

# Registration of 3D Objects Crossing Parcel Boundaries

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**Key words:** 3D cadastre, cross-boundary objects, cables and pipes, tunnels.

## SUMMARY

Property rights on real estate are registered on cadastral parcels. These parcels are the result of a delimitation of the earth by boundaries projected on the surface.

Dutch law allows the division of ownership of buildings and land in horizontal layers by establishing a right of superficies (*opstalrecht*). The result is a horizontal subdivision by reference to depths or horizons, within one parcel.

In this paper we will elaborate on the way the Netherlands' Kadaster deals with horizontal division of ownership especially in case a construction intersects with several parcels (cross-boundary object) and the limitations of the actual registration in 2D. Three cases (a railway tunnel in urban area, two utility pipelines, and a drilled tunnel in rural area) are used to illustrate this.

On the basis of the last of these cases, two alternatives will be described to register cross-boundary objects in the cadastral DBMS.

For the midterm future the concept of 3D right-objects, introduced in the research '3D cadastre' (Stoter et al., 2002), can be a way to improve the current way of registration (Stoter and Ploeger, 2002), although 'gaps' (cases where the location of the construction in 2D and 3D is not known) may still occur. Therefore the registration of the legal space of cross-boundary objects is a better solution for the long-term future.

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## 1. INTRODUCTION

Current cadastral registrations use 2D parcels to register ownerships rights, limited rights and public law restrictions on land. In most cases this is sufficient to give clear information about the legal status of real estate. But in cases of multiple use of space (when the ownership of buildings and land is divided into horizontal layers) the traditional 2D cadastre is not, or only in a limited way, able to reflect the spatial information about those rights in the third dimension. Until now the research concerning 3D cadastre (Stoter et al. 2002) focused on the way to improve the registration of property rights with a 3D component (with limitations in height and depth). Also the registration of buildings and constructions these rights have a reference to (3D physical objects) are studied in the 3D cadastre research (Stoter and Ploeger, 2002). In this paper we will focus on constructions that intersect with several parcels.

In case of these cross-boundary 3D objects, such as pipelines, the 2D parcel is strongly limiting the amount of information that can be obtained. First of all this is due to the fact that the physical object is partitioned over the many parcels it intersects with. The rights that are referring to the 3D physical object are only registered by means of ownerships rights, limited rights, and restrictions that are established on the intersecting parcels. No information on the whole object is available, neither is spatial information available on the concerning rights.

The aim of this paper is to show in what way a 3D approach of the cadastre (Stoter and Salzmänn, 2001; Stoter and Ploeger, 2002) will improve insight in situations when the projection of 3D objects as they occur in reality does not fit the original pattern of surface parcels.

First we will describe some fundamentals of current registration of long line-shaped objects in the Netherlands. Then we discuss the current way of registration of 3D physical objects that cross parcel boundaries in more detail, together with their complications based on three case studies:

- a railway tunnel and a railway station in urban area
- two utility pipe lines
- a drilled railway tunnel in rural area.

From this we conclude what the limitations of the registration of cross-boundary objects are. Then two alternatives for the registration of long line-shaped objects to improve cadastral registration are discussed. We end with a discussion.

## 2. RIGHTS AND REGISTRATION

The Netherlands Kadaster maintains an administrative DBMS for legal and administrative data related to the parcels, called AKR: Automated Cadastral Registration (*Automatisering Kadastrale Registratie*). In this DBMS the rights that are needed for the holder of a long line-

shaped construction are registered in two ways: with a right of superficies or a legal notification.

In most cases a limited real right, i.e. a right of superficies (*opstalrecht*) is established. According to article 101 of Book 5 Dutch Civil Code the right of superficies is: “a real right to own or to acquire buildings, works or vegetation in, on or above an immoveable thing owned by another.” The holder of this limited right is the owner of the constructions. As a limited real right it restricts the original owner of the land: the owner has to tolerate the existence of the construction in, on or above his land. In this his case AKR uses the code ‘OS’ for the right of superficies and the code ‘EVOS’ for the ownership right of the land encumbered with the limited real right.

In addition to the rights in rem, ownership (*eigendom*), emphyteusis (*erfpacht*), superficies (*opstalrecht*), usufruct (*vruchtgebruik*) and mortgage (*hypotheek*) the Kadaster also registers the so called ‘legal notifications’ (*‘Object belemmering’*: object restrictions) on parcels. A legal notification is an indication in the cadastral registration that a restriction is imposed on the ownership of the parcel. In most cases these are public law restrictions, e.g. the building on the parcel is a protected monument, or the obligation to tolerate a construction needed for a public work (e.g. a high voltage power line) imposed by special acts, like the *Belemmeringenwet Privaatrecht*.

In the case of the long line-shaped structures studied in this paper, the most important legal notifications used are:

- BZ (*Zakelijk recht als bedoeld in art. 5 lid 3 onder b van de Belemmeringenwet Privaatrecht*),
- OL (*Opstalrecht Leiding*), and
- OB (*Ondergronds bouwwerk*).

The code BZ is referring to a special right in rem, for pipelines and other works, which was made possible by the *Belemmeringenwet Privaatrecht*. This is a right according to private law, established by a notary deed signed by the parties concerned. This legal notification should not be confused with the earlier mentioned obligation to tolerate a construction also according to the *Belemmeringenwet Privaatrecht* (which is public law restriction). Since the introduction of the new Dutch Civil Code in 1992 it is not longer possible to establish this special right in rem. Nowadays in most cases a right of superficies will be established. However the ‘BZ’ rights established before 1992 are still maintained and not converted into rights of superficies.

The code ‘OL’ is used to specify a right of superficies that has been established for a pipeline. It is a bit confusing that in those two cases (‘BZ’ and ‘OL’) the limited real rights are treated as legal notifications.

In the case the restriction or right affects only a part of parcel, the code is followed by the suffix ‘D’ (referring to the Dutch word *deel*, i.e. part). So a right of superficies established for a pipeline that is intersecting with just a part of the parcel will get the indication ‘OLD’.

A special case is the registration code ‘OB’ (*ondergronds bouwwerk*, underground construction). This is just an indication of the existence of an underground object under a parcel. We had to conclude that in practice this solution has hardly been used. At the moment there are about 100 cases of underground objects registered in the Netherlands’ Kadaster. None of these cases has been indicated on the cadastral map. This is probably due to the fact that notaries have to get used to this new type of registration. They will only use it when it has clear public benefits to them or their customers (e.g. more legal security, less work).

## 2.1 Mapping the Physical Object

The notary deed, which has led to the registration, may be accompanied by an analogue drawing mapping the object. The contours of the underground object can be depicted in the cadastral map but this is not obliged. The inclusion of digital 3D drawings is not possible at the moment.

## 2.2 Parcels and Part Parcels

According to the Dutch *Kadasterwet* (Law on the cadastre and the public registers) in case the ownership of a part of a parcel is transferred, or a limited real right (e.g. a right of superficies) is established for only a part of a parcel (e.g. in case of a tunnel intersecting with only a part of the parcel), the existing parcel will be subdivided. The boundaries of the new parcels are based on the part of the parcel that is transferred, or is encumbered with the limited right.

However, unlike many other countries, in Dutch law it is not compulsory to obtain a permission of the authorities preceding the subdivision. Also it is not needed that the new parcels are measured and created in the cadastral system before the ownership is transferred or before the limited right has been established. Therefore it is common practise that new parcels are created months after the notary deed establishing the limited right, or transferring a part of a parcel has been registered in the public registers.

In the meanwhile the cadastral registration uses the expression “part parcel” (*deelperceel*). Awaiting the formal spatial creation of the new parcels, the administrative number of the parcels to be created is the old parcel-number followed by the suffix ‘D’ and an index number. It is important to notice that part parcels are in fact still one (original) parcel on the cadastral map.

An example will make things clear. L owner of a parcel numbered A 1000, establishes a right of superficies (held by S) on a part of this parcel. In this case the original parcel must be subdivided in two new parcels, one held in full ownership by L, and the other held in restricted ownership by L, encumbered by the right of superficies held by S. Awaiting the formal division the two part parcels will get the numbers A 1000 D1 and A 1000 D2. On the cadastral map the part parcels are on the same location mapped as the original parcel A 1000. Only after the surveyor of the Netherlands’ Kadaster has measured the new parcel boundaries, new numbers are attributed, e.g. A 1199 and A 1200 and the new parcel boundaries become visible in the cadastral map.

Not in all cases a new parcel is created when a limited right only affects a part of the (original) parcel. An important exception on this rule is the right of superficies concerning cables and pipes (art. 6 *Kadasterbesluit*). Even when the location of this cable or pipe is indicated in the notary deed establishing this right, the parcel will not be divided. The code 'OLD' or 'BZD' will be used in these cases.

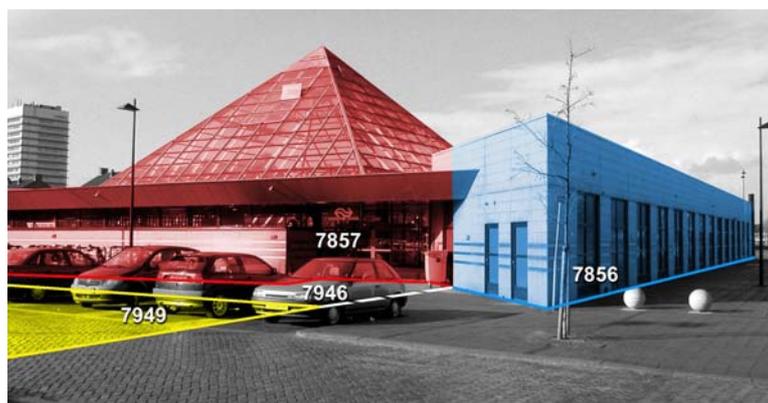
### 3. CASE STUDIES

#### 3.1. Case 1: Railway Tunnel and Station in Urban Area

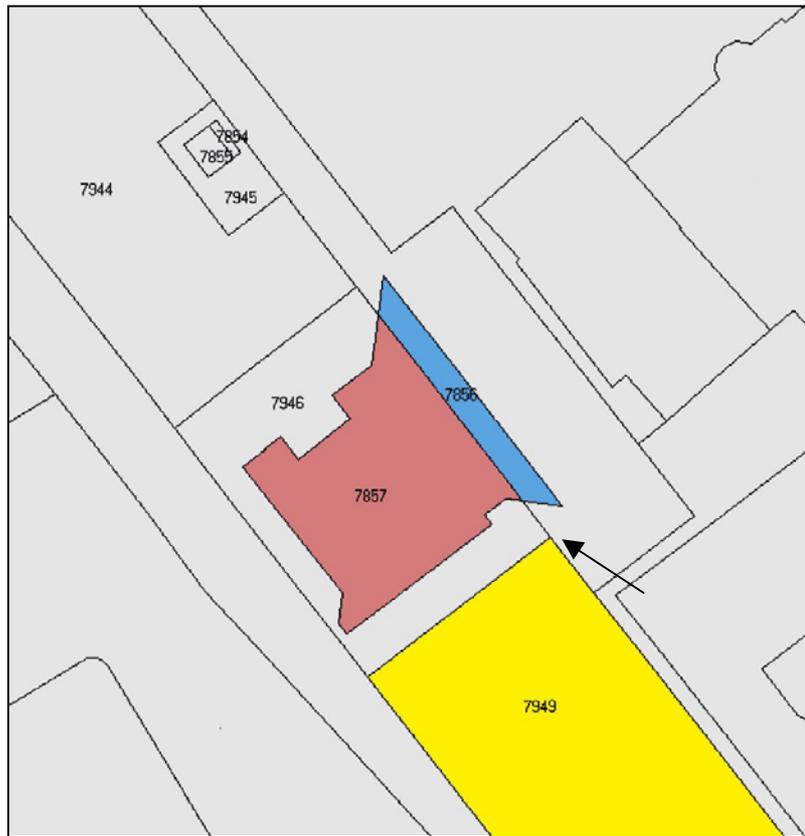
An interesting case of multiple use of space in Holland can be found in the centre of Rijswijk, a small town near the city of The Hague. Some years ago the railway line running through this town was tunnelled. On top of this tunnel buildings were constructed. A small part of the tunnel area is shown in figure 1a and 1b. In figure 2, the cadastral map of the situation is shown.



**Figure 1a:** Rijswijk railway station. The triangle-shaped object is the building of the railway station (parcel 7856 and 7857), the building on the right is a kiosk (parcel 7854 and 7855). The railway tunnel is located beneath the buildings.



**Figure 1b:** The ownership situation of the railway station building: red ( 7857) the right of superficies of NS Vastgoed BV; blew (7856) full ownership of NS Vastgoed BV and yellow (7949) the right of superficies of the municipality of Rijswijk.



**Figure 2:** Fragmented pattern of parcels based on 3D objects projected on the surface. The arrow indicates the position of the camera in figure 1b.

According to the AKR the following rights are established on the parcels:

Municip.	Section	Parcel	Type_of_right	Subject
RWK01	D	7854	OS	NS VASTGOED BV
RWK01	D	7854	EVOS	NS RAILINFRATRUST BV
RWK01	D	7855	OS	NS VASTGOED BV
RWK01	D	7855	EVOS	NS RAILINFRATRUST BV
RWK01	D	7856	VE	NS VASTGOED BV
RWK01	D	7857	OS	NS VASTGOED BV
RWK01	D	7857	EVOS	NS RAILINFRATRUST BV
RWK01	D	7944	OS	DE GEMEENTE RIJSWIJK
RWK01	D	7944	EVOS	NS RAILINFRATRUST BV
RWK01	D	7945	VE	NS RAILINFRATRUST BV
RWK01	D	7946	VE	NS RAILINFRATRUST BV
RWK01	D	7949	EVOS	NS RAILINFRATRUST BV
RWK01	D	7949	OS	DE GEMEENTE RIJSWIJK

VE = full right of ownership

OS = right of superficies

EVOS = right of ownership, restricted by a right of superficies

In this area there is:

- a railway station building, owned by NS Vastgoed BV (parcel 7856 whole parcel column; 7857 ground level);
- a railway tunnel, and platforms owned by NS Railinfratrust BV (parcel 7854, 7855, 7857, 7944, 7949 underground; 7945, 7946 whole parcel column);
- public space owned by the municipality of Rijswijk (Gemeente Rijswijk) (7944, 7949 ground level);
- a kiosk, owned by NS Vastgoed BV (7855 and 7854 ground level).

The cadastral map and the photo shows that a part of the station building, owned by NS Vastgoed, has been built for the major part above the tunnel (parcel 7857), and for a relatively small part next to the tunnel (parcel 7856). For the first part NS Vastgoed holds a right of superficies on the parcel owned by NS Railinfratrust BV, for the second part NS Vastgoed has the full ownership of the parcel.

This case is a good illustration how the 3D objects under and above the ground control the parcel pattern in the cadastral map (e.g. 7856 and 7857 for the railway station building, also the tunnel is identifiable in the patterns of parcels). Moreover the 3D physical objects are “divided” into parts according to the parcel boundaries on the surface. Therefore, the cadastral map reflects the basic principle of the current cadastre, i.e. to register rights on 2D parcels.

### 3.2 Case Study 2: Utility Pipelines

A Dutch company owning an important network of utility pipelines (hereafter: the “Company”) provided us with information on two pipelines. We imported this data into the cadastral DBMS (see figure 3). Therefore it was possible to query the legal status of the intersecting parcels. Normally this is not possible since (spatial) information on physical objects is not maintained in the cadastral system (see also van Oosterom, 2000).

The lengths of the pipelines are approximately 4 and 6.5 kilometers:

```
SQL> select sum(sdo_geom.sdo_length(shape,0.1)) from pipelinel;
```

```
SUM(SDO_GEOM.SDO_LENGTH(SHAPE,0.1))
```

```
-----  
4094803.19
```

```
SQL> select sum(sdo_geom.sdo_length(shape,0.1)) from pipelin2;
```

```
SUM(SDO_GEOM.SDO_LENGTH(SHAPE,0.1))
```

```
-----  
6480548.01
```



**Figure 3:** Two pipelines (pipeline 1 on the left and pipeline 2 on the right) used to investigate the cadastral registration of pipelines

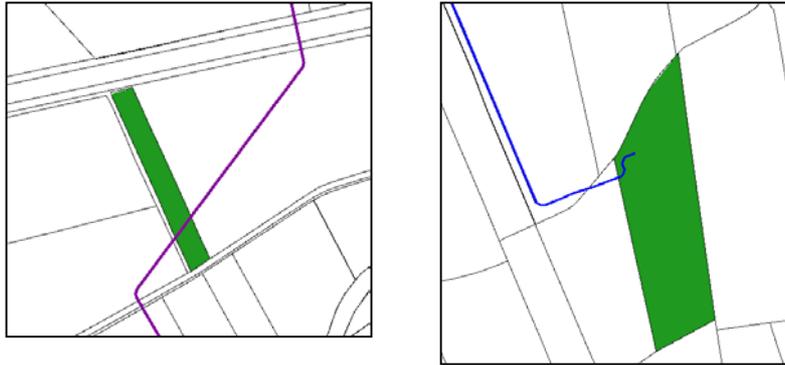
We queried the legal status of the pipelines with a copy of the cadastral registration system of June 2001. The query was a combined spatial and administrative query. The results are shown in the table 1.

First of all we can conclude that not all parcels crossed by the two pipelines have the legal notification referring to a right held by the Company. For pipeline 1, 42 parcels are intersected and 27 parcels have a legal notification; for pipeline 2, 43 parcels are intersected and 38 parcels have a legal notification. A new query showed that some of the “non affected” parcels are in full ownership with the Dutch government. In these cases a public law permit is sufficient. In most cases this is not registered in the cadastre. Recently a project has started to register those permits as well.

Also some privately owned parcels intersecting with the pipelines do not have a legal notification (see figure 4). The explanation is that the Company has a personal right to use the land (short lease). The personal right of short lease cannot be registered in the Dutch Cadastre (article 17 of Book 3 Dutch Civil Code).

	<b>Pipeline 1</b>	<b>Pipeline 2</b>
1. How many parcels are intersecting with the projection of the pipeline	42	43
2. How many parcels have a right in rem held by the Company	1	0
3. How many of the rights mentioned in (2) are right of ownership	0	0
4. How many of the rights mentioned in (2) are right of superficies	1	0
5. How many intersected parcels (including part of parcels) has a legal notification with the Company as subject	27	38
6. What are the notifications of 5	mainly BZ(D)	Mainly OL(D)

**Table 1:** Results of the queries on the legal status of the parcels intersecting with two company pipelines



**Figure 4:** For the indicated parcels no rights or legal notifications for the company are registered (pipeline1 on the left and pipeline 2 on the right) . In the case on the right, the pipeline ends on a production location rented by the Company.

The information that can be obtained from the cadastre is fragmented since only the rights on the intersecting parcels are registered. Also it is not possible to query the pipeline itself. Furthermore the location of the pipeline itself is not registered. Even that it is known, that a right has been established allowing the Company to build and hold a pipeline on a parcel (e.g. with the legal notification ‘OL’), the exact location of the pipeline (in 2D and 3D) is not known. Also, as can be concluded from those two cases the registration of pipelines is not uniform: OL(D), BZ(D), right of superficies, personal right of short lease are all used to register the legal status of pipelines. Finally, when the owner wants to transfer a part of his land, the whole parcel is affected by the limited right. Therefore all newly created parcels will ‘inherit’ the legal notification, although the pipeline does not necessarily intersect with the parcel.

### 3.3 Case Study 3: A Drilled Railway Tunnel in Rural Area

In the Netherlands the Paris–Amsterdam High Speed Railway (planned to be finished in 2006) is currently under construction (Figure 5). Since this railway is passing through unaffected rural land, it was decided to drill a tunnel for this part of the railway. The project team of the tunnel provided us with the 3D data of the tunnel, which we imported as one spatial object (a line-shaped object) into the cadastral DBMS. Therefore it was possible again to query the legal status of the intersecting parcels.

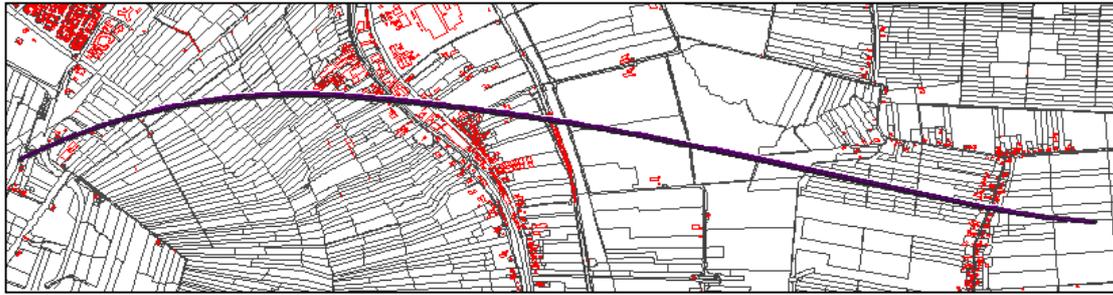
The tunnel itself is about 8.5 kilometers long: 7.160 meters for the actual drilled tunnel and two entrance sections of 660 meters and 770 meters in length.

```
SQL> select sdo_geom.sdo_length(shape, 0.1) from hsl_railwaytunnel;
```

```
SDO_GEOM.SDO_LENGTH(SHAPE, 0.1)
```

```
-----  
8580420.07
```

Note that in this case study we used a line for representing the tunnel, while the tunnel is 15 metres in width.



**Figure 5:** The railway tunnel in the “Green Heart” of the Netherlands.

In November 2001 the activities for this tunnel started. The realization of this tunnel is planned for 2004. We had access to two snapshots of the cadastral database: June 2000 and June 2001. In between most of rights needed by the Ministry of Transport and Public Works were obtained and registered. For this reason we were able to compare the different status of the rights on the parcels that intersect with the tunnel. The results of this investigation are shown in the table 2.

As can be concluded from this table, at the location of the planned tunnel many changes have taken place between June 2000 and June 2001. Of the original 104 parcels that intersect with the tunnel, 50 will stay intact. The other 54 will be subdivided because the tunnel will be built below just a part of these parcels. Most of those 54 parcels will be divided in two. A minority of them will be divided in three, or even four new parcels.

On the 104 intersecting parcels, in June 2000 the Ministry of Transport and Public Works had a right on 12 intersecting parcels (all ownership rights), while in June 2001, the Ministry had a right on 80 intersecting parcels (44 ownership rights and 36 rights of superficies). The intersecting parcels affected with those 80 rights are also affected with the legal notification ‘OB’ (underground construction), with the Ministry as subject. In the case of June 2000, none of the intersecting parcels had an ‘OB’ notification.

In June 2001, there are still 24 parcels left without a right held by the Ministry.

#### **4. IMPROVING THE REGISTRATION OF CROSS-BOUNDARY OBJECTS**

To discuss how a 3D cadastre can improve the registration of rights on cross-boundary 3D objects, we used the actual case of the HSL tunnel. We used the 3D information on the tunnel and the cadastral information to create fictive cadastral maps to illustrate the possibilities of registering 3D cross-boundary objects. Therefore, one should be aware of the fact that although the actual cadastral map of 2000 was used, the examples in this section are not intended to show the actual parcel boundaries: they are only meant to clarify the alternatives. The section starts with a description of the current practise and than two alternatives are described to improve the registration of long line-shaped objects: 1) the registration of rights in 3D and 2) the registration of the legal space of physical objects.

	June 2000	June 2001
1. How many parcels are intersecting with the projection of the tunnel	104	104
2. How many of the intersecting parcels are part parcels	0	54
3. How many parcels of (1) have a right that belongs to the Ministry of Transport and Public Works	12	80
4. How many parcels (including part parcels) have a right that belongs to the Ministry of Transport and Public Works	12	91
5. How many of the rights mentioned in (3) are right of ownership	12	44
6. How many of the rights mentioned in (3) are right of superficies	0	36
7. How many of the rights mentioned in (4) are right of ownership (registered both on part parcels and complete parcels)	12	53
8. How many of the rights mentioned in (4) are right of superficies (all registered on part parcels)	0	38
9. How many intersected (complete) parcels are affected with a legal notification	19	51
10. How many intersected parcels, including part parcels, are affected with a legal notification	19	67
11. How many of the notifications in (9) belong to the Ministry of Transport and Public Works	0	34
12. How many of the notifications in (10) belong to the Ministry of Transport and Public Works	0	36

**Table 2:** Results of the queries on the legal status of the parcels intersecting with the railway tunnel passing through the ‘Green Heart’ of the Netherlands.

#### 4.1 Current Practise: Registration in 2D

The first map (figure 6, left) would be the result if all parcels intersecting with the 3D object were completely affected with a right to build the tunnel in the underground. The location of the 3D object can (vaguely) be indicated when all parcels that are intersecting with the 3D object are selected.

This query is actually not possible in the current cadastral DBMS, since the 3D object itself (in this case the tunnel) is not maintained. Therefore, the relationships between the 3D object and the restrictions and notifications that are established are not stored. The only information that the cadastral system can provide is what rights, notifications and restrictions are established on a parcel and who are the subjects (natural and non-natural persons) of the rights, notifications and restrictions. In the case of the HSL tunnel, this subject is the Ministry of Transport and Public Works. Since the Ministry owns many other objects as well, this does not give insight in the nature of this 3D object: the object could be a viaduct, a road or a tunnel.

In addition, since the spatial extent of the objects is not maintained the following queries cannot be performed: which parcels intersect with the full 3D object; what rights, restrictions, or legal notifications are established on the parcels intersecting with the 3D object; are there any 3D objects (tunnels, pipelines) intersecting with a specific parcel etc.



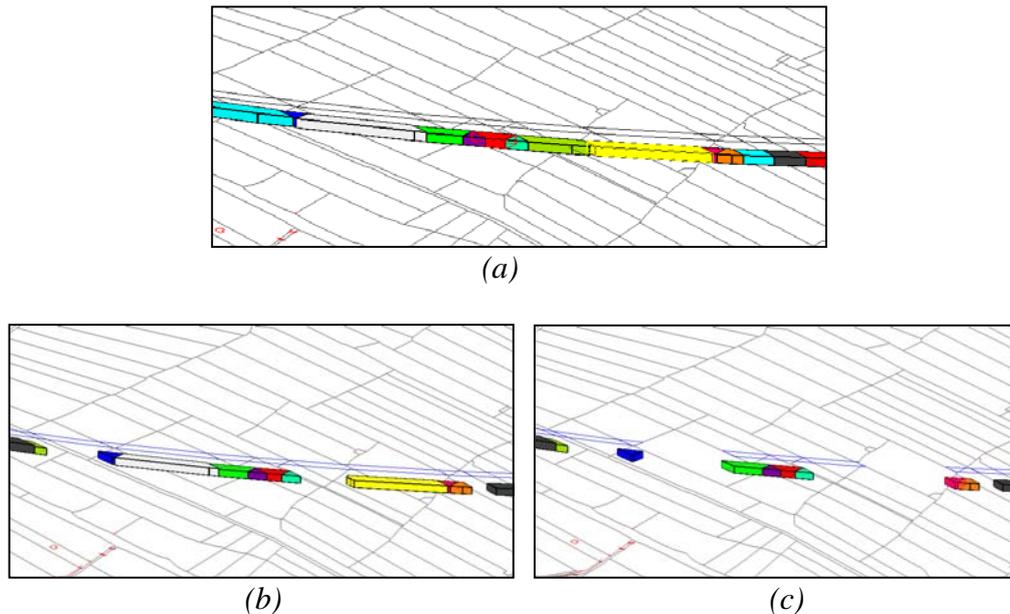
**Figure 6:** Left: whole parcel is affected, middle: new parcels are generated which results in a parcel pattern reflecting the 2D extent of the 3D object, right: combination of new parcels and parcels that are not divided.

When the tunnel intersects with a parcel only partially, normally the ownership or the right of superficies of only a part of the land will be obtained (as explained earlier). This will lead to the creation of new parcels. Figure 6, middle illustrates this situation: the Ministry has obtained rights of ownership or superficies for the extent of the tunnel (with a needed safety zone on both sides). New parcels are generated. Still the relation between the complete 3D object (tunnel) and all the parcels is not maintained in the DBMS. Because of the pattern of (new) parcels, the location and direction of the tunnel is clearly visible. But in case other constructions are built on top of the tunnel, like in the Rijswijk case, this image will be completely disturbed.

This is even more the case in the figure 6, right. It is more realistic to suppose that the Ministry is not owner of only the land right above the tunnel, but also of complete parcels. For example when the Ministry already owned some parcels before the construction of the tunnel started, or when during the negotiations they agreed to buy all the land from the original owner, and not only the small zone that was actually needed. Is this the case, there is no need to generate new parcels and no rights or legal notifications referring to the tunnel are registered on these parcels.

## 4.2 Two Alternatives

In conclusion, the current registration practise does not give sufficient insight in the 2D and 3D location of the tunnel or the vertical dimension (depth and height) of the rights established for the tunnel. Also the tunnel itself cannot be queried in the current cadastral registration system. To overcome these limitations, two alternatives have been introduced in our 3D cadastre research. These will be described in this section.



**Figure 7:** 3D right-objects representing the 3D extent of rights established on 2D parcels for the HSL tunnel owned by the Ministry. Figure 7a: all the parcels are encumbered by right of superficies, new parcels are created for all intersecting parcels. Figure 7b: as figure 7a, but now three newly created parcels are in full ownership. Figure 7c: three newly created parcels are in full ownership, two parcels that are not subdivided are in full ownership. All the other (new) parcels are encumbered by a right of superficies.

### 4.3 Registration of the 3D Extend of Rights

The current registration of long line-shaped objects can be improved by means of a 3D right-object (figure 7). This 3D right-object is the 3D representation of a right that is established on a parcel (Stoter and Ploeger, 2002). The 2D extent of a 3D right-object is the actual parcel-boundary. In this case we will use the new parcel boundaries as shown in figure 6, in the middle. The upper and lower limits of the 3D right-object are the upper and lower limits of the space where the right applies for (Stoter and Ploeger, 2002). The 3D right-object gives insight in the vertical dimension of the rights established. Now we can see that the rights are established for an underground construction and also the depth of the construction, which is a considerable improvement of current registration practise.

As was discussed in the 2D traditional registration, the registration of a right for the tunnel will not take place, when the Ministry owns the intersecting parcel. This leads to ‘gaps’ in the 3D registration. This is clearly illustrated in figures 7b and 7c. Figure 7b shows the situation when new parcels are created and some of these parcels are in full ownership with the Ministry of Transport and Public Works. For those parcels a 3D right-object will not be created (the Ministry owns the whole parcel column). The situation is even less clear in figure 7c. This will be the case when both new parcels and original parcels that are not divided are in full ownership.

#### 4.4 Legal Space of Object is Registered

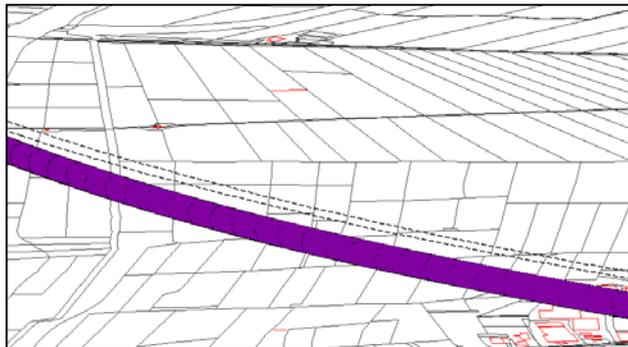
How to know the actual location of the tunnel and to avoid the ‘gaps’ in the registration? The only solution is the registration of the complete construction itself.

The most optimal solution would be to register the 3D physical object itself together with a spatial description of the legal space of the object (Stoter and Ploeger, 2002) (Figure 8). The legal space is the space that is relevant for the cadastre (bounding envelope of the object), which is usually larger than the physical extent of the object itself (for example including a safety zone).

The relationship between the legal space of the 3D object and the intersecting parcels is stored implicitly, because the holder of a 3D object is maintained. This is the same (non-natural) person who has a right on the intersecting parcels.

The solution of registering the legal space of 3D objects compensates all the complications that were met earlier. The intersecting parcels still need a kind of legal notification referring to the tunnel, but the parcels need not to be divided into smaller parcels. The spatial relationships between parcels and the (legal space of the) 3D object can be maintained with spatial functions in the DBMS.

The result is a full 3D cadastre (Stoter et al., 2002). An important disadvantage of this solution is that it requires considerable adjustments in the cadastre (Stoter and Ploeger, 2002), therefore for the mid-term future it is better to focus on a more feasible solution to improve insight in 3D.



**Figure 8:** Registration of the legal space of the HSL tunnel. The dashed line is the projection of the tunnel on the surface. Note that the parcels are not divided into smaller parcels.

## 5. CONCLUSION

Cross-boundary 3D objects are registered by means of rights, restrictions and notifications on intersecting parcels. This leads to a fragmented pattern of parcels. Also information on the 3D objects itself (with a 2D or 3D description) is not available since the object itself is not registered in the cadastral DBMS. The 3D object is divided into parts that match with the surface parcel.

In the current registration one can only see which persons have a right on the intersecting parcels, but the 3D extent of those rights is not registered. ‘Gaps’ may occur since some parcels are already fully owned by the holder of the 3D object.

To overcome these limitations, the best solution would be to register the legal space of 3D physical objects, by which intersecting parcels do not need to be divided into smaller parts. However, this requires considerable adjustment of the current cadastre.

For the mid-term future storing the 3D representation of rights established on 2D parcels (3D right-objects) improves insight in the spatial extent of rights that are established on intersecting parcels for cross-boundary objects. 3D right-objects give insight in the third dimension of rights established for a 3D object, while little adjustment of the current registration is required. The main change is that upper and lower limits of rights have to be registered.

The insight in the rights in 3D is a considerable improvement compared to the current possibilities of the cadastral registration system, although it does not give a clear representation of the situation in all cases, as was shown in this paper. Therefore, the focus for the long-term future should be on the registration of the legal space of 3D physical objects.

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## BIOGRAPHICAL NOTES

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