightly lesser degree the same is true for the proxy variables reflecting political and administrative commitment at the municipal level ('POP_no_klimaaktiv_pop', 'POP_dummy_klimabuendnis'). Finally, the relative probability of accidents and the share of third-level education in the local population have negative effects on walking shares while a high share of part-time employment among the male workforce is positively impacting walking shares. Those findings are in line with theoretical considerations (in particular when controlling for social milieus).

Note that some variables show a reversed sign in the regression model compared to the direct (zero-order) correlation with the outcome variable. While this could be a potential causer for concern, it can be made plausible by considering that the inclusion of other predictors controls for several effects that are confounded in a zero-order correlation but split across dedicated covariates once they are included in the model. To quote an example, the share of tertiary-level education among the local population has a positive zero-order correlation with walking shares. However, once we control for attitudinal features through the inclusion of social milieu variables ('POP_share_milieu', etc.) the impact of high education levels on walking shares reverses. By contrast, *traditional* milieu shares are over-represented in settlement structures typically associated with low walking shares (suburban regions, regions with agricultural land use, etc.). Once some of these effects are controlled for (through the inclusion of composite accessibility variables), the model results show that – other things being equal – attracting *traditional* population will actually help increasing the local pedestrian share.

Cycling Model

In total the model includes 22 predictors accounts for 71.9% of the cycling share among the municipalities (R^2=0.719). Like in the pedestrian model we included various variables controlling for static influencing factors having substantial impact on cycling shares. As expected, negative impacts originate from hilliness within settlement areas as well as the number of days with snow cover, which confirms the hypothesis on positive influences on pedestrian shares when it is snowing. The scenic quality along the road (variable'INF_pleasant_green_roadside') has a positive impact on cycling modal shares: this composite variable measures the share of certain land-use categories that have been considered attractive along the road network. High positive beta-values are displayed for the accessibility variables 'ENV_ratio_accessibility_pot_cycle_car' and 'ENV_ratio_accessibility_prim_schools_walk_car' reflecting the weighted POI-related accessibility ratios between cycling and motorized traffic as well as the bikeability along routes to schools. This poses a strong statement for urban planners: Better accessibility ratio and bicycle-friendly environments play key roles when aimaing at a modal shift in favour of cycling traffic.

As expected, variables typically associated with conflicts between cyclists and motorized road users (eg. 'INF_density_accident_hotspot') or the prevalence of car-centred infrastructure ('INF_dummy_highway_access', 'INF_share_roads_GT_60kmh') indicate negative influences whereas the provision of stationary cycling infrastructure generally encourages people to cycle (INF_bike_racks_per_1000_pop). In this context the sign of the distance to highway access ('INF_minimum_distance_highway') was not expected initially. However, on second thought this relationship matches with properties of remote regions that are highly dependent on car while typically having bad cycling accessibility. They therefore pose impedances to cyclists reflected by this measure of remoteness. Similarly to the pedestrian model, the municipal share of out-commuters has a negative effect on cycling shares.

Table 3. Cycling model coefficients, standardized coefficients, t-statistic, significance and correlation with cycling share (**p<.001, *p<.005)

Variable	b	ß	t-statistic	p	correlation with y
constant	0.145	-	226.077	0.000	-
ENV_no_snow_cover_days	-0.001	-0,482	-353.471	0.000	-0.317**
ENV_hilliness_settlement_area	-0.010	-0,440	-379.508	0.000	-0.495**
ENV_share_agri_areas	-0.042	-0.345	-195.986	0.000	-0.499**
ENV_ratio_accessibility_pot_cycle_car	0.001	0.350	229.645	0.000	0.612**
ENV_ratio_accessibility_prim_schools_walk_car	0.001	0.220	197,862	0.000	0.494**
ENV_bikeability_routes_schools	0.007	0.043	41.857	0.000	0.410**
INF_share_pleasent_green_roadside	0.033	0.349	229.723	0.000	-0.338**
INF_density_accident_hotspot	-1.157	-0.120	-117.715	0.000	0.322**
INF_dummy_highway_access	-0.004	-0.056	-58.815	0.000	0.106**
INF_minimum_distance_highway	-6.280E-7	-0.197	-172.320	0.000	-0.189**
INF_bike_racks_per_1000_pop	0.000	0.063	81.225	0.000	0.208**
INF_settlement_proportion	-0.005	-0.031	-20.921	0.000	0.496**
INF_minimum_distance_major_cycle_routes	-8.895E-7	-0.071	-72.060	0.000	-0.323**
INF_share_roads_GT_60kmh	-0.044	-0.090	-101.198	0.000	-0.030**
POP_share_out-commuters	0.000	-0.221	-169.553	0.000	-0.450**
POP_share_milieu_established	0.003	0.124	109.934	0.000	-0.378**
POP_share_milieu_performer	-0.007	-0.408	-187.035	0.000	0.321**
POP_mean_duration_work_commute	0.001	0.146	154.036	0.000	-0.183**
POP_dummy_klimabuendnis	0.003	0.043	52.905	0.000	0.154**
POP_years_participation_fahrradberatung	0.001	0.101	120.091	0.000	0.329**
POP_share_workplaces_agri	-0.016	0.014	-47.462	0.000	-0.531**
POP_purchase_power_index_person	-0.001	-0.155	-97.576	0.000	0.146**
R	0.848				
R^2	0.719				
R^2_{adj}	0.699				

In terms of attitudinal variables 'POP_share_milieu_established' (local population share of social milieu *established*) and 'POP_share_milieu_performer' (local population share of social milieu *perfomers*) have the most significant effects on cycling shares. On average approximately 10% of the Austrian population belong to the social milieu *established*. It represents the performance-oriented and success-oriented elite in middle age groups. With other effects being controlled for in the model, a 1% increase of *established* milieu among the total local population will increase the municipality's cycling share by approx. 0.3%. *Performers* being the younger part of the elite can be broadly characterized as being globally oriented, highly efficient, success-oriented with comprehensive skills in IT and business (making up approx. 9% of the Austrian population). Model results indicate that a 1% increase in *performers* population share will reduce the cycling share by -0.6%. Note that the zero-order correlations with *y* show reverse signs for both milieus. This is again due to the inclusion of other factors which explain large parts of the variance in cycling. Hence the milieu population shares explain unique parts of the variance. Our interpretation is that both milieus share specific patterns of other mobility relevant factors such as choice of residential location or purchase power. Once these variables are controlled for and the other factors are kept constant, the coefficients for the milieu variables express the respective net effects while other things are being equal. While *performers* have a tendency towards high performance recreational sports they do not have environmentally conscious or cost-conscious mind-sets when it comes to everyday mobility (Dangschat et al. 2012). German studies by Sinus Markt- und Sozialforschung GmbH (2017b) found similar patterns of bicycle usage in the milieus of performers. Hence we even expect rebound effects on active travel shares to be related with performers' recreational behaviour (e.g. using the car to go to cycle routes). In Upper Austria, *established* milieu shares are over-represented in settlement structures typically associated with low cycling shares (suburban regions, regions with some agricultural land use, etc.). Also they exhibit above average household sizes generally associated with below average cycling shares as well as above average income levels

and purchase power. Once we control for some of these effects, the model results show that attracting *established* population will help increase the local cycling share.
The covariates on political and administrative commitment remaining in the model are 'POP_dummy_klimabuendnis' (1 if the municipality is a member of *Klimabündis Austria*, 0 otherwise) and 'POP_years_participation_fahradberatung' the number of years since the municipality first enrolled to the *fahrradberatung.at* programme are significant in the model context and the related coefficients generally suggest that political/administrative commitment in favour of cycling has a positive effect on the modal spilt share of cycling trips. More specifically, for every year since the first enrolment to *fahradberatung.at* the municipality gains a 0.11% increase in cycling share, i.e. after approx. 9 years of taking part in the initiative the cycling share will increase by 1%. Given that the average municipal cycling share is at some 3.5% proves that the programme does have an impact. In a similar fashion the enrolment to *Klimabündnis* will increase the cycling share by 0.22% constituting a one-time effect. It needs to be stressed here that these figures are incremental meaning that they reflect the *net effect* of the respective predictor while all other variables are kept constant. In this sense supporting planning actions affecting any of the other thematic areas will add up to a more pronounced increase in cycling modal share.
Regarding the former, we tested additional variables for inclusion before committing to the final variant of the model: the number of *Klima-aktiv* supported projects in the walking/cycling domain positively correlates with y (number of projects: +0.144, no. of projects by municipal area: +0.267, both correlations are significant at a level of 0.001). The subjective evaluation of the state administration on the municipal level of pro-cycling activity (on a scale between 0 and 3; 3 is best) proved to be positively correlated with y (+0.226, significant at a level of 0.001). However, when controlling for the many other determinants affecting cycling modal shares those variables turned out not to be significant in the regression model and have consequently been excluded.

Complementary analysis: correlation between subjective and objective commitment towards cycling
In order to deepen the analysis of proxy variables depicting commitment towards cycling among local political or administrative representatives we analysed whether or not there is a correlation with the self-assessment of these stakeholder groups. We used the surveys response data (see 2.1) for the calculation of a summed affinity index of *self-assessed political willingness to promote cycling*. To solve the question whether the included proxy variables (eg. 'POP_years_participation_fahrradberatung') actually reflect the self-stated commitment, we applied correlation analyses between the above affinity index and the model proxy variables as well as the cycling modal share (s. table 4) [3]. The resulting correlation coefficients are highly significant. The medium-sized correlation (R=0.448) between cycling modal share and the affinity index underlines both the introducing statement by Raffler et al.(2019) and the findings of the cycling model: A strong political or administrative commitment towards cycling is key to achieve high local cycling shares; however it is not the only relevant factor. This is also emphasized by the model outputs (see table 3) which list the proxy variables as relevant determinants among other factors.

Table 4. Pearson correlation [R] between proxies and stated-political willingness

	Affinity to cycling	
	R	p
Cycling modal share	0.448	0.000
Number of Klimaaktiv mobil Projects	0.408	0.000
Years since 1st enrolment in Fahrradberatung.at	0.384	0.000
Years since 1st enrolment in Klimabündnis	0.537	0.000

Further inspection of table 4 shows that there exists significant ($p < 0.001$) medium to high positive correlations between the proxy variables and the surveyed affinity values. Bearing in mind that the affinity index is a highly subjective measure, the strength of the relationship with the proxy variables (being based on objective data) is quite high. This indicates that measurable variables such as enrolment in federal cycling promotion programs actually reflect the self-assessed political will to promote cycling which is an argument in favor of calculating meaningful proxy variables using existing data sources and including them in aggregated models.

Decision support and measure simulation
Our research is guided by aiming at outcomes that can actually be implemented in planning processes and agenda setting. Thus we need to come up with approaches dedicated to translating raw statistical model results into planning practice. As a first component of a decision support system for the Upper Austrian federal state government we developed 'active travel potential maps' such as presented in figure 3 for pedestrian traffic. Methodologically these maps are based on analysing the model residuals produced by the above aggregate

3 Due to the missing state wide coverage of the municipality survey it was not possible to directly test the affinity index in the context of the cycling model.

models. As not the whole variance in modal shares could be accounted for in the models (and hence by the covariates included therein) there are model residuals: a positive residual indicates that the subject municipality has a higher modal share than expected given the local premises (environmental, infrastructural, social & attitudinal, etc.). Reversely, a negative residual can be found in areas that could potentially achieve higher active modal shares if they made best use of the local conditions. Put differently, they underachieve when it comes to active mobility. As a planning tool the maps are currently being used as a means to support strategic decisions related to the extension of the Upper Austrian cycling promotion programme fahrradberatung.at.

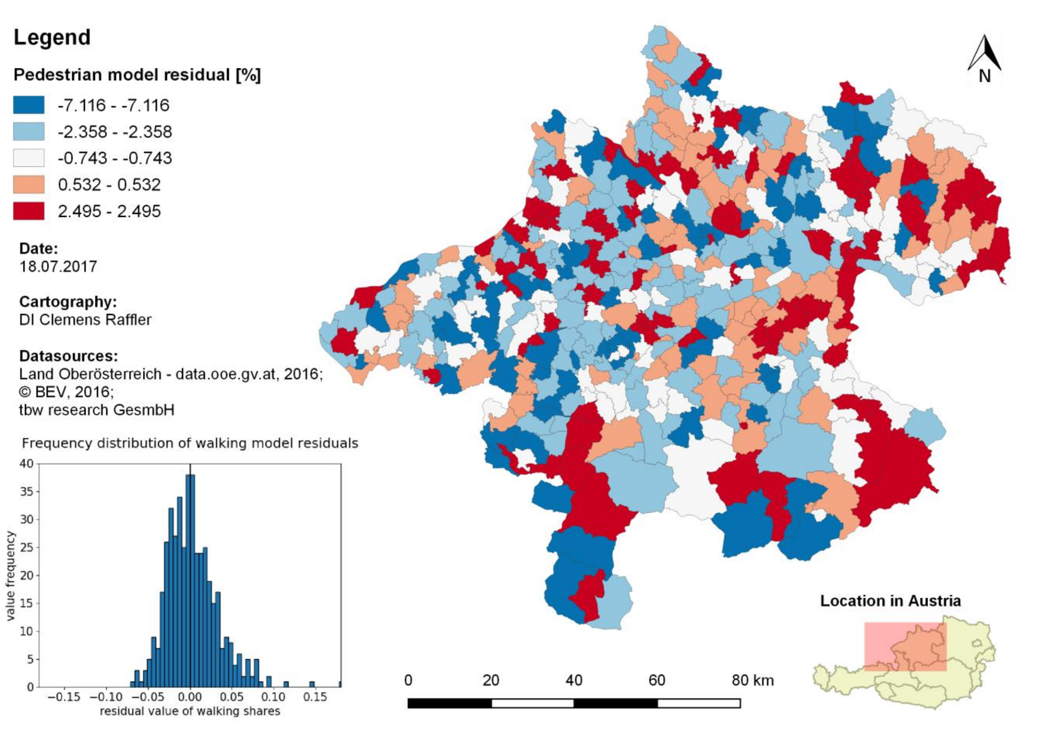

Fig. 4. Map of walking-model residuals and their statistical and spatial distribution
Negative residuals = large unused walking-potential | Positive residuals = best use of local walking conditions

From a planning perspective the areas displayed in red mark target municipalities that are likely to produce the highest return on investment in terms of pedestrian modal shares while municipalities displayed in blue mark target regions with a potential to balance out Upper Austrian disparities in walking shares (however, at the price of reduced incremental return of investment). However, the actual choice of investment strategy is ultimately a political matter rather than a scientific one: Both options are equally viable and highly dependent on the respective political agenda. In this context we see two critical questions that need to be answered by decision makers on the federal state level:

1. Should overall active shares of municipalities be levelled out among all communities?
2. Should measures to boost active shares focus on municipalities that already implemented a thriving culture of walking and/or cycling?

The first option means investing in underperforming municipalities displayed in blue with a potential to balance out Upper Austrian disparities in walking shares. Those municipalities exhibit lower walking shares than could be expected when fully utilizing their respective local conditions (infrastructure, population, topography and climate). In case decision makers choose to follow the second strategy, the recommendation is to invest in areas displayed in red. Target municipalities are likely to produce the highest return on investment in terms of pedestrian modal shares by building on an already established culture of active mobility.

Those strategic decisions pose a new scope for Austrian decision makers as quantitative measures of municipality performance in the context of modal choice by means of statistical modelling haven't yet been applied in Austrian active mobility planning. A second element of supporting decisions in active travel planning comprises the simulation of potential measures in terms of their expected impact on pedestrian or cycling modal shares prior to their implementation. This can support planning, e.g. by prioritizing potential measures subject to their impact or target achievement. Measure simulation is methodically facilitated by using the above models, adequately interpreting coefficients and entering modified values (according to the planning measure to be assessed) into the model equations. It should be noted however, that the measurement scale and dimensionality of the covariates as well as whether or not they are composite variables largely determine the way model coefficients need be interpreted in this context. Single variables measured on a metric percentage scale are most straightforward in terms of interpretation whereas composite variables or non-dimensional measurement scales require some preparatory work when simulating planning actions. To quote an example, increasing the number of bike racks at rail stations by 10 per 1000 inhabitants (currently amounting to a mean of 5 per 1000 inhabitants in Upper Austrian municipalities) will increase the cycling modal share by 0.17% (amounting to approx. 3.5% for the average Upper Austrian municipality) while other things are kept equal. Cutting the density of accident hotspots in half (e.g. by investing in construction measures to defuse accident accumulation points) will increase the cycling modal share by 0.22%. With regards to walking, the significance of interdepartmental action becomes apparent, particularly relating to policies that affect the composition of the local population: Increasing the share of post-materialists in the local population (e.g. by specifically attracting respective households through housing schemes, city marketing, etc.) by 10% will increase the pedestrian modal split by 1.1%. Increasing the population share of children below 15 years increases the walking share by 0.28%. By quoting these examples of cross-sectoral planning measures we aim at pointing out that influencing modal shares is by far not limited to traditional measures usually concerning infrastructure or accessibility, but can also be implicitly facilitated to a great extent by the composition of the local population (which again is subject to the municipalities' attractiveness for certain groups). The local share of part-time working relationships among employed men has a positive impact on walking shares: increasing the share of this kind of jobs by 1% (e.g. by attracting appropriate businesses, introducing new worktime schemes or attracting certain lifestyle types) walking shares increase by 0.17%. A potential explanation for this is the better temporal affordability for 'slower' modes of transport. As another example, the composite walking accessibility variable coefficient can be generally interpreted as increasing walking accessibility to relevant destinations will boost walking modal shares. However, since the measurement scale is non-dimensional the exact impact simulation of improving accessibility needs to be based on a re-calculation of the respective indicators after changing the path network and / or its attributes reflecting the respective measures in the GIS model in a case-by-case fashion.

4. Conclusions and outlook

At this stage our work has demonstrated that aggregated statistical models for active travel modes are methodologically feasible and that data-driven methods can actually be used to support planning and agenda setting. First results prove that a considerable proportion of the observed variation in walking and cycling modal shares can be explained by multivariate regression models including on a comprehensive set of covariates. In accordance with the aims set in section 1.4, the added value of our research lies in the following results: (1) A systematic approach to model active mode shares on a municipal level in Austria, therefore laying the foundations for evidence-based decision making in walking and cycling domains as well as in other sectors with relevance to mobility patterns; (2) Presentation of determinants on pedestrian modal shares, their strength and direction of impact, in the context of transport planning; (3) The operationalization of proxy variables reflecting the political will to promote cycling more realistically as well as the assessment of the correlational relationship between those proxy variables with an affinity index generated from empirical data.

That being said, we are aware that considerable research tasks lie ahead. Aiming at making our approach highly relevant for practical planning, widening its scope of application and improving the reliability of the model results future research threads include both methodological aspects and developing implementation tools, respectively. In terms of improving the models we aim at including additional predictor variables by forming composite variables or factors, including data to operationalize on- and off road cycling infrastructure. Another research goal lies in including non-linearity and saturation effects as well as in adding variables on infrastructural qualities that were unavailable at the time of building the models. Broadening the statistical basis by re-calibrating the model with data from other regions, both national and international (facilitated by a dedicated data interoperability concept) is regarded key in terms of making the model results even more generalizable and robust. In terms of transferring model results into planning practice we aim at developing a set of tools including an expert system in order to make our approach workable for external experts in the planning domain. This includes various interfaces for planning-relevant model input data as well as coherent ways of presenting model outputs to the target groups.

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