ACCURACY DETERMINATION FOR THE AUSTRIAN DIGITAL CADASTRAL MAP (DKM)

Gerhard Navratil, Jeannine Hafner, Dmitri Jilin
Vienna University of Technology, Austria

Abstract. *The digital cadastral map (DKM) is the digital version of the Austrian cadastral map. The data comprise data collected during the initial data capture in the early 19th century to data from coordinate-based, legally binding boundary contracts since the new law on surveying in 1969. Whereas the quality for recently collected data is well documented, the situation is more complex in areas lacking modern cadastral surveys. Deviations of the DKM from the original surveys emerge from various re-projections necessary in the last century. The size of these deviations is the topic of the paper.*
Our approach was to compare the results of surveys with the DKM. We selected areas where the boundaries have been determined in the first half of the 20th century and have not been re-defined since then. In these areas we collected the cadastral surveys and compared the dimensions shown in the survey with those computed from the coordinates. A statistical analysis then gives an idea on the quality of these data.

Key words: *digital cadastral map, accuracy, measurements*

1. INTRODUCTION

The Austrian digital cadastral map (DKM) is the digital version of the original Austrian cadastral map. The data comprise different quality levels connected to different times of data collecting from the initial data capture in the early 19th century to the coordinate-based, legally binding boundary contract since the new law on surveying in 1969. Whereas the quality for data collected in the last years is well documented, the situation is more complex in areas lacking modern cadastral surveys. Each cadastral map sheet was re-projected at least once and later digitized for the DKM. Deviations of the DKM from the original surveys emerge from these processes. The size of these deviations is the topic of the paper.

Our approach was to compare the results of surveys with the content of the DKM. The typical user is more interested in relative accuracy than in absolute accuracy of coordinates. When buying land, for example, it may be essential that the parcel has a specific length and width. The absolute position is typically less relevant. We thus executed an experiment to check the local quality of the DKM. We selected two different areas where the boundaries have been determined in the first half of the 20th century and have not been re-defined since then. The plats of the original boundary changes are still available in the archives of the local surveying authorities. Thus the

'correct' dimensions between boundary marks are known. The graphical representation changed slightly with each processing step performed for the cadastral maps because they were not based on the plats but on the maps' sheets themselves. Thus the dimensions are not equal to the original measurements when computed from the DKM data.

The remainder of the paper is structured as follows: In section 2 we summarize the basics and the general principles of the Austrian Cadastre. In section 3 we describe the DKM and the process leading to it. In section 4 we specify our research question and develop the test strategy. The results are shown in section 5. In the last section we present some conclusions and present some ideas for future work.

2. THE AUSTRIAN CADASTRE

The first system of land registration for tax purposes in Austria dates back to 1718 when the Austrian administration introduced a land register for parcels and buildings in the Italian provinces. This land register was based on a structured process of a surveying and mapping in the field. The land tax was stipulated based on the productivity of the land. The surveying of this 'Censimento milanese' covered approx. 20000 km^2 and was finished in 1723 (Lego 1968, pp. 1-13). The creation of improved land taxation systems for the whole area of the Austrian-Hungarian monarchy can be connected directly to costly wars (compare Twaroch and Muggenhuber 1997). The system still working is based on the system introduced by the emperor Franz I. in 1817 with the 'Grundsteuerpatent'. The taxation in this system is based on possible profit. Thus only rural areas were taxed. The 'Grundsteuerpatent' was the legal basis for a systematic registration of all objects (parcels) in the whole territory of the monarchy in graphical form. This method guaranteed completeness of land parcels and thus completeness of taxed objects.

The original intention was the creation of a static Cadastre ('stabiler Kataster'). The survey started in 1817 and was concluded in 1861 (Lego 1968, p. 27; 42).In the second half of the 19^{th} century it became apparent that this is not a sustainable solution because not only the land owners but also the use and the fragmentation of the land change over the years. The Cadastre needs continuous adaptation to these changes because otherwise the land tax would not be connected to the actual use of land. New regulations for the land tax were enacted to deal with that problem (Franz Josef I. 1869), which defined 15 year intervals for periodic revisions. Finally, in 1883 a law passed that required updating the Cadastre as soon as changes in the real world become evident (Franz Josef I. 1883).

As a result we now have licensed surveyors who were responsible for documenting changes in the cadastral boundaries. They created plats showing the old and new boundary lines. The cadastral authority was then able to adapt the cadastral maps such that they showed the new situation. Figure 1 shows a detail of a plat created in 1940. It contains a large number of dimension between boundary points, e.g., between the point 'g' at the bottom of the figure and the points 221 and 243. In this example the surveyor

used a traverse to determine the position of the boundary points in relation to the old situation. Other possibilities (typically used for smaller changes) were the definition of an axis and the measurement of abscissa and ordinate.

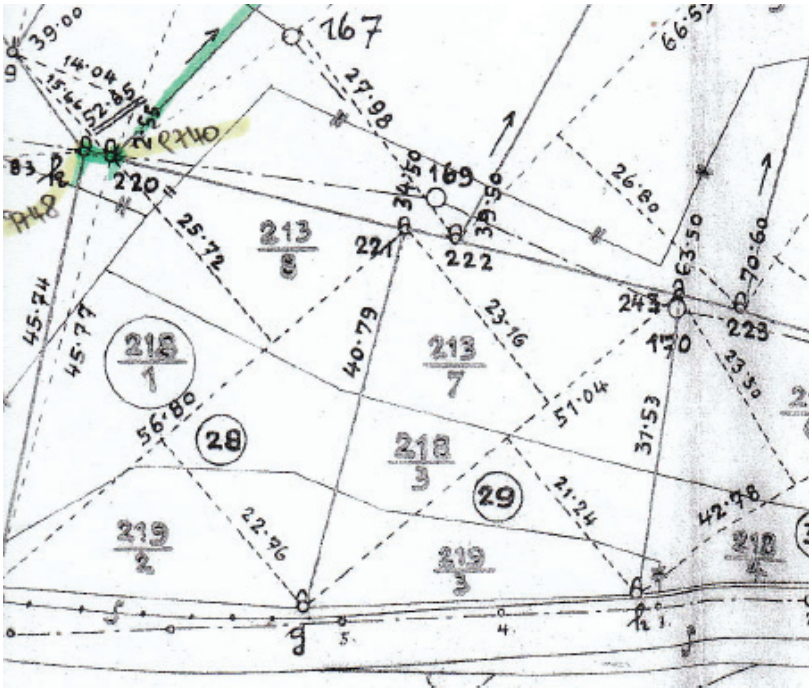

Figure 1: Detail from a map showing a changed cadastral boundary

Although these plats are the legal basis for any change in the cadastral map, there have also been changes without reference to a plat. The original cadastral survey in the 19th century was performed on the basis of several plane coordinate systems. The resulting maps covered a small enough area that distortions from the map projection were acceptable. In the 1920ies, the Austrian surveying authority (already called BEV, 'Bundesamt für Eich- und Vermessungswesen') decided to move to a better type of coordinate system, the Gauß-Krüger-projection with three strips at 28°, 31°, and 34° east of Ferro. This required a reprojection of the whole map. The maps, which were originally made on paper, were later copied on suited plastic sheets because they were less sensitive to changes of the air moisture. Frequent changes of boundary lines stressed the material and thus maps had to be copied to new sheets. Finally, the scale was changed from the history-related map scales 1:720 to 1:5.760 to simpler scales 1:500 to 1:5.000. Each of these changes inevitably introduced small deviations from the original data. These deviations have to be considered when working with cadastral maps.

In 1969 the coordinate-Cadastre was introduced (VermG 1969). In contrast to the traditional system where the relevant documentation of the boundary was done in the field (e.g., by boundary stones) the documentation in the coordinate Cadastre is done by computing and storing Gauß-Krüger-coordinates for the boundary points. The definition is done in the field and all land owners, whose boundaries are affected by a boundary point have to agree with the position. This agreement is documented by signature during a boundary negotiation. This process shall forestall future boundary disputes because the available coordinates always allow an accurate reconstruction of the points.

However, the coordinate Cadastre is not a new cadastral system. It only adds a new kind of quality to boundary points, boundary lines, and parcels. Parcels are marked in the cadastral map by underlining them with three dashes. This indicates that the whole boundary of the parcel was negotiated and agreed upon. Thus the boundaries are fixed and guaranteed. The same is then true for each boundary point along the parcels boundary. The points are marked by the letter 'G' if they are part of the coordinate Cadastre. It may happen that a specific parcel that is not in the coordinate Cadastre but one of its neighboring parcels it. Then the boundary line to this parcel is fixed and protected by the coordinate Cadastre but the others are not.

3. THE AUSTRIAN DIGITAL CADASTRAL MAP (DKM)

The increasing use of digital systems increases the demand for digitally available base data. One of the necessary data sets was the Cadastre. Thus in 1989 the Austrian surveying authority started a process to create a digital version of the cadastral maps. The goal was the creation of homogeneous data sets (Kugler 1994). Thus a simple digitization of the analog maps was not sufficient. Two problems needed to be solved either before the digitization or during the process:

- The completeness of the cadastral maps was insufficient. While the parcel boundaries were complete, boundaries between areas of different land use were not. Especially buildings were often not visible in the cadastral maps. Ignorance of this fact would have lead to significant problems when using the cadastral map as a base map for applications like spatial planning.
- The cadastral maps of different municipalities were not coordinated. It was therefore not guaranteed that digitized boundary lines of neighboring municipalities would fit together.

Solving the first problem included campaigns to check the completeness of the buildings shown in the maps. This increased the overall quality of the cadastral maps in two ways:

- it increased the completeness of buildings shown in the cadastral maps and
- it provided modern surveys for the boundaries of land use thereby validating the lines in the cadastral maps.

The second method for improvement was the use of coordinates from existing plats. Many plats created in the second half of the 20th century did not use local coordinate systems but were connected to the network of control points maintained by the BEV. These coordinates were used to improve the overall geometric quality of the cadastral maps.

Solving the second problem, however, creates another problem: The boundaries of neighboring municipalities must be distorted to avoid slivers. However, there may be surveys of high quality in the vicinity of the municipality boundary. These should not be changed when adapting the municipality boundary. We can thus assume that during the process of adapting the municipality boundaries unwanted distortions have been introduced. This will again reduce the quality of the data in the cadastral maps.

The digitizing process was completed in 2005 for whole Austria. Since that year all cadastral data are available in digital form and the digital version of the cadastral map is the legal valid representation of the Cadastre. However, the scale in which the cadastral map is captured still dates back to the scales used in the analog version of the cadastral map. This is obvious for surveyors and other people who worked with the analog cadastral maps. However, there are an increasing number of people who only know the DKM. They see coordinates with cm-precision and assume that this precision corresponds with the quality of the point definition. This is true for points in the coordinate Cadastre but not for points in the traditional system.

Figure 2 shows an example for deviations that may arise between the original survey and the DKM. The plat is the same where a part was shown in Figure 1. In some places, e.g., in the lower right corner, the boundary has changed since the original survey but even in other places deviations are visible. Most of the deviations, however, are shifts or rotations between the data sets. It must be noted that the boundary line to parcel 1112/3 is not shown and the line south of it is only an auxiliary line.

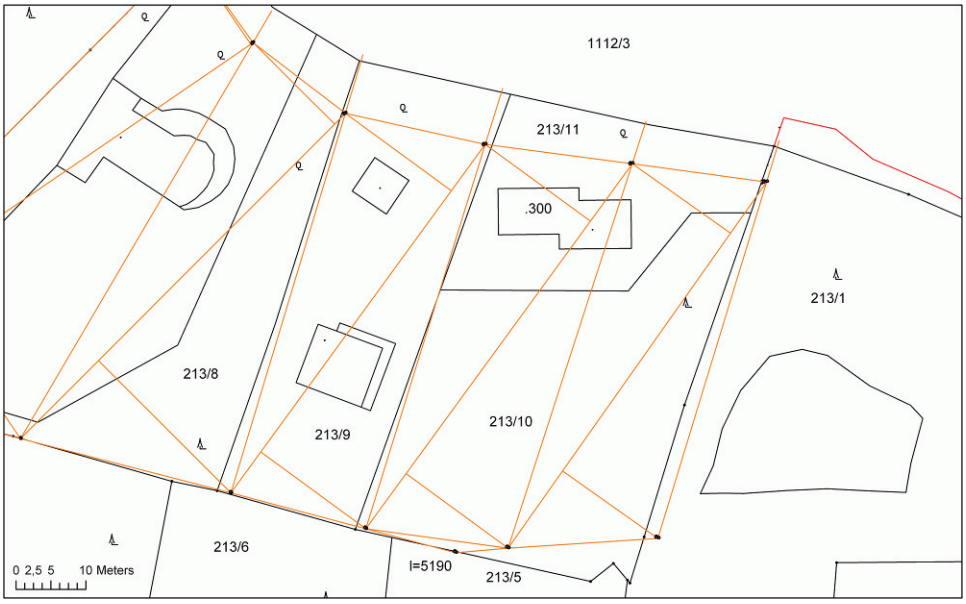

Figure 2: Comparison of the plat in Figure 1 with the DKM

4. STRATEGY FOR TESTING THE QUALITY

The idea for testing the quality of the DKM was as follows: The oldest available original survey data are documented in plats since the late 19th century. These documents can contain coordinates in a local coordinate system (abscissa and ordinate) and dimensions of line segments like straight boundary segments. This information can be used to compare the results of the original surveys with the geometry shown in the DKM. Many of the boundaries defined in these plats may have been changed later but in some cases this was the only survey since the original survey in the 19th century. In that case, the difference between the survey result and the distance determined from coordinates shown in the DKM represents the effects of processes performed on the cadastral maps. The two distances, for example, mentioned for figure 1 are 51.04 m (to point 243) and 40.79 m (to point 221). The DKM still shows these points. The computation of the distances, however, results in 50.196 m and 40.007 m, which deviates by 84.4 cm and 78.3 cm from the original measurement. These deviations show how the results may be distorted in the DKM. Lay people, however, do not know about these deviations and may rely on the results of computation based on the DKM only. In the shown example the land owner may find out that his parcel is longer than expected and there may be no negative effect. This will not always be the case whereas customers may be dissatisfied with large reductions.

In order to provide a full picture of the DKM accuracy samples should be taken from all over Austria. This was not possible due to unavailable resources. We thus selected sample areas that were easily accessible and still provide insights. We decided that

mountainous areas may contain the largest deviations but there may not be many plats since boundary changes are rare. The most frequent changes occur in rural areas due to reallocation processes and at the boundaries of cites when new parcels for building are created. These two areas are different in two ways:

- Parcels in rural areas are typically much larger than in urban areas. Thus the dimensions are larger and deviations should be, too.
- Land in rural areas is typically cheaper than in urban areas because there is abundant land available. As an effect the survey of rural land should not cost too much and it may not be essential to describe the boundary as detailed as in urban areas.

Especially the second point conflicts with the original requirements for the Cadastre. Urban land was not a tax object and thus the quality of cadastral maps in cities and villages was worse than the quality in agricultural areas. Thus plats in urban areas typically improved the quality of the may more than plats in rural areas did.

We selected a part of Vienna as an example for an urban area and an example from Carinthia for a rural area. In both areas we collected available cadastral surveys and checked that the boundaries in the DKM still show the contents of these plats. We then compared the dimensions shown in the survey with those computed from the coordinates. All plats were drawn originally in a scale of 1:2.880 and thus the results should be comparable.

5. TEST RESULTS

We could collect at total of approximately 250 pairs of distances. More than 200 pairs were collected in the Vienna area. The distances range from 5 m to 94 m. Figure 3 shows the distribution of the analyzed distances. It is evident that most of the distances are between 15 m and 35 m. These distances are typical for a parceling. Figure 4 shows the deviations of these values from the measures computed from the DKM. 176 of the 202 measures (87%) have deviations of less than 1 m, 149 measures (74%) have deviations of less that 50 cm and 88 measures (44%) have deviations of less than 20 cm. The average deviation is -7 cm with a standard deviation of 84 cm.

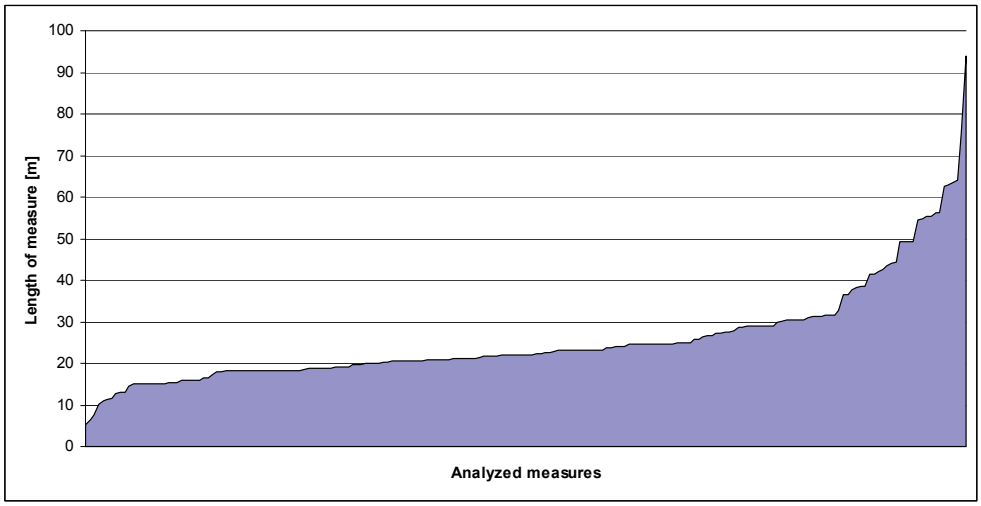

Figure 3: Distribution of the values collected in Vienna

Three deviations are larger than 3 m and may be gross errors. Gross errors may emerge in various cases:

- We may have missed changes in the boundary lines. Then the plat would not show the same boundary as the DKM and the distances are incompatible.
- There may have been an error while incorporating the plat in the cadastral maps. Any error in that process would go unnoticed until another surveyor compares the cadastral map with the plat. This is usually only done when changing parcel boundaries. Since these cases have been eliminated from our sample, there may be undetected errors.
- There may have been undocumented changes in the cadastral map.

The elimination of deviations larger than 3 m changes (3 values) the standard deviation to 40 cm.

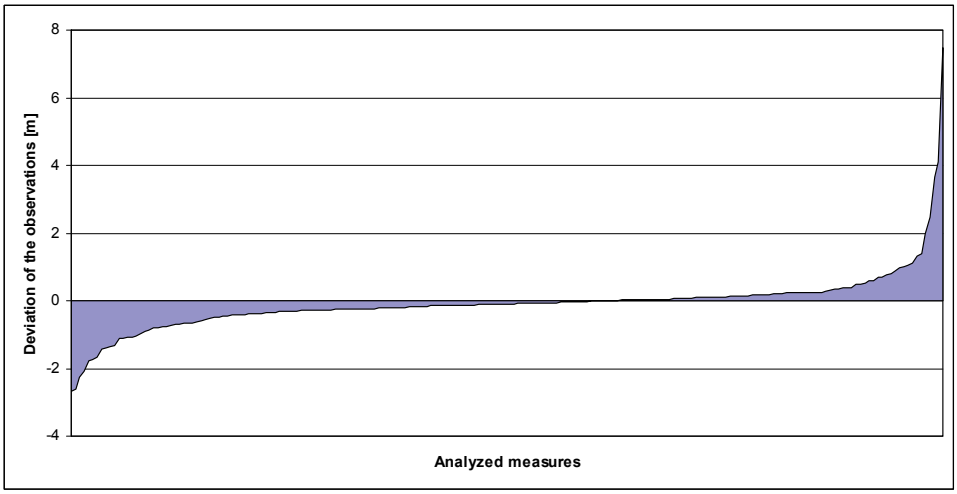

Figure 4: Distribution of the deviations collected for Vienna

39 pairs were collected in Carinthia. The distances range from 2 m to 84 m. Figure 5 shows the distribution of the distances. Half the distances are below 20 m but there in general the distribution of distances is more equal than in the case of Vienna. Figure 6 shows the deviations of these values from the measures computed from the DKM. 22 of the 39 measures (56%) have deviations of less than 1 m, 14 measures (36%) have deviations of less that 50 cm and 3 measures (8%) have deviations of less than 20 cm. The average deviation is 50 cm with a standard deviation of 213 cm.

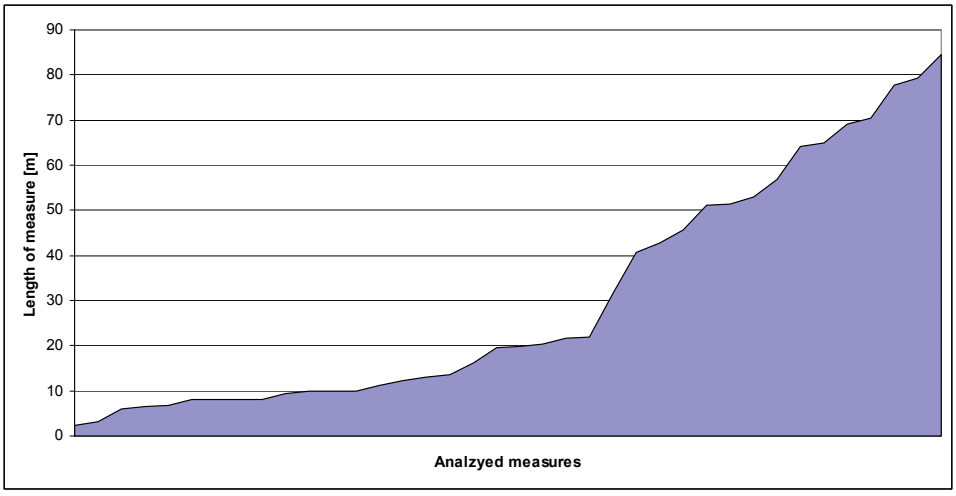

Figure 5: Distribution of the values collected in Carinthia

In this data set there is also a value that seems to be a gross error. The deviation is almost 6 m, which is 2.5 times the second largest deviation (2.3 m). Elimination of this value leads to an average of 35 cm and a standard deviation of 138 cm.

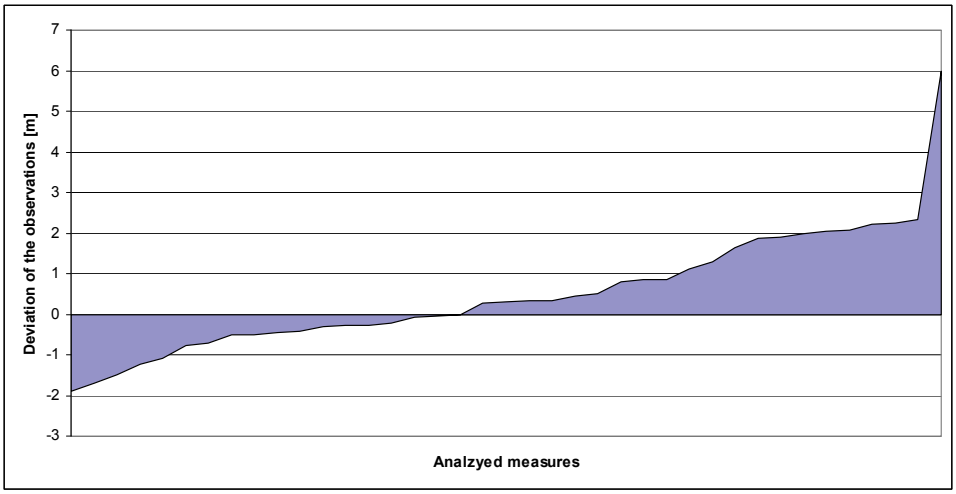

Figure 6. Distribution of the deviations collected for Carinthia

Some of the differences could originate from the different distribution of measurements. Thus we determined the same values for the distances up to 30 m. This gives standard deviations of 40 cm for Vienna and 99 cm for Carinthia. Thus even small distances are more distributed in Vienna than in Carinthia.

6. DISCUSSION OF THE RESULTS AND FUTURE WORK

The results show that the cadastral map in urban areas is more accurate than in rural areas. Even limiting the maximum distances did not change this picture. A difference between rural and urban areas could be that urban areas have a better distribution of plats. Thus there is a higher probability that recent surveys were performed in the vicinity of the measurement used in the sample. This could improve the overall quality of the cadastral map.

The analysis shows that areas surveyed in the first half of the 20th century may still have serious quality problems. Deviations of more than 1 m are not unlikely since 13% of the data in the urban sample and 45% of the sample in the rural sample exceed this value. Thus it is important to communicate to lay people that the DKM is not a very reliable source for distances even if signatures indicate that there have been surveys in the 20th century.

More work is necessary in two directions:

- The sample should be expanded to cover more of Austria to get better estimates. The sample should then also cover other scales than just 1:2.880.
- Similar investigations are necessary for areas that have not yet been surveyed. The problem with this endeavor is that the original are not documented. It is thus only possible to compare the derived result of the original measurements (the original cadastral map) with the DKM.

The goal should be finding simple quality parameters that can be communicated to lay people. This is necessary to avoid misinterpretation of the DKM, which leads to disputes and results in lawsuits. The large group in the target audience is lawyers and judges because they must advise their clients and interpret DKM data. It could be beneficial for them to have studies to rely upon.

REFERENCES

[1] Austrian National Assembly (1968). (1968). Bundesgesetz vom 3. Juli 1968 über die Landesvermessung und den Grenzkataster (Vermessungsgesetz - VermG). BGBl. Nr. 306/1968.

[2] Franz Josef I. (1869). Regelung der Grundsteuer. RGBl. 88.

[3] Franz Josef I. (1883). Gesetz über die Evidenthaltung des Grundsteuerkatasters (Law on updating the Cadastre). RGBl.Nr 1883/83: 249-268.

[4] Kugler, R. (1994). Der Aufbau aktueller und konsistenter Datenbanken des Katasters. AGIT'94, Salzburg, Austria, Institut für Geographie der Universität Salzburg.

[5] Lego, K. (1968). Geschichte des österreichischen Grundkatasters. Vienna, Bundesamt f. Eich- und Vermessungswesen.

[6] Twaroch, C. and G. Muggenhuber (1997). Evolution of Land Registration and Cadastre - Case Study: Austria. Joint European Conference on Geographical Information.