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A review of selected civil law jurisdictions**

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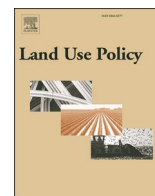
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Determination of the property boundary – A review of selected civil law jurisdictions

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ABSTRACT

The boundary of real property is the fundamental element for securing rights attached to land. Countries, even with a long-standing cadastral tradition, often face the challenge of interpreting the course of a parcel boundary on the ground based on the available evidence, as data quality is very heterogeneous. Various cadastral principles and procedures have been developed for the determination of parcel boundaries in the field, which may also be associated with resolving boundary disputes. This article documents and compares the principles and procedures applied in the determination of property boundaries in selected civil law countries based on a novel conceptual model developed for that purpose. The notion of ‘boundary determination’ used in this article refers to demarcating and surveying land parcel boundaries during the initial cadastral survey and cadastral update procedures. The selected countries include Denmark and Sweden, which apply Nordic civil law; Slovenia and Turkey, which apply German civil law; and Spain, which applies Napoleonic civil law. The demarcation principles and processes applied in the different cadastral systems, the parties involved, and the evidence taken into consideration in these processes are described and compared. The main aim is to contribute to the documentation of the reasoning applied to the property boundary determination in the selected civil law countries.

1. Introduction

A land parcel boundary is created by agreement between interested parties (Grant et al., 2018, p. 32), officially determined by cadastral surveys and represented in cadastral maps. This boundary may be changed through property formation processes, such as subdivision, amalgamation, land readjustment, land consolidation or expropriation. It may also be rectified by cadastral updating implementations, or even altered by the courts within various court cases, including dispute resolution. This article focuses on ‘boundary determination’ processes applied in the initial cadastral surveys and cadastral update works.

The process of marking boundaries aims to place boundary marks or adopt terrain features representing the location of boundary points or

boundary lines. In marking boundary points, vertices of the boundary are identified, while the course of the boundary might also be defined by the existing physical features that coincide with the parcel boundary. The former determines the precise location of boundary points set at the date of the cadastral survey; therefore, it complies with the fixed boundary approach. The latter corresponds to the general boundary concept where the boundary points’ precise location is not determined (Holstein and Williamson, 1985, pp. 5–8). The marked land parcels can be described or represented through textual or graphical methods. A well-known example of the textual method is the metes and bound system, which defines the position and shape of property by reference to the bearings and lengths of the boundary lines together with the names of adjoining properties (UN-ECE, 1996, p. 109). A graphical description

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can be provided by cadastral maps, plans, spatial databases, or land/geographic information systems (LIS/GIS) showing all parcels within a specific area (e.g. a region or a whole country) (Navratil, 2011). The boundary points are drawn on the conventional cadastral plans based on measurements made from control points. The position of the boundary points may be defined in a local coordinate system or in a regional/national spatial reference frame. If they are georeferenced according to the national reference frame, the boundary points can also be represented by their coordinates in the national datum. This is called a ‘coordinate or coordinated cadastre’ (Andreasson, 2006; Grant et al., 2018), which refers to a cadastre where ‘registered parcel is described or defined numerically by national coordinates stored in a database and visualised on a digital cadastral map’ (Andreasson, 2006, p. 5). Grant et al. (2018) distinguishes between the ‘survey coordinate cadastre’ and the ‘legal coordinate cadastre’. In the survey coordinate cadastre, coordinates are expressly assigned a status in the hierarchy of evidence but are not definitive, while, in the legal coordinate cadastre, coordinates are given primary legal status as conclusive evidence (in the absence of a proven error) (p. 57).

Fig. 1 presents a novel conceptual model concerning boundary determination and documentation. In this model, boundary determination is considered as a legal process carried out by public bodies (e.g. national cadastral organisations, publicly appointed surveyors) or judicial bodies (e.g. courts). It may also involve parties like real property owners and other land right holders, local people, and witnesses.

The boundary of real property is determined through reasoning based on the evidence provided. The evidence may be categorised as documents, boundary marks, and natural and artificial terrain features. Documents encompass sale or grant deeds, titles, judgments, local and witness statements that are prepared and signed by relevant parties. Documents also include records in public inventories and maps, such as title records, tax records, survey sketches, cadastral maps or plans, and orthophotos which may carry information related to the position of boundary points and boundary lines. These documents could be in the form of physical (paper-based documents) or digital documents. The digital structured data files or records in a (spatial) database could also be regarded as documents (database-based document).

The boundaries may also be marked on-site by boundary marks or monuments. These might be pegs, iron pins, and pillars or other materials that are placed by the surveyor or other relevant parties to indicate the position of the boundary points. The terrain features such as woods, streams, swamps, lakes, ridges, cliffs, and mountains can also be used as natural marks for the demarcation of land parcels. They indicate boundary lines instead of boundary points and, therefore, comply with the general boundary approach. Finally, artificial terrain features, which are man-made objects such as ditches, hedges, fences, and walls, are

used to show the position of the boundary lines on the ground (Strack, 2017, p. 8). Individual natural stones and piles of stones have historically also been used as marks.

This evidence may have a different degree of importance or weight in various jurisdictions based on the legal tradition, such as civil law and common law. Civil law is a legal tradition which has its origin in Roman law, and has subsequently developed in Continental Europe (Tetley, 1999, pp. 683–684). It is generally codified, based on a comprehensive compilation of legal rules and statutes. In contrast to civil law, common law is generally uncodified. Rather, it is largely based on the precedent of judicial decisions previously made in similar cases. The common law tradition emerged in England during the Middle Ages and spread to many British colonies across the continents (Cole and Wilson, 2016, p. 21).

In common law countries, natural and artificial terrain features and boundary marks overrule documents. More specifically, the common law legal system envisages that evidence which is least likely to be mistaken should have higher reliance. This principle is encapsulated in the following order: (i) Natural boundaries, (ii) Undisturbed original monumentation, (iii) Occupation that can be traced to the time of original monuments, (iv) Measurements (Holstein and Williamson, 1985, p. 3). In civil law countries, however, cadastral plans and other surveying documents have priority. Boundaries recorded on cadastral plans are binding. They are presumed correct in case of a discrepancy between the cadastral plan and other evidence (e.g. boundary marks, natural and artificial terrain features). However, many countries use a combination of these rules, as detailed in the next sections.

This article documents and compares the basic principles and processes applied in the determination of real property boundaries in the selected civil law countries based on the above-described conceptual model. In addition to the general aspects of the national cadastral system, the demarcation principles and processes, the parties involved, and the evidence taken into consideration in these processes are described and compared. The selected countries are Denmark and Sweden, which belong to the Nordic civil law family, Slovenia and Turkey, which belong to the Germanic civil law family, and Spain, which belongs to the Napoleonic civil law family.

2. Boundary determination in selected civil law countries

2.1. Denmark

The cadastral authority is today placed under the Danish Geodata Agency within the Ministry of Climate, Energy and Utilities. The national cadastral authority examines, approves, and registers the cadastral cases submitted by the practising licenced surveyors. Changes of ownership are registered in the Land Registry (administered by the court). Deeds do not include descriptions of the property boundaries, instead they include the cadastral identifier that points to the cadastral survey in the cadastral archive.

The practical work associated with cadastral cases is carried out by licenced cadastral surveyors in private practice (LL, 2013 § 4). It is the licenced surveyor who has all direct contact with affected property owners. The surveyor also handles the contact with relevant authorities, mortgagees, etc., and obtains all private legal declarations and approvals. It is the licenced surveyor that provides data used to update the cadastre (UL, 2018 § 13). The licenced surveyor is responsible for ensuring that the cadastral change and land use comply with current legislation and private agreements (UL, 2018 § 20). In fact, using the term “surveyor” is somewhat misleading. The English term “licenced surveyor” does not accurately describe these professionals, but there is no better alternative term in English. A more detailed description of the profession is given by (Elmstrøm and Torben, 2017). Licenced surveyors have the exclusive right to carry out cadastral work. The responsibility is personal and liability insurance is required in order to practise. In 1768, the Danish king started giving licences to these cadastral surveyors.

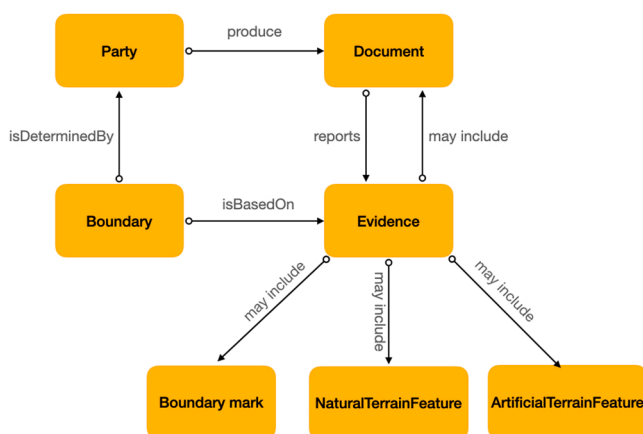


Fig. 1. Conceptual model for the legal boundary determination and documentation process.

The current cadastre in the majority of Denmark originates from the period between 1806 and 1844. The cadastre was, however, not complete for towns, forests and moors until around 1885. Negative experiences from previous cadastres gave awareness of the importance of keeping the new cadastre updated when subdivision and other cadastral changes took place. For this purpose, there was from the beginning firm legislation, procedures, and authority control to ensure that cadastral alteration was registered in the cadastre (Daugbjerg and Hansen, 2000, pp. 16–18). Hence, parts of a parcel are not allowed to be sold or mortgaged separately without a division of the property being registered in the cadastre (UL, 2018 §§ 14–16).

The Danish cadastre uses the fixed boundary approach, and all new property boundaries are provided with cadastral survey documents and property owners' written approval of the location of the new property boundary (BMA, 2020 § 3).

When establishing new property boundaries, the licenced surveyor often includes an examination and determination of the position of the existing property boundaries. In cases of subdivision for intensive use (i. e. housing), both new and existing property boundaries have to be marked, which can lead to a demand for demarcation. In addition, property owners may want existing property boundaries demarcated if the markings have been lost or if there are doubts or disputes about the location of the property boundary. The existing property boundary marks - if found or re-marked - are surveyed with the new property boundaries, and therefore many older property boundaries today are included in more recent surveys (Ramhøj, 1998, pp. 64–68).

Since the system of fixed boundaries is applied, determining boundaries means determining the position of the property boundary on the ground (on-site). According to the legislation, the licenced surveyor must for this purpose use the cadastral information as a starting point (UL, 2018 § 34). This means either the survey documents or the first version of the cadastral map/plan (from the first half of the 19th century). However, the licenced surveyor also has to determine whether there is compliance between the cadastral information and the physical situation on-site (BMA, 2020 § 4). The physical situation on-site is considered very strong evidence since this reveals information on the landowner's understanding of the ownership. The situation on-site is understood as both the position of the property marks and the position of fences and other visible evidence of use. There can be several reasons for lack of compliance: Adverse possession, faulty cadastral survey, inaccurate cadastral survey, natural changes of ambulatory boundaries (streams, coastline, lakes), removal of boundary marks (accidentally or purposely), unregistered agreements between the landowners etc. The licenced surveyor needs to find out why the property boundary has changed. If there is no compliance between surveys and the physical conditions on-site, then the property owners must be contacted and given an opportunity to provide information about the situation (BMA, 2020 § 4).

In Denmark, a property boundary in natural ambulatory boundaries (lakes etc.) normally follows the natural changes (Ramhøj, 1998, pp. 26–37), hence the natural courses and changes are the strongest of evidence. These natural boundaries are not marked. Else, the marking of the property boundary is normally considered very strong evidence if it is found and considered unaltered.

The cadastral information in itself is also of great importance, especially if there is no marking to be found on site. The surveys of the first version of the current cadastral maps were done by plane table surveying and chains. This means that the geometry of these original maps contains all the information there is left about the survey. If there have been no changes to a property boundary since the initial cadastral work, the original cadastral map is used for property boundary determination (Daugbjerg and Hansen, 2000, p. 40). In the countryside, the scale was 1:4000, and most maps were surveyed back in the late 18th century or early 19th century. As mentioned, towns, moors and forests were surveyed later. Moors and forests in scale 1:4000, towns in scale 1:800 (Daugbjerg and Hansen, 2000, pp. 28–30).

For all the changes done since this initial cadastral work, the cadastral survey was followed by a survey document. Then as well as now, it is this document - kept in the cadastral archive - that has to be used for property determination of property boundaries created after the time of the initial cadastral work.

Cadastral maps/plans were redrawn when the cadastral alteration became too plentiful, so many versions of the maps exist. In the 1990's, the digitalisation of the maps began, and it was finished in 1997. However, since it is the survey documents that are to be used for property determination, the current digital cadastral map has no relevance to the process (Daugbjerg and Hansen, 2000, pp. 32–39).

Since the oldest cadastral survey documents are from the early 19th century and the youngest is from today, naturally, the differences in accuracy are highly varied. Today's surveys are precise within 1–2 cm, where the oldest surveys hold a lower relative accuracy. When new surveys are done, they replace older surveys, and hence slowly the general accuracy is increased. In rural areas, where there has been the least development, old surveys are more common. The largest problem with the oldest measurements in both survey documents and the original (/first version) cadastral map is not their inaccuracy as such, but more the fact that the surveys are often difficult to recreate, as markings from that time are rarely possible to find if they ever existed. Thus, there are few points to position from. Instead, boundary lines that are unchanged from the first registration become relevant. The knowledge of previous traditions for placing hedges, earthen dikes, stone walls, or ditches in connection with the property boundary becomes necessary in order to combine evidence of the remains of these with the boundary lines on the survey or the original cadastral maps from the initial cadastral work.

Hence, fencing and boundaries of use are relevant to understand the old cadastral surveys, but they are also relevant in order to establish adverse possession. Because even though the term fixed boundary is applied, the Danish boundaries are anything but fixed. The majority of disputes about the position of the property boundary are not concerned with finding the position of the boundary registered in the cadastre. Instead, the disputes are normally about whether the boundary has changed due to adverse possession. According to Danish law, 20 years of possession can give the holder of the land a property right. This affects what is useful as relevant evidence in these cases. Here, historical orthophotos, private photos, building applications (if built over boundaries), and receipts for fencing materials and witnesses in the form of previous owners, neighbours, users, etc. are all relevant evidence (Skovsgaard, 2014, pp. 159–160 & 198).

2.2. Slovenia

The Slovenian land administration system is a dual system consisting of a cadastre and a land registry. The cadastral domain is coordinated by the Surveying and Mapping Authority (SMA) while the land registry is organised at the court. The land cadastre is managed by the SMA and its local offices, while the land surveying is primarily carried out by private licenced surveyors, registered at the Slovenian Chamber of Engineers after passing the formal requirements.

The land cadastre itself follows the parcel-based German cadastral concept. A land parcel boundary is a legally valid line that determines the geographical extension of a property, distinguishing it from the neighbouring property. They are usually documented by written documents, maps, measurement data and demarcated by boundary point marks or indirectly by natural or man-made features in the field, e.g. hedgerows, fences.

The origins of the cadastre date back to the 19th century. In 1817, the Land Tax Law (germ. *Grundsteuerpatent*) provided the legal framework for systematic cadastral surveying in Slovenia, which was at that time a part of the Habsburg monarchy. In the following decades, the so-called Franciscan Cadastre was introduced (Liseč and Navratil, 2014). However, the demarcation of real property boundaries has been known for centuries. There are still some preserved boundary stones from the

feudal period, particularly along the land boundaries of former dutchies, feudal lords, church, etc., known in the broader region (Waldhäusl et al., 2020). Boundary signs usually stood as visual proof for neighbourly agreement on the course of a land possession boundary. In the initial systematic cadastral survey, considering the old boundary markers and the active participation of landowners/possessors were important principles (Lego, 1968). These principles have been kept in the cadastral system for two centuries, including the current legislation.

Since the first systematic land survey, the changeable institutional framework, technological development, and purposes have been shaping the evolution of the land cadastre. These changes are reflected in the heterogeneity of cadastral map quality. For example, cadastral mapping from the 19th century was conducted in the field using plane tables and chains, in regional coordinate systems. In the countryside, the mapping scale was 1:2880, forests and Alps were mapped in 1:5760, while the towns were in 1:1440. If there have been no changes to a property boundary since the initial surveying, these maps, now in digital form, are still used for property boundary determination. For the correct interpretation of cadastral data, the cadastral historical background has to be considered in addition to the current legal framework (Berk and Ferlan, 2016; Čeh et al., 2019).

The first breaking point in the development of the land cadastre dates back to 1883, when the legislation introduced the documentation for cadastral procedures in the form of field books. Field books, which have been documenting the changes in the land cadastre since then, are part of the land cadastre archive, and they have to be used when determining a land parcel boundary. Exceptions are the areas where the complete new cadastral survey took place, e.g. within land consolidation projects or new survey in urban areas, where field observation data of higher quality is available, together with field books documenting changes after the new cadastral survey.

In 1974, the Land Cadastre Act (ZZKat, 1974) introduced the principle of legal land parcel boundary determination based on the official decision of the surveying authority. Since 1974, the determination of land parcel boundaries on the ground has been based on the written consent of the neighbouring landowners, accurately surveyed and documented in such a way that the location of any boundary point can be reconstructed. According to the current Slovenian legislation (ZEN, 2006), the coordinates of cadastral boundary points are to be determined in the national coordinate reference system. The required accuracy of measured cadastral boundary points is specified with the semi-major axis of the standard confidence ellipse, which should not exceed 4 cm (Berk and Ferlan, 2016). The idea of the so-called coordinate cadastre has been to provide better legal security for landowners and other land rights' holders.

The parcel boundaries, the location of which is determined on the basis of the administrative cadastral or court decision, with coordinates in the national reference coordinate system with a prescribed positional accuracy, cannot be the subject of the cadastral process "determination of parcel boundary". Such boundaries can only be set out and marked or changed by mutual agreement in a separate cadastral procedure, while in any subsequent judicial procedure, their position is assumed as "determined".

In the case of uncertain parcel boundaries, the determination of the boundary can be initiated by the landowners. This process can be also associated with other cadastral processes, such as subdivision. The owner commissions a licenced surveyor to take the necessary steps, which include the data and document retrieval from the land cadastre and its archive, and surveys the current situation. After this preparatory phase, the landowner(s) and all neighbouring owners are invited to an on-site boundary determination process, which can also be understood as a negotiation process. The legislation outlines the importance of landowner participation (ZEN, 2006, Article 36): "During a boundary settlement, landowners of neighbouring parcels show the land surveyor, or describe in detail, the boundary location on the ground." The same article indicates the role of the land surveyor in a boundary settlement in

relation to landowners: "If the boundaries shown are different than those entered in land cadastre records, while the landowners from the first paragraph disagree on their position, the land surveyor shall endeavour to reach an agreement among them (i.e. landowners)". A similar provision is also in the case, that the neighbouring landowners show different courses of the boundaries, but in both cases the course is within the positional and geometric accuracy of cadastral maps. This provision gives the land surveyor an important role as a third neutral party to solve the boundary dispute, following the cadastral data that has to be correctly interpreted. For example, in the areas with the old cadastral data acquired by plane tables, the determination of the course of a cadastral boundary provides a "buffer zone", where the land surveyor has to consider all the past rules and circumstances of cadastral mapping and updating maps. If no agreement between the landowners is reached, then the land surveyor determines the position of the cadastral boundary following the rules of the surveying and engineering profession (see also Golob and Liseč, 2022).

The course of a parcel boundary on the ground is documented in the field book, where surveying data with a detailed map and protocol of the parcel boundary determination process undersigned by all parties involved are included. This documentation has to be attached to the application submitted to record the data in the land cadastre at the SMA. Here the legislation foresaw three scenarios (ZEN, 2006):

1. If the application with the surveying documentation fulfilled all the requirements and there was a written consent of all involved parties, the SMA issued an official decision, which was the basis for updating the data in the land cadastre.
2. In the case that not all owners of the neighbouring parcels were present during the field work, the SMA sends the invitation to sign the agreement in their office within 14 days. If one or more landowners did not follow the invitation, it was assumed that they agreed with the proposed (cadastral) parcel boundary.
3. In the case that there was a disagreement between the landowners on the course of the boundary line, the landowners were invited to the negotiations at the SMA, but if they did not agree even in this phase, the surveyor at the public authority could not force a solution. In this case, the involved parties could initiate a juridical determination of the boundary at the local court. If they did not decide for the court process within 30 days, the proposed (cadastral) boundary was recorded as a "determined" boundary.

The new legislation (ZKN, 2021) that came into force in April 2022 has brought some changes, but it has not drastically changed the concept of land parcel boundary determination. The main change is that the legislation has introduced the "second independent surveyor opinion" if the party does not agree with the course of a cadastral boundary in the field, while it has cancelled the negotiations at the surveying authority.

In case of a subsequent judicial decision on the course of the boundary, instituted by landowners, the court may take a substantive decision in line with the Law of Property Code regulating the legal arrangements concerning real rights (SPZ, 2002, Article 77), "the court shall determine the boundary on the basis of the last peaceful enjoyment of possession" or according to a "fair assessment".

In the case that the cadastral data does not reflect the agreed possession boundary in the field, other cadastral or court processes are available to delineate land parcel boundary, depending on the reason for this inconsistency, e.g. faulty cadastral survey, inaccurate cadastral survey, natural changes of labile boundaries, removal of boundary markers, adverse possession etc.

2.3. Spain

In the Spanish system, a boundary is established by agreement between interested parties, but it is not necessary to officially determine the boundary in the field by cadastral works. The determination of the

boundary must be done on the single official cadastre digital map that is published open and free of charge. This official cadastral map is complete and continuous for all of the Spanish territory, and it is published in the electronic office of cadastre where notaries, land registries, public administration departments and citizens can access to get information about the boundaries. When there is a change in the boundaries of a parcel, citizens and public administrators are obligated to define the new boundaries in this official single map. An extract of this map (cadastral certificate) is added to the deeds.

With the information and the tools that the cadastre makes available for citizens and public organisations, this kind of field work is not necessary in most of the cases, because the cadastral map interoperated with the orthophoto or with other information is enough to permit the owners to see clearly where the boundaries are. Nevertheless, the citizens can ask privately for a survey of their parcels, but this information must be included in the single cadastre map to become the official information; the technicians of the Directorate General for Cadastre (DGC) checks whether the information provided by citizens and public entities is correct, and makes the new information official, publishing the result with open and free access by everybody at the electronic office of cadastre, thereby ensuring its transparency and correctness.

The Spanish law establishes that the Cadastre is a register describing rural and urban real estates. This description includes legal, physical and economic characteristics, featuring title holders' data and their rights to the real estate; geographical representation, location, cadastral reference, surface, usages, class of crop, buildings, graphic representation among other physical characteristics; and cadastral values that are the basis for real estate taxation. Even the position, structure and characteristics of all the buildings and the representation and ownership of every unit and floor plans are included.

Like other countries being investigated, the Spanish land administration system is based on a dual registration system consisting of a cadastral as well as land registry parts. After validation and incorporation into the cadastre, the notary or property registrars can obtain a "Descriptive cadastral and graphic certification" to elaborate the deed and to register in the land property register. This certificate contains not only the graphic information of the parcel in GML format but also a list of coordinates.

The continuous official digital cadastral cartography was created by the DGC in the period 1980–2000 (renovation period) with detailed topographic maps in urban areas (1:500–1:2000), and orthophoto (1:2500–1:5000) in rural areas. In this renovation period, for each municipality, deeds, titles, contracts, old cartography and other documents and declarations were studied to reflect them in the orthophoto or topography map, and field work was done to include in the cadastre all characteristics of the parcels and resolve the disputes of boundaries. The result of this work was included in the cadastral information system creating the unique official digital cartography with all the cadastral parcels as a continuous map.

The cadastral information system includes integrated textual and graphical information of all private properties as well as public land (e.g. rivers, lakes, coastline, roads and paths, train tracks etc.). There are no gaps and no overlaps between the parcels. It is continuous, homogeneous, and complete for the entire surface of Spain. This single official cadastral map is open and free for viewing and downloading from the Internet by citizens and public organisations that work in the territory since 2004.

The Cadastre provides this minimum homogeneous cartography for all the territory. If someone wants to improve the quality of the cadastral representation, a more accurate representation can be presented but always with the conformity of the adjoining titleholders. In the same way, if someone thinks that what is in the cadastral map is wrong, a correction can be asked for. Then, as it is defined by law, the DGC solicits the conformity of the neighbours that are obligated to answer. If conformity by all is not a given, the DGC proceeds with the change and the parties will have to go to court. The DGC collaborates to resolve the

conflict giving all information (current and past) to the technicians assigned by the court, and once the issue is resolved and the boundary is clear, the cadastral map is updated (if necessary). There are not many conflicts since the cadastre now is very mature.

Agreement between neighbours is the first in the list of hierarchy of evidence. However, in case of disputes, no hierarchy of evidence is established and the resolution depends on the situation and is based on the cartographic, legal, and physical reality.

To maintain updated cadastral information, the incorporation in the Cadastre of a new real estate, or the alterations of its characteristics, is mandatory by law. After the creation of this continuous digital cartography, in the process of day by day updating, better cartography and better technologies have been used.

In Spain, there are no licenced surveyors, and it is not obligatory to mark the land boundaries in the ground. Any modification of the physical characteristics of the cadastral parcels must be done taking as reference the cadastral cartography, which is the unique official geographic representation of the cadastral parcels.

The interested parties agree where the boundary is located without the intervention of any cadastral civil servant. If they want, they can contract a private land surveyor to obtain the coordinates to be reflected in the cadastre (in case it is difficult to reflect the boundaries in the cadastral map), but our experience is that normally it is not necessary, and seller and buyer can reflect the new parcel in the cadastral map easily with the tools that the cadastre provides, and in combination with the interoperable information that the cadastre offers in its electronic office: orthophoto, urban planning, old cadastre etc.

The surveyor (hired by the citizen), or a technician of a competent public organisation, can download the information of the boundaries and their coordinates from the cadastral office. It is distributed in several formats. Since 2015, as per the new law for coordination between cadastre and land registry, they must use the "INSPIRE cadastral parcels and buildings GML format"; that being the only file, legally admitted and required, for the exchange of information between technicians, legal operators (notary and property registrar) and the DGC. INSPIRE is the European Union directive for creating an infrastructure for spatial information in Europe (European Parliament, 2007).

By law, the citizens and all the public administrations that work in the territory are obliged to declare in the DGC any modification of the cadastral parcels after the agreement between the parties. They must provide information on the technical conditions as defined by the DGC. The DGC verifies that the graphical and textual information is correct. The final decision whether to insert this information in the cadastral database, and thus make it official, pertains to the DGC.

2.4. Sweden

Lantmäteriet, the Swedish mapping, cadastral and land registration authority, was founded in 1628, and among other responsibilities given the task to produce large scale maps of the country, and in the 18–19th centuries the execution of land reforms improving the very fragmented ownership structure in rural areas. Despite the centralised efforts to produce a more effective ownership structure, no centralised and nationwide regulations for demarcation and registration of property throughout Sweden for urban and rural areas were introduced until 1972 with the Swedish Land Code (JB, 1972). However, initial work regulating the demarcation of boundaries and registration in the land register and the cadastral index map started earlier, resulting in the "ownership boundary law", *Ägogränslagen*, in 1932. Organisational changes were also made, e.g. by the creation of a new governmental agency, the Central committee for property data, (*Centralnämnden för Fastighetsdata, CFD*), which was responsible for digitalization of the analogue land books and other real property documentation in order to develop a national digital Swedish real property register. CFD was later merged with Lantmäteriet, thus being overall responsible for the property formation, real property registration and cadastral mapping.

Real property formation is not solely a governmental affair. Since 1996, municipalities can apply for the right to perform cadastral procedures within their domain. Today, 39 large municipalities have been granted the right to perform cadastral procedures. Private companies are not allowed to conduct cadastral formation procedures in Sweden. A property boundary is the legally valid line which in its horizontal plane limits the geographical extension of a property, thus distinguishing it from the adjacent property. The properties are defined with legally fixed and technically well-defined boundaries (Andreasson, 2008), as the extension of the boundary normally is documented using written documents, maps, measurement data and boundary marks.

The markings of property boundaries have a strong legal protection, and it can be a criminal offence to remove, move or even damage a boundary marking. It is, however, not uncommon for boundary markings to have disappeared and it may therefore be difficult to determine the extent of a boundary (Julstad, 1998). Through property determination in accordance with the Real Property Formation Act (FBL, 1970), it is, however, possible to produce in the future a legally binding decision on certain issues concerning the division of properties, such as the extension of a boundary. Through special boundary marking, boundary marks can be reconstructed or supplemented. If the extension of an unclear or contentious existing boundary is decided for the future, it will, for the first time or again, be legally determined. Boundaries are normally marked, where possible, but are not obligatory and there is no standard for marking boundaries (Julstad, 2006, p. 463), although instructions and guidelines exist (Lantmäteriet, 2019).

A cadastral plan showing the location and coordinates of the boundary marks is created in connection with the field survey. If a new boundary is created between existing boundary marks, there is no need for a field survey. The national cadastral map can be described as an index map, i.e. it does not report primary information but only provides a reference to it and has no legal force (Andreasson, 2008). Detailed information about the boundaries and markings has instead to be taken from the respective properties' cadastral documents. The same applies to rights of various kinds, such as easements and utility rights, as well as plans and regulations. The Land Code states that the legally determined boundary has the extension which is marked on the ground. This principle is also applied when the administrative documents and the markings on the ground do not match. Two complementary rules to this main principle exist (Ekbäck, 2016). If the marking can no longer be determined with certainty, the boundary shall have the intended extension, based on the administrative cadastral map, documents, holdings and other circumstances. If the extension of the boundary is not marked on the ground in legal order, the boundary shall have the route shown on the map and associated documents. When maps and documents are incomplete, other factors may also be taken into account, e.g. prescriptive rights. If a boundary has not been legally determined, the marks that have been considered valid by age to mark the boundary apply, such as fences, cairns, ditches, hedges, etc., to determine the boundary. Even today, centuries' old existing boundary markers, consisting of for example erected stones, still have legal force if they have not been unlawfully obscured.

There are no specific rules concerning the geometrical accuracy for surveying boundaries, but guidelines from the national cadastre agency exist (Lantmäteriet, 2019). The reason is that there are huge differences in the geometrical accuracy of boundary marks throughout Sweden. In rural and woodland areas, the accuracy is less, up to about a few decimetres on markings consisting of erected natural stones, than in urban areas, where markings, normally consisting of iron poles, today are surveyed with centimetre accuracy. Markings have been surveyed in different ways for more than two centuries - ranging from old surveyor's chains to modern surveying instruments.

The Swedish cadastral index map has a huge range in accuracy from Level 1 to Level 6 as described in Grant et al. (2018), i.e. from Digitised Spatial Cadastre to Survey Coordinate Cadastre. The reason is that the index map initially was constructed in the 1990-ies by digitising existing

analogue maps from different scales, typically 1:10 000. Newer survey plans of individual properties were thereafter sometimes manually digitised to fit into the index map, especially in rural areas. In urban areas, the accuracy is much higher. The map has no role in cadastral surveying, since the legal information and measurements are found in the individual cadastral dossiers for each property unit. Today, much effort is being put into correcting the geometrical accuracy of the index map, to make it suitable to use together with other information in Sweden's national geographical data infrastructure, but it is an index map only and has no legal value. The index map is available online; some restrictions in use apply.

In Sweden, properties can as mentioned above only be formed or reformed through government or municipal decisions. Boundaries are created today mainly through property formation according to the Real Property Formation Act. However, boundaries can also be added in other ways, even if they are rarely used. For example, in accordance with the Act on Property Rights Investigation and Legalization, a cadastral procedure may result in a previously completed private land division being recognized afterwards. Property formation measures mean that new boundaries are added or validated, while others lead to existing boundaries being removed.

Cadastral procedures concerning certain compulsory purchase according to the Joint Facilities Act and the Utility Easements Act, respectively, are directly property-forming, and the result is similar from a boundary perspective to the usual property formation measures in such a way that these boundaries are also legally determined. Compulsory purchase measures that are handled in a different way than in the case of a cadastral procedure can also give rise to new boundaries. Expropriation according to the Expropriation Act occurs to a certain extent, while compulsory purchase according to the Planning and Building Act, the Environmental Code, the Roads Act, the Railway Construction Act and the Minerals Act, respectively, are relatively unusual measures. None of the aforementioned coercive measures gives rise to legally determined boundaries.

It is the officers at the public cadastral authorities (State and municipal) who are responsible for the cadastral procedure where the boundaries are formed, including boundary survey and marking. Other actors take active part in the process, such as the applicant of the procedure, which is often the property owner or right holder, other concerned authorities, citizens and Court (if appealed).

Digitalization of real property processes and digital document management has since long been of interest for the cadastral authorities for updating cadastral information, and much of the cadastral formation work is done digitally. An example is the Swedish Real Property Register where the cadastral index map is included. Maps are digitally produced in the real property formation and updating processes, and their content is used to update the national digital index map, which is updated on a daily basis by the Lantmäteriet and the municipal cadastral agencies. It is, however, the map registered in the cadastral document for each real property that has legal force. The digital index map is for overview purposes only. The geometric quality of the map is high in urban areas, but less in some rural areas. There is work in progress improving the geometric quality in certain rural areas. In recent years, the conversion of detailed cadastral information, such as 3D property and the visualisation of the same, has been subject to research, see e.g. Andréée et al. (2018a), (2018b); Karabin et al. (2018); Larsson et al. (2018), and the topic of digitalization is in rapid development with recent Swedish development and research projects (see for example Smart Built Environment, 2019, and Ekbäck, 2019). There is at present no initiatives to establish a coordinate based digital legal cadastre.

The cartographic and verbal description of boundaries becomes particularly clear for three-dimensional properties and three-dimensional property spaces, which are defined both horizontally and vertically. The boundaries of three-dimensional properties are, as opposed to traditional boundaries, normally not marked physically, but only indicated on maps or drawings and with coordinate information, as

well as described verbally in the cadastral documents.

Disputes concerning the location of boundaries are handled by the cadastral authority and the decision can be appealed to the courts.

2.5. Turkey

Land registration and cadastre in Turkey is maintained by the General Directorate of Land Registry and Cadastre (*Tapu ve Kadastro Genel Müdürlüğü, TKGM*). It provides services with one central, 24 regional, 81 local cadastral, and 943 local land registry offices. Also, according to the Code on Licenced Survey and Cadastre Engineers 5368 of 2005, some cadastral services are provided by licenced cadastral surveyors under the supervision of TKGM.

The modern cadastral surveys in the republic period started with the [Turkish Cadastre Act, \(1925\)](#). The cadastral surveys were spread over the whole country with different acts enacted from 1925 through 1966 ([Yıldırım et al., 2021](#)). The current works are being carried out in accordance with the [Turkish Cadastre Act \(1987\)](#). Like many countries belonging to the German civil law family, 'title registration' and 'fixed boundary' approaches are applied.

In 1926, the Turkish Civil Code, a translation of the French version of the Swiss Civil Code, was enacted ([Oguz, 2005](#)). Since then, cadastre has been used as an instrument for the establishment of land registry envisioned by the [Turkish Civil Code \(1926\)](#). A 'systematic adjudication' process (cf. [Zevenbergen, 2002](#)) was applied in the whole country to determine the geometric and legal status of real properties. Land parcels were demarcated on the site and on the cadastral plans, and property rights and holders of these rights were ascertained and registered into the land registry. These initial surveys were completed across the country by the 2000 s.

The initial cadastral surveys involved several parties, such as surveying teams, inspection commission, property owners, and witnesses. The surveying team consists of cadastral officers and people selected from the local community. The cadastral officers are responsible for the demarcation and ascertainment processes. Village administrators and elected locals are obliged to provide true statements and objective opinions to the cadastral officers about the geometric and legal status of the property that is being ascertained. Cadastral officers may also consult statements of witnesses, if needed. The disagreements that may occur during the demarcation and ascertainment of real properties are investigated by the inspection commission consisting of the administrators and surveying engineers working in the local cadastral office.

The evidence taken into consideration in the boundary demarcation process of the initial cadastral surveys were documents, boundary marks, and natural and artificial terrain features. Documents include public inventory records which are title records, tax records, maps produced by other public organisations, plans, and ortho-imageries, as well as deeds and contracts provided by the parties. The signed statements of the village administrator, local people, and property owners can also be considered as supportive proof. The following principles were applied in the demarcation of land parcels: The documentary evidence has a higher priority; thus, boundary points are established based on the documentary evidence which may include a graphical description in terms of a map, plan, or sketch. Demarcation may also be made according to the undisputedly used boundary marks or terrain features on the site when the graphical description cannot be applied, or the graphical description is not consistent with the evidence on the site. In case of a dispute between the neighbouring owners about the evidence on the site or there is not any evidence on the site, then demarcation is made through the interpretation of the graphical description. The documentary evidence may even include only verbal descriptions of parcel boundaries. If the verbal description refers to a boundary that is used by the neighbouring owners without any dispute, demarcation is made according to the verbal description. Nevertheless, if the boundaries indicated by the verbal description are changeable and suitable for expansion, then demarcation is made based on the surface area of the

land parcel recorded in the original documents (e.g. titles, deeds, tax records).

Various spatial reference frames, terrestrial (e.g. orthogonal, tacheometric, Global Navigation Satellite Systems [GNSS]) and photogrammetric (e.g. aerial photogrammetry) surveying methods have been used during the initial cadastral surveys. Consequently, cadastral maps ranging from 1:200–1:10 000 scales with different positional accuracy have been produced. TKGM currently invests in systematic updating projects to improve the quality of cadastral data. In addition to sporadic property formation procedures (e.g. subdivision, amalgamation, land consolidation and land readjustment), two systematic update methods are being applied: (i) Digitization and (ii) renovation of cadastral plans. The cadastral plans that cannot be applied to the field, or do not meet the accuracy criteria, or do not show the boundaries correctly because of cadastral errors, are being renovated by systematic, countrywide, parcel-based renovation projects. Cadastral plans, which are not needed to be renovated, but also not linked to the current national geodetic datum (i.e. Turkey's National Geodetic Reference Frame based on the International Terrestrial Reference Frame at 2005.0), are being digitised and transformed into the current national datum through digitization projects.

The cadastral update aims at eliminating cadastral errors, and thus improving the quality of cadastral data and obtaining coordinates of all boundary points based on the current national geodetic datum. So far, boundary coordinates of almost all land parcels have been obtained. About 2/3 of these parcels are defined in the current national geodetic datum, while about 1/3 of these parcels are defined in different datums. Accordingly, the status of cadastral data varies in a range from Digitised Spatial Cadastre (Level 1) to Survey Coordinate Cadastre (Level 6) as described in [Grant et al. \(2018\)](#). The 11th National Development Plan (2019–2023) of Turkey aims to complete the modernization of cadastre by switching to a single coordinate system in all Turkey (Article 681.2).¹ However, this should not mean that the Turkish Cadastre will be a legal coordinate cadastre since these coordinates are not legally binding. They can be relied upon if they do not contradict other stronger evidence, such as cadastral plans.

The cadastral renovation is a very similar process to the initial cadastral surveys in terms of boundary identification. Like initial cadastral surveys, it involves surveying teams, inspection commission, property owners, and witnesses. In the cadastral renovation, boundary points indicated by the original cadastral documents are compared with the evidence on the site, the boundary points are re-measured through terrestrial, e.g. tacheometry, GNSS survey, aerial photogrammetric or LiDAR (Light Detection And Ranging) survey, using different platforms, including Remotely Piloted Aircraft Systems (RPAS). Their coordinates are calculated based on the national datum, and new cadastral plans are drawn. Original cadastral plans, surveying documents, and land registry records are used as evidence, in addition to the boundary marks, and natural and artificial terrain features. Similar to the initial surveys, the signed statements of the village administrator, local people, and property owners can also be considered as supportive proof.

The following rules are applied in the re-establishment of boundary points: The original cadastral documents have the highest priority. Therefore, boundary points should be re-established based on the original documents. If the original documents cannot be applied to the site or the boundary indicated by the original cadastral documents does not fit the evidence on the site, then the property is demarcated according to the evidence on the site. In this case, one of the following conditions must be met: (i) It is confirmed by original documents or statements of locals that the position of the evidence on the site has not been changed ever since the first registration. (ii) It is confirmed by original documents or statements of locals that the position of the evidence on the site

¹ https://www.sbb.gov.tr/wp-content/uploads/2021/12/Eleventh_Development_Plan_2019-2023.pdf

changed because of earth movement (e.g. earthquake). (iii) It is declared by the neighbouring owners that the evidence on the site is used as the boundary without any dispute. If one of these conditions is not met, the boundaries are re-established by applying following rules: (i) In case that the original cadastral measurements are validated that they do not include any errors, boundary points are re-established according to the original measurements. (ii) In case that the property is adjacent to land belonging to the state (e.g. forests, pasture), then the adjacent boundary is considered unstable and available for change. Thus, boundary points are re-established according to the registered area of the property. (iii) In case that there is not any documentary evidence, then boundary points are re-established by the adjustment of the registered area with the factual area of parcels.

As mentioned above, the cadastral update also covers the digitization of cadastral plans which are not based on the current national geodetic datum. The digitization procedure is carried out by cadastral officers. Contrary to the initial and renovation surveys, property owners, local people, and witnesses cannot participate in the digitization process. The digitization method is applied as follows. The coordinates of the cadastral parcels are calculated based on the original survey documents and cadastral plan. Then calculated coordinates of boundary points are staked-out and compared with the evidence on the ground. If there is a difference between the marked boundary point and the evidence on the site within the tolerance limit, then the evidence on the ground gets priority. In this situation, evidence on the site is re-surveyed and its coordinates are calculated based on the current national geodetic datum. If the difference is over the tolerance limit or there is not any evidence on the site for comparison, then boundary points indicated by the original cadastral documents get priority. In this situation, the calculated coordinates of boundary points according to the original survey documents and cadastral plan become valid.

The parcel boundaries determined based on the above-mentioned cadastral procedures or court decisions can be set out and marked by licenced surveyors based on original cadastral data, or can be altered by separate property formation procedures (e.g. subdivision, amalgamation, land readjustment) performed upon the request of landowners or administrative decisions.

3. Comparison

All investigated countries have dual cadastral systems. In Denmark, Slovenia and Spain, cadastre and land registry are kept by the national cadastral organisations and courts, respectively. In Sweden, there is one governmental organisation which is in charge of the real property register, but there are several municipalities that do property formation and cadastral work within their jurisdictions. In Turkey, cadastre and land registry are maintained by one national organisation that performs through its local cadastre offices and land registry offices.

In Denmark, Slovenia and Sweden, the initial cadastral surveys were completed in the 19th century. Current works include boundary rectification through sporadic cadastral update or dispute resolution procedures. For instance, there are areas that were completely surveyed in the past century within land consolidation, land readjustment or new cadastral surveys where cadastral maps of a higher quality with surveying observations are available. Also, in Slovenia, there was a systematic new cadastral survey for selected urban areas in particular in the second half of the 20th century due to the urbanisation needs; in addition, many agricultural areas were included in land consolidation projects. In Spain, land parcel boundaries were determined by first registration or initial cadastral surveys and included in cadastral maps in the 1950 s and updated in paper until 1980. During 1980–2000, the renovation process was carried out, generating a single digital cadastral map of sufficient quality for all territory. This map has been corrected and improved with the changes that have occurred in the territory that have been surveyed with more precise techniques. These updates and corrections have been incorporated into the only official cadastral plan,

always with the agreement of the owners of the adjoining plots to maintain a continuous plan, thus improving the quality. In Turkey, land parcel boundaries were determined by first registration or initial cadastral surveys completed in the 2000 s. Now the quality of cadastral data is being improved through digitization and renovation of cadastral plans in addition to property formation surveys.

Boundary marking on the ground is obligatory in Slovenia, Turkey and Denmark, while the marking of boundary points in the field is not obligatory in Spain, where surveying and field work is optional, and Sweden where boundaries are normally marked, but it is not obligatory. In Denmark and Sweden, boundary marking and surveying are under the responsibility of licenced surveyors and cadastral surveyors, respectively. In these Nordic countries, property owners can be asked to comment on when there is no compliance between the cadastral data and the evidence on the ground; they do, however, not have a formal role in the property formation process. It is the responsible surveyor that examines the cartographic, textual, and physical evidence and decides on the location of the boundaries and markings in question. In Slovenia, uncertain parcel boundaries are determined by licenced surveyors in the field upon the request of the landowners. Yet, boundary determination is seen as a negotiation process that involves all affected parties led by a licenced surveyor. In Turkey, initial cadastral surveys, renovation surveys, and digitization procedures are carried out by the cadastral officers working in the national cadastral organisation. Property owners, village administrators, local people and witnesses under special conditions can participate in the boundary determination processes in initial and renovation surveys. Uncertain property boundaries can be re-marked on the ground by the cadastral officers or licenced cadastral surveyors upon the request of landowners. In Spain, the information that is offered by the electronic office of cadastre permits interoperate orthophoto and other cartographic maps with the cadastral map and offers the tools that permit to reflect the new boundaries in the cadastral map and generate the digital document with the new parcel boundaries and coordinates. When the interpretation of the course of a boundary on the ground is not clear based on this digital data or in the case of the request of an owner, surveys can be conducted in the field. The resultant information on the course of a boundary must be reflected in the single official cadastral map with the conformity of neighbours (if they are affected) and it must validate in the cadastral information system.

In Turkey, cadastral plans are legally binding, which means that they are presumed correct in the event of any discrepancy between the cadastral plans and the boundary marks if there is not any fault in the original cadastral measurements and plans. In Slovenia, Sweden and Denmark, the cadastral plan, measurements, etc. have legal force, whereas the nationwide (digital) cadastral index map is for overview purposes only and has no legal force. The digitization of cadastral plans was completed at the end of the 1990 s in Denmark, Slovenia and Spain. Digitization and renovation works still continue in Turkey. The cadastral information used for boundary determination in Denmark are the survey documents. These cadastral data vary in precision and using the terminology of Grant et al. (2018), the data can be classified as going from Digitised Spatial Cadastre (Level 1) to Survey Coordinate Cadastre (Level 6). Especially the rule of adverse possession prevents the coordinates to be authoritative in Denmark. The Swedish cadastral index map has a similar range in accuracy from Level 1 to Level 6. Similar can be observed also for Slovenia, where digitised index maps with the origins in the 19th century can be classified as Digitised Spatial Cadastre (Level 1), while new cadastral data as the result of individual cadastral processes (e.g. subdivision, land boundary determination), or of massive procedures (e.g. land consolidation), can be classified as Survey Coordinate Cadastre (Level 6). In Turkey, systematic digitization and renovation works continue to obtain coordinate values of all parcels in the country. This is an aim to reach Survey Coordinate Cadastre (Level 6). However, the status of cadastral data varies from Digitised Spatial Cadastre (Level 1) to Survey Coordinate Cadastre (Level 6). In Spain, the inscription in the Property Right Registry is voluntary and the cadastre is

obligatory. From 2015 (Coordination law between Registry and Cadastre) the cadastral graphic geo-referenced descriptions must be included in the Property Rights Registry. When this process is done, a cadastral parcel has the qualification of “coordinated by the land registry” and the boundaries and the coordinates become legal. The process of coordination is ongoing with the day by day updating and status of cadastral data is passing from Survey Coordinate Cadastre (Level 6) to Legal Coordinate Cadastre (Level 7) according to the classification suggested by Grant et al. (2018).

The description of national cases revealed that different decision-making approaches are applied for the determination of boundary points in the investigated countries. In Slovenia and Turkey, original cadastral data is considered as the primary evidence. On the contrary, the evidence on the ground has priority in Denmark and Sweden. In Spain, agreement between neighbours is the first in the list of hierarchy of evidence, but in case of disputes, no hierarchy of evidence is established and the resolution depends on the situation and is based on the cartographic, legal and physical reality.

In Denmark and Slovenia, disputes are resolved by licensed surveyors in the first instance and in courts in the second instance. In

Slovenia, the cadastral officers in the national cadastral authority used to have also an important role in resolving boundary disputes before the case went to the court, but this provision was cancelled by the new legislation (ZKN, 2021); the exception is when two independent surveyors provide different solutions and, in this case, a special commission is foreseen to solve the problem. In Turkey, boundary disputes are handled directly by the court, while in Sweden, in the first instance it is the cadastral authorities who resolve the disputes and then the court. In Spain, neither surveyors nor the cadastral organisation resolves disputes after the described renovation process. The cadastre is considered officially good and any change in the boundaries must be based on the agreement of neighbours. In the case of disagreement, the court must resolve the issue. (Table 1).

4. Conclusions

This article documents and compares the principles and processes applied in the determination of property boundaries in Denmark, Slovenia, Spain, Sweden and Turkey through a novel conceptual model developed for that purpose.

Table 1

A comparison of matters related to boundary determination procedures in the selected countries.

Attribute / Country	Denmark	Slovenia	Spain	Sweden	Turkey
Dual system of cadastre and land registry	Yes, maintained by different organisations	Yes, maintained by different organisations	Yes, maintained by different organisations	Yes, maintained by the same organisation	Yes, maintained by the same organisation
Type of land registry	Title registration (German style)	Title registration (German style)	Deed registration (French /Latin style)	Title registration (German style)	Title registration (German style)
Function of cadastre	Identification for land registration	Identification for land registration	Identification for taxation	Identification for land registration	Identification for land registration
Status of coordinate cadastre according to Grant et al. (2018)	Ranging from ‘Level 1 - Digitised spatial cadastre’ to ‘Level 6 - Survey Coordinate Cadastre’	Ranging from ‘Level 1 - Digitised spatial cadastre’ to ‘Level 6 - Survey Coordinate Cadastre’	‘Level 6’ and working to become ‘Level 7 - Legal Coordinate Cadastre’	Ranging from ‘Level 1 - Digitised spatial cadastre’ to ‘Level 6 - Survey Coordinate Cadastre’	Ranging from ‘Level 1 - Digitised spatial cadastre’ to ‘Level 6 - Survey Coordinate Cadastre’
Accuracy	Depends on situation	Heterogeneous - depends on situation	Depends on situation	Depends on situation	Depends on situation
Cadastral update methods	Updated by a licenced surveyor in connection with cadastral work.	Updated by a licensed surveyor and surveying and mapping authority in connection with cadastral work.	Continuous update by obligation of citizens and relevant public administrations.	Through routine checks and corrections; digitization, and systematic map renovation work.	Through routine checks and corrections; digitization, and systematic map renovation work.
Binding cadastral plan	Together with adherent cadastral documents	Together with adherent cadastral documents	The cadastral plan is derived from the single official map. It is binding after coordination with the land registry.	Together with adherent cadastral documents	Together with adherent cadastral documents
Obligatory boundary marking on the ground	Yes	Yes (before 2006 and since 2018)	No	No, but boundary points are normally demarcated.	Yes
Hierarchy of evidence	(1) Natural and artificial features (2) Original cadastral data	(1) Original cadastral data (2) Natural and artificial features	Agreement between neighbours is the first. No hierarchy of evidence in case of dispute. Depends on situation and based on all cartographic, legal and physical information.	(1) Natural and artificial features (2) Original cadastral data	(1) Original cadastral data (2) Natural and artificial features
Actors for boundary determination and rectification	Licenced surveyor (Private sector)	Licenced surveyor (private sector), in some cases also public cadastral officers	No	Cadastral officers (Public sector)	Cadastral officers (Public sector)
Actors for boundary survey and marking	Licenced surveyor (Private sector)	Licenced surveyor (Private sector)	Optional for private business. Surveyors of public administration in the public-private business	Cadastral officers (Public sector)	Cadastral officers (Public sector) Licenced surveyor (Private sector)
Active participation	Applicant (property owner or right holder), concerned authorities	Applicant (property owner or right holder), concerned authorities	Applicant (property owner or right holder), concerned authorities, citizens	Applicant (property owner or right holder), concerned authorities, citizens	Property owners and right holders, local administrators, elected local people, witnesses in initial and renovation surveys.
Actors for dispute resolutions after initial cadastre	(1) Licenced surveyor (2) Courts	(1) Licenced surveyor (2) Cadastral officer (3) Courts	Courts	(1) Cadastral organisation (2) Courts	Courts

We found several similarities, for example that geometrical accuracies of cadastral demarcation are inhomogeneous in all countries due to historical reasons. However, the studies also revealed differences related to the demarcation of boundaries. An example is a distinction between the Nordic civil law tradition about the hierarchy of evidence. In Denmark and Sweden, evidence on the ground (e.g. natural and artificial terrain features) has higher priority than the documentation stored in the cadastral dossiers, whereas in Slovenia and Turkey, belonging to the German civil law tradition, the documentary evidence (e.g. cadastral plans and survey documents) has higher priority. Spain, belonging to the Napoleonic civil law tradition, has no hierarchy of evidence in case of dispute, where agreement between neighbours has the highest priority. Other differences are for example that some countries have an obligation to physically mark boundary points, whereas other countries have not. Nevertheless, it is concluded that boundary determination is understood as a legal decision-making process where the property boundaries are settled by authorised surveyors based on examination of all cartographic, textual, and physical evidence, with the active participation and input of the landowners, in all investigated countries.

Except for Spain, the status of cadastral data in the investigated countries ranges from Digitised Spatial Cadastre (Level 1) to Survey Coordinate Cadastre (Level 6) according to the classification presented by Grant et al. (2018). Level 1 refers to a status where 'cadastral data is built by digitising the boundary information on the paper maps' (p. 58), whereas Level 6 refers to a status where 'coordinates of boundary points are expressly assigned a status in the hierarchy of evidence but not definitive' (p. 62). Only Spain aims at reaching Legal Coordinate Cadastre (Level 7) where 'coordinates have a preeminent legal status' (p. 63). We think that all investigated countries have the institutional and technical capacity to reach a full Legal Coordinate Cadastre. However, possible legal consequences for such a transformation, for instance matters such as liability of the State in cadastral errors related to coordinates of boundary points, should be carefully considered (see Yildiz et al., 2022a; Yildiz et al., 2022b).

Recently the fit-for-purpose land administration approach has been recommended by the International Federation of Surveyors and World Bank to developing countries for building their land administration systems quickly and cheaply (Enemark et al., 2014). This approach suggests the use of general boundaries rather than fixed boundaries, demarcation of boundaries through aerial imageries rather than field surveys, and selection of accuracy criteria according to the purpose rather than technical standards. In this article, we presented a spectrum of cadastral update approaches. At one edge of the spectrum is Spain, where a sort of fit-for-purpose cadastral update takes place, and at the other edge is Turkey, where a systematic, parcel-based cadastral update takes place. Between these two edges, there are Denmark, Slovenia and Sweden, where property-formation-based sporadic cadastral update are practised. Further research is needed to evaluate the effectiveness of conventional and fit-for-purpose update approaches.

Data availability

No data was used for the research described in the article.

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