4D Land Administration Solutions in the Context of the Spatial Information Infrastructure

Fatih DONER, Turkey, Rod THOMPSON, Australia, Jantien STOTER, Christiaan LEMMEN, Hendrik PLOEGER and Peter van OOSTEROM, the Netherlands

Key words: Cadastre, Land Management, 3D Cadastre, 4D Cadastre

SUMMARY

The increasing complexity of modern world requires that Land Administration (LA) systems need an improved capacity to manage the third dimension. As the world is per definition not static, this implies that we must handle the temporal (forth) dimension as well, either integrated with the spatial dimensions or as separate attribute(s).

Several important types of LA objects can be considered in a 3D+time (4D) context; for example apartments and utility networks. Currently individual apartments are usually not visible on the cadastral map, only the outline of the building is visible. However, the individual rights are attached to the individual apartments. Often it is possible to access (analogue or digital) drawings of the apartment building showing the individual units. But this is not integrated with the cadastral map. However, the building registration in more and more countries is geo-referenced and contains in some cases the 3D spatial description of apartment units to which the LA could refer. A similar approach could be taken for the registrations of utility networks, that is, refer to the utility network physical information source via the (Spatial Information Infrastructure) SII. An important characteristic of utility networks is that in general they will cross many parcels, and are located in a part of each parcel. In this way, they resemble certain types of restrictions, which are currently registered in some countries as restrictions with their own geometry (e.g. in Queensland Australia, a restriction related to a path has its own geometry). The geometry of these restrictions crosses/overlaps several 2D parcels (similar to a utility network). In this paper we will focus on the registration of utility networks as a case study. Three options for the registration by the LA are being considered: 1. keep it as it is today, 2. copy the 3D information into the cadastral system (and adjust own system), 3 refer from the cadastral system to 3D descriptions in external building and network registrations.

In this paper, utility networks are considered in 3D+time (4D) context. The Turkish and Dutch cadastres are examined for these objects to determine similarities and differences in practice. Since utility networks are suitable for being registered as separate real property in the land administration system, the legal (at the cadastre) and physical/technical information of utilities (at the source) in the Netherlands are investigated. In addition, registration of restrictions/easements with 2D and 3D geometric descriptions in Queensland Australia are examined for possibilities of registering objects which cross several parcels. Then,

alternatives and modeling approaches of the land administration domain model (LADM) for 4D LA are evaluated. Some advantages and disadvantages in relation to this are presented.

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1. INTRODUCTION

Traditional two dimensional land administration (land registration and cadastre: LA) systems have shown limitations to cope with increasingly complex rights, restrictions and responsibilities which occur in today's modern world. Although every country has its own laws and cadastral regulations and approaches, it can be generally said that access to information with respect to the third dimension of land is poor in land administration systems (UN and FIG**,** 1999; Van der Molen 2003). As the world is per definition not static, this implies that we must handle the time (fourth) dimension as well to be able to manage the dynamics in land administration. The temporal dimension can be handled by either integrating with the spatial dimensions or as separate attribute(s).

One of the solutions for improving land administration in case of need for 3D representations is to keep the geometry of 3D objects in the databases of organizations that are responsible for them (e.g. registrations of buildings, tunnels, cables, pipelines and other constructions) and to refer to this information from the land administration when needed. This whilst realizing that the geometry of the 3D legal space does not always have to be the same as the geometry of the real world object. We call this the 'Spatial Information Infrastructure (SII) approach'. In this context the temporal aspect is a key aspect where one registration is referring to objects in another. The referred object may change over time (or even be deleted), therefore to keep the references correct and the systems consistent, one must be able to refer to a specific version in time (that always has to be present). This is specifically important in case the reference is not only used for querying but also to identify the spatial extent to which rights apply in the land administration.

In this paper we consider utility networks in a 3D+time (4D) 'legal space' context and section 2 starts with an introduction of the conceptual basis of 4D land administration. This is followed by an explanation of the usefulness of the SII, especially when referring to 3D geometries in another registration (section 3). The LA of Turkey and the Netherlands are examined to determine similarities and differences in practice in respectively sections 4 and 5. Since utility networks are suitable to be registered as distinct real properties in the Netherlands, the legal registration (maintained by the cadastre) and the physical and technical information on the utilities (maintained for each separate network by the owner) in this country are researched. In addition, registration of restrictions/easements with 2D and 3D geometric descriptions in Queensland Australia are examined to show possibilities of registering objects which cross several parcels (section 6). In section 7 we discuss the temportal side of land administration. Then, respectively sections 8 and 9 consider the alternatives and modeling approaches in the context of the land administration domain model

(LADM) for 4D LA. Some advantages and disadvantages are presented and the main conclusions are given in section 10.

2. CONCEPTUAL BASIS OF 4D LAND ADMINISTRATION

From a conceptual point of view, one of the foundations of the 2D LA is that there can be no gaps or overlaps in the parcelation on which the rights are based, that is, a planar partition of the surface (implying property volumes defined by the space columns above and below the ground surface parcel). The same foundation (a partition of space with no overlaps or gaps) is also the basis of the conceptual thinking with respect to 3D LA (Stoter, 2004). This conceptual view is not per se directly translated into an identical 3D technical implementation. The most advanced translation would be to have a system based on a complete 3D topological structure based on volumes, faces, edges and nodes (as extension of the current systems based on a 2D topology with faces, edges and nodes). However, in the short term a practical technical solution for the implementation could be: use the 2D parcels as basis (with their implied column volumes) for the partition of space, but subtract from this the 'exceptional' cases of volume parcels with a complete 3D description (e.g. in the form of a polyhedron).

The conceptual foundation of a 4D LA is again the partition concept: no overlaps or gaps in the rights (Van Oosterom et al., 2006). In this case it is not only space, which is considered, but also in parallel the time dimension. So, every right is attached to a primitive in 4D space. The boundaries mark the discontinuity in the relationships (rights) between people and land. Within a 4D volume primitive, the rights are homogenous. A boundary can be a spatial boundary, in the traditional sense, the separation between 2 parcels, but a boundary can also be a temporal boundary: the right has been transferred from one (or more) person(s) to (an)other persons. In theory there could be mixed boundaries, in case of dynamic objects; e.g. a moving river as boundary or a moving right belonging to a nomadic group. The 4D partition is in fact the foundation of our (legal) cadastral thinking on the organization of rights. Similar to the 3D LA implementation, the next question is how to implement these concepts in a system. The most natural option may be to use a 4D space-time topological structure as the foundation, which will guarantee the consistency. However, these 4D topological structures are not yet available in the current software packages (DBMS, GIS, CAD systems) and more R&D is first needed. An alternative is a technical solution based on 3D spatial attributes and separate temporal attributes. In this solution, there is no natural guarantee that the result is a 4D partition. Additional constraints should be formulated to obtain (or at least to get close) to the partition. For example, if one 3D volume parcel is split into two new volume parcels, then one has to make sure that when the old 3D volume object becomes invalid, at the same moment the two new 3D volume object becomes valid. This can be enforced by defining constraints on the 3D space and time attributes of the instances of the LA system. So, there is no moment in time when the same location (point) in space is covered by none or two or more conflicting rights (such as unrestricted ownership/freehold). It remains an open issue whether dynamic objects could also be modeled in the technical solution of independent 3D space and time attributes; due to the continuous movement there are 'non-vertical' walls in the temporal dimension. [1]

3. LAND ADMINISTRATION WITHIN THE SII CONTEXT

Regarding the spatial nature of the land data, SII has gained great importance to use the spatial data in an efficient and flexible way thereby address to problems of current land administration systems that show a limitation to mange the complex and dynamic relationship between public and private rights, restrictions and responsibilities on land. At this stage, land should be considered not only as a certain surface area of the earth but also the materials beneath the surface, the air above the surface, and everything attached to the surface. Via SII, current LA can benefit from distributed registrations (e.g building registration) that deal with objects located in third dimension of land.

Main objects in LA with 4D characteristic are apartments and underground utilities. Currently individual apartments are usually not visible on the cadastral map, only the outline of the building as related to the ground is visible. However, the rights are attached to the individual apartments. Often it is possible to access (analogue or digital) drawings of the apartment building showing the individual units. But this is not integrated with the cadastral map. However, the building registration in more and more countries is geo-referenced and contains the 3D spatial description of apartment units to which the LA could refer. A similar approach could be taken for the registration of rights on utility networks, that is, refers to the source of physical information on the utility network (geometry) via a SII. A characteristic of utility networks is that they cross many parcels, and the infrastructure is located in a part of the parcel. In this way, they resemble certain types of restrictions, which are currently registered in some countries with their own geometry (e.g. in Queensland Australia, a restriction related to a path has its own geometry). The geometry of these restrictions crosses/overlaps several 2D parcels (similar to a utility network). In this paper we will focus on the registration of utility networks as a case study because this registration shows some specific temporal aspects, which are initial creation (moment of birth), changes during life time (including splitting and merging networks), and finally deletion (moment of dying). The LA has three options for the registration of objects with 3D geometries: 1. keep it as it is today, 2. copy the 3D information into the cadastral system (and adjust the cadastral system), 3 refer from the cadastral system to 3D descriptions in external registrations of utility networks.

4. CURRENT SITUATION OF UNDERGROUND UTILITIES IN TURKEY

Rights and registrations

In many countries, underground objects such as pipelines, tunnels, cables and their legal relationship with private properties are situations in which the current 2D LA systems have shown limitations in the registration of the legal situation. This is equally true for Turkish

[1] Parcels with static geometry generate vertical walls in temporal dimension (see figure 8), but parcels that continuously move will generate non-vertical walls as boundaries in the temporal dimension.

situation. In Turkey, from legal point of view, underground objects are not considered as immovables and therefore are not described in transaction deeds nor registered in LA. Moreover, many underground objects related to infrastructure (utility networks) are located under public lands (e.g. roads). According to the Article 16 of Cadastre Law (1987), public lands are not registered. Hence, the legal ownership situation of the utility infrastructure crossing these public lands remains unknown unless it crosses a private property. In addition to this, if the owner of the underground object is the same as the owner of the parcel no right/restriction is established on the parcel (e.g. in case an underground construction for water utility crosses a parcel owned by the municipality). Generally, easement rights are used to establish the legal situation when the utility network crosses parcels owned by a private person or corporation. The holder of the easement right is the owner of the underground object. Establishment of this easement right forces the owner of the parcel to tolerate the construction below, on or above his parcel and sometimes also to provide access to the utility construction. Another approach is to expropriate the parcels that a network crosses. In this approach, the full ownership of the parcel belongs to the owner of the network. Therefore no right or restriction is established in the land administration that could indicate the existence of the underground network. In addition, the owner of the parcel can be forced to tolerate underground constructions (e.g. tunnels) which are built for national transportation purposes as long as existence of the constructions do not cause any inconvenience (damage, vibration etc) on the surface construction. It is not clear in the law if this situation can be registered as a restriction or not in LA.

In Turkey, three cases can be distinguished in LA for the representation of the legal status of lands and underground utilities:

- The owner of the underground utility is entitled to use the space above or below the surface parcel by means of limited rights such as superficies and easement rights. If easements rights are not applied to the full parcel, 2D drawings are used to describe the location of the underground objects.
- The person who holds a utility network is also the owner of the surface parcel. No limited rights are registered. In case of expropriation before construction of the utility, the situation is the same because ownership of the parcel passes to the owner of the network.
- The owner of the surface parcel is forced to tolerate a network under his or her parcel unless there is justifiable objection against this usage. In this case, the person using space above or below the surface is not owner of the surface parcel and has no right on the surface parcel. In this case, no spatial information (2D/3D) can be found about the underground utility in LA.

In all cases the construction itself above, on and below the surface is not registered in LA. For the first case, an indication of the existence of these objects can be found by examining the limited rights that are established on surface parcels intersecting with a construction. For the last two cases, no information can be found in land administration about the underground construction.

Surveying and mapping the underground utilities

Since the ownership of underground objects are not subject to registration, LA does not deal with surveying and mapping this kinds of objects in Turkey. Apart from a legal notification on the parcel in LA, drawings for the limited rights can be included to LA if only some part of the surface parcel is affected by the limited rights. However, these drawings are only available as separate documents and not digitally linked to records describing the associated rights in land. Full geometry of the object (neither 2D nor 3D) does not exist in LA. At this stage, an exception is given for high voltage power lines. The whole geometry of a high voltage power line is drawn on cadastre map if the line crosses several parcels (see Figure 1). In addition, for affected areas in case of high voltage power lines, easement plans are presented in 2D. This means that only the footprint of the area is defined. The owners of interesting parcels still own the land under the cables, but they are restricted in the remaining use of this land. This restriction is determined by other organizations based on different legislation, and the cadastre does not get involved in this question. However, this restriction on a surface parcel can be notified in the land administration (Doner and Biyik, 2007).

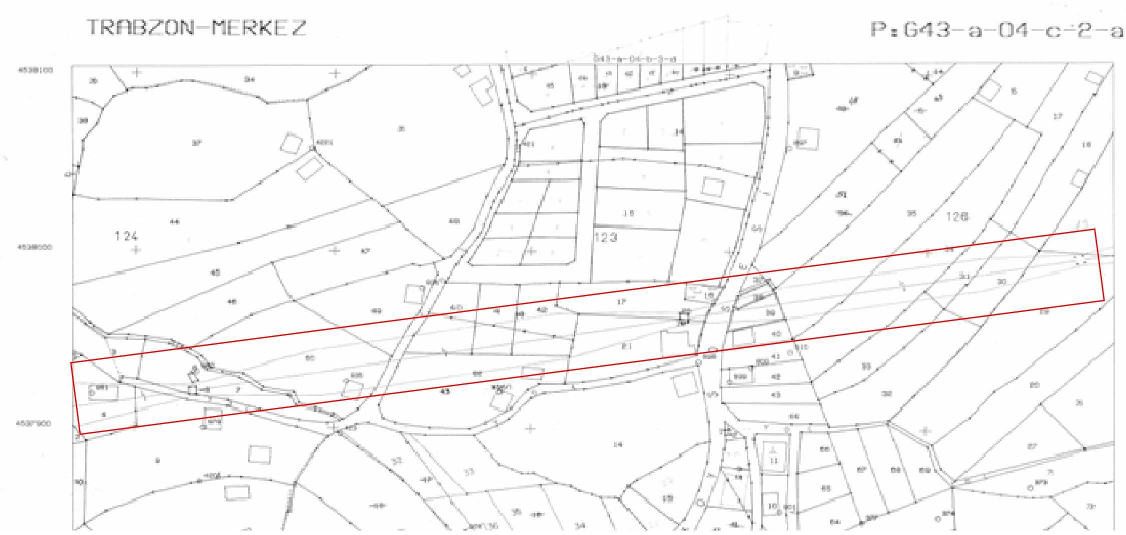

Figure 1. A cadastre map with high voltage power line (from Demir et al., 2008)

Several organizations are responsible for establishing utility services but in most situations, no integration and data sharing exists. Every organization maintains its own data related to the utilities with different systems and standards. In some situations it is even impossible to find spatial information (2D/3D) showing the location of the network. Often insufficient/incomplete documents are available describing previously existing pipelines or some of those documents are not accurate enough. Insufficient and unclear information about location and depth of underground utilities have caused various problems and even resulted in tragic accidents. For example, it was reported that in Bursa, the economic loss of the damage to gas pipelines was two hundred thousand US dollars in 2005 (Karatas, 2007). Also, in Istanbul, with its over fifteen million population, some accidents have occurred during excavation operations which resulted in damage to telecommunication networks and subway line and caused important amount of direct and indirect economic loss.

To provide coordination between different organizations which are responsible for infrastructure facilities within 500.000+ cities, a law (number 3030) was put into practice and the Infrastructure Coordination Center, AYKOME, was established in 1984. It is the responsibility of the AYKOME to plan, coordinate and inspect the projects for water, electricity, tramway, subway, gas, telecommunication etc. Primary objective of the establishment of AYKOME is to determine how space is occupied by public infrastructure objects in cities. Thereby it enables a more efficient spatial planning, safer implementation of under/above ground spatial activities, and better economical management of infrastructural objects. However, accuracy of positional data provided sometimes does not allow defining the underground objects clearly. Also in most situations, location of the object is in a local reference system and 2D. Apart from AYKOME, some municipalities have developed projects to maintain information for utilities on their territories with the help of GIS (Geographical Information Systems). Figure 2 is an example from a municipality in Istanbul. It shows natural gas and water supply pipelines together with other cadastral data sets such as buildings and parcels.

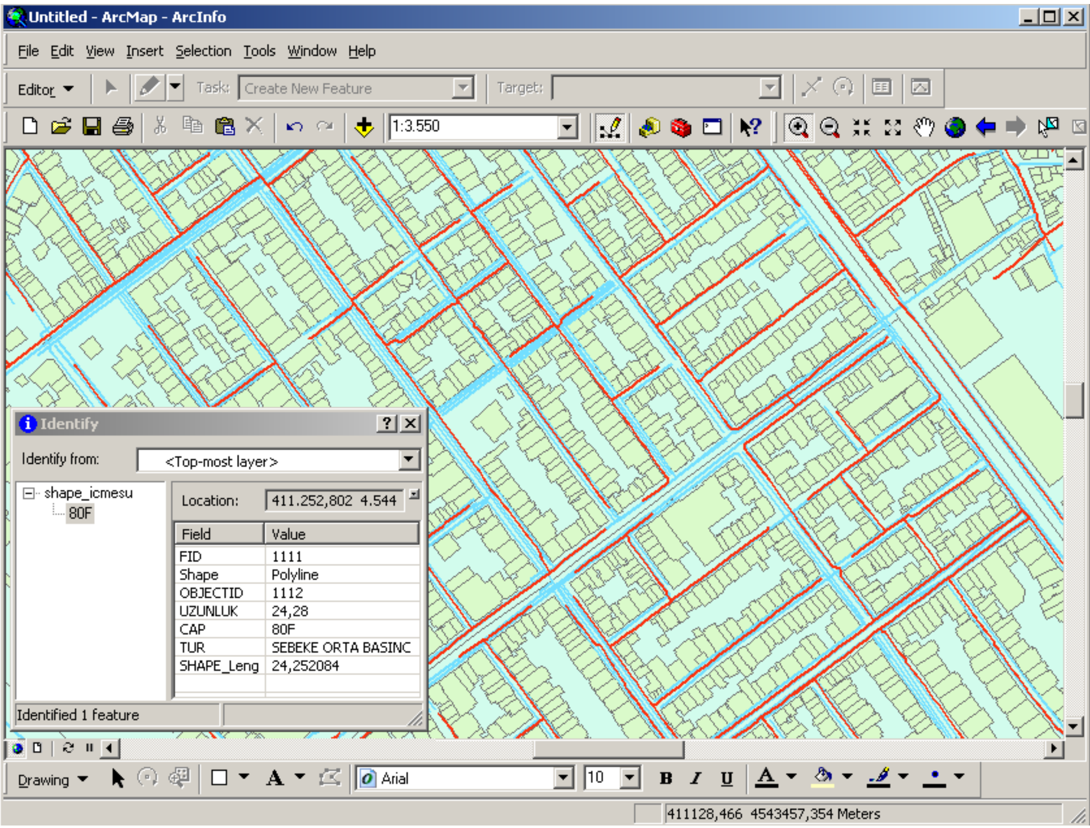

Figure 2. Network map of gas (red) and water (blue) supply pipelines together with cadastral data

Physical underground objects and their legal relationship with private properties is one of the situations in which the current 2D LA has shown limitations. At this stage, the current LA could benefit from information that is maintained by other organizations. A 4D (3D+time) land administration solution which integrates both legal registration at cadastre and physical information at the source can contribute to improve current practice in case of 3D situations in LA and to provide better information about underground utilities.

5. REGISTRATION OF UTILITIES IN THE NETHERLANDS

Dutch law provides two registrations of utilities: a technical registration (geometry) and a legal registration. In both registrations the Netherlands' Kadaster plays a central role. This might easily give the (wrong) impression that there is a direct link between both registrations. It is therefore very important to discern between the aims of the registrations.

a) Technical registration: the registration of the geometry, in order to avoid damage to the utility in case of works by third parties
b) Legal registration: the registration of the utility network as an object of property rights (and registration of the property rights themselves).

The first registration has the oldest roots. The need to protect underground (and therefore normally invisible) cables and pipes against damages, triggered in the 1980's with the establishment of the so-called KLIC's (Cable and Pipeline Information Centre). These centres were private institutes, and the result of the cooperation between several utility operators. The KLIC's did not (and still do not) register the networks themselves, but maintain a registration of network operators, in order to get easy access to the relevant parts of network maps kept and maintained by the operators, and therefore to ascertain the location of any utilities in case of planned works in the subsurface. In short, the system works in this way: if one planned works in the subsurface, he may contact the KLIC, providing the exact location of the works. The KLIC notifies all the known network operators in this area, and these will send their own (paper or digital) map of the relevant part of the network directly to the applicant. Alternatively a network operator may also choose to send a surveyor to the location to indicate to the contractor the location of their infrastructure.

In 2008 the Dutch parliament agreed on an act to regulate this information exchange. The Act on Information Exchange Underground Networks (WION, Wet Informatieuitwisseling Ondergrondse Netwerken), transferres the actual KLIC service to the Netherlands' Kadaster. Furthermore it makes it obligatory for the network operators to take part in the service, and for the contractors to do inquiries (by use of the service) before starting the work. In the near future a new system for exchange of information between network operators and the users will be introduced. In this system after the inquiry, the Kadaster computer will automatically set a request for information to the network operators. After the Kadaster has obtained the information, the inquirer will receive one map. For this system to work, a requirement is that the maps of the network operators are digitally available in the national reference system. Main characteristic of this registration is that the spatial information on the network is still maintained by the network operators.

This technical registration differs fundamentally from the legal registration. The legal registration of networks by the Netherlands' Kadaster had to be established after a judgment of the Dutch Supreme Court in 2003. Until that moment the legal position of networks (movable or real estate?) was disputed. In practice some networks were transferred as being movable property (chattel), and therefore not registered. If networks were considered to be real estate, the rule *superficies solo cedit*, stating that fixtures will follow the ownership of the land, offered serious problems in the case a network was located in several parcels. However, the solution that the whole network was owned by a collection of landowners, each for the (small) part the network was located in, seemed very impractical. Also in this interpretation of the law, the (ownership of the) network, or the geometry was not registered in the LA. Only rights established on parcels for the construction of the networks, like real rights and restrictive covenants, are registered in the LA (per parcel). Personal rights (contracts) or public law permits are not registered at all. (Ploeger and Stoter, 2004).

After the 2003 judgment it became clear that underground networks were real estate objects, and therefore property that needs to be registered. This means that, according to the general rules of the Dutch Civil Code, the ownership has to be transferred by a notarial deed, and that the deed needs to be registered in the public registers.

Until 2007 only in the case of telecommunication networks, the Act on Telecommunication gave a clear provision for the ownership. In that special case, the whole network is owned by the operator. In fact this Act gave the provision that the construction of the network in the land would not change the ownership of the network, therefore giving a explicit exception for the rule *superficies solo cedit*. For the registration and transfer of telecommunication networks the Kadaster, in consideration with the Dutch notaries, designed in 2003 a provisional method. Because at that time the Cadastre Act didn't gave any provision for a cadastral identity for networks as such, the deed had to refer to a ground parcel (a *reference parcel*), e.g. the parcel where the starting point of the network could be located. In the Cadastral Registration, a reference to the network, its owners and other rights in it, would be made by use of this parcel number. One should note, that it was not needed that the network operator / network owner would also be the owner of the reference parcel. Therefore the use of this parcel number was just an administrative method for registration of telecommunication networks within the cadastre (Ploeger and Stoter, 2004).

In the beginning of 2007 the Dutch Civil Code got a new provision, stating that a network "of one or more cables or pipes, for the transport of solid material, fluids or gas, energy or information, that is constructed in, on or above the land of an other person, is owned by the competent constructor, or its legal successor." (Book 5, article 20 section 2 Civil Code). A "competent constructor" means that the constructor has the right (e.g. because of a lease, an easement or a contract) to put the cable (or pipeline) in the land of another.

In connection with this new provision of the Civil Code, the Cadastral Act was changed in such way that a network as such could get its own number, like a parcel. This identifier consists out of the prefix 'Netwerken' (networks), the name of the cadastre office of the area where the network is located, a letter that refers to the type of network, and a succeeding number. E.g. ‘Netweken Rotterdam’, T 1 is the frst telecommunication network registered in Zoetermeer office of the Dutch Cadastre. See Figure 3


Kadaster-on-line

Contact | Woordenboek | Documentatie

Kadastraal bericht object

Dienst voor het kadaster en de openbare registers in Nederland
Gegevens over de rechtstoestand van kadastrale objecten, met uitzondering van de gegevens inzake hypotheken en beslagen

Kadaster

Betreft: NETWERKEN ROTTERDAM T 1 — 19-2-2008 14:48:41

Toestandsdatum: 18-2-2008

Kadastraal object
Kadastrale aanduiding: NETWERKEN ROTTERDAM T 1
Grootte: 1 ca
Omschrijving kadastraal object: NETWERK
Ontstaan op: 17-8-2006

Publiekrechtelijke Beperkingen
Het kadastraal object is onbekend in de gemeentelijke beperkingenregistratie. Er kan geen informatie over gemeentelijke beperkingen van de gemeente NETWERKEN ROTTERDAM worden geleverd. Neem contact op met de gemeente NETWERKEN ROTTERDAM.

Gerechtigde
EIGENDOM
ONS CAI B.V.
Van Heekstraat 15
3125 BN SCHIEDAM
Zetel: SCHIEDAM
(Gerechtigde is betrokken als gerechtigde bij andere objecten)

Recht ontleend aan: HYP4 ROTTERDAM 40982/ 84 — d.d. 2-5-2006
Eerst genoemde object in brondocument:
NETWERKEN ROTTERDAM T 1

Internet — 100%

Figure 3. The Netherlands: Example of registered network (telecommunication) in Kadaster-on-line The lay out of the screen is exactly the same as for parcels. Translation of some of the expressions: ‘grootte ’: ‘area’, ‘omschrijving’: ‘desciption’, ‘publiekrechtelijke beperkingen’: ‘public restrictions’, ‘gerechtigde’: ‘holder of the right’, ‘eigendom’: ownership.

The actual legal registration of networks is based on the temporarily method developed for telecommunication networks in 2005. An unregistered network (existing before 2008 or newly constructed after 2008) will be registered by the registration of a notarial document in the registry of deeds. This document must include a network map. The network map is in fact made by the Cadastre itself, by an overlay of the network geometry, as supplied by the network operator, on the cadastral map. The network operator has the choice to represent the network as a line, or a polygon.

To understand the meaning of the network map, one should notice that:

- The network map has the aim to identify the network as an object of property rights, but does not aim to provide the exact geometry or location of the network.
- The cadastral map (with the parcel boundaries) is maintained by the Kadaster itself. The network map is made, by use of the information provided by the network operator. The Kadaster will *not* check the accuracy or even if the network really exists!
- The network map is a “snapshot” of the situation at the date of registration. That means not only that the size and location on the map is as per the date the overlay has

been made, but also the cadastral map (and therefore the parcels and parcel numbers) on that day. If the next day one of the intersecting parcels is subdivided (in which case the newly created parcels will get new numbers), this will not (and can not) change the registered network map. Therefore, the older the network map, the bigger the chance that an actual parcel cannot be traced on the map. When the network changes in size, or location, a new network map needs to be registered.

- A change in the physical network (extension or reduction) means that a new notarial document, and a new network map must be registered.

Once registered, in future transactions, the deed needed for the transfer of the ownership of the network, or the establishment of limited rights on it (e.g. a mortgage), will refer to the cadastral identifier of the network (like the reference to the parcel number in the case of the transfer of a piece of land).

6. REGISTRATION IN 3D AND 4D: QUEENSLAND CASE

As mentioned before, in most land administration system, geometric description of 3D objects (e.g. buildings, underground utilities) is only available on separately maintained documents and not digitally linked to cadastral maps. In addition, spatial information on limited rights such as easement and superficies are provided only for complete affected parcels.

Compared to other countries, land administration in Queensland, Australia offers many possibilities to register 3D objects. For example, easements can be registered for public utilities such as the supply of water, gas, electricity, telecommunication facilities, and can be drawn on volumetric survey plan with their own geometry and therefore they may cross several parcels. These easements can also be restricted vertically in both depth and height and defined as volumetric easement on a volumetric plan. Vertical restrictions of the easements are described on these volumetric plans reference to Australian Height Datum together with details of the Permanent Mark on which this is based. There is little restriction on the shapes that are allowed in defining 3D cadastral objects, including easements, provided that an unambiguous definition of the extents can be determined. In practice, the survey plan must contain plan, elevation and isometric views that make the shape and location of the parcels clear, with the necessary bearings and distances annotated (Figure 4).

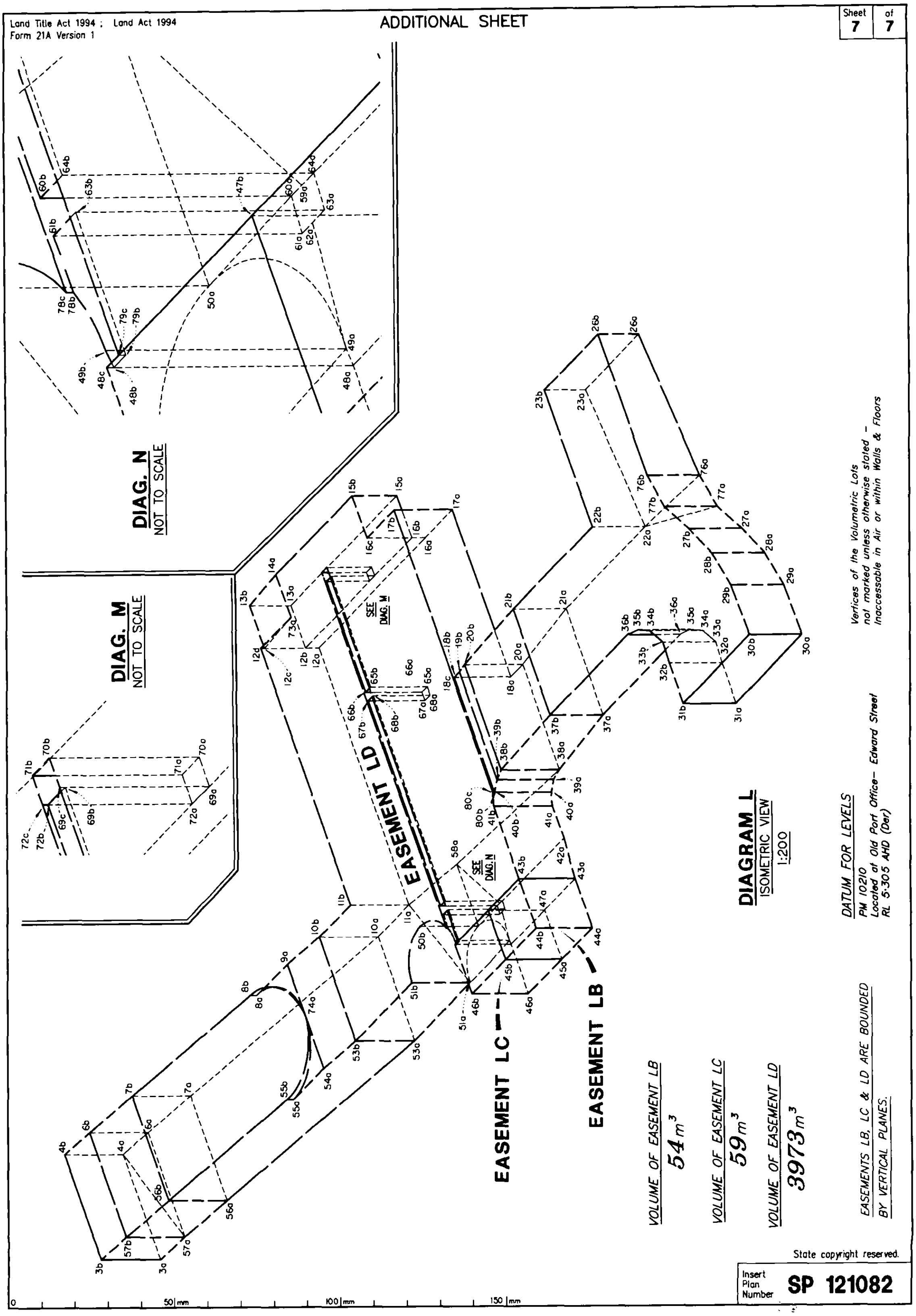

Figure 4 Example of volumetric survey plan for easement

In Queensland, all secondary interests such as easements, are initially defined when the base parcel is surveyed. The rule is that each secondary interest parcel is defined as existing within a single base parcel, and therefore cannot cross a base parcel boundary. Three situations may be identified: 2D only; 3D secondary interests over a 2D base parcel; or a full 3D subdivision of space. As time passes, a 2D base parcel may be subdivided, with the secondary interest parcels not necessarily being redefined, leaving secondary interest parcels which cross base parcel boundaries (Figure 5).

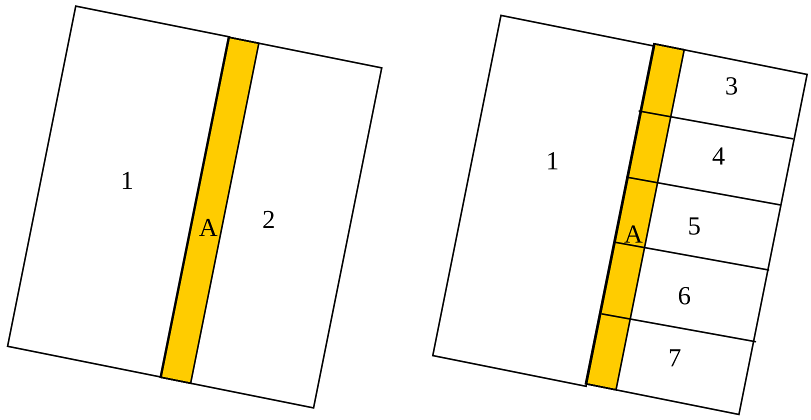

Figure 5 In the situation on the left, easement A is defined over parcel 2. On the right, parcel 2 has been subdivided to form parcels 3 to 7, with easement A applying to them all

This is unlikely in the case of a full 3D subdivision. In this case, the volume of space will be completely re-defined, including all easements. At present, all 3D parcels which represent secondary interests are defined as a region in space, which represents a secondary interest on the base 2D parcel. The base parcel is not re-defined into a 3D parcel to explicitly excise the volume of the secondary interest (Figure 6).

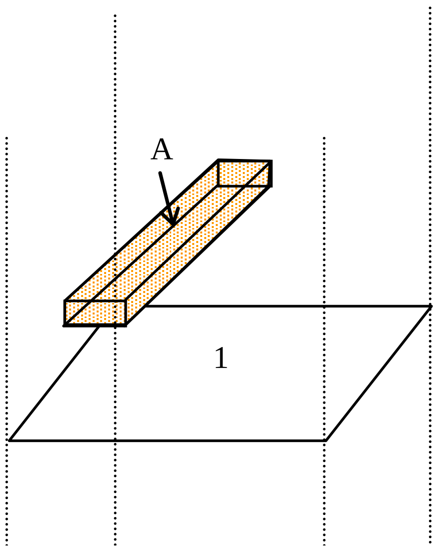

Figure 6 A 3D easement "A" as a secondary interest in a 2D parcel "1".

For this reason, it could be expected that a 3D secondary interest in the form used in Queensland may intrude into more than one base cadastral 2D parcel in the future.

By contrast, where there is need to reserve space in a building for infrastructure which would be thought of as a secondary interest in the 2D cases, the full volume will be subdivided, with the infrastructure parcels being properly constructed 3D parcels which do not overlap other 3D parcels (and are therefore not seen as secondary interests).

Although only footprints of easements on surface are currently shown in cadastral geographical data set in Queensland, the availability of 3D geometric description of easements offers the possibility of incorporating the information in land administration (Figure 7).

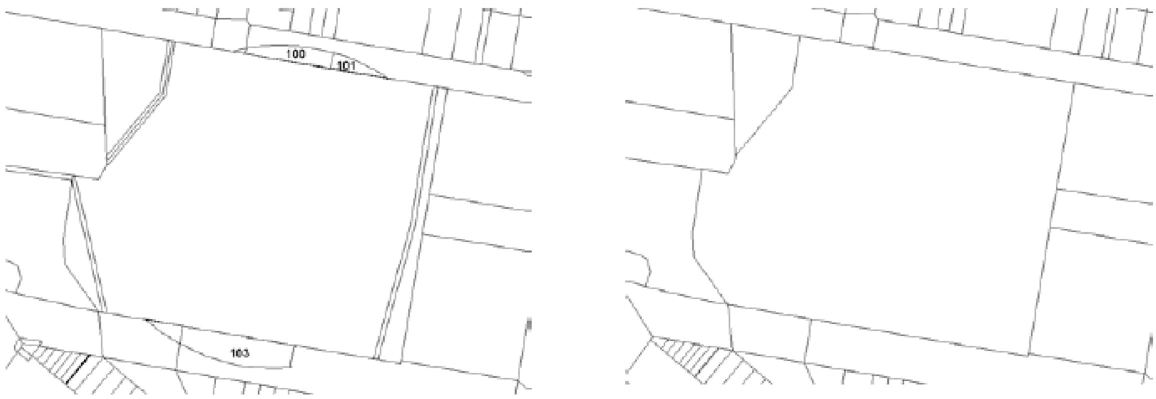

Figure 7 Cadastral maps from Queensland with/without the footprints of the 3D parcels (100,101) and easement (103) (Stoter et al., 2004)

7. TEMPORAL SIDE OF 4D LAND ADMINISTRATION

In most cadastral registration databases, the time dimension is represented by a versioning of the objects (the state-based model). This takes the form of time stamps that indicate the creation and destruction of objects (see Figure 8) (van Oosterom 1997). Also many cadastral databases, record only the history of the database representation of the cadastre. Thus for example, if an error is discovered that applies to both the current parcel and a prior version of the parcel, it is corrected in the current parcel only. A result of this is that if the database is viewed as at an earlier epoch, any errors that have been corrected since that time will still be present. If there is no provision for parcels to be given a temporal extent apart from the above timestamps, there is no provision for periodic tenure, or moving rights (van Oosterom, Ploeger et al. 2006).

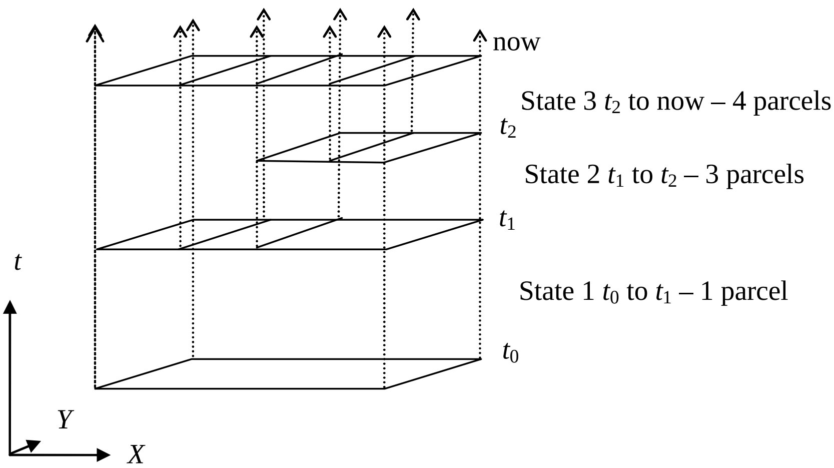

Figure 8 Changes of state of a subdivision.

An alternative approach to these 4D conceptual situations is possible, where each parcel is also considered in the implementation to be a 4D hyper volume, with its extents being defined by 4-dimensional hyperplanes, which meet in vertices, which are 4-dimensional points (x,y,z,t). This may have advantages where such issues as moving rights (e.g. grazing rights where the position of the right varies with time), or "slow and imperceptible" changes (where a property boundary is defined by a natural feature such as a riverbank, which moves slowly with time),) occur. However, with the current limited availability of 4D technology but generally a feasible and simpler system is obtained by adopting the state-based model (with separate attributes for geometry and time in the implementation), as does the Land Administration Domain Model (LADM), formerly known as the Core Cadastral Domain Model (van Oosterom and Lemmen 2006).

8. LADM APPROACH TO UTILITY NETWORKS IN CONTEXT SII

In general, the resolution of problems in society requires more information than provided from one single data set, and this is equally true for problems with a spatial concept. To address these problems availability of well-maintained links between spatial data sets and other basic or key data sets, for example, on addresses, persons, companies, buildings, land rights, etc. is inevitable. Therefore, an effective spatial information infrastructure (SII) is necessary for integration and multiple use of spatial information (Groothedde et al., 2008). Nowadays, different organizations perform applications to representations of the same objects. This requires further attention for one important component of the SII – standardization– which enables these involved parties to communicate describing digital data and services. If we mention about SII, it is important to agree on what we understand from objects. This is achieved by describing objects, attributes and relationships in the standard.

The Land Administration Domain Model (LADM) (van Oosterom and Lemmen., 2006) is an attempt to achieve standardisation in the area of cadastral data following conceptual framework of Cadastre 2014 (Kaufmann, Steudler, 1998). The standardization of the land administration domain provides common definitions for land information and facilitates the effective use, understanding and automation of land related data thereby enhances data sharing.

The LADM is developed according to the rules for application schema as defined by ISO 19109. At the class level the model includes Immovables such as LegalSpaceBuilding and OtherRegisterObject (geometry of an area where a restriction or responsibility is valid, such as a right of way, protected region, LegalNetwork: legal space around utility object, etc.). In addition it contains the following concepts: SourceDocument such as SurveyDocument or LegalDocument (e.g. deed or title), Responsibilities, Restrictions (defined as Rights by other Person than the one having the ownership Right) and Mortgages. The model offers several levels of Parcel representation (depending on the data acquisition methods and the use of existing spatial data sources): Parcel (solid, face, edge and nodes based on ISO 19107), SpaghettiParcel (only geometry), PointParcel (single point), and TextParcel (no coordinate, just a description). The geometry and topology (2D and 3D) are based on the ISO/TC 211 standard classes. The model is specified in UML class diagrams and it is indicated how this UML model can be converted into an XML schema, which can then be used for data exchange. Figure 9 shows an overview of LADM.

8.1 Spatial and Temporal Aspects in LADM

The LADM is fully compliant with already accepted and available standards on geometry and topology published by ISO 19107 (van Oosterom and Lemmen., 2006). Parcels have a 2D or 3D geometric description. In 2D a geometry area is defined by at least three SurveyPoints, which are per definition in the same horizontal plane (as they have no z-value, i.e. they are on the earth surface). In 3D a geometry area is defined by at least four non-partition SurveyPoints; this would result in a tetrahedron, the simplest 3D volume object. Constraints are used to indicate valid representations in the 2D and 3D case. It is important to realize that there is a difference between the 3D physical object itself and the legal space related to this object. The LADM only covers the ‘legal space’. That is, the space that is relevant for the LA (bounding envelope of the object), which is usually larger than the physical extent of the object itself (for example including a safety zone).

There are two different approaches when modeling temporal changes: event and state based modeling. The LADM covers both event (via the SourceDocuments) and state based temporal modelling (via VersionedObject). In event based modelling, transactions are modelled as separate entities within the system (with their own identity and set of attributes). When the start state is known and all events are known, it is possible to reconstruct every state in the past by traversing the whole chain of events. In state based modelling, on the other hand, the states (that is the results) are modelled explicitly: every object gets (at least) two dates/times, which indicate the time interval during which this object is valid. Via the comparison of two succeeding states it is possible to reconstruct what happened as a result of one specific event. It is very easy to obtain the state at a given moment in time, by selecting the object based on their time interval (tmin-tmax). In the LADM, every object class that needs versioning, inherits from VersionedObject class. Therefore, it is not needed to explicit add the tmin and tmax attributes to the main classes RegisterObject, RRR and Person (Lemmen and Van Oosterom, 2006).

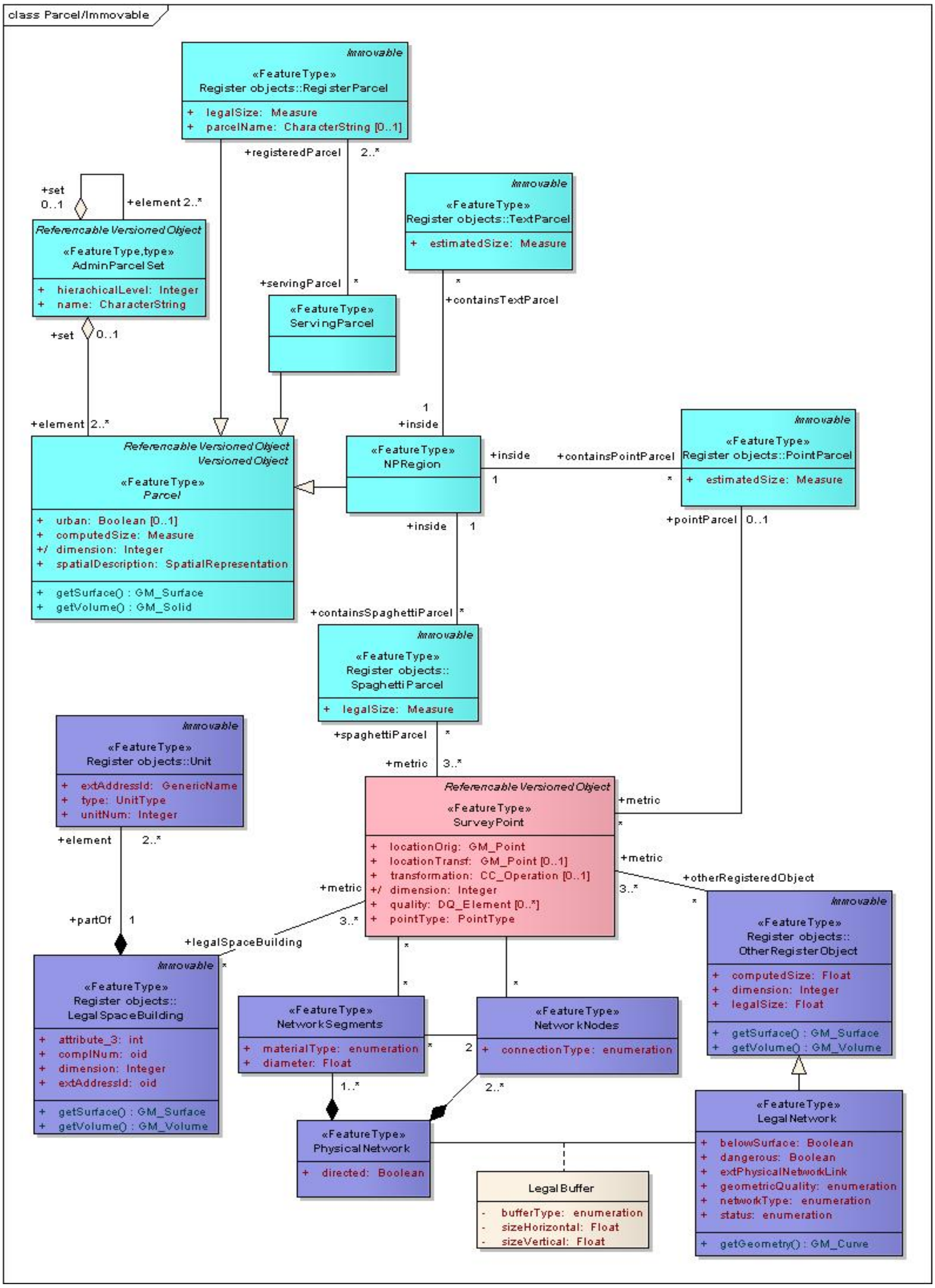

Figure 9 Overview of Land Administration Domain Model

8.2 Specification of LADM for Utility Networks

Legal network is an extension of the LADM as specialization of OtherRegisterObject to meet the requirement of accessing information of networks, which is organized into external databases, from LA. This class has an external reference to a physical network description (in the information source at the organization responsible for the network). Other relevant attributes are belowSurface and dangerous (both Boolean), networkType (gas, water, telecom, etc.) and networkStatus (planned, inUse, outOfUse). At this stage, difference between physical and legal objects in LA should be recognized. Boundaries of the legal objects (rights) do not necessarily coincide with physical objects (as is in underground utilities). Therefore, it is not the utility network registered itself in LADM but only the legal space (2D/3D) related to the utility network. As the LegalNetwork is a subclass of RegisterObject, it is related to a Person via RRR (Figure 10). Since there is a strong relationship between the legal object (maintained by the cadastre) and the physical object (maintained for each separate network by the owner), the physical and legal representations should be updated consistently within a given amount of reasonable time when a utility network is updated.

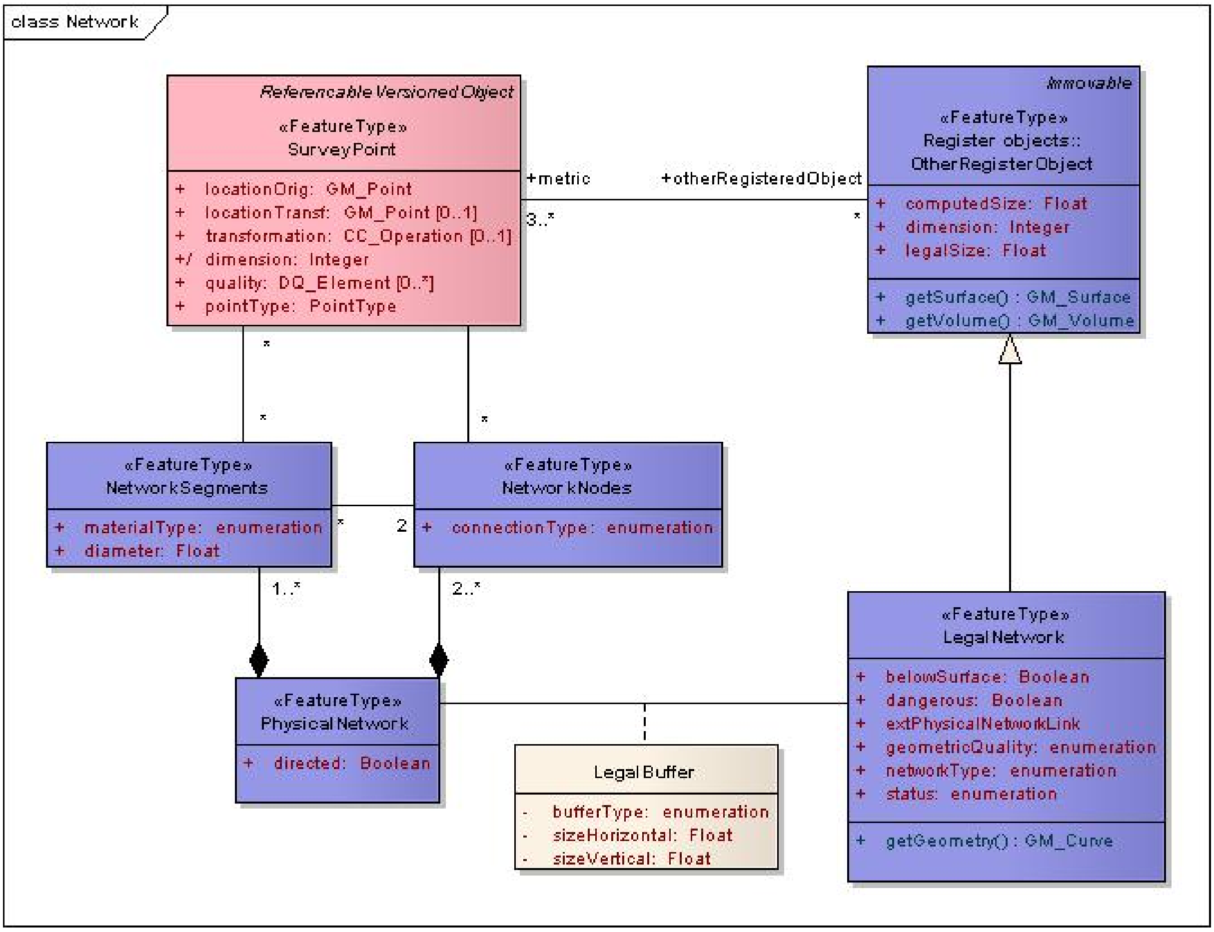

Figure 10 Conceptual model for registration of utility network represented in UML

The object LegalNetwork has a method getGeometry(), this method determines the geometry based on LegalBuffer and the associated PhysicalNetwork. It is very well possible that registration will be organized in a distributed environment: LegalNetwork at Cadastre and PhysicalNetwork at the registration of the network holder (owner). The relation between both LegalNetwork and PhysicalNetwork types of is that geometry of the LegalNetwork can be derived from PhysicalNetwork by buffering (shape and extension). It has to be noted that in such a distributed environment the network holder (owner) has to keep historical versions of the network (in order to keep references from LegalNetwork consistent). In case of updates (changes) of the PhysicalNetwork a signal has to be sent to Cadastre, which must then decide to move (or not) from the existing version of LegalNetwork to the new version. In this scenario id's and timestamps are of crucial importance ((Groothedde et al., 2008).

9. EVALUATION OF THE ALTERNATIVES OF LINKING CADASTRAL REGISTRATION WITH UTILITY REGISTRATION

At this stage, three alternatives are distinguished in LA. First one is to link to documents in relation to utility networks as attribute. The second is to copy 3D geometric description of the utilities into LA. The last is to refer from the LA system to 3D descriptions in external registrations of utility networks.

Based on different laws, in land administration systems, the right on a land can include objects on the surface and object beneath and above the surface. In existing situations, the most distinctive objects that have 3D characteristic are buildings or individual units on parcels. One basic solution to model this situation in current practice is to link the units to the parcel as an attribute. Although simple, the method neglects the fact that the building units have their own spatial characteristics. This solution works well as long as one or several buildings belong to the same parcel. This solution can also be improved by using external references in order to access to separately maintained digital or analog drawings of individual apartment units. Since the drawings are not integrated geographical part of the cadastral database, however, they could not be recognized and queried spatially. A similar approach can be adopted for underground utility networks. The main difference is that theses objects can cross several parcels and drawings describing 2D/3D restrictions on the parcels can only be found for the affected part of the every parcel.

Second option may be to copy the information of 3D objects (buildings, underground networks, tunnel etc.) into the cadastral geographical database. Different from the first approach, the second option takes the geographical characteristic of the objects into consideration. In case of utility networks, a 3D geometric description of the physical object can be obtained from the network operator and the whole network can be stored (registered) in the Cadastre as an independent object.

The third alternative requires using of SII to access to information of utility networks from LA. The idea behind the option is that LA can benefit from distributed registrations within a SII which provides the possibility to link information of utility networks maintained in different databases. In this approach, geometry of utilities can remain and be maintained at their original source while this information can be accessed from LA.

The first option is a solution which is currently being applied in many land administration systems. Main disadvantage of this option is that it neglects geometric characteristic of objects. This can be overcome with the second option. To apply the second option, however, it can be required to adjust the current system by organizing objects in three layers, a layer for each space (e.g. surface for parcels, below surface for objects such as underground utilities, above surface for buildings). The main advantage of such an approach is that it preserves also the current surface layer. The advantage of the last option (also the second option) is that the availability of the physical object (2D/3D) in the LA could improve the current situation in case of utility network. For example, in this way, gaps which may be caused by obligations to tolerate constructions for public purposes or which may be met when no rights are established on the parcel could be avoided and traced (Stoter and Ploeger, 2003). In addition, the physical network can be used for registration of legal space which encloses the physical network object. Consequently, the real situation above, on and under land is better reflected in LA. The last option is the ideal solution because it supports sharing and multipurpose of spatial data.

10. CONCLUSIONS

Due to the complex management tasks, modeling dynamic and multi-dimensional spatial information has become one of the challenging topics in current land administration systems. Land administration systems have already dealt with the higher dimensions, i.e. 3D (2D space and height information) and 4D (3D and time) within their current technical and institutional structure. As a practical approach, temporal and multidimensional information are treated as attributive data. However, the separated approach has shown limitations in certain situations. In this paper, we propose a foundation of land administration for in 4D which implies a partition both in space and time without gaps or overlaps. To overcome the limitations and to implement (after analyzing its impact) the conceptual thinking, the best way may be to use a 4D space-time topological structure as the foundation, which will guarantee the consistency. In the short term a separate 3D and time attribute model can be an option. However, this option requires using constraints and adding additional rules to the model.

The most typical objects which are located above or below the surface parcels are utilities. It can be concluded from this paper that problems are similar for legal and technical management of these 4D objects in different countries although the countries have different legislation on land administration. The ideal solution could be to take advantage of SII to share spatial information of utilities maintained by organizations responsible for the operation of the network while registering legal space of these physical objects in the land administration. At this stage, the difference between legal and technical objects should be recognized. Land administration systems deal with legal objects and these virtual objects may not necessarily coincide with physical objects as is in utility networks. Therefore, adjustments in land administration can be required to apply this solution.

Since 4D land administration can benefit from distributed information, we finally focused on LADM to determine if it is suitable for integrating separate registrations in order to improve current situation within SII context. We argue that LADM might be able to support the 4D land administration in case of utility networks adopting available international geo-information standards and conceptual legal framework of land administration.

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BIOGRAPHICAL NOTES

Fatih Doner graduated from the Department of Geodesy and Photogrammetry Engineering at KTU in 2002. He received his MSc degree with the thesis entitled "Mobile Geographic Information Systems: Basics and Applications" in August 2005. After that time he started to his PhD study on 3D cadastre for Turkey. He is currently carrying on his study at Delft University Technology as exchange PhD student. His research interests are cadastre, land information systems and relevant GIS applications.

Rod Thompson has been working in the spatial information field since 1985. He designed and led the implementation of the Queensland Digital Cadastral Data Base, and is now principal advisor in spatial databases. He obtained a PhD at the Delft University of Technology in December 2007.

Jantien Stoter graduated in Physical Geography at Utrecht University in 1995 before beginning her career as a GIS specialist with the District Water Board of Amsterdam and later in the Engineering Office of Holland Rail Consult. Her university career started in 1999 as an assistant professor, section GIS technology, Delft University of Technology. In 2004 she finished her PhD research on 3D Cadastre, for which she received the professor J.M. Tienstra research award. In 2004 she started as assistant professor at the Geo-Information Processing department at ITC, Enschede. Since 2006 she holds the position of associate professor. Her main research and education responsibilities are generalisation of geo-information, multi-scale databases, 3D geo-information, and user issues of geo-information.

Christiaan Lemmen holds a degree in geodesy of the University of Delft, The Netherlands. He is an assistant professor at the International Institute of Geo-Information Science and Earth Observation ITC and an international consultant at Kadaster International, the International Department of the Netherlands Cadastre, Land Registry and Mapping Agency. He is vice chair administration of FIG Commission 7, ‘Cadastre and Land Mangement’, contributing editor of GIM International and guest editor on Cadastral Systems for the International Journal on Computers, Environment and Urban Systems CEUS. He is secretary of the FIG International Bureau of Land Records and Cadastre OICRF.

Hendrik Ploeger studied law at Leiden University and the Free University of Amsterdam, The Netherlands. In 1997 he finished his PhD-thesis on the subject of the right of superficies and the horizontal division of property rights in land. After an assistant-professorship in civil and notary law at Leiden University, he is since 2001 assistant-professor at Delft University of Technology, The Netherlands and teaches several subjects in the field of land development, land law and land registration. His research interests are land law and land registration, especially from a comparative legal perspective. Hendrik is national delegate to FIG Commission 7.

Peter van Oosterom obtained a MSc in Technical Computer Science in 1985 from Delft University of Technology, The Netherlands. In 1990 he received a PhD from Leiden University for this thesis "Reactive Data Structures for GIS". From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague, The Netherlands as a computer scientist. From 1995 until 2000 he was senior information manager at the Netherlands' Kadaster, were he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology (OTB) and head of the section 'GIS Technology'. He is European editor of the International Journal on Computers, Environment and Urban Systems (CEUS).

CONTACTS

Fatih Doner
Karadeniz Technical University, Gumushane Faculty of Engineering
Department of Geodesy and Photogrammetry Engineering
29000 Gumushane,
TURKEY
Tel. + 90 456 233 7425
Fax + 90 456 233 7427
Email: fatih@ktu.edu.tr

Rod Thompson
Queensland Government, Department of Natural Resources and Mines
Landcentre,
Main and Vulture Streets,
Woollongabba
Queensland 4151
AUSTRALIA
E-mail: Rod.Thompson@nrm.qld.gov.au

Jantien E. Stoter
International Institute or Geo-Information Science and Earth Observation
P.O. Box 6
7500 AA Enschede
THE NETHERLANDS
Tel. +31534874444
Fax +31534874400
E-mail: stoter@itc.nl
Web site: www.itc.nl

Christiaan Lemmen
Cadastre, Land Registry and Mapping Agency
P.O. Box 9046
7300 GH Apeldoorn
THE NETHERLANDS
Tel.+31.55.5285695
Fax +31.55.3557362
E-mail : chrit.lemmen@kadaster.nl
Web site: www.kadaster.nl

And:

International Institute or Geo-Information Science and Earth Observation
P.O. Box 6
7500 AA Enschede
THE NETHERLANDS
Tel. +31534874444
Fax +31534874400
E-mail: lemmen@itc.nl
Web site: www.itc.nl

Hendrik D. Ploeger
Section Geo-Information and Land management, OTB Research Institute
Delft University of Technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
Tel.: + 31 15 2782557
Fax: + 31 15 2782745
Email: h.ploeger@otb.tudelft.nl
Website: www.juritecture.net

Peter van Oosterom
Delft University of Technology
OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
Tel. +31 15 2786950
Fax +31 15 2782745
E-mail: oosterom@otb.tudelft.nl
website http://www.gdmc.nl