Paper prepared for the 24th Biennial Conference on Regional and Urban Statistics

UNDERSTANDING CHANGE

May 19–21, 2004, Minneapolis, USA

Territorial structure and standard regional reference systems in Switzerland

by

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Abstract

The paper starts with an overview of the general advantages and disadvantages of vectorized area units versus a raster or grid based approach. On the one side, area delimitations that follow political, administrative or physical boundaries are meaningful and, often, perceivable in reality. On the other side, they lack temporal stability and make it difficult if not impossible to achieve reliable and significant statistical time series. Therefore, a neutral approach ignoring any geographic as well as political preconditions could provide a solution from this obvious conflict of objectives or intentions.

Switzerland knows since its inception a three-level administrative subdivision of the country into canton, districts and communes. The number and names of these has, however, proven to change frequently, making them less than optimal to present statistical results over longer time periods. Already more than 30 years ago, planners established a hectare grid system proposed to function as geographical reference for a variety of statistical variables.

With the last population census, this information database was complemented by a new register on dwellings, supporting cross-referencing of any relevant addresses from statistical surveys with a comprehensive and georeferenced list of all residential buildings in the country.

Since many years, therefore, a multitude of statistical data is available and is being disseminated at the hectare level. Although such a precision provides certain concerns regarding data protection, this issue becomes of high importance regarding data dissemination for individual buildings (and, individually defined aggregates of buildings). The general problematic in this respect is outlined and a few measures to avoid disclosure of confidential or personal data identified.

While many problems remain to be solved and issues to be tackled, our conclusion affirm the enormous value of being able to locate statistical information accurately and precisely on the ground, irrespective of changes in the political structure and the geography of a country. Only the identification of individual survey records with their corresponding buildings provides a stable system of satisfactory reliance, event though dissemination of such very detailed results may often not be feasible.
1 Introduction

1.1 Vector shapes and grid cells

GIS systems as well as graphic applications for computers traditionally distinguish between raster and vector formats for data and images. Geographical information, therefore, is presented in two ways: as vector data describing the geographic primitives points, lines and areas (polygons); or as grid data in the form of uniform, systematically organized cells [1] (Fig. 1). The same two basic data models also lend themselves to define standard regional reference systems for the collection and dissemination of georeferenced statistical data.

Vector data has the advantage of allowing an efficient representation of simple data models as well as a complex pattern of spatial information, and is, basically, unaffected by considerations of scale and spatial resolution. The accuracy and precision of its points (and lines, polygons) defines its (geometric) data quality and, consequently, the correspondence between reality and the (vector) data model describing it.

Raster data structures follow a more simple concept and do not need to take into consideration topological, geometric and other aspects of the objects they describe. The size of the grid cells is the only determining factor of accuracy and usefulness of the data for various applications or map scales. There is a dispute whether vector models store (GIS) data more efficiently, such as suggested by the following citation: “One of the major problems with raster data is its (file) size, because a value must be recorded and stored for each cell in an image” [2]. File size may sometimes translate in higher hardware requirements, specifically to process detailed information for large areas and to satisfy high demands on spatial resolution. Today’s computer systems, however, make these aspects appear less significant.

We may conclude, therefore, that the nature of the data to store and process is the most influential factor to decide on the appropriateness of either the raster or the vector data model. Point data such as the coordinates of all police stations or all radio antennas of a certain area, line data such as road or river networks, or polygon data such as boundaries of administrative areas rather call for a vector-based GIS and vector-based data processing. For typical image data (e.g. aerial photographs or from satellite sensors), terrain models, distribution models for meteorological features, pollutants etc. the raster data model and grid data processing are doubtlessly faster, easier, more efficient and flexible.

1.2 Stability and time series versus political relevance - conflicting objectives

Using vector data, i.e. polygons, as standard regional reference system, usually provides the opportunity to define the standard regions in a way they are meaningful for the collection and/or dissemination of statistical data. Standard regions such as enumeration areas, administrative, election, or political regions are also easy to deal with for a wide public of potential data users, since these concepts are familiar to them and relevant in their everyday life.
Using a standard grid as basic reference system for an area or a country, on the other hand, has the advantage of establishing a completely unbiased, objectively defined georeference framework, which can easily be kept stable over time and does not require the frequently excessive amount of maintenance most vector-based reference systems do. They need to be constantly updated to reflect changes in the real features they are based on, such as administrative boundaries, population counts (for electoral districts as well as census-defined areas).

**Fig. 1  Representation of real-world objects in the raster and vector data models [from 2]**

<table>
<thead>
<tr>
<th>The raster view of the world</th>
<th>Happy Valley spatial entities</th>
<th>The vector view of the world</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Raster View" /></td>
<td><img src="image" alt="Vector View" /></td>
<td><img src="image" alt="Vector View" /></td>
</tr>
<tr>
<td>Points: hotels</td>
<td><img src="image" alt="Vector View" /></td>
<td><img src="image" alt="Vector View" /></td>
</tr>
<tr>
<td>Lines: ski lifts</td>
<td><img src="image" alt="Vector View" /></td>
<td><img src="image" alt="Vector View" /></td>
</tr>
<tr>
<td>Areas: forest</td>
<td><img src="image" alt="Vector View" /></td>
<td><img src="image" alt="Vector View" /></td>
</tr>
<tr>
<td>Network: roads</td>
<td><img src="image" alt="Vector View" /></td>
<td><img src="image" alt="Vector View" /></td>
</tr>
<tr>
<td>Surface: elevation</td>
<td><img src="image" alt="Vector View" /></td>
<td><img src="image" alt="Vector View" /></td>
</tr>
</tbody>
</table>
Finally we cannot avoid to admit the fact that the commonly proposed objectives for standard regional reference systems for statistical information are contradictory and cannot be satisfied equally with any single reference system alone. Comparisons over time and space, visualization of time series, objectivity and independence from any political background and statistical preconditions, minimal requirements for maintenance and actualization of the systems, these issues can best be met by a grid reference system. User friendliness, directly conceivable political relevance, optimal support to organize data collection (such as in the context of national censuses), strict adaption of flexibly defined data protection requirements are the strengths of a (continuously updated) vector-based reference system.

2 Administrative units in Switzerland relevant for statistics

2.1 The long established system of cantonal and communal (local) authorities and areas of influence

Since 1815 the territory of Switzerland as a whole remained basically stable. The next step of administrative and political subdivision beneath the national level are 26 largely autonomous cantons which are again subdivided in altogether 185 districts (these units, however, do not exist for many of the smaller cantons and are not called the same in some of the remaining ones). For statistical purposes as well as to provide regions for Switzerland compatible with the European regional statistical NUTS (nomenclature des unités territoriales statistiques) system, the cantons have been regrouped by the Swiss Federal Statistical Office into seven main regions (equivalent to the NUTS level 2) a few years ago (Fig. 2).

The basis for all regional, administrative statistics in Switzerland are the political communes. While in 1990, there were still 3021 communes in the 26 cantons, their number has in the past years significantly diminished to reach only 2842 by the beginning of last year. The Swiss communes among themselves are highly inhomogeneous, be it regarding their surface area (ranging from 32 ha to 28’221 ha) as well as the number of their inhabitants (from around 20 to more than 300’000 for the most important cities).

In addition to the hierarchy of communes, districts and cantons, there are a few special areas which are not incorporated into this logical system and possess a special, often for each unit individually defined legal status. These are briefly presented in the subsequent chapter.
2.2 Special areas and problematic issues

Lakes and waterbodies

Many of the larger lakes in Switzerland are directly subordinated to cantonal authority; their surfaces are not, or not contiguously, divided among districts and communes bordering the lakeshore. The legal situation is, however, very heterogeneous, sometimes even within the area of just a single lake in the sense, that its surface area coming to one canton may be the total of legally defined communal lake portions, while in the neighboring canton there is no assignment to local authorities, or their area of competence and jurisdiction is limited to a coastal belt (of a size which again may vary from canton to canton). For the purpose of federal statistics, a more homogenous model seemed highly desirable, as well as an interpretation avoiding any bias or shifts over time for regional comparisons. It was therefore decided more than ten years ago to exclude all lakes larger than 5 km² from the area definition of districts and communes and to identify them as special water surfaces belonging to one or more of the adjoining cantons.
Contrary to a recommendation of the European Union, Switzerland has not made any provisions to specially identify and enumerate linear water bodies such as larger rivers or canals in order to exclude their surface areas for the calculation of densities etc. This is not only due to conceptual problems to define clearly what is the width of a river (its water area – at which time of the year, or its river bed?). In addition, the lack of objective and useful data of this nature forms the major constraint to advance in this direction.

Cantonal and pluri-ownership areas

A cantonal forest of about 2½ km² as well as three tiny land areas under the ownership of three monasteries are the only land areas directly administered by cantons. They can be and are accounted to districts as well, but not to communes. In order to achieve a correct area total of the country as a whole, these areas must be equally considered as the communes and lake areas. Statistically, however, only the Galm Forest near Fribourg is of importance, while the other, monastery areas, usually are incorporated to the area figures of the largest of the adjoining commune due to the insignificance of their small areas.

Five areas, four in the canton of Ticino and one in the canton of Valais, are jointly owned by two or more communes (some of which may not even have a common border with them). For these, we use the Italian term «communanza» and treat them statistically as if they were independent communes themselves. In many tabular statistics, they are however omitted completely, since all of them are not permanently inhabited and therefore of little interest for population and economic statistics. Their neglectence can lead, again, to errors in calculating surface areas for Switzerland as a whole or the affected cantons.

Computation of area figures

Proper identification and consideration of these special areas is of utmost importance for any statistical tabulations not only revealing the results of typical statistical surveys such as population, economic entities, financial and infrastructural findings etc., but surface areas, environmental or agricultural facts as well. This also includes the calculation of densities (population...) which is very common in statistics and often a prerequisite for the production of meaningful thematic maps.

An additional potential source of error are sometimes also the two foreign exclaves Campione d’Italia bordering the Lake of Lugano and Büsingen (Germany) bordering the river Rhein between Schaffhausen and the Lake of Constance. It is important to assure that their surface areas are excluded when summing up totals for the entire country.
3 The establishment of a standard hectare grid

3.1 From an information raster to GEOSTAT

Already in the 1970s, the Institute for Local, Regional and National Planning at the Federal Institute of Technology in Zurich proposed to establish a standard grid of 100×100 m cell size for statistical and cartographically deduced data, and set up a reference system called “information raster” which contained administrative data at the commune level as well as such a hectare grid. Grid information coming from the national censuses of 1970 and, later on, 1980, as well as land use information derived from available national topographic maps formed the nucleus of this raster information system.

In 1976 this information raster was officially transferred to the Swiss Federal Statistical Office with the mandate to maintain and further develop the system, to increase the number of information it contained and to optimize using it for analysis and applications for a large and diverse customer base. This changed the formerly task-specific concept of the database to an open system, whose spatial data were, stage by stage, expanded.

In 1987 the decision was taken to procure a modern geographic information system and to set up a specialized unit at the Federal Statistical Office – the GEOSTAT user service – to manage the new system and above all to counsel the data users. Since then, there has been a vast growth in the amount of data and in the requested evaluations, analyses and digital products. GEOSTAT has matured into an operational system and service facility held in high esteem by numerous specialists.

3.2 Characteristics of the Swiss standard hectare grid

Defining a standard grid may seem to be very simple, but still requires a few important and potentially influential decisions. While the cell size defines its spatial resolution, the number of available information units for analysis and applications for a given area, but the demands for survey and projects to assemble this information as well, the definition of a map projection is another mandatory step. By selecting a map projection, one implicitly defines the compatibility of its information with other data sources, especially of cartographic nature (in an analogue or digital form) or grid information from other data suppliers and/or neighboring areas. The most evident solution for Switzerland was found to adopt the widely used standard map projection from swisstopo, the Swiss National mapping agency. Its true-angle, oblique cylindrical projection with its main axis through Bern city is used for all its topographic and other map editions, as well as for all geodata made publicly available in recent years. It is, however, a projection not found anywhere else in Europe and, most likely, in the world, so that Swiss geoinformation, including from our standard grid, cannot seamlessly be combined with any available similar information from all our neighboring countries.

In principle, the border coordinates of a cell grid may be chosen entirely arbitrary, but to make matters simple, one would normally tend to use somewhat round figures according to the chosen reference map projection. In Switzerland, therefore, the grid’s edges are also the 100 m coordinate grid lines found in topographic maps.
3.3 Data conversion from raster to vector geometry

From dealing with satellite data as well as other digital imagery, we know that grid information can be easily recalculated to adjust to different grid layouts (e.g. map projections or cell edges) as well as different cell sizes. For continuous data, a huge variety of more or less sophisticated transformation algorithms to achieve optimal results under different circumstances, exist and are commonly implemented in most of the available, user-friendly software packages. These functions are widely known as sub-, down-, and resampling an image or corresponding raster data. Things are more complicated when dealing with discrete data and even more, with arbitrarily chosen codes, such as e.g. typical land use data. Nominal codes cannot be added, subtracted etc. from each other, since two numerically adjoining codes do not necessarily express any close relationship or similarity of the real objects they stand for. It is not the subject of this paper to further explore this interesting subject and theoretical and practical solutions for it.

Within geographical information systems it has become very common to convert data from raster to vector format and vice versa. Regarding statistical data and its interpretation, such conversions again pose special problems and points for discussion. Quite simple methods as well as highly sophisticated ones may be used to calculate figures for given polygon areas (such as administrative or planning areas) from a standard grid reference system. On this subject too, we cannot provide in-depth information and delve into an intensive discussion. Still, the table below demonstrates empirical results achieved in Switzerland and illustrates the order of differences to the (equally known) exact figures for 11 communes of one of our smaller cantons. We may conclude from this, that often (but not always), the more sophisticated calculation algorithms also lead to results deviating less from the “true” figures.

<table>
<thead>
<tr>
<th>Commune</th>
<th>Inhabitants according to exact, metric building coordinates</th>
<th>Hectometric values according to lower left edge</th>
<th>Hectometric values according to center point</th>
<th>Hectometric values according to largest portion of surface area</th>
<th>Hectometric values proportional to relevant portion of surface area</th>
<th>Hectometric values proportional to inhabitants in neighboring cells</th>
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<tr>
<td>Baar</td>
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<td>4512</td>
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<td>23028</td>
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<td>22843</td>
<td>22891</td>
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<td>98445</td>
<td>99827</td>
<td>99821</td>
<td>99578</td>
<td>99752</td>
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</table>
4 Georeferencing buildings

4.1 The National Censuses of Population and Housing

Basic, comprehensive population data on Switzerland are provided by national censuses of population, buildings and dwellings which are organized by the Federal Statistical Office every ten years. Through an elaborate process of geocoding, geographic coordinates are assigned to residential buildings, transferred to the building record which also includes information about dwellings and to the computerized register of census data.

A unique building number establishes the relationship between buildings and dwellings and the census of persons and households. Thus, determining the position of the building simultaneously pinpoints the dwellings, households and persons surveyed. In the 1990 census, geocoding of residential buildings was organized for the first time as a compulsory, full-scale effort, resulting in georeferenced census data covering the entire country. The same survey effort is repeated again for the 2000 census, so that updated information is expected to become available before the end of the present year.

Building coordinates are surveyed using various procedures, based on cadastral survey plans (which become increasingly often available in digital formats), local plans, national maps and building registers. The first step is to record and number the building’s exact position. Each building is represented by a centroid point, which must be located inside of its floor plan. Afterwards, each building is assigned hectometric coordinates according to its location in the hectare grid.

Up to ten staff members were working for the geocoding of the national population censuses of 1990 as well as 2000. More than 400 standard variables were defined for aggregation at the hectare level and the transfer into the geographical information system of GEOSTAT. This allows now to analyze census data according to arbitrary spatial perimeters and to combine it with other data sets available with GEOSTAT, such as for example land use types, legal construction zones etc.

Geocoding or georeferencing of the results of censuses and other statistical data collection endeavors is an essential prerequisite in order to provide the GIS data necessary for interesting analyses of statistics and for attractive presentation of regional results. The amount and diversity of geocoded census data offers new and exciting possibilities for interpretation and presentation. Fig. 3 may serve as an example for such, sometimes unusual ways to illustrate the urban area and the population density of a city.
Fig. 3  Presentation and visualization possibilities of population density and urban areas: example of the city of Zurich, Switzerland

Urban or built-up area of Zurich  
Source: Swiss land use statistics 1979/85

Population/inhabitants per hectare  
Source: Swiss national census of population 1990

Natural terrain of Zurich, 3D view from SE  
Source: GEO-STAT digital terrain model

Population/inhabitants per hectare, simulated 3D view from SE  
Source: Swiss national census of population 1990

The darker an area appears, the denser it is inhabited. Up to 524 people live on black hectare grids.
4.2 The National Censuses of Agriculture, Enterprises

In order to complement the existing database for spatial statistics with economic information, geocoding of the census of business and enterprises 1995/96 was decided for the first time on a compulsory basis covering the entire country. This was repeated again with the censuses of 1998 (sectors 2/3), 2000 (agriculture), and 2001 (sectors 2/3), so that we can provide hectometric time series about all economic sectors. For that purpose, in addition to the coordinates for the residential buildings, coordinates for all places of work (geographically separated and identifiable parts of companies and enterprises) and any relevant newly built houses since 1990 had to be established. This effort includes agricultural holdings as well as economic activities of the second and third sector. Knowing these coordinates, the census results can then be made available aggregated per hectare and a standard set of variables permanently integrated in GEO-STAT. The application potential of this vast and powerful data treasure has so far not yet been exploited to its full extent. Sample evaluations and analyses at a small-scale, regional level such as the one represented in Fig. 4 will hopefully trigger more interest for scientific studies and commercial applications in the future.

Fig. 4 Employees according to economic sector (Bern-West, Switzerland)

★ more than 60% of employees per hectare in economic sector 2
▲ more than 60% of employees per hectare in economic sector 3
◆ 40–60% of employees per hectare in economic sectors 2 and 3

Map base taken from the National Topographic Map 1:25,000, sheet 1166 Bern, © Swiss Federal Office of Topography
5 The establishment of a national register of dwellings

In the context of the last national census of population and housing in Switzerland in the year 2000, the Federal Statistical Office launched an important sub-project targeted to establish a permanent register of dwellings in order to simplify future censuses and reduce the workload especially for cantonal and communal authorities as well as for the persons to be questioned. The register should furthermore be developed into a basis for the definition and selection of (address) samples for a wide variety of statistical sample surveys. Thanks to a comprehensive and regularly updated database of harmonized information on all residential buildings of Switzerland, the register also permits to obtain instantaneous snapshots reflecting the state and size of Swiss housing and dwelling assets.

Based on results of the census of housing 2000 and the experience and identification variables of previous geocoding activities since 1990, the register became operational in 2002. Among the key contents which are indispensable for the identification of buildings are unique ID numbers for buildings as well as apartments of the entire country. In addition, the register strives to establish a standardized and harmonized addressing system for its buildings and makes use of available official numbers from cadastral surveys (for land parcels), building insurances (which are compulsory in many of our cantons), property registers of cantons and city, and other sources. The exact geographic location of each of its objects is also recorded directly in metric coordinates which provide another unambiguous identification system as soon as they are completely established and free from errors and omissions.

The register is updated in coordination with the national statistical survey of construction activities in Switzerland (which includes renovations and significant changes outside and inside present buildings). In the coming years, and as a preparation for its operational utilization to organize the next national population census, the many registers of inhabitants maintained decentrally by the local authorities will have to be harmonized (regarding contents and procedures). Each person registered there will need to be directly linked to an existing building/apartment in the register of dwellings. Once this target is reached, the register will not only be highly useful for the census and for statistics as a whole, but it will also simplify and speed up the enforcement of legal responsibilities and obligations of local authorities (property management, settlement planning, protection of the environment, public utilities such as water, gas, electricity, sewerage etc.). By its very nature, the geocoded totality of buildings and dwellings will also ease the dispute on establishing standard regional reference systems, since it permits a flexible and lossless data aggregation on any arbitrary system proposed in the future.

6 Data protection and data dissemination

The finer the geographic or regional resolution of statistical data, the easier and more likely an identification of persons or individual objects of a survey (such as buildings, enterprises, agricultural holdings etc.) becomes. For statistical offices the rule of disclosure of individual data is mandatory, however. If we are moving away from statistics based on administrative units to a (significantly finer) grid system, the risks of disclosure are multiplied as well as the measures to be taken to prevent them. This undisputed
problematic in mind should not lead, according to our opinion, to the conclusion to renounce of the advantages of the freedom of analysis provided by hectometric or similar geographic resolutions. The option to gradually reduce a standard reference grid’s resolution up to a level that is not considered problematic any longer for the majority of its related statistical data, again seems us to be a highly undesirable resolution approach.

On the long-term it seems advisable to me to review the legal foundations of an administration’s statistical activities (or, as a matter of fact, of public data production processes as a whole) in such a way as to promote, rather than restrict, a multiple and flexible utilization in the frameworks of the emerging GDI’s (national and regional geographical data infrastructure). Since the collection, maintenance and regular updating of such data is very cost-intensive, it is in the interest of all to generate the maximum possible use and effect out of it. This aim must be counterbalanced by the legitimate demands of individual persons and companies not to disclose confidential or sensitive information about them. It is questionable, however, whether information such as the number of inhabitants per hectare or in a particular building, their sex or age composition, or the number of floors or apartments in a building, or the cultivated surface area of a farm, are really sensitive enough. For many types of such information, the public might also have a justified interest in order to take qualified decisions and to be able to function as an informed and knowledgeable member of a democratic and participatory society.

In Switzerland, and related to our standard reference 100×100 m grid as a means for the dissemination of statistical data, present praxis requires not to disclose any individual values or attributes. This translates to the dissemination of an aggregated value of “1–3” for grid cells containing less than four surveyed objects of a particular type (i.e. population of a certain age group, work places of a labor force between 5 and 10 employees etc.). For planning, research and statistical purposes however, exemptions are possible restricted to particular projects or applications, by signing a restrictive data protection contract. No special measures have been taken so far to automatically prevent and control any leakage of information through the way of ordering several times (or under a different name) data subsets (geographical or attributive subsets) which eventually could reveal more details than desired by combinations and recalculations. Any reliable and easy to implement system of such advanced measures of data protection would be highly welcome. The increasing implementation of uncontrolled, automatic data delivery (through the Internet or similar procedures) without human intervention and supervision at the producer’s side makes it unavoidable to concentrate further research and more attention to this very important aspect and problematic.

7 Conclusions

In Switzerland, based on a long tradition of more than 30 years of development and experience, we reached the conclusion that an independent, neutral regional reference system unaffected by changes over time is highly desirable and, in the long-term, cost-effective. A standard grid of a comparably fine ground resolution (of 100 m in our case) proofed to provide high flexibility for a wide range of analyses and applications and therefore to satisfy the data demands of the large majority of potential users. We con-
sider this system to be more logical to deal with and much easier to maintain and to communicate than any (vector-based) subdivision of the established administrative hierarchy with the commune as its lowest level. These communes are too inhomogeneous and frequently too large to serve as an acceptable dissemination reference system for geostatistical data. Due to their differences in surface area, population as well as due to the continuous changes of their number, names and boundaries, they cannot be seen as a satisfactory framework for regional (as well as temporal) comparisons. Even as framework for thematic maps they require high manual investments for data preprocessing and harmonization, for maintaining the nomenclature as well as the geometric border files. In addition, specific measures need to be taken to improve their visual comparability (such as combining small and comparably homogeneous communes to groups or subdividing large cities into quarters etc.). For political reasons and to meet user expectations, however, data dissemination and visualization at the commune level (and at higher administrative units) certainly must continue complementary to data dissemination at the grid level.

Data collection at the hectare level, on the other hand, requires substantial (additional) investments, which must, at least partially, be repeated for every census or statistical survey to be geocoded. We are therefore convinced that the most effective long-term solution is to establish registers of the relevant survey objects, in particular for the buildings of a country. Such registers must be continuously updated not only to include new constructions (and exclude demolitions), but to maintain the exact locations of these buildings expressed as geographical coordinates as well as (postal) addresses too. Such registers allow a faster, cheaper and more efficient organization of any census or statistical survey, and – very important in today’s fast-living society – they help to reduce very substantially the time delay between a survey and the dissemination of its results – and especially the results geocoded to the standard hectare grid. In addition, the fact that buildings (and other objects such as enterprises) are geographically not only referenced by the hectare, but more accurately by a unique pair of coordinates, establishes a permanent and unambiguous identification that reduces the georeferencing workload for any new survey as well as the need to contact local authorities to identify buildings or enterprises to an absolute minimum. In addition, precise geographic coordinates of survey results (at a resolution of meters, not only hectares) allows additional flexibility for analysis and data dissemination in combination with other geodata, such as polygon areas of any nature, or for research and planning purposes concentrating on concepts such as accessibility, impact studies, social desegregation, regional disparities, and many others.

Sources and references

