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Cadastral Feedback on Spatial Planning

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1 ABSTRACT

Spatial planning shall guarantee that the limited resource land is used efficiently. One problem connected to such a task is the control of the result's quality. In case of spatial planning the question is, whether the proposed usage and the legal framework requirements actually fit the needs of the society. A problem in such an assessment is the time frame. Planning of concrete situations, e.g., of a large bus stop, is implemented quickly and thus feedback can be collected by the people who were doing the planning. The results on strategic development plans, however, may take decades to become visible and thus it is difficult to learn from mistakes or find examples where the planning was successfully implemented.

In this paper we propose using the cadastre as a source for feedback on spatial planning. The idea is that the cadastre contains all data to show the effects of spatial planning. However, it does so in a way that is not supporting any feedback. The cadastral data must be rearranged in order to extract the effects of spatial planning. We discuss the information hidden in the cadastral data sets and show some directions for implementation issues.

2 INTRODUCION

Land is a limited resource and as such has to be used efficiently and sustainably. The goal of spatial planning is to optimize the utilization of land. This requires a balance between two contradicting goals: To guarantee the prosperity of society and to preserve the beauty of the natural environment for future generations. However, achieving this goal is not simple (compare Laistner & Laistner, 2012) and feedback is necessary to improve the planning procedures. In order to assess the quality of spatial planning, different measures can be taken. Faludi, for example, only discusses strategic plans, which he sees as coordination efforts between project plans. He argues that the quality of strategic plans can only be measured by their performance in subsequent communication processes and not by the conformity of the outcome with the intentions (Faludi, 2000). The difficulties of such an approach are visible when trying to define concepts, e.g., the notion of the "quality of life" (Ryser, 2011). Receiving feedback directly is essential and although the evaluation of Internet questionnaires can produce interesting insights (compare Pešek, Fialová, & Špačková, 2012), the process of questionnaire development is not trivial, the methodology only works if Internet access is available and will not produce an unbiased sample. Thus a different method to obtain feedback is necessary. The main idea is that the effects of spatial planning will lead to changes in the spatial structure of rights. Observation of these changes is possible if adequate land administration is in place. In the paper we discuss the use of the cadastral maps and explore the boundaries of such an approach.

The goal of spatial planning can be split into two different categories: (i) determining the spatial distribution of different processes and (ii) analyzing the spatial distribution of objects to enable such processes (compare Navratil, 2006). The result of the first category is usually a map showing the intended use of land. Depending on the planning scale, this may be an overview to identify large regions, e.g., national parks, or large-scale maps representing detailed parameters, e.g., for new buildings. The result of the second category is an implementation—or at least guidelines for an implementation—to solve a practical problem.

3 LAND MANAGEMENT AND LAND ADMINISTRATION

Since land is a limited resource, its utilization has to be organized. Resource utilization is typically a part of management, which can be defined as the "organization and coordination of the activities of a business in order to achieve defined objectives" ("management," 2013). Land management is management of the resource land. It comprises various processes including land planning, land reform, land market control, etc. and defines land-related policies and strategies. The implementation of these policies and strategies requires base data on land. These data are provided by various organizations, which together establish land administration (Williamson, Enemark, Wallace, & Rajabifard, 2010, p. 5). The organizations involved in land administrations may vary between countries, but the types of data are similar. The data describe geometrical, physical, and legal attributes of land. The types of data necessary are mainly defined by the key tasks of a cadastre. These tasks are (Creuzer, 2002, 2007)

- the registration of all real estate,
- the maintenance of base information, and
- the provision of secure land markets and property transactions.

Modern land administration systems have to adopt a multi-functional approach to meet the demands of society. Although differences are clearly visible between different countries, e.g., between Austria and Serbia (Mansberger et al., 2011), the society needs are similar worldwide. A separation between geometrical, legal, and economic description of pieces of land (usually called "parcels") is not compulsory but often visible. In Austria, for example, the cadastre provides the geometrical description, the land register ("Grundbuch") provides the legal description, and the economic description (the value of land) is missing. The reason in Austria is the difference between private land public law and the differences in the legal processes attached to these types of law. Dealing with both types in a single organization is more difficult than to have two organizations.

One of the problems of land administration is the changing needs of society. The original task of land administration was simply the documentation of the current status of land to support land taxation and land ownership protection. Today, land administration supports a wide variety of different tasks including agro-subsidies, environmental protection, and financial services (Muggenhuber, Navratil, Twaroch, & Mansberger, 2011). This requires more data on land than the original tasks. Each new task may require additional data sets leading to extensive data collection campaigns. A simple example would be a visibility analysis for new constructions (What is the area from which a new construction can be seen?) because it requires 3D data which is usually not included in 2D cadastral systems because it is not necessary (Navratil & Hackl, 2007). However, new demands of society may always lead to new elements in the cadastre, if the demands justify the additional expenses. In Austria, for example, the need of improved boundary reliability led to the implementation of a coordinate-based boundary cadastre.

4 ELEMENTS OF A CADASTRE

As mentioned before, a cadastre maintains administrative, legal, ownership, usage, and geometric information about land. Thus in a first step, pieces of land have to be defined such that the data can be attached to these pieces. The smallest spatial unit is typically the parcel and the data are either related to one parcel or a group of parcels. The cadastre defines the spatial extent for each parcel and assigns a unique identifier to each parcel. The cadastral processes must also guarantee that the parcels do not overlap and completely cover the area of the country, i.e., they do not allow for areas that are not part of any parcel. Ownership of land and other private rights on land are registered in Austria at the land register. The rights are registered for a specific land registration item. A list of parcels is connected to each item. Thus the rights have a defined spatial extent even if the pieces are not necessarily connected.

The cadastre maintains the cadastral map, a graphical representation of the parcel boundaries and some additional information. Additional information is, for example, the area and the postal address. The graphical representation is a set of lines representing the boundaries between the parcels. Depending on the jurisdiction, the quality of these lines and their legal status may differ but mapping proved to be a simple method to avoid inconsistencies in parcel boundary definitions. The graphical representation guarantees that overlapping parcels or gaps between parcels would be easily detected. The quality of the boundaries varies since the sources range from digitization of old maps to modern surveys and different surveying methods also result in different quality. The parcel boundaries are then used to determine the parcels. A parcel is the area surrounded by boundary lines. Each parcel is assigned a unique identifier. Austria, which is a rather small country, currently consists of approx. 12 Mill. parcels (Abart, Ernst, & Twaroch, 2011, p. 105). In order to avoid huge parcel identifiers in local processes, the cadastre is organized in almost 8000 small administrative units. Each of these administrative units has a unique identifier and the identifiers of the parcels only have to be unique within the administrative unit. Additional data shown in the cadastral maps are land use and some data for orientation. Names of important roads, for example, can be placed on the map. The same is true for major water bodies. In addition, the direction in which rivers and rivulets flow can be indicated with an arrow. However, only the information on land use is compulsory. Land use may not be unique on a parcel. A parcel may, for example, consist of a house and the adjacent garden. These are two different land uses and thus the cadastre in Austria can separate different uses of land with a specific type of line, a land use separation. These allow for, for example, identifying buildings and their geometry even if the building is not a separate parcel.

Figure 1 shows an example of an Austrian cadastral map. It shows the parcels boundaries and the parcel identifiers. It also shows symbols representing the current land use and the outlines of buildings. However, neither correctness nor completeness is guaranteed for the buildings. The buildings do not have separate parcel numbers. Thus they are not parcels themselves but areas of the parcels with a different type of use.

Fig. 1: Sample from the Austrian cadastral map (data © BEV)

Since a cadastre shall reflect the real situation, the cadastre must be constantly adapted to the real situation. The geometry of the parcel may prohibit a special use of the land. If a parcel is too small, for example, the owner of the parcel has to buy adjacent land to place a building. Since buildings are not allowed to cross parcel boundaries, the owner must adjust the boundary or merge the parcels. A parcel may be split into two or more parcels, if the owner wants to sell a part of it. Thus, frequently, parcels are split up and merged and parcels boundaries are changed. All these changes must be documented in the cadastre. The principle of private-public-partnership was introduced in Austria and many other countries to fulfil this task, i.e., private surveyors perform the surveys and the public authority inserts the changes into the cadastral map. The communication between these two groups requires survey documents specifying the change. These documents contain the old and the new situation including some administrative information, e.g., the new areas of the changed parcels.

These survey documents are used to update the cadastral map whenever a change occurs. However, various errors may occur in the whole process of map update: Misplaced lines in the old or new situation of the survey document, misinterpretation of the land owner’s intention by the surveyor, misinterpretation of the survey document by the cadastral authority, etc. Additionally, manual revisions of the cadastral maps were necessary when the maps were maintained in analog form because the carrier (paper or transparencies) were worn out by use. This created additional problems and resulted in a mismatch between the original measures taken in the field and the distances observed in the cadastral maps (compare Navratil, Hafner, & Jilin, 2010).

Thus it is essential to keep a register of all survey documents to be able to correct these errors. The survey documents are time stamped. These time stamps can be used to filter changes that occurred in a specific region since an arbitrary date. Assuming that all changes are documented and implemented correctly, this allows restoring the geometry of the cadastral map for any point in time since the first survey. A cadastral database that supports this type of query could be called a temporal cadastre.

Some data in the cadastre are easily observable, e.g., the outline of a building. Other data are difficult to observe. Land use is an example for this. Land use is a process but only a status is easy to be observed, e.g., the extent of a lake, the area where trees exist, or the position of a fence protecting grassland. However, this is only land cover and the boundaries between different types of land cover. Although there is a high correlation between specific types of land cover and land use (Ippoliti, Clementini, & Natali, 2012), difficulties will arise on a number of occasions. Grassland protected by a fence may be used as a garden, as a playground of a kindergarten, as a sports field (e.g., a golf course) or as a military training area. In order to determine the exact use, these processes have to be observed. This may be difficult because the processes will not take place constantly. Some evidence may be visible, though. Shape and extent of areas used as gardens are usually different from that of a golf course and military training areas are usually connected to a complex owned by the military. Thus in combination with land cover information, shape, size, and context can provide evidence for land use.

5 DETERMINATION OF LAND USE FROM THE SHAPE OF PARCELS

Changes in cadastral data are interrelated with spatial planning inasmuch changing the planned land use for a set of parcels can affect parcel boundaries: For example, areas fit for agricultural use have a different size than areas for industrial or residential use. A parcel with an area of 500m2 can be sufficiently large for residential areas because it allows the creation of a small building and still leaves some room for a garden. 500m2, however, are much too small for modern agricultural use because the advantages of modern machinery cannot be utilized. Changes in the spatial planning, thus, must have an effect on the cadastral geometry. However, spatial planning is an authoritative process initiated by the local administration whereas the change of cadastral boundaries is a privately organized process managed by the respective land owners. The land owners will react promptly to any change in spatial planning, if the change is in their advantage. Farmers, for example, can sell land profitably if

- the land lies in areas intended for residential use,
- their loss in productivity is small, and
- there are sufficient potential buyers to spike the prices.

This will become visible in the cadastral maps because a number of small parcels will be created. However, the farmers will not sell, if above conditions are not met and thus the geometry in shown in the cadastral map remains unchanged. Thus, the effect of spatial planning on the cadastral geometry reflects the concord between concepts developed by the administration and needs of land owners and the local society. The delay between change of spatial planning and changes in the cadastre can serve as a measure for concord.

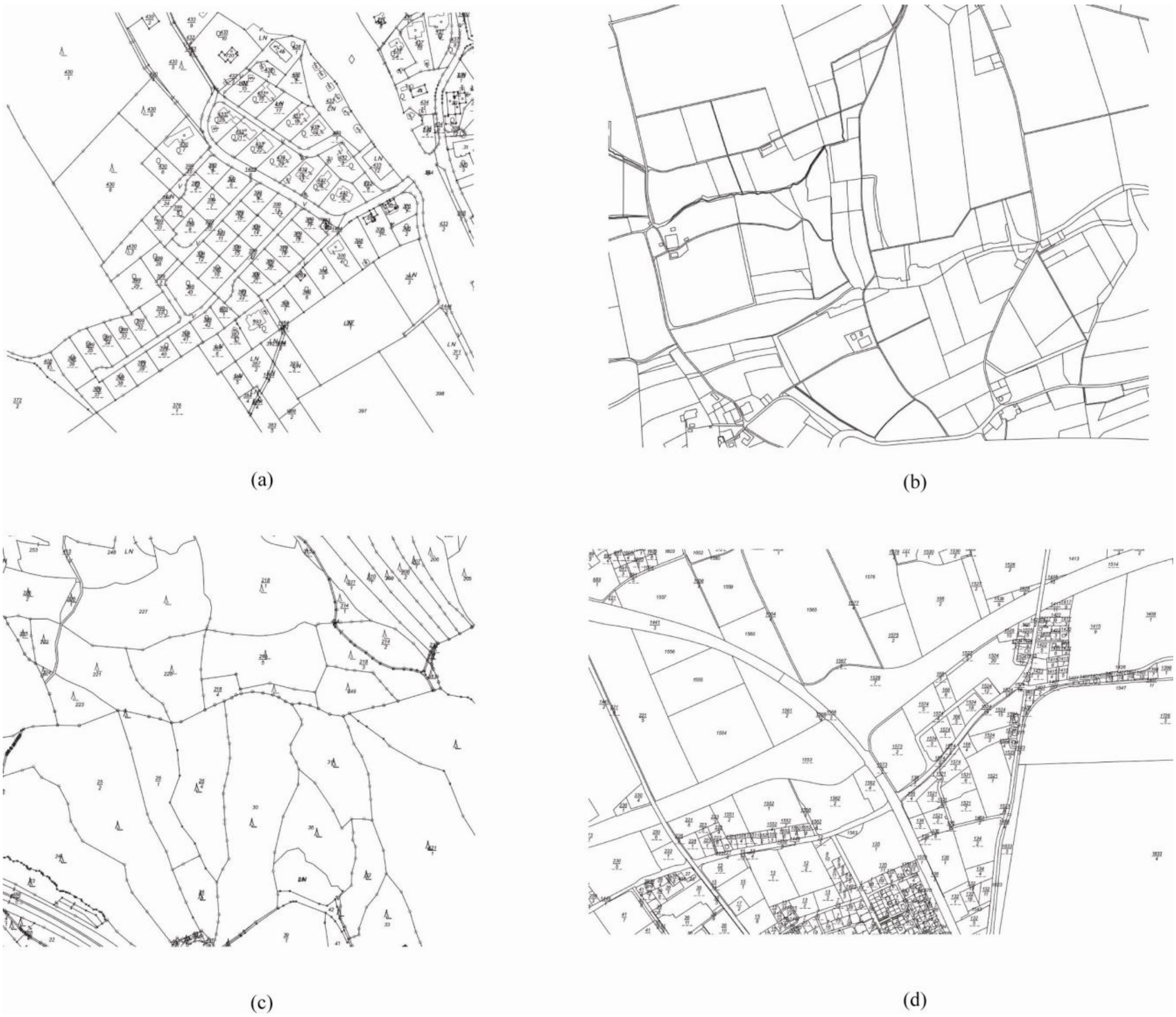

Fig. 2: Parcel patterns of four different types of land use: (a) residential area (b) agricultural area (c) forest (d) intersection between highway on-ramp (examples from DORIS, the Upper Austrian land information system)

Figure 2 shows different types of land use and how the land use affects the shape of the parcels. Residential areas (Figure 2a) are composed of small, parcels of similar size. Rectangular shape simplifies the construction of buildings and thus rectangular parcels are predominant. In city centers, the pattern may vary because high buildings require larger area and old road networks are rarely orthogonal. However, the land use in old city centers typically does not change much. Since all parcels must have access to the public road network, there is a dense network of roads in residential areas. Most of these roads will be quite narrow to restrict through traffic. Typical parcel width for these roads is in Austria 8m. Agricultural areas (Figure 2b) have a similar pattern than residential areas. However, the parcels are typically much larger and there are often rectangles with a large difference between length and width. In addition, the access to the agricultural areas is granted by narrow paths with a width between 3 and 4m in Austria. Therefore, the ratio between productive area and roads is different from that in residential areas. Forests (Figure 2c) may have parcels of similar size than agricultural areas. However, forests parcels have to consider topographical elements like ridges more than agricultural areas. The last example is constituted by traffic areas (Figure 2d), which consist of long, narrow parcels.

The development of a temporal cadastre to provide feedback for spatial planning requires different steps. The first step is providing the technical basis for such a system. This requires digitizing all survey documents, storing them in a computer system, and connecting them such that all necessary evaluations become possible. In a second step, it is necessary to be able to detect patterns related to spatial planning. It must be possible to automatically detect, for example, agricultural areas based on the geometrical characteristics. This step is more complicated than the first one because the characteristics will vary between countries and probably even regions of the same country. There may also be a temporal component. Agricultural areas, for example, became much larger with the development of efficient machines because one farmer could handle much larger areas if they were arranged in pieces of suitable size. The third step is then to identify the lag between a change in the spatial planning documentation and its effect on the cadastral geometry. How long, for example, does it take for a new residential area to be used for living? The answer may vary for different areas and research can then concentrate on areas where concepts of spatial planning were implemented slower than average.

6 DATABASE ISSUES

In this section we present an overview of database issues that have to be addressed in order to enable the type of cadastral feedback for spatial planning we discussed above. More specifically, main challenges raised by the suggested approach are made explicit and an overall analysis of today's technologies that are better suited to tackle such challenges is carried out.

Any kind of spatial information system, including cadastre and spatial planning applications, typically relies on spatial database management systems (DBMS) in order to optimize data storage and retrieval. Any DBMS, in turn, implements one of a variety of theoretical data models, as well as a series of data access methods. Each data model is better suited for the treatment of a certain type of information (e.g., scalar, multi-dimensional, hierarchical) whereas requires cumbersome adaptations for the treatment of other types. Thus, it would be reasonable to think that, according to the type of information to treat, each application relies on the most appropriate data model. Unfortunately, because of historical reasons, this is not the case. Conversely, only one data model is predominantly used today: the relational data model (Codd, 1970). That is, the majority of cadastres and spatial planning applications relies on relational DBMS.

According to our previous analysis, two central features required to exploit cadastral feedback are: document storage and temporal support. Relational databases are not very well suited to implement these features. The documents that have to be treated can possibly be in either a paper-based or an electronic format. Moreover, since they come from different sources or authorities (or even from different time periods), they do not posses, in general, a common structure. This raises the following two issues: (i) as a first step, paper-based documents have to be digitized. But according to which structure? (ii) The second issue is related to the inefficiency of the relational data model to treat structureless data: relational databases usually store structureless data in a raw format as a so-called binary large object (BLOB). This is greatly inefficient in terms of both, storage space and retrieval time. Indeed, it is very hard to find and eliminate redundancies within this kind of data (storage inefficiency). Moreover, it is not possible to index (retrieval inefficiency) BLOBs in a meaningful way (i.e., according to the pieces of information they contain) because of the unpredictability of their content.

Temporal support is also not provided natively by relational DBMS. A possibility in this case would be to resort to data warehousing: a design technique for relational databases that allows for designing the schema of the database in such a way that historical data can be maintained and analyzed efficiently.

An interesting alternative to the relational model is provided by document-oriented databases (Strauch, Sites, & Kriha, 2011, Chap. 5): non-relational databases whose functionalities are developed around an abstract definition of document. Such kind of database natively supports the management of unstructured or semi-structured data, allowing for optimality in data storage and retrieval. Two representative document-oriented databases are CouchDB (http://couchdb.apache.org/) and MongoDB (http://www.mongodb.org/). They both natively provides the requested temporal support: every time a document insertion, update, or deletion occurs, the database system does not change its state; rather a new state is created according to the issued action while the previous one is marked as obsolete (but not deleted). Because of their features, CouchDB and MongoDB are excellent candidates to keep trace of and analyze temporal changes.

7 CONCLUSIONS

It will not be possible to use this kind of feedback for all kinds of spatial planning activities. Nature protection areas, for example, will not show on cadastral maps because nature protection prohibits a wide range of activities. Most of the allowed activities do not produce much revenue for the land owner. This restricts the resources put into the development of land and optimizing the parcel shape is one of the development activities. Of course, this should not come as a surprise because it is the basic idea of nature protection to restrict development activities. On the other hand, parcel boundaries may adapt to the shape of the nature protection zone and the zone itself may become visible.

An automatic system to detect land use can present areas where the changed land use is not implemented. This provides one source of feedback that spatial planners can use to optimize the utilization of land. It can also provide feedback in the opposite direction. Sometimes the assumptions under which spatial planning was working are not adequate. The economic and social situation of the regions next to Czechoslovakia, for example, changes significantly with the opening of the borders in 1989. Concepts of spatial planning had to be adapted to these changes and old concepts were maybe not optimal in the new context. However, if some of these outdated concepts were already implemented, how long does it take to correct these problems? A temporal cadastre could help addressing questions like that.

An automatic system can also be used as the bases for even more advanced analysis. Changes in spatial planning typically have an effect on land market. The classification of land as residential land, agricultural land etc. has a dramatic impact on the value of land. Thus, the land owners in some areas will benefit from the change, the owners in other areas will not. This leads to new questions, e.g., about compensation payments. However, a different question could also be who the persons are that profit most from a change in spatial planning. In general we can assume that from a statistical view all land owners will benefit equally from spatial planning. However, what happens if always a specific class of land owners profits? Such statistics can be produced automatically if sufficient data is available and the historic development can be modeled. The effect would be a more transparent system of spatial planning where (at least some) hidden agendas could become visible.

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