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Conference Paper

SALUD: A spatial microsimulation application to support regional health planning in Austria

53rd Congress of the European Regional Science Association: "Regional Integration: Europe, the Mediterranean and the World Economy", 27-31 August 2013, Palermo, Italy

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Tomintz, Melanie N.; Kosar, B.; Garcia-Barrios, Victor M. (2013) : SALUD: A spatial microsimulation application to support regional health planning in Austria, 53rd Congress of the European Regional Science Association: "Regional Integration: Europe, the Mediterranean and the World Economy", 27-31 August 2013, Palermo, Italy, European Regional Science Association (ERSA), Louvain-la-Neuve

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**SALUD – a Spatial Microsimulation Application to
Support Regional Health Planning in Austria**

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ABSTRACT

The Austrian Federal Ministry of Health aims to improve the health of all people living in Austria and to decrease health and social inequalities. This leads to a careful planning and distribution of the available health care resources to meet government aims.

The research project SALUD, funded by the Federal Ministry for Transport, Innovation and Technology and the Austrian Science Fund, focuses on building a Spatial Microsimulation Model for Austria by combining survey and census data to model small area health issues based on individuals or households where no data exists, so called missing data.

Within this project, a first prototype of simSALUD is developed, which is a Web-based spatial microsimulation application for health decision support as to date no flexible and free-available Web application in the area of spatial microsimulation exists. simSALUD targets two groups: experts in the area and health policy decision makers (HPDM). The present work focuses on the latter group and will present first results showing the benefits of simSALUD for HPDM, as they are mainly interested in the results and not primarily in the underlying modelling process.

1. INTRODUCTION

The expenditure for health care costs is increasing and resources are getting scarce. Especially health problems related to a bad life style are problematic, e.g. obesity, smoking, type 2 diabetes. This work focuses on the health issue of smoking, as smoking is still the most preventable cause of developing health problems caused by a bad life style. In Austria, the health care system is seen as a good one among other European countries. The Austrian population has high life expectancy, above the average in Europe (OECD, 2011). Women have a life expectancy of 83 years and men have a life expectancy of 78 years. This sounds good but in fact Austria is among the bottom ranking when it comes to live a healthy life when aging (Bundesministerium für Gesundheit, 2012). In 2002, Austria has the highest smoking rate with 36% among all European countries (EuroStat, 2002). Latest OECD figures show that the smoking rate in Austria is 23.2% and therefore 0.2% above the EU27 countries (OECD, 2012).

An unhealthy lifestyle, especially smoking, bad eating habits, less activity to name a few, is responsible for many diseases, such as cardiovascular disease or cancer. Illness or death caused by an unhealthy lifestyle is preventable and therefore measures need to be set. In Austria, cardiovascular diseases count the highest rate of deaths with 37.1% for men and 47.1% for women, followed by cancer (28.9% males, 23.6% females). The consumption of tobacco products, including cigarettes, is responsible for many diseases and can even be the trigger for death. In Austria, around a fifth of women (19%) and more than a quarter of men (28%) in the age of 15 and above smoke on a daily basis. So far, the percentage of male smokers is still higher, however, the gap between men and women is unfortunately closing, especially in young ages. For instance, the smoking prevalence for people between 15 and 29 years are 29% for women and 32% for men. Unfortunately this trend continues with increasing smoking prevalence and therefore smoking related deaths for women and decreasing smoking prevalence and smoking related deaths for men (Statistik Austria, 2012). A study conducted by most of the OECD countries allows a comparison of the smoking behaviour among 15-year-old children in terms of smoking and alcohol consumption in 2005/2006. It is shown that Austria is on top among youth smokers (30% girls, 24% boys) in comparison to all other OECD countries, followed by the Czech Republic, Germany and Finland. A big issue here is that smoking is an addiction and is often taken into adult life. Least 15-year-old smokers are found in the USA followed by Sweden, Canada and Norway (Statistik Austria, 2012).

It is important to target smoking groups locally to provide most effective actions against smoking. A methodology for small area modelling are spatial microsimulation models that makes it possible to build up large-scale synthetic microdata based on individuals or households. We can differentiate between two main approaches to create synthetic microdata: *synthetic reconstruction* and *reweighting*. Synthetic reconstruction can be classified as Iterative Proportional Fitting (IPF) and data merging whereas reweighting can be classified as CO (combinatorial optimization), IPF and GREGWG (see Hermes and Poulsen 2012, Williamson 2013).

The aim of this paper is simulating the smoking population at municipality level in Carinthia, Austria, by building a static spatial microsimulation model. The results are important for the Carinthian health departments for distributing their resources and taking increased action for smoking cessation. The study area is Carinthia, a county in the south of Austria, with a population of approximately 55,000 people. Carinthia is divided into 10 districts and 132 municipalities. The remaining chapters show the datasets that are used and processed for the spatial microsimulation model, namely being the Austrian Health Survey 2006/07 and the census 2001. Then the methodology and framework used is described in detail. After that the validation and results follow and end the document then ends with a summary and future outlook.

2. DATA

In Austria, the Statistics Austria collects data regarding different conditions in Austria, including health, employment market, population, education, tourism, energy and environment, to name a few. Depending on the topic, there are different datasets available, some of them are free to use and for others payments are required, even when they are needed for academic/research purposes. The following chapter shows the relevant datasets for this study and explains the data processing steps to prepare the data in a way so that it can be used for the simulation model (see chapter 3).

2.1 Micro- and census data

For this research, two datasets are important. First, we need individual or household data that holds information on demographic, socio-economic and data related issues, in our case about the smoking habits of a person. Second, we need data for small areas with demographic and

socio-economic information in it as no health related data at municipality level (small area) exist in Austria. A match of key variables (so called constraint variables) is important for the modelling process.

The health condition of the Austrian population is collected through health survey by the Static Austria since the 1970s. The last national survey on health was conducted in 2006/2007, called the Austrian Health Survey (AHS) 2006/2007, where data on demographic, socio-economic and health issues are questioned from people aged 15 and above. This, so called microdata set, can be accessed and used free of charge for academic purposes. The AHS 2006/2007 consists of 15.494 cases and 658 variables. The next Austrian Health Survey will be conducted for 2014/2015. This will be very interesting to see the trends. However, the collection of detailed health related data is around every 10 years, which leaves a big gap.

The Austrian census data was collected every 10 years with 2001 being the last collection in traditional way with paper form. Then, they decided to replace the traditional data collection with a digital data collection by obtaining data from the registers office. The first test collection was for 2006 and the next collection is for 2011, where the results are being in publishing process in the course of writing this paper. A negative smack are the costs for the data as they are not free to access for academic and research purposes. Data are provided in different packages and the costs depend on the area and resolution chosen. Costs can sum up till € 10.000,-. However, census data at municipality level is available to use for research purposes at the institution from 2001 and therefore this data was used for the first modelling attempts to explore the modelling behaviour for municipalities before buying expensive spatial data at other spatial scales (for instance small area raster data). The available census 2001 dataset consists of 41 variables, already split in categories, in which 22 categories are provided as absolute numbers and the remaining variables provide information about the same content but as portion instead of absolute numbers. In summary, 9 variables are available and this restricts

2.2 Data processing

The datasets need to be analysed for suitability and processed in a form that is required for the modelling process. Further, statistical tests are performed on the AHS dataset to explore, which variables are most suitable as constraint variables for the model. Therefore, simple

analysis and regression analysis were done to see which variables predict the smoking population.

The census data was ready to use and no extensive data processing is needed. The data is available as a Shape file, which is a common used data format for geographic information (GIS) system software. Within GIS software, spatial data can be visualized in form of maps to present values from different attributes. Further, data in form of tables can be exported for further usage in Microsoft Excel or statistical software packages.

The AHS was processed using the statistics software SPSS 19. First, all the dataset was controlled for invalid cases although all 15.474 cases could be used as they were complete for all constraint variables. Then, the categories of the constraint variables are adjusted and recoded according to the constraint categories of the census data. After that, some basic analysis, for instance frequency analysis, is done to explore the data. Table 1 shows the percentages of the current smoking behaviour of the Austrian population. It can be seen that 22% smoke daily, 2.6% smoke sometimes, 17.6% do not smoke at all and for a high percentage of 57.8% there is not answer provided. The latter is a problem, as the cases cannot be counted as non-smokers or smokers and during writing this document no explanation on what ‘Filter’ means was found. For the simulation, we have put the daily and not frequently smokers together as a category as each cigarette harms the health of a person.

		Incidence	Percent	Valid percent	Cumulative percentage
Valid	Filter	8946	57,8	57,8	57,8
	Yes, daily	3398	22,0	22,0	79,8
	Yes, sometimes	400	2,6	2,6	82,4
	No	2730	17,6	17,6	100,0
	Total	15474	100,0	100,0	

Tab. 1: Numbers and percentage of the current smoking behavior from the AHS dataset

An independent t-test is also performed to explore which groups of people significantly smoke more in comparison to other groups. Table 2 shows the results and all of them are not surprising except gender, where the results show that significantly more women smoke in comparison to men. Unfortunately the gap of smoking rates between men and women is closing, this means that luckily the smoking rate for men continuously decreases whereas the smoking rate for women increases.

	Smoker / Non-smoker
Nationality	Significantly more Austrian citizen smoke
Gender	Significantly more female people smoke
Age	Significantly more young people smoke
Marital status	Significantly more divorced people smoke
Education	Significantly more lower educated people smoke

Tab. 2: Independent t-test between the smokers/non-smokers and constraint variables

3. METHODOLOGY

The simSALUD methodology combines data from two sources (survey and small area data) and uses two algorithms for simulating the smoking population for small areas in Austria. The first algorithm is the deterministic reweighting algorithm and uses two equations for allocating people to the geographic areas. The second one is the optimization algorithm and is applied right after the reweighting to get only “whole” people as simulated values. These two algorithm have to be applied for the given survey sample size (around 15.000 individuals) for all small areas. Due to the fact that simulating these values using a spatial microsimulation with common approaches (e.g.: Microsoft Excel, Access etc.) are either not user friendly or simply not realizable for such big data, so that alternatives had to be found. On the market some microsimulation models focusing on health care demand exist (Clarke and Spowage 1984, Falkingham & Hills 1995, Abello and Brown 2007, Morrissey et al. 2013, Tomintz et al. 2013). Many models are not flexible enough regarding user handling (e.g.: changing model input parameters, etc.) and are not accessible for everyone.

Therefore, the motivation is to develop a flexible Web-based spatial microsimulation for health decision support with an easy-to-use graphical user interface (wizard) for experts and non-experts (especially health policy makers) to produce, map and analyze microdata without programming skills. At the moment no such a flexible and free available web application in the area of spatial microsimulation exists. An overview of the Web application simSALUD is shown in **Fehler! Verweisquelle konnte nicht gefunden werden..** The application targets

two user groups: the first group is targeting experts in the area of spatial microsimulation (currently in development), where they know how spatial microsimulation works and how to prepare data in a way so that it can be used in the Web application. The second group focuses on non-experts (e.g. health policy decision makers (HPDM)), which are mainly interested in using validated microdata, that are produced by experts, to visualize the results in form of maps. The map results allow the HPDM to show pockets of areas with highest smoking rates for different population groups.

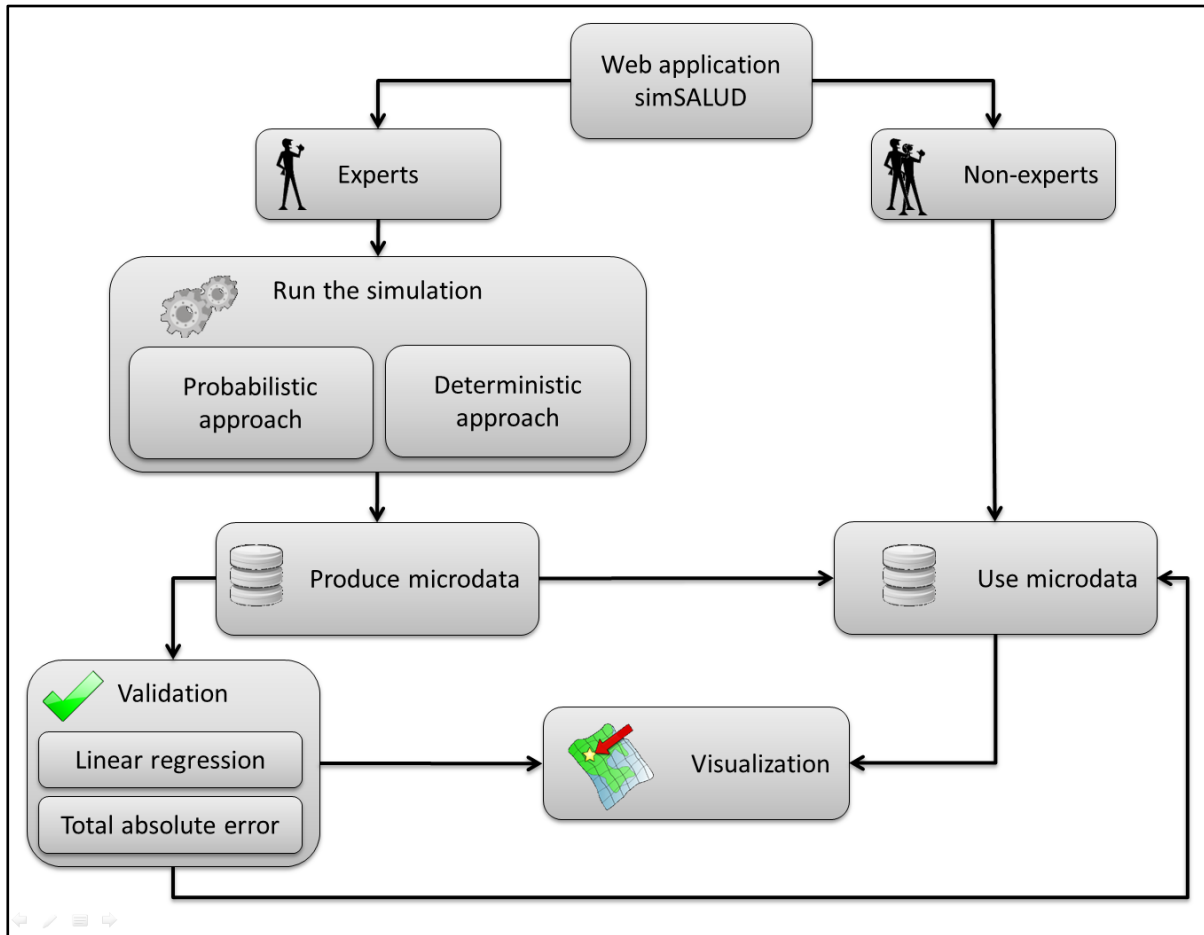


Fig. 1: Overview of simSALUD

In the current version of the Web application simSALUD a deterministic reweighting approach is implemented. It is possible to upload different datasets (survey and small area datasets), match the different constraint variables (allocate small area constraint groups to coded number of the survey file) and run the simulation. After the calculation is finished, the results can be downloaded as csv. files (simulated health variable, in our case simulated variable ‘smoking’ and the constraints for each municipality).

Before data can be uploaded to the simSALUD framework some key issues need to be considered when preparing the data for building a spatial microsimulation model. A well-prepared data is the fundamental for an accurate and robust model of the small area results produced from the simulation. Building a static spatial microsimulation includes also numerous issues that may come up with preparing the data for the simulation. Some of the considerations and issues that may arise include data requirements and data sources, resolving differences in variable definitions and data scope and the absence of particular variables or population in the dataset being used (Cassells, et al. 2013). Spatial microsimulation models typical include data from national surveys (e.g.: health-related data) and reliable small area data sources (e.g.: national census data). Once the datasets are selected it is then necessary to use only constraints that are associated with the health-related simulated variable (e.g.: smoker, obesity). These constraints should be strong predictors of the variable being estimated. The requirement for selecting those predicting constraints is that all these constraints are comparable in both (small area and survey) datasets depending on the data availability. In the majority of cases an adjustment for each constraint is required. If for example the constraint age is categorized in the survey dataset in 2 groups (15-50 years and 51-90 years) and in the small area dataset in 3 groups (15-50 years, 51-70 and 71-90 years) an adjustment has to be made (summarize the small area groups into 2 groups) to get the same comparable categories. For identifying the predictors for the variable to be estimated some statistical methods can be applied. Beside some basic descriptive statistical methods such as contingency tables also some correlation, regression and compare means methods such as the Independent-Samples T Test should be applied. Depending on the variable the independent t-test compares the means between two unrelated groups. So it is possible to assess the significance of the difference between two constraints (e.g. smokers in terms of their age).

If simulated variable with their corresponding constraints are validated and well prepared the data can be used for the simSALUD model. But before the experts can use their data for the simulation they have to make sure that the data is valid according to a fixed template. The template for the survey data can be seen in **Fehler! Verweisquelle konnte nicht gefunden werden.**, image a. The first column should always contain a unique identification number (ID) that normally correlates with the individual of the survey. The second column can hold a weight for each individual, which is commonly given from the survey organization to compensate survey biases. If no weight is given then the value one has to be used (equal weights). The third column contains the variable, which has to be simulated (e.g.: smoker,

obesity). Each value represents one characteristic explicitly declared from each individual at the survey (e.g.: 1: smoker; 2: Non-smoker). All other columns can be arranged randomly and illustrate all constraints (e.g.: sex, age, etc.) which should be strong predictors of the simulated variable. The small area files also have to be adjusted to the simSALUD template. As illustrated in **Fehler! Verweisquelle konnte nicht gefunden werden.**, image b, required is a single file for each constraint which contains in the first column the small area code (e.g.: municipality ID) and all other columns are storing the individuals living in the area with the specific subconstraint (e.g.: number of married people for each area). The number of columns in the small area files representing the subconstraints should be same as distinct numbers for that constraint column in the survey file (e.g.: “1” in the survey file means “male” in the small area file and “2” for “female” individuals).

a)

Template:				
ID*	WEIGHT*	SIMULATING VARIABLE*	CONSTRAINT 1	CONSTRAINT 2
1	1	1	3	2
2	1	2	2	3
3	1	2	2	4
4	1	1	1	2
5	1	2	1	1
6	1	2	2	2
7	1	2	1	3
8	1	1	2	1
9	1	1	1	4

*Fixed column position

b)

(Single file for each constraint)				
imunicipal_id	male	female		
imunicipal_id	1 kid	2+kids	no kids	
imunicipal_id	married	lone parent	other	
20101	4556	3644	4524	
20102	9785	3967	1564	
20103	123	78	412	
20104	451	145	452	
20105	4565	3644	354	
20106	456	787	154	
20107	132	352	135	
20108	456	463	686	

Fig. 2: Survey (a) and small area (b) data input templates

The workflow of the the simSALUD framework using a deterministic reweighting approach is shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** and is in the current version implemented only for the user group “experts”. At first the user of the simSALUD framework has to select their prepared survey file on their local computer and upload the file on the server. Then the next step is to upload all prepared single constraint files (small area data), which the experts has specified as strong predictors of the variable being estimated before. After both data types are successfully upload to the server the user has to match the survey data with the small area data values. Therefore the user has to match the survey constraint values (column content shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**, image a) with the constraints from the small area data (column header shown in

Fehler! Verweisquelle konnte nicht gefunden werden., image b) using the drag and drop technique. For the next step the user has to start the simulation and the server starts to calculate the simulated data using the deterministic reweighting algorithm.

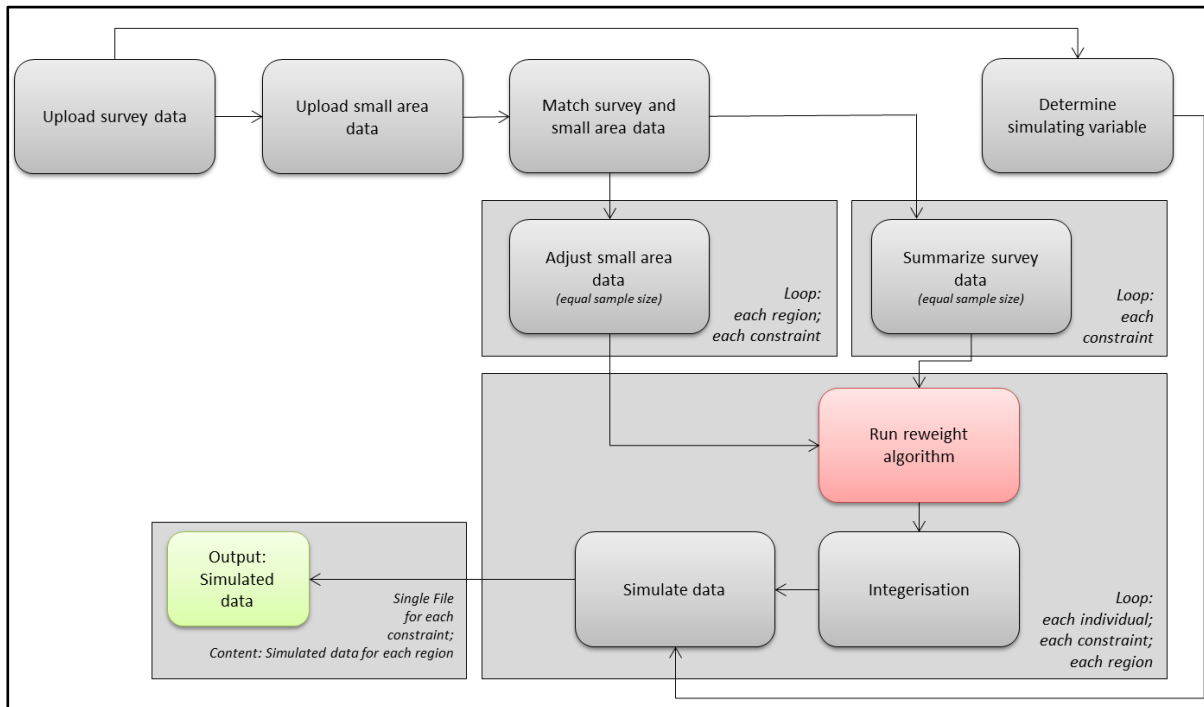


Fig. 3: Workflow of the simSALUD framework using a deterministic reweighting approach

The simSALUD methodology combines data from two sources (survey and small area data) and uses two algorithms for simulating the smoking population for small areas in Austria. The first algorithm is the deterministic reweighting algorithm and uses two equations for allocating people to the geographic areas. The second one is the optimization algorithm and is applied right after the reweighting to get only “whole” people as simulated values. These two algorithms have to be applied for the given survey sample size (around 15000 individuals) for all small areas.

The simSALUD framework uses two algorithms, which consist of three equations. As mentioned before, the first deterministic reweighting algorithm is used to allocate people to the geographic areas. The two datasets are subdivided into summary tables, which are simply the total number of people for each constraint category (e.g.: male) and area. The derived small area summary table shows all areas listed as rows and the columns are the sum of people for that category in that area. Each constraint table should have the same number of

people (total population) in that area. If there are any deviations (different population for the same area but different constraint) an adjustment should be applied to ensure a consistent dataset (Edwards et al. 2010). The derived summary table from the survey dataset consists also of the total number of individuals for each constraint category but summarized in one row (only survey data). The first equation (see Equation 1.1) uses an initial weight for each individual (if specified in the survey dataset) to compensate the bias of the survey. The reweighted algorithm determines what combination of individuals from the population dataset best matches the constraint aggregations for each geographic area (KIMBERLEY 2012).

1st equation: $X_{ij}(k) = X_{ij}(k-1) * C_{ij}(k) / S_{ij}(k)$ (Equation 1.1)

2nd equation: $Y_{ij}(k) = X_{ij}(k-1) * \text{Sum}(C_j(k)) / \text{Sum}(X_{ij}(k))$ (Equation 1.2)

1st equation:	$X_{ij}(k)$:	New weight
	$X_{ij}(k-1)$:	1st run: initial weight then previous new weight
	$C_{ij}(k)$:	Geographic dataset: Constraint value (e.g.: male)
	$S_{ij}(k)$:	Survey dataset: Constraint value (e.g.: male)
2nd equation:	$Y_{ij}(k)$:	New weight (aggregated with the previous constraints)
	$X_{ij}(k-1)$:	New weight from the previous equation
	$\text{Sum}(C_j(k))$:	Sum of people for one constraint (e.g.: male + female)
	$\text{Sum}(X_{ij}(k))$:	Sum of the new weights for all people from the previous equation in one area

The outcome of the algorithm is a dataset, which contains the final weight for each individual for each area. These values represent the likelihood that an individual would reside in that area and has to be multiplied with each constraint and the simulated variable to get the total number of simulated people for each area.

The second algorithm (integerisation) is then applied to allocate only “whole” people to the final dataset. The algorithm uses an iterative methodology to convert the decimal values from the results of the first algorithm to integers.

The Web-based application simSALUD is developed in JAVA and uses the open source web application framework Struts2. The first prototype of simSALUD can be used either offline or online and is therefore accessible anywhere and anytime. Functionally it consists of three modules (see Fig. 4) called (i) Spatial Microsimulation Framework, (ii) User Interaction wizard and (iii) Web Mapping Framework.

- The User Interaction wizard (UIZ) represents the graphical user interface of the web simulation. The wizard allows the user to upload all required datasets as well as match the survey and the small area data together using a drag and drop technique. The UIZ also holds the results manager where the user can download the simulated data file and see all the results as table, chart and map visualized. The visualisation area presents an interactive map with different standard functionalities, including zoom and pan.
- The Spatial Microsimulation Framework (SMF) can be also seen as the server module. The SMF represents the calculation unit of the system. On the server the algorithms are applied, so that for the users system (e.g.: notebook, etc.) no further calculation are necessary.
- The third Web Mapping Framework component can be seen as geoprocessing tools and allow doing spatial analysis on data to answer what-if scenarios. The Map Provider with its Map Communicator allows users to process and edit geospatial data.

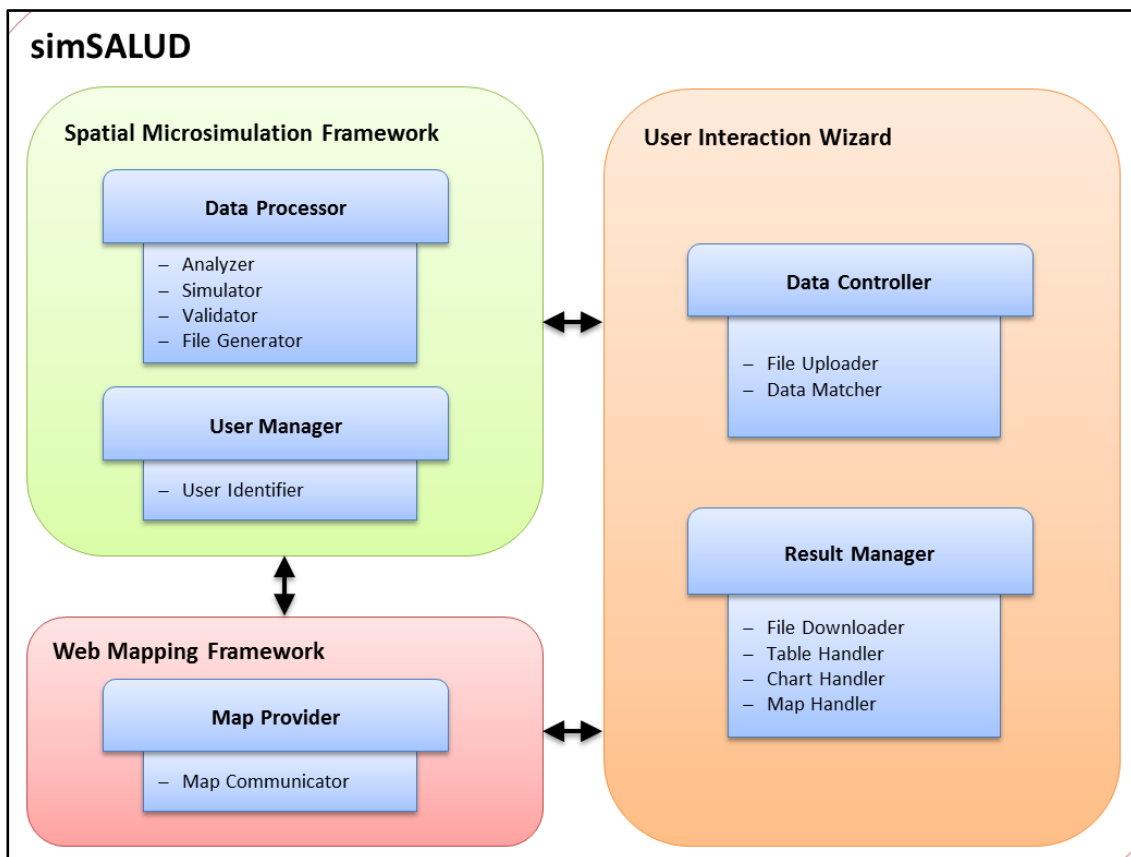


Fig. 4: System architecture of the simSALUD Framework

In general, the main advantage of simSALUD is to build synthetic microdata without programming an own program from scratch. Further, HPDM can use the application and

perform various spatial analyses without needing specialist skills in spatial microsimulation modelling or geoinformation science. The first prototype of SimSALUD will be introduced to our project partners, University of Leeds and Sheffield (experts), as well as Austrian health departments in order to evaluate its practical usefulness and relevance in the area of regional health planning. Hence, with simSALUD we hope to make a positive contribution for the area of spatial microsimulation modelling, as it is the first open accessible Web application so far.

4. RESULTS

For the spatial microsimulation model five constraints (16 categories) are used to predict the smoking population. The results can be downloaded as comma separated files for further analysis and consists of the simulated ‘missing’ variable that is here ‘smokers’ and the simulated constraint variables. As there is no data on smoking available at community level we used the Total Absolute Error (TAE) to receive information on how good the model fits real world data as a first step. There are other validation methods available, including the Standardized Absolute Error or the Standard Error Around Identity but the TAE is a value that can be quick prepared and analysed to receive some indication about the simulation results. The TAE simply compares the simulated data with the census data for each municipality to identify which areas have a high deviation and which areas are a good fit. Table 3 shows the TAE for all constraint categories. The closer the value is to 1, the better is the fit of the simulation. It can be seen that on average the male and female population was modelled well. Further, the age group 20 to 39, the group Austrians and persons with a university degree are modelled close to the real population. The population from groups age 15 to 19, single, having another citizenship than Austria or EU 15 and having A-level or no A-level as last finished degree are over predicted by the model. On the other hand, people in the age of 60 or above and people being divorced or widowed are under predicted by the model. One reason to explain this can be the lower number of persons in these groups, which makes the modelling and matching of variables more difficult.

Constraint	TAE
SEX	
Male	1.05
Female	0.96
AGE	
Age 15 - 19	1.40
Age 20 - 39	1.03
Age 40 - 59	0.81
Age 60 +	0.77
Marital Status	
Single	1.34
Married/Living together	0.74
Divorced	0.66
Widowed	0.73
Citizenship	
Austrian	1.00
EU 15	0.84
Other citizenship	1.96
Last degree finished	
University degree	0.99
A-level	1.29
No A-level	1.21

Tab. 3: Total Absolute Error for constraint variables

The smoking population is simulated at municipality level. The values are aggregated to district level to see if there variations within district level exist. Further, this map should show the need for results at municipality level. There are ten districts in Carinthia and as Figure 5 shows the smoking population only ranges from 26.5% to 28.8% with Hermagor being in the lower third and Villach, Feldkirchen and Wolfsberg being in the upper third. However, there some districts are large areas and it can be assumed that hotspots of higher smoking rates within such districts are hidden.

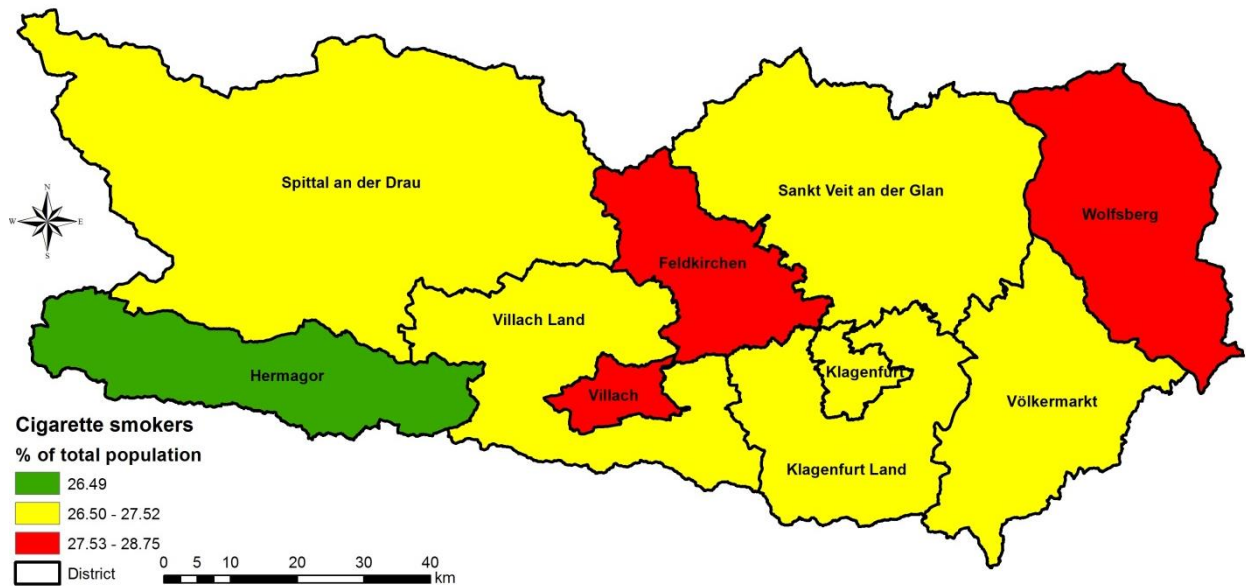


Fig. 5: Simulated smoking population at district level

Figure 6 therefore shows the smoking population at municipality level ranging from 23.1% to 30.6%, hence having a higher variation than at district level. Hidden hot spots are definitely explored in Spittal an der Drau, Villach Land, Klagenfurt Land and Völkermarkt as they are the districts showing areas with low and high percentages of smokers.

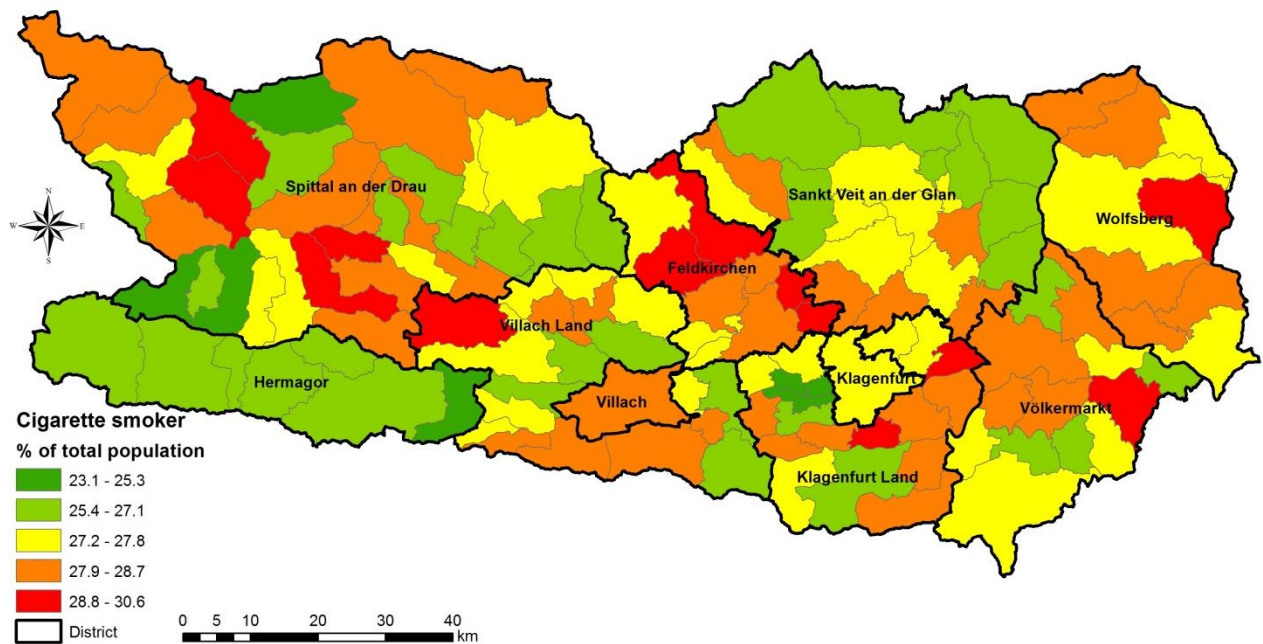


Fig. 6: Simulated smoking population at municipality level

The results will be discussed with the Carinthian health departments to explore reasons for the variations in certain districts and to receive detailed information about smoking cessation measures in Carinthia. Based on these results it will be interesting to model specific population groups, for instance people in the age of 40 to 59 being divorced, to help targeting population groups high on the policy agenda.

5. SUMMARY & FUTURE OUTLOOK

This conference paper shows the first results of applying a spatial microsimulation model to simulate the smoking population at municipality level in Carinthia, Austria as no data on smoking exists at this geographical scale. First, a Web based application was developed to build the framework for the modelling procedure, where first the deterministic reweighting approach is implemented to simulate the smokers at municipality level. This Web application is in on-going developed and improvement throughout the research project. The current simulation is based on the Austrian Health Survey 2006/07 and the census data 2001. One problem that occurs is the high figure of missing responses for the current smoking behaviour from the survey. They count for almost 60%. Leaving the numbers of non-response within the model then the results for the smoking population varies between 23.1% and 30.6% at municipality level, whereas aggregated percentages at district level range from 26.5% and 28.8%. These results are interesting as local variations within municipality level are found. Especially interesting are the districts Spittal an der Drau, Villach Land, Klagenfurt Land and Völkermarkt as within these districts the percentages of the smoking population ranges from lowest to highest. The district Hermagor in the south-west of Carinthia on the other hand has the lowest smoking population for all municipalities whereas Feldkirchen shows highest rates. The results are validated using the Standardized Absolute Error to explore which categories of the constraint variables have a good fit and which are over- and under predicted by comparing the constraint variables of the census with the simulated constraints.

The first results of the research project will be presented to persons from the Carinthian governmental health departments to show them the importance of small area health data and the advantage of the small area modelling approach. Further, together we want to explore possible reasons for higher and lower smoking rates for certain municipalities with expert knowledge. In addition it is aimed to define what-if scenarios for future modelling so that the

results have benefits for the Carinthian health decision makers. Another outlook is to model the smoking population for whole of Austria at the municipality level.

ACKNOWLEDGEMENT

This research project SALUD is funded by the Federal Ministry for Transport, Innovation and Technology (bmvit) and the Austrian Science Fund (FWF) (project number TRP280-G16).

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