
Considerations for a 3D Cadastre

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Summary: *The Land Registration Office (Cadastre) is mandatory to register the legal status of real estate objects. To be able to do this, the objects (parcels) are digitally stored and maintained in a spatial information system. Until now the spatial information system that is used by the Netherlands' Kadaster to register the legal status of land is a two dimensional system. Parcels are defined by 2D juridical boundaries.*

Since there is a growing interest in using space below and above the surface, 3D information becomes increasingly important in registering today's world. In the Netherlands, the 2D system that is used to register the legal status of real estate objects meets complications in some cases. Therefore, research is needed for a registration system, which is able to take the juridical relevant information in the vertical dimension into account as well.

At the Delft University of Technology, Department of Geodesy, research is done in collaboration with the Netherlands' Kadaster to study the 3D issue of cadastral registration in the Netherlands in a fundamental way. During this research the needs, possibilities and constraints to develop a 3D cadastral registration system are examined.

A 3D Cadastre consists of both juridical and technical aspects. This research will mostly focus on the technical aspects, although the link with the juridical aspects is considered to be important as well.

The potentiality to register property in three dimensions (including under and above the surface) will make adjustment of the current 'flat' legislation possible, which is based on a division of land in 2D parcels. It also could start a process of changes in the registration of properties and characteristics of the Kadaster, as far as the vertical dimension is concerned.

This report contains an analysis of the background and of the definition of the research problem.

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Chapter 1

Introduction

A cadastre is normally a parcel-based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g. valuation and equitable taxation), legal purposes (conveyancing), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection [3].

The Netherlands' Kadaster (the Dutch Cadastre and Public Registers Agency) is responsible for the cadastral registration in the Netherlands. It is responsible for registering the boundaries of the parcels and for registering the legal status of the parcels like the right of property and limited rights established on the parcels [11]. The registration of the legal status of parcels is the only registration of real estate objects in the Netherlands: building registration does not exist, although research is currently carried out to set up such a registration in the future [6].

In order to increase the efficiency and to make network access possible to the data involved, the Netherlands' Kadaster uses a spatial information system with a completely computerised cadastral map for maintaining the geometry and topology of parcels. Buildings are also maintained on this computerised map. The legal status of the parcels is kept in a separate administrative database-system. A link between those two subsystems exists by the unique parcel number [8]. The two subsystems are kept consistent by a built-in protocol and a technical implementation of this protocol in the network.

Until now, the juridical boundaries used for registration are fixed in 2D space. The whole country is divided into parcels which are defined in the 2D spatial information system. The parcels are the basis for the registrations done by the Kadaster. The vertical dimension of the legal status of real estate objects, which may be important, can not be reflected in the spatial information system and can therefore only be registered administratively, as an attribute of the defined parcels.

In areas with an intensive use of land, like the Netherlands, there is a growing interest in using space under and above the surface. To be able to define and manage the juridical situation satisfactory, 3D information becomes therefore indispensable in registering to-

day's world. According to the Dutch Civil Code [4], the right of property of a parcel is not limited in the vertical dimension and hence the property extends to the middle point of the earth and into the sky. This definition of property needs reconsideration when the use of space under and above the surface comes into play.

In the Netherlands more and more situations occur in which the vertical dimension is an important factor in registering the legal status of real estate objects. The Kadaster is confronted to register those situations within the current registration possibilities, which leads to divers registrations and other complications. Since it is expected that the Netherlands' Kadaster will meet registration complications in the future, research is needed for a 3D cadastral registration system.

Therefor a research is carried out at the Delft University of Technology, Department of Geodesy in collaboration with the Netherlands' Kadaster to study the 3D issue of cadastral registration in the Netherlands in a fundamental way. During this research the needs, possibilities and constraints to develop a 3D cadastral registration system are examined. The possibility to register property in three dimensions (including under and above the surface) will facilitate the separate use of spaces. It might also stimulate the improvement of the legal security of spatially complex rights.

The aim of the research is to develop a prototype of a Land Information System, which can take the juridical relevant spatial information in the vertical dimension into account. The emphasis will be on the technical aspects of the topic: what (spatial) information is needed and how can this information be collected, maintained, distributed etc. adequately. However, the juridical aspects will also be closely looked at during the research.

The research focuses on the situation of the cadastral situation in the Netherlands. For sure, other countries with an intensive use of land encounter or will encounter the same problems as well.

This report contains the results of the first (explorative) phase of the research. In chapter 2, the research questions are given. These are divided into two kinds of questions. The first group of questions covers the theoretical background of the research. Those questions are to a large extent answered in this report. The second group covers the experimental part of the research. In chapter 3 to 8 the answers to the first 7 questions are given that have been found so far.

Chapter 2

Research questions

The needs, possibilities and constraints to develop a 3D cadastral registration system are studied in this research. However, it is not an attempt to find one final solution to the complexities met by the Kadaster in registering the vertical dimension. Moreover, this research tries to look for possible solutions, which join today's technologies and concepts. The main question that will be answered in this research is the following:

What are the needs, possibilities and constraints to develop a 3D cadastral registration system for the Kadaster?

In order to answer this question a number of background questions has to be dealt with, which will give more insight in the scope and definition of the research problem and which will help to answer the main question. Those questions are the following:

- 1. In which situations is the current system of the Kadaster not efficient to register the legal status of real estate objects?*
- 2. How are those situations currently registered? What are the technical and juridical registration difficulties in those situations? Is/are there one or more common problem(s) and can therefore those situations be approached from the same point of view?*
- 3. What are the actual needs of the Kadaster for a 3D registration system? Which information is exactly needed in the considered situations (2D, above/under, 2.5D, multiple 2D or 2.5D layers, 3D)?*
- 4. What are the technical and organisational starting points and essential preconditions to develop a 3D registration system?*
- 5. Do systems exist similar to the system where this research is looking for (editing / registration / maintaining / defining of 3D geo-information)?*
- 6. Are there similar cadastral situations with a 3D component and with accompanying complications in other countries? And if so, what are the existing solutions?*

The above questions are answered by literature study, interviews with experts and a study to the current practice by visits to regional offices of the Kadaster. This report gives the

answers to the above questions that have been found so far.

The fundamental research questions cover the experimental part of the research. Those questions will provide the technical solutions to the research problem. The next phase of the research will try to find an answer to them. The following fundamental questions are set up for this research:

1. *What are the existing conceptual (OpenGIS and ISO) solutions to handle datatypes in more than two dimensions (geometry, topology, attributes, history)?*
2. *What are the existing implemented solutions to maintain (DBMS), edit (GIS/CAD) and visualise (viewer) such datatypes?*
3. *Which data models and processes are needed to register real estate objects with a vertical component?*
4. *How can concepts (found in the former question) be technically implemented in a way that the information needed by the Kadaster can be collected, stored, edited, queried, and visualised?*
5. *In what way can the developed and realised concepts and techniques be incorporated in the existing system of the Kadaster? (Proposal for technical and organisational methodologies)*
6. *How can different situations (2D, 2.5D, 3D etc.) in adjacent regions be implemented in one system preserving the link between those regions?*
7. *To what extent do the developed and implemented concepts fulfil the needs of the Kadaster? (an evaluation of the developed prototype)*
8. *What is the relation of the developed concepts and techniques to the juridical-administrative structure of the Kadaster?*

Chapter 3

Real estate objects under and above the surface

In which situations is the current system of the Kadaster not efficient to register the legal status of real estate objects?

The 2D registration system that is used by the Netherlands' Kadaster was not originally developed for representing registration situations in which the third dimension is an important factor. Nowadays situations occur in which the third dimension is relevant in bounding the legal status of real estate objects.

The registrations at the Kadaster that encounter or will encounter the 3D issue can be distinguished in three activities:

- registrations according to Private Law
- registrations according to Administrative Law
- maintaining factual objects

3.1 Private Law

Regarding Private Law, the registration activities where 3D information might be relevant are (the Dutch terms are added in italic, between braces):

- right of property (of parcels and of buildings) (*eigendomsrecht ten behoeve van vastgoed*)
- limited property rights (*beperkte rechten*):
 - right of building, i.e. the right to erect buildings under, on or above land owned by a third party (*opstalrecht*)
 - long lease, i.e. a third party becomes the right to use the parcel (including space under and above the parcel) as if he were the owner (*erfpacht*)
 - easement, i.e. a third party becomes the right to use the parcel for a certain purpose (*erfdienstbaarheid*)

- right to an apartment or condominium right (*appartementsrecht*)
- joint ownership (*mandeligheid*), i.e. the shared ownership of an immovable good that is for the general benefit for the parcels of the shared owners, for example walls, roads, parking places, swimming pools, tennis courts, aerials, drains etc.

3.2 Administrative Law

The Kadaster registers restrictions dictated by Administrative Law (*Publiekrechtelijke Beperkingen*). Restrictions with a potential 3D component, are:

- obligation to the owner of land to tolerate construction for public good, like lamp-posts, electrician cables, water pipes, telecom pipes (*Belemmeringenwet Privaatrecht*)
- deprivation of minerals in the ground of the landowner (*Mijnwet*)
- registration in order to protect historical monuments (*Monumentenwet*)
- registration of severe soil pollution (*Wet Bodembescherming*)

In all those cases, the parcels are affected with a restriction in the right of property. Those restrictions are registered, not the factual objects, which cause the restriction (cable, pollution etc.).

3.3 Factual situations

Apart from registrations dictated by Private Law and Administrative Law, factual situations sometimes demand a 3D approach. These concern objects that do not need to be registered themselves, but that are (or will be) maintained by the Kadaster in a certain way, since they have a relation to registration activities. Such cadastral registration situations in which a 3D component has occurred to be important are the following:

- constructions under/above the surface (metro stations, subterranean parking places etc.) (see figure 3.1)
- super- and subterranean infrastructure (see figure 3.2) (tunnels, metros)
- apartments
- ownership and location of cables and pipes
- polluted areas

Since the cadastral system is parcel based, the objects in the mentioned situations are not treated as registering objects themselves. Apart from apartments, there are no formal rules for the registration of the legal status of those objects, neither for the registration and maintenance of other characteristics like the (2D or 3D) location and the extent.

How those situations currently are registered and maintained by the Kadaster is described in the following chapter.



Figure 3.1: A situation in which defining right of property in a 2D database is complex: a road, a bridge and a building on top of each other, all with different owners.



Figure 3.2: Subterranean infrastructure and constructions like metros demand a further going juridical partitioning of space than a 2D partitioning (this map contains a sketch of a tunnel; it is not a cadastral map).

Chapter 4

Current registration of 3D situations

How are '3D' situations currently registered? What are the technical and juridical registration difficulties in those situations? Is/are there one or more common problem(s)?

Common to all situations mentioned in section 3.3 is the importance of considering the 3D characteristics of real estate objects. The existence of such registration situations has confronted the Netherlands' Kadaster to look for ad hoc solutions within the current registration possibilities. The solutions have in common that they are all administrative solutions, reducing the 3D situations to the partitioning of the country into 2D parcels.

The current cadastral registration is based on the property relations in a column: the 2D parcel on the surface is the entrance for registration activities. A horizontal division in the legal status of property is made by establishing rights and limited rights on the parcel (see figure 4.2 and 4.1).

Insight in the 3D situation can be given by adding an analogue drawing to the deed concerned, which is obligatory in some situations (in the case of apartments). The administrative database gives access to the drawings by a link to the location of this deed.

As mentioned, the Kadaster has to register the legal status of the situations with a vertical component by means of the available juridical and administrative tools. The methods currently in use at the Netherlands' Kadaster to register situations with a vertical component and their shortcomings will be described further on.

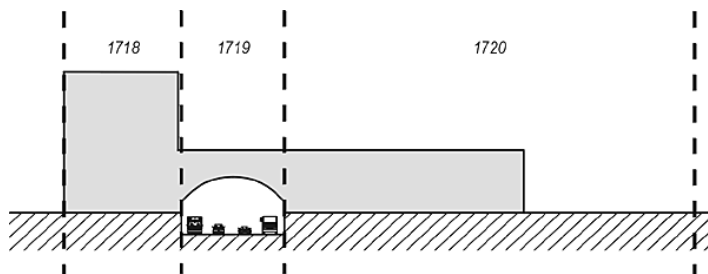


Figure 4.1: An example of the possible complexity of the current registration methods. This is the cadastral situation of the photo of figure 3.1. As one can see, a parcel can contain several objects and/or functions.

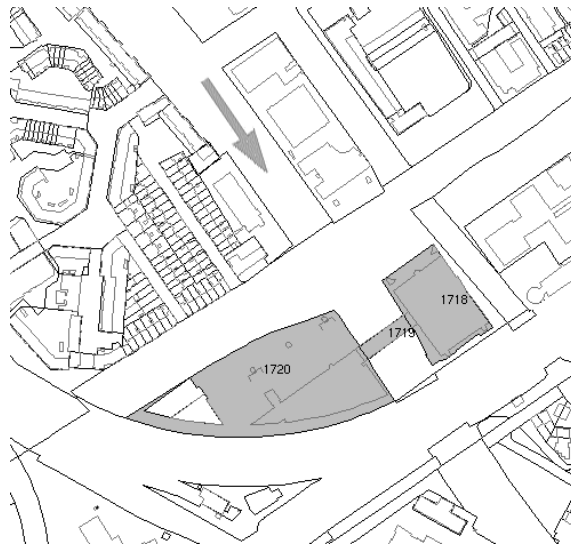


Figure 4.2: Illustration of how property relations in the vertical dimension are registered based on 2D parcels. This figure represents the cadastral situation of the photo of figure 2. The arrow indicates the position of the camera. The building is divided into three parts to be able to register the legal status of the building. The firm 'Nationale Nederlanden' possesses the whole building. The rights and restrictions of the parcels concerned are as follows: the municipality possesses a restricted property on parcels 1719 and 1720. 'Nationale Nederlanden' possesses an unrestricted property on parcel 1718, a right of building on parcel 1719 and a right of long lease on parcel 1720.

4.1 Registrations according to Private Law

The most included right that a person can have is the complete right of property (*volle eigendomsrecht*). The right of property of a parcel contains a 3D component, since the property should be defined in the vertical dimension when the vertical dimension of this right comes into play. Concerning this, according to the Dutch Civil Code [4] the right of property contains:

- the overground
- the earthlayers beneath it
- buildings and constructions which are permanently fixed to the ground (directly or by means of other constructions)

The competence to use the owned land includes the use of space above and under the surface of the owned parcel. The use of space above and under the surface is permitted to third persons, as long as this is done as high or as low, that there is no sense for the owner to object to this use. This quotation from the Civil Code indicates the vagueness of the way the right of property is defined in the vertical dimension.

4.1.1 The legal status of constructions and infrastructure under/above the surface

Constructions and infrastructure under or above the surface are not registering objects themselves. Therefore, the legal status of those objects needs to be registered by other means.

Vertical accession to real estate

Constructions under or above the surface are permanently fixed to the surface. Therefore, the owner of the construction can be found via the owner of the above or under lying parcel, if no other rights or restrictions have been established on the parcel (*verticale natrekking*) [10]. In most cases, the owner of the construction under or above the surface is not the same as the owner of the land parcel. The Kadaster possesses a few juridical instruments to register the legal status of those situations.

Horizontal accession to real estate

When the legal status of property under or above the surface is not registered explicitly, the legal status can be obtained by 'the horizontal accession to real estate' (*horizontale natrekking*) [2]. According to the Dutch Civil Code [4], the owner of a real estate is also the owner of the components of the real estate. When the property situation is not clear, the owner of a component (like a tunnel) can be found by finding the point, and thus the parcel, where it is fixed to the surface. With this, a factual horizontal division in property takes place (see figure 4.3). The disadvantage of this method is that the right itself is not explicitly registered, neither is the object of the right.

The horizontal accession to real estate might conflict with the definition of the right of property, for example in the case of tunnels, cables and pipes. After all, according to the Civil Code the right of property contains all constructions that are permanently fixed to the parcel (*verticale natrekking*) [15].

Right of building

The Kadaster is able to register the legal status of objects under or above the surface by registering a 'right of building' to others than the owner (*opstalrecht*) on the surface parcel. This right is a restriction in the right of property for the owner of the parcel. 'Right of building' is a right to erect buildings on, above or under land owned by a third party. This right can therefore be used when the owner of the construction is not the same as the owner of the parcel. By means of this right, a horizontal division in property takes place [1]. The right itself is registered for the parcel concerned, as well as the person who possesses this right (the 'third' party). However, the function of the building and whether it concerns a building on, above or under the surface is not registered.

The registration provides the possibility to dictate restrictions in the right of use to the owner of the land on which the right of building is established in order to avoid damage to the construction [12].

To specify a subterranean construction the code 'OB' (*Ondergronds Bouwwerk*) can be added in the registration, as well as a link to a drawing to illustrate the factual situation.

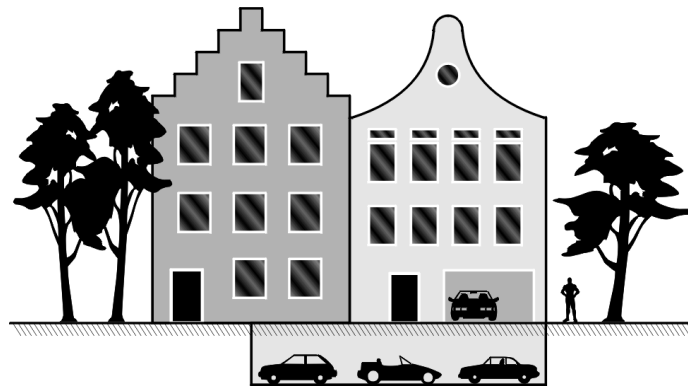


Figure 4.3: An illustration of 'the horizontal accession to real estate'. The part of the light grey house that is situated under the dark grey house (garage) belongs to the owner of the parcel under the light grey house since this part is a component of the light grey house.

This drawing is not obliged. With this, the cadastral registration offers at least the possibility to indicate in the administrative database that there is a subterranean construction [10].

Although a drawing of the property situation is not obliged, the Kadaster emphasises the necessity to store drawings when deeds are drawn up in those situations and encourages notaries to do this since 1999 [7].

The inadequacy met in the above solutions is that the right itself is administrated, but not the geometry or location or even the function of the object (underground infrastructure, metro station, subterranean parking place etc.). Another disadvantage is the problem mentioned before, that large constructions are divided into parts that match the above lying parcels, instead of considering them as objects themselves.

Right of long lease

The Kadaster can also register the legal status of constructions under or above the surface by the right of long lease. This right gives the long leaseholder the permission to hold and use the parcel of the bare owner. With a right of long lease, no horizontal division in property takes place: the right of long lease includes the surface parcel as well as the space under and above the parcel. Usually the bare owner of the parcel is the 'user' of the construction. The long leaseholder has the right to use the parcel above (or under) the construction. By means of conditions imposed to the long leaseholder, the use and protection of the construction can be arranged. This registration is applied to (parts of) the metro in Amsterdam [2]. The factual situation is not known on the cadastral map, nor in the administrative database. The only place where information can be found on the factual situation is in the Public Registers [2].

Belemmeringenwet Privaatrecht

The legal status of tunnels and other subterranean infrastructure can be registered via the *Belemmeringenwet Privaatrecht* [10]. This is a registration according to Administrative Law and further described in the following section.

Condominium right

Another instrument for the Kadaster to register the property above or under a parcel is to use the right to an apartment (see next paragraph). Though this way of registration offers the best possibilities to register different owners in the vertical dimension, it is not the optimal solution, since this right was not actually founded for those situations. Moreover, the registration of the right to an apartment also encounters complications, as will be seen in the following.

4.1.2 The right to an apartment

Right to an apartment (*appartementsrecht*) is a right existing of [11]:

- a share in an apartment building (this may be a group of buildings) and in the underlying ground
- a competence to the exclusive use of a certain part of this building (*exclusief gebruiksrecht*)

The parts are called 'apartments' and the division in parts is based on a deed of division (*akte van splitsing*). A drawing is obliged in the deed in which the apartment building is divided into individual apartments. This drawing should give a clear picture of the cadastral situation by giving a cadastral overview of every floor.

Disadvantage of this registration is that only the groundparcel(s) of the apartment building is maintained on the cadastral map in the spatial information system and therefore the individual apartment parcels can not be recognised on the juridical cadastral map. This would be difficult, since those parcels are situated on top of each other and the juridical map of the Kadaster is 2D. The individual apartments are registered in the administrative database with a reference to the deed of division, which contains a reference to the accompanying drawing.

Another complication is that a person does not legally own one apartment, which makes this situation different from other ownership situations. A last disadvantage that can be mentioned is that an analogue drawing is always needed to clarify the cadastral situation, while digital information becomes increasingly standard and a paper archive is more difficult to maintain.

4.2 Registrations according to Administrative Law

4.2.1 The location and owner of cables and pipes

Cables and pipes (with their location, owners) are not registered as such by the Kadaster [2].

According to Administrative Law (*Belemmeringenwet Privaatrecht*) the owner of land can be obliged to tolerate construction for public good like lampposts, electrician cables, water



Figure 4.4: To avoid damage to cables, first digging by hand is necessary (De Volkskrant, (Dutch Newspaper), 6 July, 2000).

pipes, telecom pipes etc. [11]. The Kadaster registers the establishment of this restriction in property on a parcel. The restriction is stored in the administrative database. With this, only the parcels are known under which a cable or pipe is situated and not the exact (horizontal and vertical) location of the cable or pipe. According to the law (*verticale natrekking*), the owner of the parcel becomes the right of property when there is no question of horizontal accession to real estate, since the cable or pipe is permanently fixed to the surface.

The registration does not give the possibility to impose precisely described limitations to the user of the parcel, while on the other hand the owner of the parcel becomes the owner of the cable and pipe and can therefore be held responsible for damage [10].

The establishment of a right of building on behalf of cables or pipes provides the possibility to keep the right of property with the cable or pipe holder. This special case of right of property can be registered as such by the Kadaster by the addition of the code 'OL' (*Opstalrecht ten behoeve van leiding*) in the administrative database [2].

The administrative registration of the locations of cables and pipes results in a few problems and limitations. When the parcel is subdivided, it is not known in which part of the parcel the cable or pipe is situated. The database becomes polluted when the parcel is subdivided, since in that case all child parcels are charged with a restriction due to the (potential) presence of a cable or pipe. The registrations are therefore less accurate in comparison to the real situation.

Furthermore, to manage the use of space below the surface it is important to register 3D information on cables and pipes. For example, knowledge about the location of cables and pipes can avoid damage during digging activities (see figure 4.4). In addition, by means of 3D information, a more exact limitation could be laid on the owners of the land to do anything that could damage the cables or pipes.

Another reason why it is desirable to define the exact location of cables and pipes is that owners of cables and pipes are obliged to pay the owners of the above lying parcels to

use those parcels. By knowing the exact locations, the persons involved can be more accurately determined.

Finally, as was seen before, the cables and pipes are divided into parts that match the above lying parcels, instead of considering them as one object themselves. With this, the attributes of the cables and pipes (owner, date of deed, etc.) are stored with every above lying parcel. Besides the redundancy of information, this is a potential source for inconsistency of the database.

The obligation of toleration by law does not hold for all cables and pipes. Consequently, for those cables and pipes, for which not a right of building is established, nothing is registered. In those situations, when there is no question of horizontal accession to real estate, the owner of the parcel becomes owner of the cable or pipe and can therefore be held responsible for damage [10].

4.2.2 Registrations according to the Law on Soil Protection

According to the Law on Soil Protection (*Wet Bodembescherming*), severe soil pollution has to be registered by the Kadaster. The pollution is registered in the administrative database of the Kadaster by establishing the decision on a parcel. The four big cities of the Netherlands (Rotterdam, Amsterdam, The Hague, and Utrecht) and the provinces are obliged to report such pollutions to the Kadaster. With this report a (2D, analogue) drawing is obliged. However since the accuracy of those drawings is not prescribed, the exact locations of the pollution is still very unclear in most cases. Besides, 3D information on those locations is totally lacking. The drawings are maintained in a paper archive by the Kadaster.

The disadvantage of this registration is that, with the lack of an exact drawing, the whole parcel becomes affected by the decision. The exact location (in the horizontal direction as well as in the vertical direction) of the pollution is not registered. However, the 3D location of soil pollution would give more insight into the actual situation and would give better facilities to manage soil pollution.

Another disadvantage, that was already mentioned with the registration of the right of an apartment, is that a digital representation of the situation instead of an analogue drawing would offer better registration possibilities and a paper archive is more difficult to maintain. Furthermore, digital information makes public access to the information possible via the internet, which is desirable in today's society. It also facilitates the exchange of information between and within Kadaster offices, municipalities and provinces.

4.3 Registrations of factual situations

The cadastral registration (the administrative database) and the cadastral map barely contain any information about the actual existence, the legal status and the function of constructions under and above the surface. Although the cadastral map does contain the contours of constructions above the surface, the contours of subterranean constructions are till recently not maintained on the cadastral map [7].

The restrictions that are established on parcels can not be found on the cadastral map either, although those restrictions would give insight in the situation of the under- and overground regarding the present registration procedures. The Kadaster has developed a digital tool, which enables visualising rights and restrictions on parcels by a link between the administrative database and the digital cadastral map [14]. Until now, this query tool works on a half-year copy of the database and is therefore not up to date enough in some cases.

The current policy of the Kadaster is to reflect subterranean constructions on the cadastral map by means of a dashed-line [10].

The possibility to add the code 'OB' (*Ondergronds bouwwerk*) and 'OL' (*Opstalrecht ten behoeve van leiding*) with the registration of a right of building is helpful, since it indicates in the administrative database that this concerns a special case of a 'right of building'. This is purely an addition to the description, not an additional registration of a right. Although a drawing of the property situation is not obliged, the Kadaster emphasises the necessity to store drawings when deeds are drawn up for constructions under the surface and encourages notaries to do this since 1999 [7].

4.4 Summary of current cadastral registration of 3D situations

The following table gives an overview of the occurring cases of factual registration situations with a 3D component. It also gives the current registration methods of the Kadaster in the situations concerned and the characteristics of the different registrations.

factual object	cadastral registration	horizontal division in legal status	drawing 2D situation*	drawing 3D situation*	explicit registration	visible on cadastral map	is object of registration	function as such known in AKR**
constructions under/above the surface	vertical accession	n			n	n	n	n
	horizontal accession	y			n	n	n	n
	right of building	y		A	y	y	n	y
	right of long lease	n			y	n	n	n
	condominium right	y		O	y	n	y	y
sub/superterranean infrastructure	right of building	y			y	y	n	y
	right of long lease	n			y	n	n	n
	horizontal accession	y			n	n	n	n
	<i>Belemmeringenwet Privaatrecht</i>	n			y	n	n	y
apartments	condominium	y		O	y	n	y	y
ownership/location of cables/pipes	vertical accession	n			n	n	n	n
	horizontal accession	y			n	n	n	n
	<i>Belemmeringenwet Privaatrecht</i>	n			y	n	n	y
	right of building	y			y	n	n	y
polluted areas	<i>Wet Bodembescherming</i>	n	O		y	n	n	y

* A=Advised, O=Obliged

**AKR Automated Cadastral Registration

Table 4.1: Summary of current cadastral registrations and accompanying complications.

Since the current cadastral registration is a parcel-based registration, all situations in the table above are projected on the 2D surface. The legal status of the real estate objects in the situations is registered by establishing rights and limited rights on the surface parcels. The objects themselves are not used as an entrance for cadastral registration.

Complications of the current methods to register the vertical dimension:

- the registrations are administrative ones, a spatial definition of the legal status would support a better maintenance and management of the juridical part
- horizontal division of property takes place only in the case of:
 - right of building
 - horizontal accession to real estate
- current registrations are used in situations for which they were not originally meant
- current registrations are ad hoc and divers for similar situations: standardised methods would increase legal security and ease the work of notaries
- a digital representation of the (3D) situation would offer:
 - better registration possibilities
 - public access via the internet
 - a better maintainable archive
 - better exchange of information between and within Kadaster offices, municipalities, provinces
- the parcel is used for registration and not the object (tunnel, cable/pipe, pollution) itself, this leads to the following complications:
 - constructions are unnaturally divided into parts that match with the surface parcels
 - the location, function, and geometry of objects are not known; knowledge about the location, geometry and extent of the objects would support the management of space below (and above) the surface and the maintenance of the 3D juridical space
 - the database becomes polluted when parcels are divided
 - redundant information is a potential source of inconsistency

Chapter 5

The actual needs of the Kadaster for a 3D registration system

What are the actual needs of the Kadaster for a 3D registration system? Which information is exactly needed in the considered situations (2D, above/under, 2.5D, multiple 2D or 2.5D layers, 3D)?

5.1 The meaning of 3D

Geo-data can be represented in two clearly distinct Euclidean dimensional contexts [5]:

- 2D: a spatial object or region which is defined in 2D space by measurements on axes x,y
- 3D: a spatial object or domain extending through 3D space defined by axes x,y,z

According to the dictionary 3-dimensional means: having, or appearing to have, three dimensions (length, breadth and depth). In the geo-scientific sense fully 3D means, that every point in space can be approached by means of a x-, y-, z-co-ordinate. When the z value is stored as an attribute of a 2 dimensional point, line or polygon it is called to be 2.5D or 2D+1D. With this, only a single z value can be stored for each x,y location and thus the surface can not be overfolded [5].

In the Netherlands a 2.5D surface is available for the whole country (Actual Height model of the Netherlands (AHN)), which has a density of at least one point per 16 square meters. This 2.5D surface has been obtained by the use of airborne laser altimetry [13]. In the future, this information could be very useful in cadastral registrations that consider the vertical dimension.

5.2 The actual needs of the Kadaster

The growing need for maintaining vertical information by the Kadaster is evident. The current solutions to 3D situations of the Netherlands' Kadaster described in chapter 4

operate reasonable, although these solutions lead to some complications as mentioned in section 4.4. The risk of not being capable of executing the formal tasks adequately becomes higher, as the amount of (different) situations will grow for which the existing 2D system is not basically qualified. Furthermore, regarding the 3D component of the legal status of real estate objects would better reflect the situation in the real world. It should be looked at to what extent a 3D system will offer improvements in order to complement the presently used 2D system.

A complete 3D spatial information system seems to be the solution for the problems met by the Kadaster. In the ideal case, the juridical boundaries of real estate objects and parcels are maintained fully three dimensionally, in which every point of a boundary of a registered object is defined by a x-, y- and z-co-ordinate. This would support legal security of spatially complex rights by supplying the possibility to register, to manage and to query the legal status of real estate objects in three dimensions. However, this solution might be too complex for the purpose that it has to serve. Besides one should not only consider the development of such a system, but also the availability of the needed 3D data to make the system operational. Also incorporating the system into the present system, into the working processes and into the present legislation are important factors for contemplation. A less detailed system might therefore be more appropriate and more realistic to fulfil the needs of the Kadaster.

In order to develop a useful 3D registration system it is very important to examine the real needs of the Kadaster: what information is actually needed to perform the cadastral tasks. To answer this question not only the present situation should be considered, but also possible adjustments of legislation and possible changes in the registration of properties. Whether and to what extent the Kadaster needs a full 3D spatial information system should be subject of research.

Depending on the registration situation, it must be examined which of the following registration possibilities is required:

- 2D, without any vertical information
- the use of 'under' or 'above' labels, without metric information
- 2.5D
- a multi-layer approach of two or more 2D or 2.5D layers
- complete 3D

The optimal solution per region may differ, but a good connection between the different kinds of vertical (and horizontal) information is essential.

In conclusion, the meaning of the expression 3D in the sense of developing a 3D registration system for the Kadaster depends on the actual requirements of the Kadaster (now and in the future) and is therefore an item for further research. (At the moment a substudy is carried out at the Kadaster to study the actual needs of the Kadaster.)

Chapter 6

Considerations for maintaining the 3D juridical world

What are the technical and organisational starting points and essential preconditions to develop a 3D registration system for the Netherlands' Kadaster?

6.1 A spatial approach

In order to be able to register property in more than two dimensions this research looks for a digital, spatial solution to maintain the needed (3D) information. This provides better possibilities for managing the 3D juridical world. In this research a prototype of a Land Information System will be built, which can take the relevant juridical spatial information in the vertical dimension into account. This prototype will be based on a 3D spatial system which supports:

- appropriate datastructures
- editing of 3D data
- storage of 3D data
- representation of 3D data
- preserving the quality of the data
- a connection to and incorporation into the current system and working processes

The aim of the 3D system is the development and implementation of concepts. The system will consist of software to maintain (DBMS), edit (GIS/CAD) and visualise (viewer) 3D data.

6.2 From analogue drawings to digital 3D models

To clarify the legal status of situations with a 3D aspect (constructions under or above the surface, apartments) drawings are added to deeds. Since until now this is not a digital

document, this method does not use the possibilities of today to increase efficiency and standardisation. Moreover, since a digital link between the objects in the drawings and objects in the (administrative) information system is lacking, the legal security is not optimally preserved.

Therefore, this research looks for a digital solution to represent the 2D and 3D information of objects. Digital CAD drawings can be used, but they have to be converted from a local co-ordinate system to the co-ordinate system of the 'real' world, that is currently used to represent and to maintain the cadastral map.

6.3 Integration of (3D) CAD en GIS

Most commercially available Geographical Information Systems (GIS) are only designed to handle 2D spatial data. Some systems contain limited 3D functionalities for surface modelling or for visualisations by assigning an attribute for z values (such as elevation) to a set of x,y locations. Here only the x,y locations are stored within the spatial indexing system and the z value is defined as an attribute [5].

In Computer Aided Design (CAD) fully 3D modelling is better established. While many 3D modelling systems have been developed for high quality CAD, these systems have limitations for geoscientific applications: these systems are primary developed for visualisations, which cannot be analysed or interrogated. Moreover, CAD systems have no or limited facilities for data management: they are project-based instead of database-based and operate with local co-ordinate systems instead of one 'real-world' co-ordinate system [5].

Increasingly, GIS software offers 3D realistic visualisations exploiting the CAD technology. Whether GIS really needs full 3D modelling is still a relevant and living question [17].

Nowadays a lot of research is done on the subject of linking 3D GIS en 3D CAD. The research to develop a 3D registration system for the Netherlands' Kadaster will join the findings in this research area.

6.4 OpenGIS solution

Within the context of OpenGIS, research is done on the developments of standards for 3D data structures and 3D data models and on the development of standards for cadastral systems [9]. The membership of our department of the OpenGIS Consortium (OGC) makes it possible to join the findings of the OGC and to have a significant influence on the development of standards. The active participation in the Special Interest Groups (SIG's) of OGC assures to use the newly developed technologies and standards, which are world-widely accepted. A SIG on Cadastres is currently founded.

Joining the OGC standards also implies joining the ISO standards, since ISO standards and OGC standards are being harmonised and accepted and certified by both.

Chapter 7

3D information and other disciplines

Do systems exist similar to the system where this research is looking for (editing / registration / maintaining / defining of 3D geo-information)?

To ensure the legal security in general the 3D character of situations should get more attention when the 3D environment comes into play. It is expected that other disciplines are or will also be confronted with the fact that 3D geo-information becomes more and more important in managing and registering the real world. Consequently, other disciplines will also look for solutions to collect, maintain and distribute 3D geo-data.

For instance, there is a growing need for encountering 3D characteristics in zoning plans and regional plans. The construction of 3D visualisations of planned infrastructure and buildings enables obtaining more insight into the vertical planning of the region [2]. Nowadays virtual reality techniques can be used to visualise (3D) geo-data. At our department, a 3D GIS-Virtual Reality system has been developed, with which it is possible to create a 3D-visualisation based on a GIS-database [16].

Maintaining 3D information also enables one to deal with the 3D characteristics of objects. Examples are calculating the contents of buildings (important knowledge for imposing taxes), dictating a maximum construction height and depth and obtaining information for spatial modelling, like the modelling of noise levels.

In the oil-industry the maintaining of 3D information has also appeared to be important.

To be able to join findings of other disciplines and to build on developments of other disciplines, similar systems will be surveyed in the continuation of the research.

Chapter 8

3D cadastres abroad

Are there similar cadastral situations with a 3D component and with accompanying complications in other countries? And if so, what are the existing solutions?

To look for similar cadastral situations in other countries, a survey is carried out. Till so far, this has yielded the results reported below.

Iran

At the Technical University of Tehran research is carried out to develop a 3D Land Information System. The emphasis in this research is on the modelling of 3D objects.

Norway

In Norway a law has been proposed to register the property of constructions under and above the surface. According to this law a construction can be defined by a 3D parcel and it can be registered as such. The construction is defined by 3D co-ordinates which are stored as attributes in an administrative database. A spatial information system to maintain or visualise the 3D data still has to be built. The 2D projection of the 3D construction is visible on the cadastral map.

Israel

At Technion, the Israel Institute of Technology, a research is carried out for a multi-layer 3D Cadastre. The research focuses on two main subjects: the geodetic aspect of multi layer engineering reality and registration of ownerships and properties in all land spaces.

Singapore

The registration of the cadastre in Singapore recognises parcels on top of each other. Rights of way and other subterranean boundaries are treated as an other cadastral layer and legally registered as such. And yet the cadastre of Singapore does not put emphasis on 3D cadastre, since they are still in the process of revamping the cadastre in a co-ordinate based system (in 2D).

Australia

The cadastre in Australia is expected to be able to register properties in 3D space. The visit of professor I.P. Williamson (University of Melbourne) at our department this autumn will make it possible to analyse the situation in Australia.

Chapter 9

Epilogue

At the moment, there are no formal rules for registering the legal status, the (2D or 3D) geographical location and the extent of real estate objects, which do not have to be registered as such. The actual objects can be important in cadastral situations and other maintaining activities as was shown in this report. It could improve the legal status of spatially complex rights to see the world not only in 2D parcels, but also look at the representation and definition of objects under and above the surface as a whole. This could lead to a change in the registration of properties and in the definition of characteristics of the Kadaster in the future.

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