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Swiss residential property price index: the use of geolocalised information for quality adjustment in location

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Abstract

The Swiss Federal Statistical Office (FSO) is currently working on implementing an official residential property price index (RPPI). One of the biggest challenges is adjusting for the quality differences in properties from different survey periods. To counter this challenge, the FSO plans to develop a hedonic repricing model, to be used in combination with stratification. Hedonic models allow us to evaluate properties' individual attributes as well as their overall quality. Property characteristics include structural variables (e.g. number of rooms, net living area and age), usage variables (primary or secondary residence) and location variables (e.g. distance to public transport, view, exposure and noise pollution). Location characteristics are collected from geolocalised data made available by the Swiss government. This paper illustrates how the hedonic model will be implemented, focusing in particular on the use of geolocalised information.

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1 Introduction

Switzerland is in the process of constructing an official residential property price index. The first set of quarterly results is expected to be released in 2018, covering single-family houses and condominiums.[1] In addition to the fundamental question of sources as well as the methodological aspects, we also addressed the need to adjust for differences in property quality. Due to the diversity of Swiss landscapes and the limited size of the residential property market (roughly 50,000 transactions per year), the quality of properties varies considerably. Some of the features influencing quality include size (number of rooms and surface area), age (year of construction), property condition, construction quality and, last but not least, location. We will revisit this last item later in this paper.

After evaluating different quality-adjustment methods, we eliminated those least appropriate for the creation of a price index for the residential property market in Switzerland:

- Applying the stratification method alone was not a viable option, given the small size of the Swiss residential property market and the diversity of individual properties. Combining a large number of price-determining characteristics with few property transactions would result in overly disparate stratification cells containing insufficient data.

- The repeat sales method is appropriate for large, high-turnover property markets, which the Swiss market is not. Moreover, it requires a broad pool of data covering a long period of time, which Switzerland is not able to provide.

- Appraisal-based methods can only be applied if accurate appraisals are available for all properties. In most countries, such appraisals exist for tax purposes. However, Switzerland has 26 different tax systems, and property taxation varies considerably from one canton to the next. Moreover, in the majority of cantons, property-tax value does not align perfectly with market value.

We therefore turned to hedonic regression methods. Hedonic models are based on the definition of goods as a bundle of different attributes or characteristics[2], including – as far as residential is concerned – information on physical structure, usage and location. A property's quality can be determined by such characteristics. Therefore, real estate values can be estimated by the very same characteristics. This is similar to a basket of goods whose overall price is determined by the prices of its constituent products. The only difference is that the prices of the different property characteristics cannot be observed individually. However, marginal (or implicit) prices can be determined through regressions, by using a hedonic equation that optimally reproduces the price of any property. Using these implicit prices, the quality of sold properties can then be evaluated and adjusted for. The hedonic equation is as follows:

$$p_{it} = \beta x_{it} + \mu_{it} \qquad (1)$$

p_{it}	Transaction price of property i in period t
x	Vector of the explanatory variables (structure, usage, location) in period t
β	Vector of the coefficients of the explanatory variables (implicit prices)
μ	Error term in period t

[1] see Federal Statistical Office (2016). Creation of an official real estate price index in Switzerland: objectives and challenges. UNECE Meeting 2016, Geneva.

[2] see Triplett, J. (2006). Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes: Special Application to Information Technology Products. Paris, OECD, Organisation for Economic Co-operation and Development.

2 Our choice: hedonic repricing combined with stratification

There are **various ways** to create a price index using hedonic models. They can be roughly categorised as the time dummy, the characteristics prices, the hedonic imputation and the hedonic repricing method.[3] Hedonic methods can also be combined with other techniques, such as stratification. **Stratification** divides sold properties into subgroups – so-called strata, or layers. For each subgroup, subindices (or elementary indices) are calculated which are then weighted and aggregated into an overall index. Adding a stratification to the hedonic model improves quality adjustment and relaxes the rigid assumption that implicit prices are the same for all property segments. As part of the conceptual work performed during the project stage, the FSO evaluated a range of variants, testing them by using real transaction data. The results indicated **hedonic repricing** to be the most promising method for the FSO's purposes. One advantage of hedonic repricing is that the econometric model does not have to be recalculated for each period, reducing the amount of work required in comparison with other hedonic methods. Furthermore, this stable model allows us to calculate indices with period-specific prices and quality attributes. Unlike the hedonic imputation and characteristics prices methods, indices do not need to be calculated for the very-same standard properties in every period. The FSO therefore chose to apply the hedonic repricing method combined with stratification – which has already proven its worth in the official rental price index[4] and which is supported by the external feasibility study for the statistical survey of property prices, conducted prior to the project.[5]

Hedonic repricing adjusts **price changes** in each stratum by removing quality differences. To do this, both a price-change index as well as a quality-change index are calculated for each cell of the stratification. The quotient of these two indices corresponds to the quality-adjusted price change (see formula 2). Thanks to the hedonic repricing method, the observed change in average price can be divided into two components: one for quality and the other focusing exclusively on price. This enables us to monitor not only pure price trends, but also changes in the quality of properties. The formula for calculating the quality-adjusted index using the price-change index and quality-change index is as follows:

$$I_t^{ajust} = I_t^{brut} \div I_t^{qual} \qquad (2)$$

I_t^{ajust}	Quality-adjusted index point in period t
I_t^{brut}	Index point of the price change in period t
I_t^{qual}	Index point of the quality change in period t

The **quality-change index** is determined through a hedonic equation which uses the average property characteristics of each cell within a period. As this hedonic equation is used solely to weight property attributes and derive quality-adjustment factors, it does not have to be recalculated as often as other hedonic methods, which use the equation to estimate price changes. This means that a broader sample can be used to estimate the hedonic model.

[3] a) see e.g. Eurostat (2013). Handbook on Residential Property Prices Indices (RPPIs).
b) see e.g. Hill, R. J. (2012). "Hedonic Price Indexes for Residential Housing: A Survey, Evaluation and Taxonomy." Journal of Economic Surveys.

[4] see Lüscher, A., M. Salvi, A. Bröhl and A. Horehájová (2010). Qualitätsbereinigung im Mietpreisindex - Schlussbericht Zürcher Kantonalbank (ZKB). (German)

[5] see ARGE EPFL, Econability and HEG (2012). Machbarkeitsstudie für die statistische Erfassung der Immobilienpreise. (German and French)

Ultimately, the deciding factor for selecting the hedonic repricing method was the **hedonic model's stability**. However, the implicit prices of quality characteristics are subject to change over time. If this occurs and the hedonic model is not revised accordingly, the index may become distorted. As a preventive measure, the FSO plans to calculate a second index, using the rolling-time dummy method, in addition to the hedonic repricing method. This second index will not be published, as it serves solely as an internal benchmark and to monitor the development of implicit prices.

The **rolling-time dummy** method is a variation of the standard-time dummy method, which includes period-specific dummy variables in the hedonic model in addition to structural, usage and location variables.[6] The coefficients of these dummy variables provide a period-specific value corresponding to the effect of time, i.e. the different periods, on prices. As the model's functional form is usually half-logarithmic, specific index points can be derived directly from the exponential values of the time dummy coefficients. Unlike the standard-time dummy method, the rolling-time dummy method does not pool all transaction data from the various periods. Instead, a rolling time window is defined, corresponding to a fixed number of periods. The hedonic equation is as follows:

$$ln(p_{it}) = \beta x_{it} + \delta_t D_t + \mu_{it} \tag{3}$$

p_{it}	Transaction price of property i in period p
x	Vector of the explanatory variables (structural, usage, location)
D_t	Time dummy (value = 1 if transaction is in period t, otherwise 0)
δ_t	Time dummy coefficient for period t
μ	Error term in period t

The rolling-time dummy method features all of the **advantages** of the standard-time dummy method.[7] These include, for example, the ability to derive the index directly from time dummy coefficients as well as the ability to pool data from different periods. The rolling window enhances the robustness of the model's estimated parameters. At the same time, the method provides scope for the marginal prices of quality attributes to change from period to period, which is not the case for standard-time dummy models.

However, the rolling-time dummy method also has a significant **disadvantage**, namely that a separate hedonic model must be created for each stratification cell, thus requiring a correspondingly broad pool of data. In a country as small as Switzerland, it would therefore hardly be possible to calculate highly granular subindices. This is why the rolling-time dummy method was eliminated as an option for calculating official indices. Instead, it is used solely as a benchmark for the hedonic repricing index and to monitor implicit prices, a purpose for which it is well suited as the coefficients of the rolling-time dummy model can change from period to period.

In principle, the hedonic repricing model will be **revised every five years**, as are the FSO's other price statistics. However, if the rolling-time dummy model indicates an abrupt change in implicit prices, the FSO may recalculate the hedonic repricing model before the next official revision. By combining a stable hedonic

[6] see Diewert, E. (2010). Alternative Approaches to Measuring House Price Inflation, Department of Economics, University of British Columbia, Vancouver.
[7] see Eurostat (2016). Detailed Technical Manual on Owner-Occupied Housing for Harmonised Index of Consumer Prices (draft of the revised paper).

model with ongoing monitoring of implicit prices, we are able to take advantage of the benefits of each type of model to create a high-quality property price index.

3 Data and sources

Various data are required to create and produce the new residential property price index. In addition to information on individual transactions (property identifier, transaction date and transaction price), additional data are needed to adjust for the quality of the properties. These include physical structure (structural variables), use (usage variables) and location (location variables). Efficient quality adjustment and a methodically valid property price index are only possible if the quality of the properties surveyed is realistically reflected. Finally, the FSO wants to determine the universe of all relevant transactions, collecting data on the number and volume of such transactions.

The property **transaction process**, from the initial advertisement to negotiations and the final entry in the land registry, often takes several months. Various parties are involved, collecting and recording transaction data at different points of the process. As part of its project research, the FSO examined which institutions record property transactions and which of these could serve as data sources for the new index. Under the Swiss Federal Statistics Act[8], the Ordinance on the Conduct of Federal Statistical Surveys[9] and the Charter of Swiss Official Statistics[10] (which aligns with the European Statistics Code of Practice), the FSO is required to minimise the effort and costs borne by data suppliers and to give priority to the government's existing data sources. It is therefore our practice to review the available data from national, cantonal and municipal authorities first when compiling new statistics. If this does not yield satisfactory results, data may be collected from private companies. As a last resort, households may be surveyed as well.

Our analysis has shown that **various sources of data** are required to create an official property price index. Information regarding transaction dates, prices and properties' physical attributes are collected quarterly from mortgage institutions (banks, insurance companies and pension funds). This is the only source that records the necessary transaction data, including price, in a full and timely manner. Mortgage institutions also keep additional information on file regarding the quality of properties they finance. As mortgage institutions' operational and strategic business decisions are built on these data, its quality is excellent.

Data from mortgage institutions are able to cover a huge portion of all property transactions as, in Switzerland, there are financial advantages to purchasing property with a mortgage. However, it is clear that not all transactions are financed by a third party. To ensure that the property transaction sample is representative and not distorted, the FSO will collect data on the entire transaction universe, including each transaction's property identifier, **from land registries** as these registries record each and every transaction. The transaction universe will be determined once annually in order to identify any gaps in data collected from mortgage institutions (primarily those transactions not financed by a third party). Unfortunately, currently it is not possible to create a property price index solely on the basis of land registry data, as these registries record neither transaction prices nor additional information regarding the structure of the properties sold. Moreover, land registries are often updated long after the transaction has taken place.

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[8] see FStatA, SR 431.01 https://www.admin.ch/opc/en/classified-compilation/19920252/index.html
[9] see https://www.admin.ch/opc/de/classified-compilation/19930224/index.html (German, French and Italian)
[10] see https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-45890.html

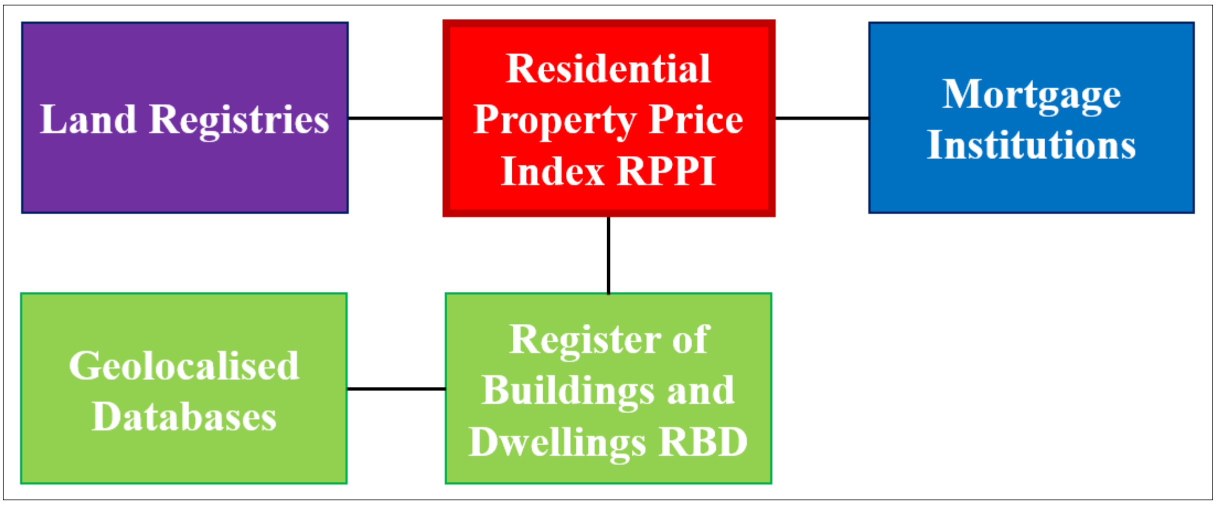

Figure 1: Combination of different data sources for the residential property price index

Data from mortgage institutions are supplemented by information from the **Swiss Federal Register of Buildings and Dwellings** (RBD). The RBD contains essential basic administrative data on buildings and dwellings in Switzerland. Cantons and communes rely on it to carry out their statutory duties and it is also used for statistical, research and planning purposes. This register is maintained by the FSO in cooperation with construction-trade authorities and other specialists from federal, cantonal and communal offices. In addition to unique building and dwelling identifiers, the RBD contains addresses, coordinates and information such as building category, construction year, and number of rooms and storeys. While the structural variables from the RBD (building category, construction year, and number of rooms and storeys) serve to supplement data from mortgage institutions and to validate their plausibility, the extracted coordinates are used to link transaction data with geolocalised information. These geographic data are required to determine the quality of the location of a sold property in order to compare it with other properties.

RBD data must be linked with the corresponding transaction data from the mortgage institutions before they can be used for the index. **Linking is done using property addresses**, a method that has already been applied successfully for the FSO's official rental price index. Initial examination of test data has shown that some 90 percent of all properties can be identified by their address, allowing them to be supplemented with the aforementioned RBD data. The remaining 10 percent are either new buildings that have not (yet) been recorded in the RBD or transactions with incomplete or erroneous addresses. These properties cannot be linked directly with the corresponding entries in the RBD (and consequently cannot be supplemented with structural data from the RBD). However, there is an alternative approach to supplement these properties at least with coordinates. If no exact house number is available, the coordinates can be imputed using the street name and the surrounding street numbers. This type of imputation has allowed us to supplement a further 8.5 percent of properties with coordinates. Tests comparing coordinates taken from the RBD with imputed coordinates have shown that imputation does not cause any major discrepancies. As most location data do not change fundamentally from one metre to the next, there is no reason not to work with the imputed coordinates. All geolocalised information is either taken directly from federal administrative data, which are freely accessible, or can be derived from such data (see section 5).

Currently, we cannot say with certainty which structural, usage and location variables will ultimately be used in the hedonic model. We will, however, describe the spectrum of available options in the following sections, with a particular focus on location variables taken from geolocalised data.

4 Structural and usage variables

Structural variables are information that describe a property's physical features. As mentioned above, the FSO will collect the majority of these variables, along with the transaction identity and price, from mortgage institutions, supplementing them with specific variables from the RBD. Experience in Switzerland[11] and other countries and testing by the FSO indicate that structural variables will play a key role in quality adjustment.

The main attribute of the new residential property price index is the **property type**. We plan to stratify properties by type and publish subindices for single-family houses and condominiums. The FSO will also generate a separate hedonic model for each of the two property types. If applicable, the two property types will be further divided into various subtypes. For single-family houses it appears to be particularly significant whether the property is free-standing, attached or terraced, while condominiums can be subdivided for example into penthouses, flats with a garden and full storey apartments.

In addition to property type, **size** must also be taken into consideration. Living-area data collected for single-family houses usually reflect the building's volume, i.e. cubic units, as well as the surface area of the corresponding plot of land. By contrast, the size of condominiums is measured as the net living area. Size data for single-family houses and condominiums are key components of the hedonic model without which it would be impossible to adjust for quality differences effectively. The number of rooms, bathrooms and parking spaces are also recorded for both property types.

As the value of property **depreciates** over time, it makes sense to include the construction year, i.e. the **property's age** at the time of the transaction, in the quality adjustment. Because depreciation can be counteracted through renovation, Eurostat[12] posits that any renovation work should also be reflected in the hedonic model. However, given the sources available in Switzerland, we are unable to make any nationwide observations regarding renovations from which to observe whether values have been maintained or increased. Instead, we plan to use **property condition** as an alternative variable, which mortgage advisors record in the form of a grade in the bank's IT system as part of the credit check. This allows us to compensate for the missing data on depreciation and renovation. Nevertheless, it still makes sense to include the construction year in the hedonic equation, as this information serves as an indicator not only of depreciation but also of price differences resulting from changing construction methods. When creating the hedonic model for the official rental price index, it was found that the impact of age on price was not linear. As properties got older, their prices were adversely impacted, but only up to a certain age, after which prices began rising again, reflecting the appeal of renovated old buildings[13]. Besides assessing the property's condition, mortgage advisors also record **construction quality** in the form of a grade. This information should also be included in the hedonic model.

In addition to structural variables, the FSO will also record information on the designated **use** of the property. Whether properties are used as primary or secondary home has become a contentious issue since the

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[11] see e.g. Lüscher, A., M. Salvi, A. Bröhl and A. Horehájová (2010). Qualitätsbereinigung im Mietpreisindex - Schlussbericht Zürcher Kantonalbank (ZKB). (German)
[12] see Eurostat (2013). Handbook on Residential Property Prices Indices (RPPIs).
[13] see Koev, E. (2003). Combining Classification and Hedonic Quality Adjustment in Constructing a House Price Index.

second-homes initiative[14] was enacted, prohibiting communes whose holiday residences exceed 20 percent of total homes from building any more secondary residences. The question therefore arises whether the prices of holiday residences in the communes concerned evolve differently to those of other properties. Even if conclusive statements cannot yet be made about the new law's effects, there already seems to be evidence that it has impacted prices. According to Lehner[15], ever since the second-homes initiative became law, the housing market in certain popular tourist towns and cities has split into two: one for primary residences and one for holiday homes. As a result, it may be useful to distinguish between primary and secondary residences in the hedonic model. Banks financing single-family houses and condominiums record whether these properties are primary or secondary residences as these two usage types are subject to different statutory requirements with respect to mortgage financing and amortisation schedule.

5 Location variables

In addition to structural characteristics, location variables also affect property prices. Location variables encompass all information pertaining to a given location or region. For the purposes of the property price index, a property's location is determined by its address or coordinates, giving each property a unique location that distinguishes it from all others. However, property location is not just limited to geographical coordinates. It is also defined by various factors influencing its site. A property's location can therefore be defined as the collection of all factors influencing that space. Nevertheless, the assessment of a location is ultimately always subjective, with the value ascribed to location characteristics depending heavily on one's life situation and opinion. For example, some people may place a premium on accessibility by public transport and motorised private transport, while others find the resulting noise a nuisance. The hedonic model assigns an objective value to location on the basis of the prices paid by various home buyers.

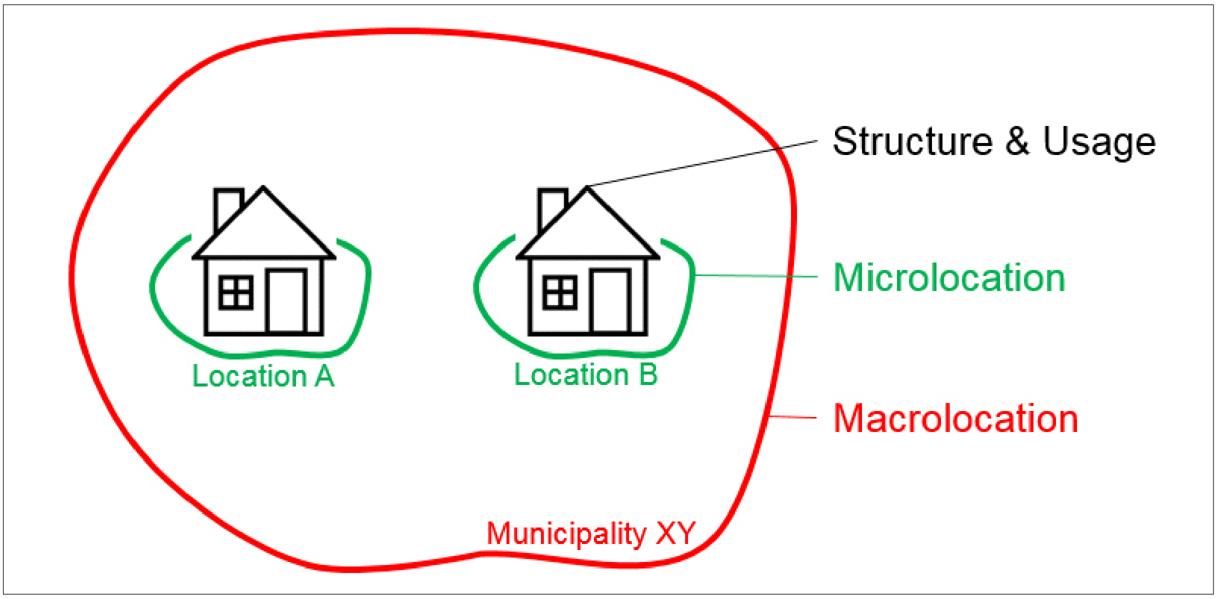

Figure 2: Data categories in the quality-adjustment model

[14] see https://www.are.admin.ch/are/de/home/raumentwicklung-und-raumplanung/raumplanungsrecht/zweitwohnungen.html (German, French and Italian)

[15] see Lehner, M. (2015). Messbare Preiseffekte der Zweitwohnungsplafonierung. Neue Zürcher Zeitung 13 March 2015. (German)

The FSO divides location variables into **micro and macro location variables**, with the boundary between the two drawn at municipality level (see Figure 2). Any information pertaining to areas below commune level are considered as micro location variables, while the rest are macro location variables. This distinction is important because different requirements and procedures apply when supplementing transaction data with micro location variables as opposed to macro location variables. While macro location factors can be assigned to properties by commune or region, micro location variables require property-specific coordinates.

Fortunately for the FSO, Switzerland makes vast amounts of high-quality **geolocalised information** freely available through various federal offices. It makes sense to use these sources for quality adjustments in the property price index.

5.1 Macro location

Macro location variables are location variables available at communal level or above, for example, **the average travel time** to core cities and urban centres, which is calculated and prepared for all communes by the Federal Office for Spatial Development (ARE).[16] Assuming that easy accessibility has a positive effect on prices, such data would be useful in the hedonic model.

Other data compiled at communal level include the number of overnight stays and beds available for tourists. These **tourism-related figures** originate from FSO sources and are prepared by the Tourism Section.[17] Testing has yet to be conducted to determine whether and how property price trends for tourist communes differ from those of other communes. If they do differ, tourism-related figures will be included in the hedonic model.

The FSO also includes two socio-economic variables, **tax burden** and **taxable income**, in its analysis of location factors. With socio-economic variables, it is often difficult to separate cause from effect. For example, noise pollution negatively influences property prices[18], but one would also expect areas affected by noise to have lower incomes on average. Although it is unclear whether these socio-economic variables will be included in the hedonic model, tax burden[19] and taxable income[20] are generally considered as good indicators for property prices. We believe the impact of both variables on property prices should be examined more closely. Taxable income and tax burden figures are prepared annually for all communes by the Federal Tax Administration (FTA).

In addition to various location characteristics, dummy variables for territorial communities can also be used in the hedonic model. If a property is located in a particular territorial community, the dummy variable equals 1, otherwise it equals 0. This allows us to take into account regional price differences not accounted for by any of the other location variables. In this case, regional dummy variables serve as a proxy for varying

[16] see https://www.are.admin.ch/are/de/home/verkehr-und-infrastruktur/grundlagen-und-daten/verkehrserschliessung-in-der-schweiz.html (German and French)

[17] see https://www.bfs.admin.ch/bfs/en/home/statistics/tourism/tourist-accommodation.html

[18] see e.g. Willhelmsson, M. (2000). The impact of traffic noise on the values of single-family houses. Journal of Environmental Planning and Management Vol. 43, No. 6: p. 799 - 815.

[19] a) see e.g. Oates, W. E. (1969). The Effects of Property Taxes and Local Public Spending on Property Values: An Empirical Study of Tax Capitalization and the Tiebout Hypothesis. The Journal of Political Economy, 77(6): p. 957 - 971.

[20] see e.g. Federal Tax Administration (FTA) (2013). Steuerwettbewerb und Immobilienpreise in den Kantonen - Die Kapitalisierung interkantonaler Steuerbelastungsunterschiede in den Immobilienpreisen. (German)

location quality and price differentials. While any number of similar regional dummy variables can be created, existing typologies such as cantons, major statistical regions[21] and the FSO's commune categories[22] are a good place to start. It also makes sense to use homogeneous regions that differ from other territorial communities. Regional dummy variables are widely used in hedonic models for property price indices. The FSO's official rental price index also relies on dummy variables for all cantons.

5.2 Micro location

As explained previously, micro location variables comprise all location data below communal level. In order to assign these data to a specific location, they are recorded in the form of geolocalised information. The property coordinates from the RBD are then used to link this geolocalised information to transaction data. The various information is brought together in ArcGIS, a geographic information system, by extracting data from different layers and assigning them to properties.

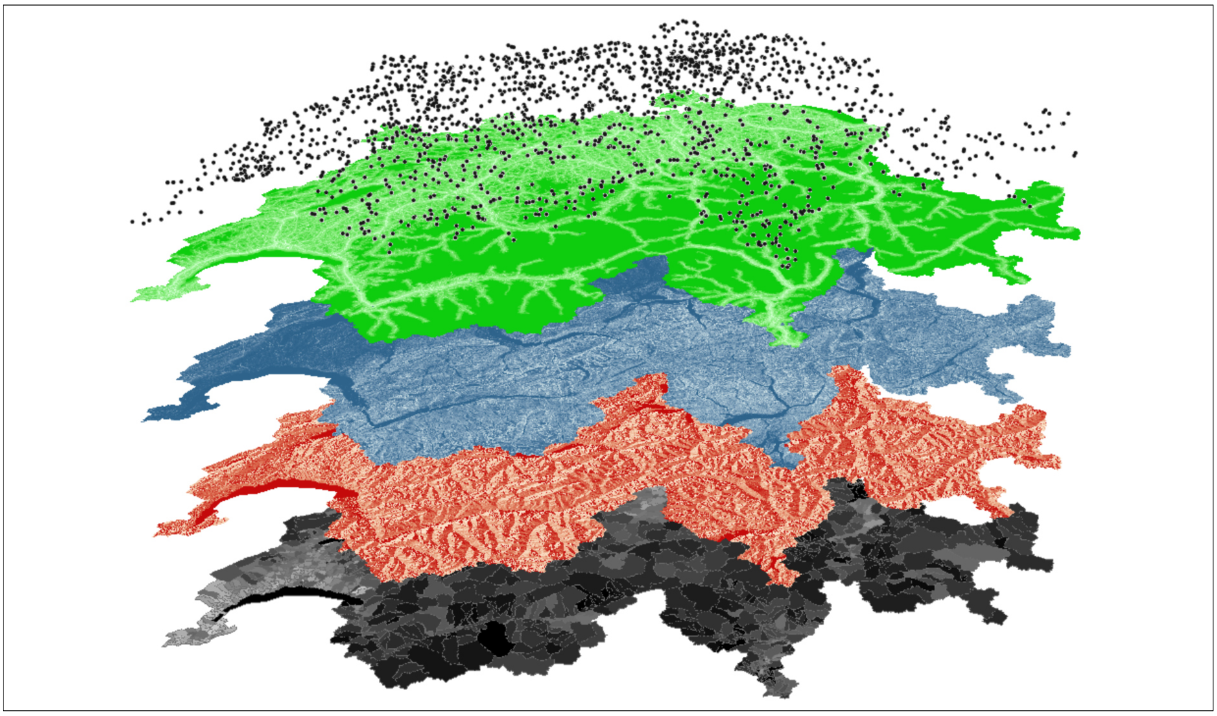

Figure 3: Supplementing property transaction data with geolocalised information

This geolocalised information includes **construction zone types**. Every five years, the Federal Office for Spatial Development (ARE) collects geolocalised cantonal information about construction zones for statistical purposes. Data are taken from each canton's spatial planning authority or the appropriate GIS offices. The ARE then harmonises the cantons' construction zone types and publishes geolocalised data for Switzerland as a whole[23], distinguishing between the following types of construction zones: residential, commercial, mixed, central, public-use, restricted, tourism and recreation, traffic zones within construction zones and

[21] see https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/raeumliche-analysen/raeumliche-gliederungen/analysregionen.html (German and French)
[22] see https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/raeumliche-analysen/raeumliche-gliederungen/raeumliche-typologien.html (German and French)
[23] see https://www.are.admin.ch/are/de/home/raumentwicklung-und-raumplanung/grundlagen-und-daten/bauzonenstatistik-schweiz.html (German, French and Italian)

other. Construction zones in Switzerland currently total 228,480 hectares, nearly half of which (47 percent) are categorised as residential. Given that some 64 percent of Switzerland's population live in a residential zone, we may distinguish only between residential zones and the remaining zones in the hedonic model. We believe residential zones will have less immissions from other usage types, and that they will be more accessible than the remaining construction zones.

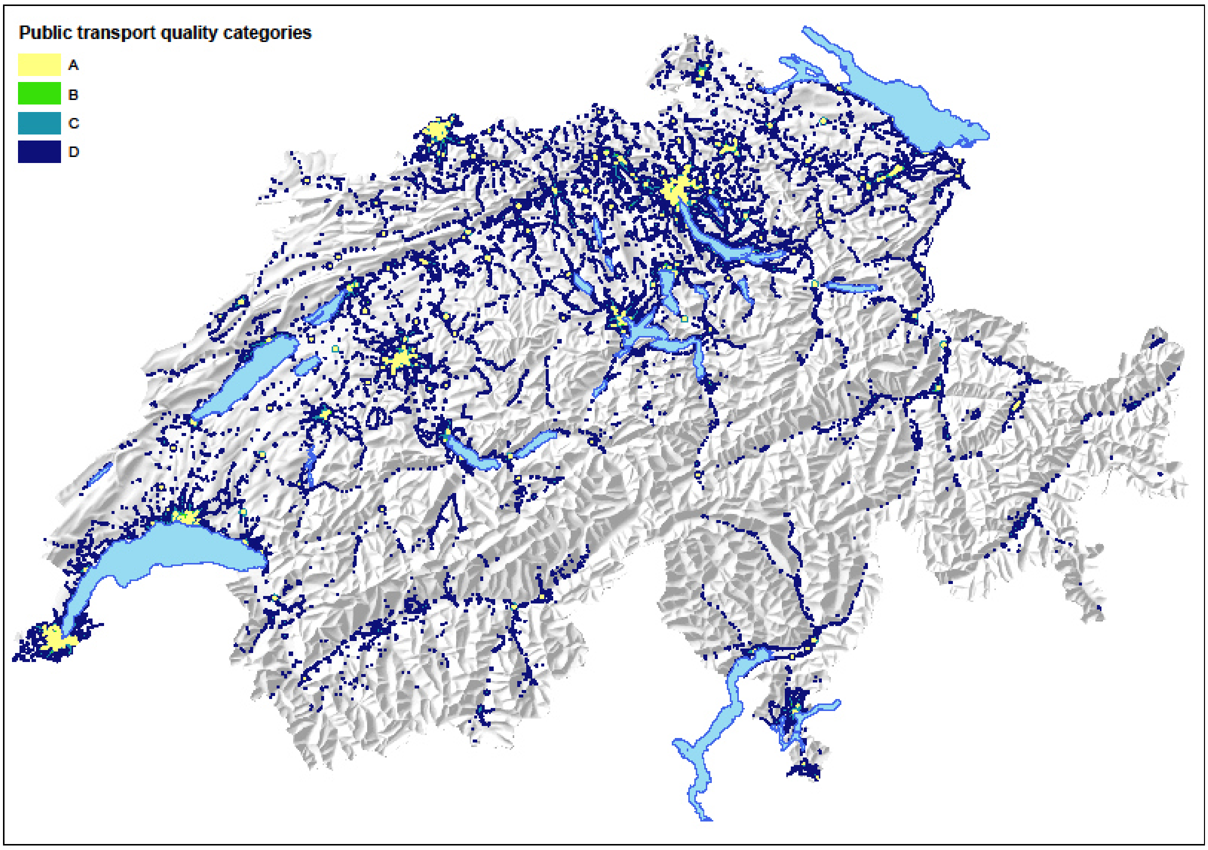

Figure 4: Public transport quality categories

The ARE also supplies geolocalised data on the quality of public transport other than average travel time to core cities (see section 5.1), which serve as an indicator of a location's **accessibility by public transport**. The ARE prepares the relevant data and geolocalised information[24] using the digital timetable of Swiss transport companies (HAFAS). The first step in determining the public transport quality categories is to classify all public transport stations and stops in Switzerland. This is done using the criteria of transport type (railway hub, railway line, tram, bus, postbus, on-call bus, ship and funicular) and frequency. Another parameter, distance to stop/station, is also added in order to reflect the accessibility of stops and stations on foot. Accessibility is measured in concentric circles of no more than one kilometre (linear distance) from the station or stop. This, combined with the station/stop categories, determines the quality of public transport. A total of five accessibility categories are available (excellent, good, average, low and marginal to no accessibility).

[24] see https://www.are.admin.ch/are/de/home/verkehr-und-infrastruktur/grundlagen-und-daten/verkehrserschliessung-in-der-schweiz.html (German and French)

In addition to accessibility by public transport, a sufficient **supply of products and services** necessary for daily life is also a key quality-of-life factor. Most people want to spend as little time and effort as possible to meet their consumer needs. Convenient service accessibility is an important factor in a region's attractiveness and it can therefore be expected to influence property prices.[25] The FSO's Environment, Sustainable Development and Territory (ESDT) section calculates the distance to the nearest service provider in different categories for an annual publication reviewing regional disparities in the availability of services[26]. This is performed for all populated hectares in Switzerland. Accessibility is measured on the basis of travel time by motorised personal transport. As such, these are not linear distances, but rather routes taken on Swiss roads. The FSO's ESDT section has provided the project team with geolocalised information on distances to some 30 stationary, everyday services. These include, besides others, grocery stores, restaurants, banks, post offices, schools, universities, hospitals, petrol stations, bakeries, government offices.

The Federal Office for the Environment (FOEN) provides additional geolocalised information for quality-adjustment purposes. As part of its sonBASE project, the FOEN calculates a nationwide base of geolocalised data on **noise pollution** in Switzerland[27].

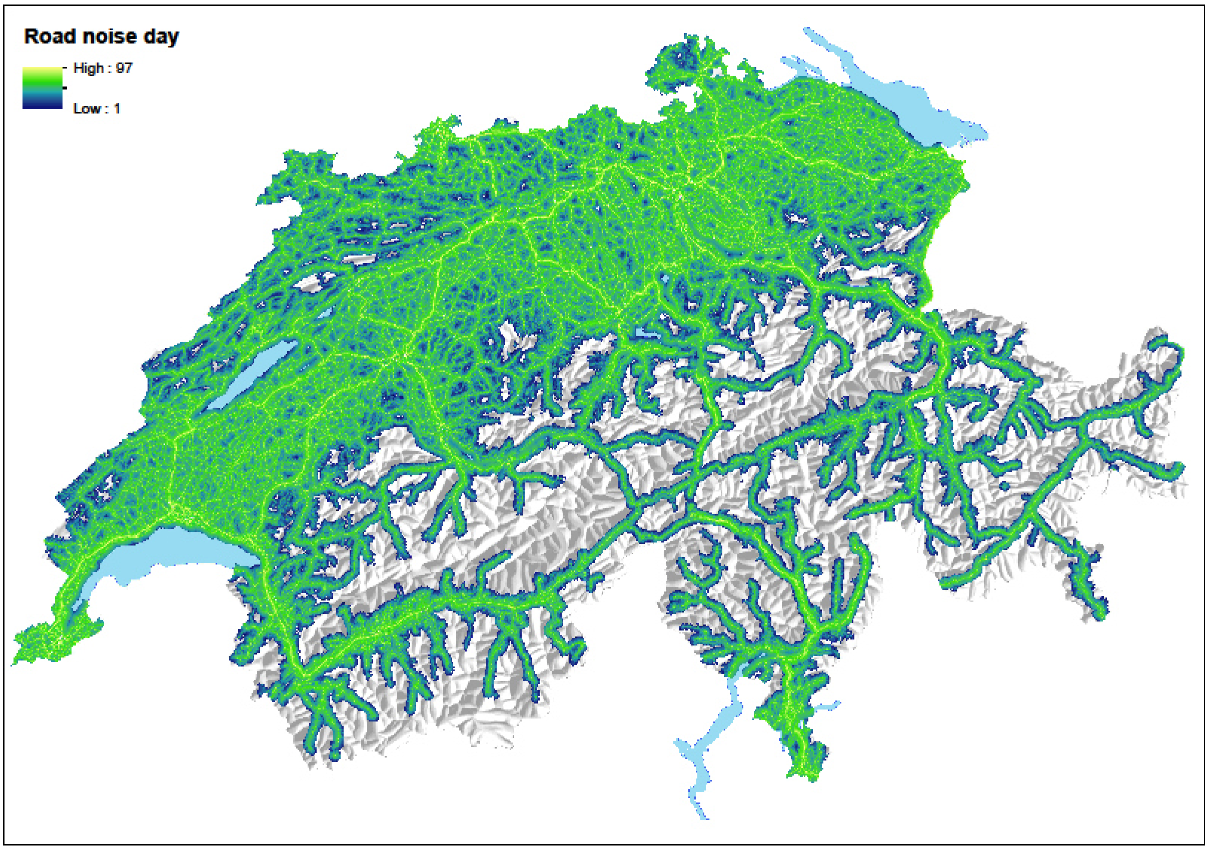

Figure 5: Road traffic noise during the day

The sources of noise taken into account are road, train and air traffic. For all noise types, data are published for daytime (06.00 to 22.00) and night-time hours (22.00 to 06.00). Noise immissions are indicated by Lr

[25] see e.g. Kockelman, K. M. (1997). The Effects of Location Elements on Home Purchase Prices and Rents: Evidence from the San Francisco Bay Area.
[26] see https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/raeumliche-analysen/dienstleistungen-bevoelkerung.html (German and French)
[27] see https://www.bafu.admin.ch/bafu/en/home/topics/noise/state/maps/geodata.html

(level rating), which consists of the noise level (in decibels) as well as various noise characteristics, such as time of occurrence, pulse and tonality. This geolocalised information is recorded in a grid of 10m x 10m quadrants and can be obtained from the FOEN (for roads and railways) and the Federal Office of Civil Aviation (FOCA). Noise pollution is generally considered to be disruptive and can also be detrimental to people's health. It is therefore hardly surprising that noise pollution negatively impacts property prices – a finding that has been documented in various studies.[28] Noise is also included in the hedonic model for the official Swiss rental price index. The geolocalised information detailed above are data layers that can be used without any further processing. The competent authorities have prepared them such that the influencing factors can be extracted directly using properties' coordinates. However, other geolocalised data exist from which additional information must first be derived before they can be used for quality-adjustment purposes. These include, for example, landscape and infrastructure elements that add or diminish value and for which the distance to a property can be calculated. In this case, the FSO will rely primarily on basic data provided by the Federal Office of Topography (swisstopo[29]). **Elements that add value** include lakes, larger watercourses, forested areas and vineyards, for example.

By contrast, **elements that diminish value** include high-voltage power lines, antennas and power plants. Instead of determining distances, another option is to calculate the density of value-adding or value-diminishing elements within a specific perimeter. In this case, depending on whether the component is characterised as a point, line or polygon, the number, aggregate length or percentage of surface area is determined, respectively, for a defined radius. This ensures that all elements within the radius are accounted for, not just the closest one to the property.

The FSO also obtains various **elevation and surface models**[30] from swisstopo. These data layers allow us to derive the slope gradient and exposure at different locations. The slope gradient can have either a positive or a negative effect on property prices. On the one hand, a steeper slope will increase construction costs. On the other hand, constructing on a slope with good exposure can be beneficial, as buildings facing south-southwest, for example, receive plenty of sunshine and are therefore in demand.

In addition to slope gradient and exposure, elevation and surface models can also be used to calculate which areas are visible from a particular location, allowing us to generate probabilistic **view models**. This is relevant to the property price index as view is a key argument made when selling and buying property. A good view can increase the sales price or rent of a property significantly, while a poor view can influence the price negatively. Extensive scientific research has been done on the effect of view on property prices and rents.[31] However, what qualifies as a good or bad view is always a subjective perception, making it a huge challenge to assess visible areas. The easiest way to do this is by measuring the area determined as visible, as it generally can be assumed that a large visible area has a positive effect on property price. In order to reflect the quality of the view, the visible areas are intersected with layers documenting lakes and mountain peaks. This gives us three variables pertaining to view: the visible lake area, the visible land area and the number of visible mountain peaks.

[28] see e.g. Willhelmsson, M. (2000). The impact of traffic noise on the values of single-family houses. Journal of Environmental Planning and Management Vol. 43, No. 6: p. 799 - 815.
[29] see https://www.swisstopo.admin.ch/en/knowledge-facts/topographic-landscape-model.html
[30] see https://shop.swisstopo.admin.ch/en/products/height_models/alti3D
[31] see e.g. Yu, S.-M., S.-S. Han and C.-H. Chai (2007). Modeling the value of view in real estate valuation: A 3-D GIS approach. Environment and Planning B: Planning Design 2007; 34: p. 139 - 153.

The FSO will use a two-step procedure to calculate the view model. This in order to anticipate calculation time. First we will calculate the so-called "view potential" for each populated quarter-hectare (50m x 50m) in Switzerland, based on a surface model without vegetation or buildings (see figure 6). In other words, for each 50m x 50m quadrant, we will determine which area is theoretically visible from a height of two metres above the centre of the quadrant. The radius for visible areas and lake views is 20 km, while a radius of 130 km is used for mountains. View potentials are calculated only once, resulting in a new layer that is used to assign a specific view potential to each property.

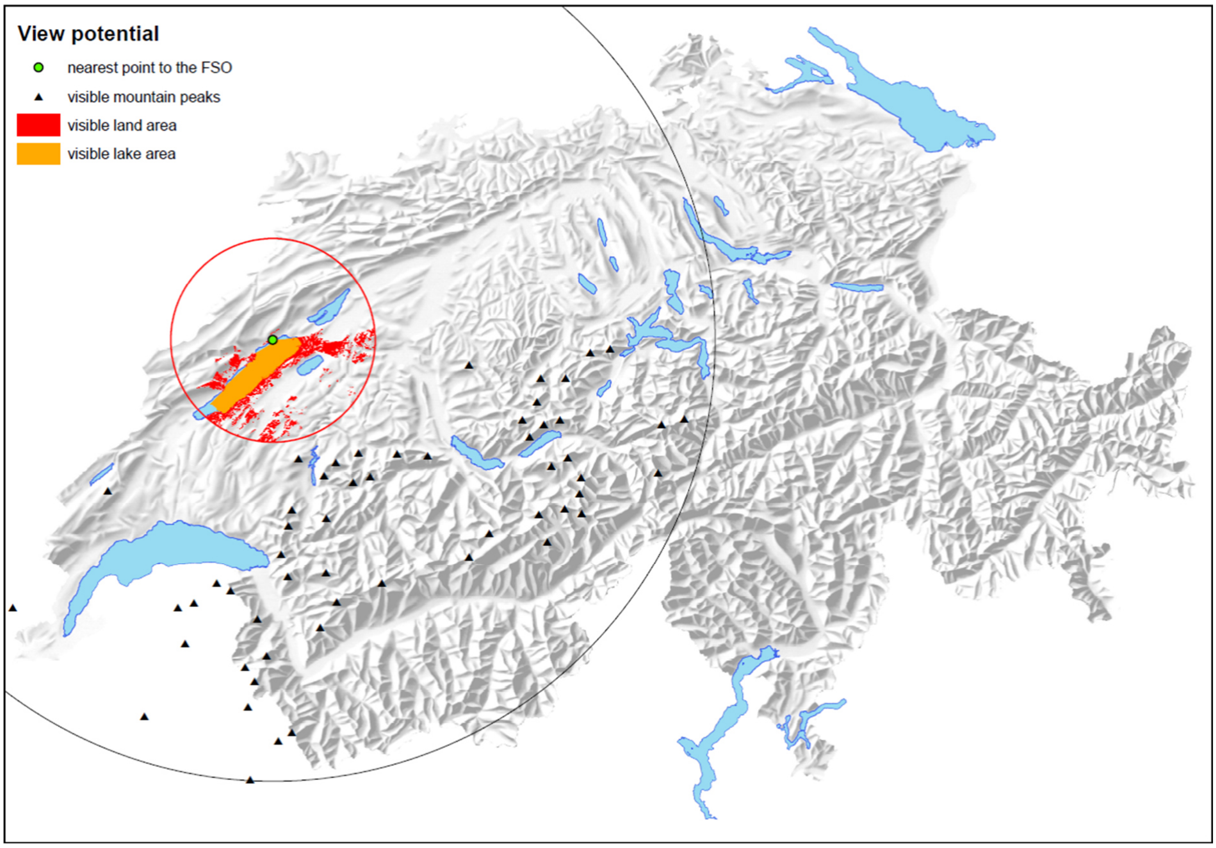

Figure 6: View potential for the FSO building

The next step is to review whether and to what extent the view potential is obstructed by other buildings, trees or bushes (see figure 7). This is carried out using a more detailed and data-intensive surface model that also contains information on buildings and vegetation for each transacted property at survey time. As our only purpose is to identify anything that would restrict the view potential, the radius used for this second round of calculations, which is performed anew for each property sold, can be much shorter than for the view potential. Based on the visible area within this radius, the property's view potential is weighted.

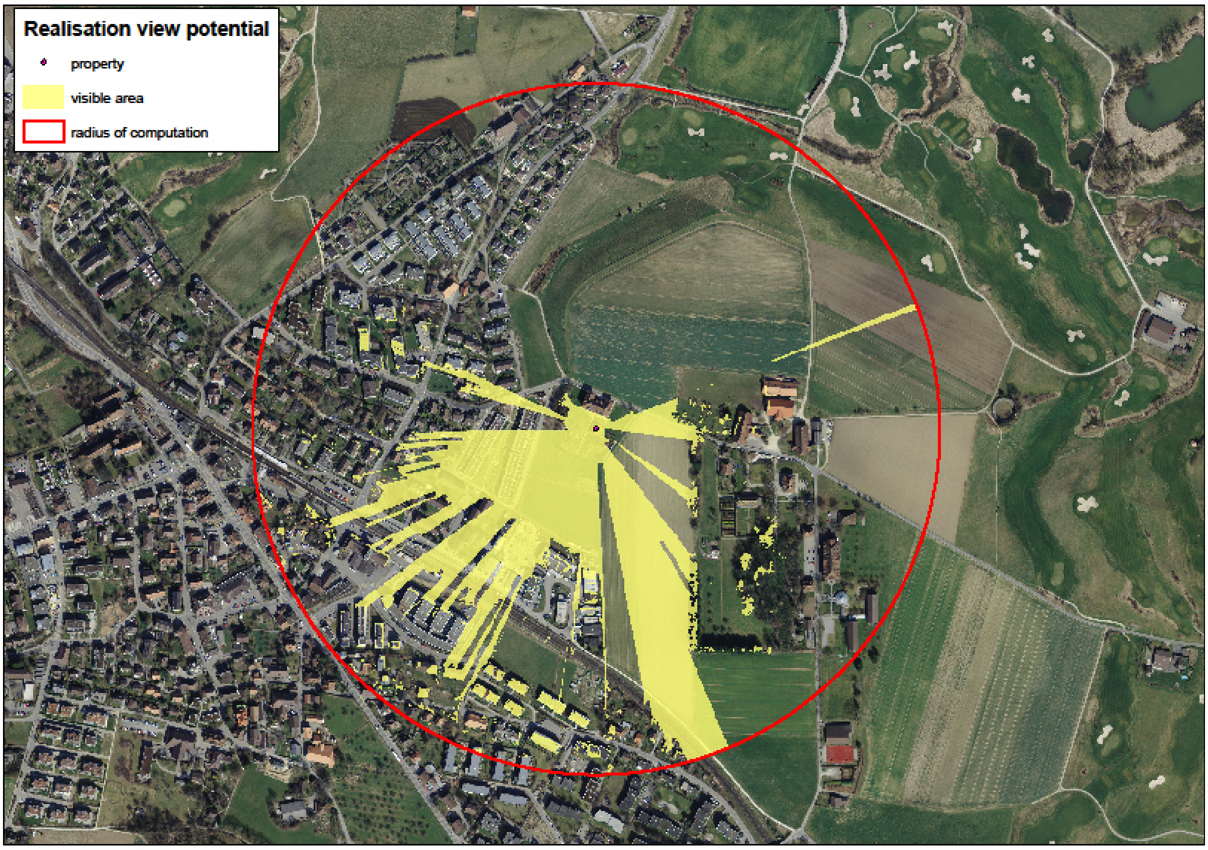

Figure 7: Calculation scheme for the realisation of the view potential for a property in the Canton of Bern

6 Conclusion

Adjusting for differences in quality between properties from different periods is an indispensable part of creating a property price index. During the conceptual stage of the property price index project, the Federal Statistical Office (FSO) decided to adjust for quality differences using a hedonic repricing model in conjunction with stratification. For this method to work properly, various information is required pertaining to the transactions themselves as well as to the quality of sold properties, i.e. their physical structure (structural variables), use (usage variables) and location (location variables). The FSO will obtain this data from various sources. While the overall transaction universe will be determined using land registry data, information on specific sold properties will be obtained from mortgage institutions, as this is the only data source which records all required transaction data, including price and physical characteristics, in a timely manner. The FSO will then supplement the data from mortgage institutions with information from the Swiss Federal Register of Buildings and Dwellings (RBD), which supplies additional structural variables as well as property coordinates. These coordinates are used to link and enrich transaction data with various geolocalised information. Switzerland offers a large selection of freely accessible geolocalised data, from which the FSO hopes to obtain location indicators to improve quality adjustment further. Which structural, usage and location variables will ultimately be used in the hedonic model will be determined during the implementation stage. The FSO will document the methodological principles as well as details of the quality-adjustment process and publish them following the introduction of this new index.

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