

An Object-Oriented, Formal Approach to the Design of Cadastral Systems - How Much Have the Anglo-Saxon and the Continental Method in Common?

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ABSTRACT

Modeling GIS or applications of GIS with object-oriented tools is difficult for the practitioners. There are numerous issues involved, from technical to conceptual. In this case study the deed registration system is studied using formal, object-oriented tools. The level of formalism reveals particular properties of 'administrative logic', which is less strict than the standard assumptions for database query processing.

The deed registration system used in the USA and the property registration system in Europe appear as different solutions to a similar problem. How much do they have in common? A formal modeling approach will demonstrate the functional similarities, due to the similar social demands, and the differences owing to different historic developments. The approach taken here starts from the most fundamental operations of a property registration system.

It is found that the models are comparable and the rules are fundamentally similar. The checks for a valid transfer of ownership are quite similar (but differ in detail even within the USA), but the time of checking is different. A Continental title registration system checks documents when they are received, whereas the US counterpart registers first without checking and only later the validity is checked by a prospective buyer's lawyer.

Several results from this study can be generalized to other administrative GIS applications:

- The question of identity plays a primary role and several types of 'identities' may be hierarchically nested.
- Administrative rules are less strict than database logic on what constitutes an entity or an identifier (the 'unique name assumption' is maintained only within a context)..
- Administrative time for a registry is a simple ordered scale.

These results are of practical importance for the design of GIS software which includes a 'land ownership layer' and should be applied in countries with different property registration systems. It shows the designers of property registration software, what can be built into a general, widely usable system and where a system must leave scope to adapt to local rules.

The study was motivated by efforts to design a property registration system for a reform country. In this situation, one has to understand how social demands and legal rules relate to the technical solution. To design formal models is the best way to achieve this.

1. INTRODUCTION

There is an international interest in the design or improvement of property registration systems. Several studies show a linkage between economic development and cadastral systems [Dale, 1988]. The common recommendation for the installation of a GIS points to the 'ownership layer' as the desired base for a GIS [National Research Council, 1980; National Research Council, 1983]. This study was motivated by an effort to design a property registration system for Moldavia, a newly independent country of the former Soviet Union, but similar problems are posed in other countries. The goal was to understand the linkage between social demands, legal rules and technical solutions for property registration. The formal method presented here revealed dependencies and led to design rules.

To make progress with the study of cadastral systems - and with other related administrative GIS applications - the administrative and legal context must be included in the formal (computer) model. Application designers do this routinely, but the resulting code rarely demonstrates principles of the system - it just works. Better tools are necessary to bring about various solutions to overcome the linguistic differences between the descriptions of different systems and to render the descriptions in a comparable format.

The deed registration system used in the USA and the property registration systems in Europe appear to be quite different solutions to a similar problem. How much do they have in common? This is important for the design of commercial GIS software which includes a 'land ownership layer' and should be applied in many countries with different property registration systems. What can be built into a general, widely usable system? Where must a system leave scope for adaptation to local rules?

It is found that the models are comparable; the rules are fundamentally similar and many of the differences in real estate law do not affect the operations of the registry, properly speaking. The checks for a valid transfer of ownership are quite similar (but differ in detail even within the USA), but the time when a check is carried out is different. A Continental property registration system checks documents when they are received, whereas the US counterpart registers every document without checking and only later prospective buyers check the validity.

The formal modeling approach can demonstrate the functional similarities, due to the similar social demands, and the differences, related to different historic developments and initial technical solutions. It can point out the options for change and what changes in legal rules or administrative process would be required. It becomes evident that many of the recommendations to improve the U.S. deed registration system do not address the roots of the problem, but are - at best - a superficial technical improvement [Dale, 1988].

Modeling GIS or applications of GIS with object-oriented tools is difficult for the practitioners. There are numerous issues from technical to conceptual. In this case study, property registration systems are studied using formal, object-oriented tools. The approach taken here starts from the most fundamental operations of a property registration system and shows how they can be expanded later. The tools used here lead to an extremely compact design document (3 pages of code for the core part of the registry and 3 pages to code a simplistic model of relational database).

Several results achieved can be generalized to other administrative GIS applications:

- The question of identity plays a primary role and several types of 'identities' may be hierarchically nested.
- Administrative rules are less strict than database logic on what constitutes an entity.
- Administrative time for a registry is a simple ordered scale.

It is necessary to point out that any discussion about the 'typical' legal rules must generalize broadly and specific countries may have adopted different ones. The discussion here is further complicated by the substantially incompatible legal theories and jargon describing Anglo-Saxon deed registration systems and European property registration.

2. THE CHARGE OF A PROPERTY REGISTRY

In very general terms, society needs a method to determine ownership of land. Ownership of small scale objects is determined by possession, the person holding an object is assumed to be the owner. A legal theory from Roman times protects good faith in the appearance of ownership: If you buy in good faith a watch from a thief, then you become the new owner.

Ownership of land is not apparent; today it is not possible any more to grant ownership only to persons physically living on a piece of land. 'Absentee landlords' are a necessity in our society, despite the fact that some legal systems strongly favor the present possessor and make it difficult for absentee landlords to maintain ownership (often in Latin America, e.g. Ecuador).

Acts of transfer of ownership were originally rituals. In medieval Germany, it was required to live on a piece of land for seven days and maintain a fire for seven nights. Transfer of ownership was later declared by the courts during their annual sittings (where everybody was present). The court registration book documented all properly executed transfers and made them known to anybody with a need to know. This registration system replaces the rituals and publicizes (in the sense of "to make publicly known") the transfer of ownership, to give everybody notice of the ownership rights of the new owner. Nobody can claim not knowing facts, which are properly registered in this public register. In this respect, a property register is similar to other public registers.

A charge to a property registration system might be described as:

The property registry maintains a record of transfers of ownership of land with the date and time of their registration. It reports all transfers which affect a piece of land in order of their registration. These records constitute evidence for the ownership of land.

It is implied that one can sell a part of a parcel, which means spatial subdivision. It is also generally possible to transfer other rights than full ownership. Most important is the use of real estate for collateral to secure a loan - here called a mortgage - often received to improve the property and build a building. Encumbrances are rights granted to others, which diminish the value of a property. Liens are laid against a property to secure debts arising by law.

The fact that ownership of land is not readily visible allows different types of fraud: selling a parcel one does not own, selling the same parcel to two different buyers etc. The registry must help a reasonably careful buyer to avoid such problems. It must be possible to establish if a seller owns the land he sells and a mechanism must be available to prevent selling the same piece more than once. In this case, the time of a transfer of ownership is crucial. The general rule is something like: Who comes first in good faith, owns the land and the other one can only try to get his money back from the seller. The legal effects are (often) bound to the time of registration, as only this time is easy to prove and only from this time on another buyer can check the registry and detect the potential fraud.

3. LEGAL HISTORY OF A PARCEL

The registry must help the owner prove his right to the land. In theory this is very simple: the current owner receives his rights from the previous owner, reduced for all this one transferred away. The previous owner received from his previous owner what that one had received, again reduced for what he had transferred away, and so forth till one reaches the original grant from the emperor (or whoever in modern times replaces the emperor), whose ownership cannot be questioned, as it is assumed to be 'directly from God' (or some similar theory). The metaphor underlying is that ownership is like a bundle of sticks, each signifying a particular right. The owner can give away specific rights or transfer ownership (i.e. all that remains in the bundle). Nobody can transfer more than he owns.

To prove ownership the owner has to produce the valid document with which he acquired ownership plus all the valid documents of his predecessors. The registry must store all these documents and make them available on demand. This is practically difficult and several countries have improved the registration method in different directions.

A search in a registry starts with the name of the current owner and the document with which he acquired the parcel. One has to find all events where this owner has transferred rights to others because he holds only the remainder (*search forward in time from the data of his document*). From his document (naming the person transferring ownership to him) one must find the document with which the previous owner acquired ownership (*search backwards in time*). It is often customary, to do all the backward search first (to establish a so-called 'chain of titles') and then search for all the intervening documents.

Documents are registered chronologically to assure their precedence. Precedence is assumed here to be strictly by registration time, but when a document was signed may also play a role; for an extensive discussion of temporal issues in the property registration system from a database point of view, see [Al-Taha, 1992]. Searching for a document in chronological order is very time consuming and a grantor/grantee index is generally provided, which lists under the name of a grantor or grantee all documents he appears in and reduces the search time.

With this index it is possible to find the previous document for the grantor of any successive documents, as the grantor of the successive document must be the grantee of the previous one. Thus using the simple grantor/grantee index the chain can be established.

Once all the relevant documents are found, they must be examined for their validity. A lawyer can then produce a 'legal opinion' and declare the title to be merchantable, i.e. of sufficient quality to be bought or mortgaged.

4. FORMALIZATION

The formalization starts with the core of the application to achieve rapidly a prototype. This is an efficient way to understand the major charge of an administrative unit without getting lost in the additional functions which are added in the course of time.

4.1. SIMPLIFIED ONTOLOGY

The ontology, i.e. the entities and operations relevant can be deduced from the charge. Essentially the nouns form the object types and the verbs the operations. For the most typical case, it consists of the following classes of objects:

Persons transfer parcels (from and to). Persons are characterized by a name.

Parcels with an identifier are owned by persons. Parcels can be sold as a whole or in part. Their boundaries are described in the documents registered.

Documents (technically called instruments) are the evidence of the transfer of ownership or other rights to land. They must be signed and registered.

The registry, which received the contracts to transfer ownership (documents), gives them a register number (id) and a time stamp when received. All documents regarding a parcel can be retrieved and presented in the order they were received for registration.

4.2. FORMALIZATION AND PROTOTYPE CODE

A functional programming language [Bird, 1989], namely Gofer [Jones, 1995; Jones, 1994] used here, produces readable specifications and, at the same time, the code can be executed at least as a prototype to check out if it captures the intentions correctly [Frank, 1995].

A very simple view of the registry gives the following code, which is then refined, but gives the principle ideas in an overview form.

```

type Parcel = Int
type Name = String
type Date = Int

class Registers r where
  register :: Contract -> r -> r
  history :: Parcel -> r -> [Contract]

class Contracts c where
  close :: Name -> Name -> Parcel -> Date -> c
  refParcel :: Parcel -> c -> Bool

data Contract = Contract Name Name Parcel Date

type Register = [ Contract ]

instance Registers Register where
  register c r = c:r
  history pp r = filter (refParcel pp) r

instance Contracts Contract where
  close s b p t = Contract s b p t
  refParcel pp (Contract s b p t) = pp == p

```

4.2.1. ENTITIES

For the entities *parcel* and *person* nothing else than an identifier is necessary. For the level of detail permitted in this paper, details of the boundary definition are not considered.

Time is modeled by the integer series, so that two events can be compared (total order). For the registry, it can be excluded that two events happen at the same time. There are no requirements for calculating time differences in this simple legal situation.

Transfer documents come in different types: to transfer ownership or ownership for part of a parcel, and to establish a mortgage (as an example for limited rights). In the class Transfers the operations that apply to all kinds of transfers are gathered: a document is signed and registered. Observer's operations allow to retrieve specific information of a document (the grantee, the grantor, when the document was signed, registered, etc.). There are finally operations to compare two documents: which one was signed or registered earlier, which one transfers less rights than the other. The often used test for earlier registration date is the order relation on documents.

```

type Parcel = Int
type Person = String
type Money = Int

class Transfers d where
  signTransfer :: Person -> Person -> Parcel -> Time -> d
  register :: Time -> d -> d
  seller, buyer :: d -> Person
  parcelNew, parcelFrom :: d -> Parcel
  signed, registered :: d -> Time
  sigBefore, regBefore :: d -> d -> Bool
  encumbrance, ownershipTransfer, isOriginalGrant :: d -> Bool
  lessEqRights :: d -> d -> Bool

```

The class `SpecialDocs` groups the operations that are particular for a special type of transfer.

```

class Sales d where
  makeGrant :: Person -> Parcel -> Time -> d
  closeSale :: Person -> Person -> Parcel -> Time -> Money -> d
  closePartialSale :: Person -> Person ->
    Parcel -> Parcel -> Time -> Money -> Float -> d
  establishMortgage :: Person -> Person -> Parcel -> Time -> Money -> d
  amount :: d -> Money

```

The data type for Documents can be one of 4 kinds, each of them including the common elements found in the `GeneralDoc`, which groups the grantee, the grantor, the parcel, time of signature, time of registration and an identifier.

```

data Doc = Sale GeneralDoc Money |
  SalePart GeneralDoc Money Float Parcel |
  Mortgage GeneralDoc Money |
  OriginalGrant Person Parcel Time OID

data GeneralDoc = GeneralDoc Person Person Parcel Time Time OID

```

The code for the operations is written in 'instance' declaration. Here an example:

```

instance Sales Doc where
  makeGrant p1 pa t = OriginalGrant p1 pa t unknown
  closeSale p1 p2 pa t m = Sale (signTransfer p1 p2 pa t) m
  establishMortgage p1 p2 pa t m = Mortgage (signTransfer p1 p2 pa t) m
  closePartialSale p1 p2 paOld paNew t m f =
    SalePart (signTransfer p1 p2 paNew t) m f paOld
  amount (Sale d m) = m
  amount (SalePart d m f dp) = m
  amount (Mortgage d m) = m

```

4.2.2. THE REGISTRY

The registry has two operations: register documents and produce the history for a right. The registry consists internally of a clock, which is strictly incremented (here with every document registered) to assure that the registration events are totally ordered. The registry consists of the books, here only the actual collection of documents (in a relation indexed by document id).

The operations for clients of the registry are to register a document and get history to a document (the document is representative for the right acquired with it). The first step in registration is stamping the document with the current time indicated on the clock in the registry and then passing it on to the books for registration.

```

class Registries r where
  registerDoc :: Doc -> r -> r
  history :: Doc -> r -> ChainLink
data Registry = Registry Time TheBooks
instance Registries Registry where
  registerDoc doc (Registry now rs) =
    Registry (now') (registerDoc (stamp now' doc) rs)
    where now' = tick now
  history d (Registry now rs) = history d rs

type DocRel = Rel2 Doc
data TheBooks = TheBooks DocRel

```

```
instance Registries TheBooks where
  registerDoc doc (TheBooks ds) = TheBooks (store3 putOID doc ds)
  history d ds = makeChain ds (CL d [] [])
```

There are internal operations of the register, namely get the previous document to a given document (search backwards) and to find all intervening, possibly adverse transfers, to two documents. The logic for this processing is based on a filter of the collection of documents. The backward search looks for a document with the same name for the grantee as the name of the following grantor, regarding the same parcel (i.e. the parcel acquired previously must be the same as the parcel now to be transferred) and the document must precede the current one. In the forward direction, one searches for every document of the grantee concerning the same parcel; here the search is limited to the time between the registration of the first and the document of interest.

```
class RegistryInternals r where
  previousDocs :: r -> Doc -> [Doc]
  interveningDocs :: r -> Doc -> Doc -> [Doc]
  oneLink :: r -> Doc -> [ChainLink]
  makeChain :: r -> ChainLink -> ChainLink
```

For a given document, several documents may be candidates for the acquisition - at least in pathological cases - and each of them must be further investigated to decide which one produces the correct chain. Therefore for a given document, all possible previous documents must be found and for each of them, the intervening documents collected and separated in adverse transfers and other transfers which reduce the ownership rights. To collect all potential documents which could be part of the chain of titles to a given document, a recursive data structure is built, which starts with a document, reconstructs all the possibly preceding documents and then expands these to the same. This is the history of a document, as found in this style of registry.

```
instance RegistryInternals TheBooks where
  previousDocs (TheBooks ds) d = sort1 (<=) (filterR2 c ds)
    where c d' = (seller d) == (buyer d')
            && (parcelFrom d) == (parcelNew d')
            && (registered d) > (registered d')
  interveningDocs (TheBooks ds) d d2 = sort1 (<=) (filterR2 c ds)
    where c d' = (buyer d) == (seller d')
            && (parcelNew d) == (parcelFrom d')
            && (registered d') > (registered d)
            && (registered d') < (registered d2)
  oneLink books doc = cls
    where cls = [ CL pd (otherSales pd) (encumbrances pd)
                  | pd <- previousDocs books doc]
            intervDocs p = interveningDocs books p doc
            otherSales p = filter (not. encumbrance) (intervDocs p)
            encumbrances p = filter (encumbrance) (intervDocs p)
  makeChain books cltree = exp cltree
    where exp (CL pd os es) = (CLeX pd os es (oneLink books pd))
            exp (CLeX pd os es cls) =
              (CLeX pd os es [exp cl | cl <- cls])
```

4.2.3. ASSESSING THE CHAIN OF TITLES

The chain of titles produced from the registry must be assessed to determine if the title is valid. A chain must fulfill certain formal conditions to be valid, but then additional assessment of each instrument is necessary by a professional lawyer. This can be programmed to perform only the first type of checks.

Any branch of the tree of titles which does not lead to 'original adjudication', i.e. a transfer, granted by an authority which cannot be questioned, is not complete. The decision what an authoritative document is, depends on local customs and is - at least in the USA - often replaced by the limitation that chains are checked only for a certain length.

Second, no adverse transfers may occur in any link of the title chain.

The current ownership rights are the original rights as they follow from the authoritative title reduced for all encumbrances, sales of part of the land, mortgages erected etc.

5. INTERNAL OPERATION OF THE REGISTRY

5.1. FLOW OF INFORMATION

This formalization just models the registry seen from the outside. Real registration offices suffer from some physical limitations in the flow of information, which should be modeled:

The contents of the document, which is necessary for entry in the register, is not immediately available. Personnel of the registry must carefully prepare the abstract, which takes time. Documents are presented for registration sometimes in rapid succession. Thus a document cannot be fully processed before the next is received, but the order of presentation for registration must be preserved. This is generally solved by stamping documents with the time of receipt and entering them very quickly in a chronological registry. Processing is then asynchronous to reception, working on the queue of documents received.

The chronological registry, typically called diary, is an important device to avoid tampering with the order of reception of documents. This was a major concern with the designers of registries in the last century as is demonstrated by overly detailed rules about keeping the diary.

To form an opinion of the current legal situation of a parcel, one must consult the history from the registry and check the documents pending for registration if they affect the parcel in question.

5.1.1. INDICES

A realistic registry is so large that a sequential search for all documents affecting a parcel is impossible. If the documents are registered and filed chronologically, then it is necessary to establish indices to help in the search. Indices make operations faster, but do not change the logical result from a query compared with a sequential scan. Indices are thus necessary for actual implementation, but do not contribute to the design or the logic of the problem.

6. ENTITIES, IDENTITIES AND NUMBERING METHODS

Much of the discussion of design of property registration systems is concerned with identifiers. There are two aspects to this discussion: the practical, directly visible, of the selection, formation and distribution of the identifiers, and the implied, theoretical one of identities. An identifier implies that two things with the same identifier are identical, at least in some aspects [Al-Taha, 1994]. Any time an object with a given identifier is referenced, one implies that the same object is referenced. This assumption is fundamental in database systems and the logic of their query languages [Reiter, 1984].

When does an object change and become a new object? This is a crucial question, which does not always have a single answer. We have a very clear understanding of the identity of a person, but also are aware that during a lifetime, this same person will change in many respects. Administrative systems define the identity of objects and which operations change the object into a new one depending on the requirements. The cadastral system relaxes the assumption that unique names identify unique objects and requires only unique identifiers within a context (i.e. not globally unique).

6.1. DOCUMENTS

The contracts physically presented for registration are obvious entities with an identity similar to other physical objects. But documents in the legal sense, have their identity through their contents (physical copies of a single document can exist): to produce two different documents which read exactly the same is very unlikely. In most practical circumstances, the elements abstracted (grantee, grantor, date of signature, parcel affected) are sufficient to identify a document. Once registered, every document gets a unique identifier, which is the book and page on which it is recorded.

6.2. PARCELS

There are multiple interpretations of parcels. One might assume that the boundary of a parcel makes the parcel and any change in the boundary makes a new parcel with a new identifier. This is a notion which is sometimes used, but the technicalities of registration in most legal systems allow, at least minor, changes in the boundary and continue the parcel identifier unchanged for the changed parcel. If by parcel we understand the set of rights, then anytime a limited right is given away or part of the land is transferred to another parcel, this notion of parcel is changed.

In most practical systems, parcel identifiers remain the same despite apparent changes in the geometrical boundaries. Parcels identified in this way are changing objects and to identify a definite piece of land and a set of rights, the identifier must be given together with a date.

6.3. PERSONS

Natural persons are not modeled as true entities in the registry. For the registry, it is sufficient to establish that the grantee and the grantor of the successive transfers is the same person. Person names are used for indices on grantees and grantors. For this to work, the name must be an identifier for the person, which despite the many limitations and exceptions is a workable assumption within the context. The numerous spelling variants of a name (especially first names) and the habit to change the name of women when they marry, makes this difficult to automate.

The cadastre does not require that names are globally unique. Only the identity of the grantor with the grantee of the previous transfer is checked. If the name alone is not sufficient to establish this identity, then additional evidence may be necessary (but this is relatively seldom).

In a property registry, the unique name assumption is possibly violated [Reiter, 1984]: there may be several persons registered as grantees or grantors with exactly the same name, but also the same person may appear under different names. With the current administrative rules, it is not possible for a registry to resolve such possible ambiguities. But there is also no need, as in any case when the identity must be established, additional documents are exchanged to establish it. But only, when necessary!

7. CONDITIONS FOR A WORKING REGISTRY

From the analysis one can deduce some conditions for a registry to work properly:

- Registration in the competent registry,
- Registration of all titles and other documents,
- Consistent use of identifiers (at least within the context of a parcel).

The first two points assure that the documents necessary are contained in the registry, the second that one can find the documents.

According to most legal systems, for registration to have full effect, it must be performed by the competent registry, which is the registry of the political subdivision of space in which the real estate is situated. In every country, a simple rule of competence of registries depending on the location is established. It follows the standard rules to determine the competent court.

The registry can only work as described if all documents relevant for the transfer of real estate are collected in a single place. This is a problem, as many important documents are registered with the courts (or other public registries) and do not require registration with the cadastre.

To achieve completeness, the legal protection for unregistered documents can be reduced compared to registered ones. This forces registration even in a system like the USA where registration is voluntary. This does not work for documents which are already registered with other public registers. To obtain these documents, some registration systems recognize the validity of the document without registration, but request that the owner provide copies of these documents before he can transfer ownership or other rights he acquired with them.

8. IMPROVEMENTS OF A REGISTRY

The solution for a registry of deeds as presented above is the method where the least amount of public effort is used - the registry accepts any document for registration, keeps the minimal index necessary to establish a chain of titles and leaves the construction of the chain and the assessment of the chain of titles to the client. Low public costs incur with this solution, but high private costs (i.e. high transfer costs), in total, an expensive system. In the USA, where this system is used in its purest form, only few complaints are heard and a fundamental reform of the system has not been achieved. The reason is probably the fact that from the total cost of a transfer of real estate property, the cost of property registration etc., is only a small part. In the USA the other costs, especially realtor costs, seem to be less than in other countries.

Practically, a registry of deeds is difficult to use, for one, because some documents are not included, and for one because improper documents are registered. It is customary to demand that the registrars work more careful [Dale, 1988], but without the power to refuse to register inappropriate documents, a fundamental improvement is not possible. It is somewhat surprising to realize that the major difference between a US registry of deeds and a continental property registration system is in the power of the registrar to reject a document presented for registration or to demand additional documents before registering a document.

Any improvement of this registration method depends crucially on giving more competence to the registrar. Rules on how a document must be drawn up and what references it must contain are necessary and the registrar must be empowered to enforce them and to deny registration (or grant registration with less effect) to documents which do not fulfill these rules.

Such rules must be simple and formalistic to be viable. They must not demand complex interpretation or independent collection or evaluation of facts: the applicant must deliver documents and the registry must have formal rules to check. Every instrument registered in the registry designed so far must have a name for a transferee and transferor. This is a formal legal requirement without which a document cannot be registered.

8.1. CHECK GRANTOR

The registrar checks that the seller named in the current document and the buyer of the previous one are the same person, he establishes the identity of a person within the local context of these two consecutive documents.

If the grantor is the same as the grantee, but has changed his name, or the grantee has received the title through another legal document (e.g. court order), which would not require registration, the registrar must demand that copies of these documents are produced and registered to maintain the chain of titles.

It is often demanded that addresses of the persons involved are maintained. This is not a requirement of a property registry, but other functions the registry could fulfill would require means to communicate with the owners. The difficulty is not with capturing this information initially, but to maintain it. Maintenance of a list of owner addresses must therefore be in function of their use. The same goes for legal demands that a person should not own more than a certain amount of property (or similar rules), which requires globally unique identifiers for persons. These rules are not enforceable in most systems today.

8.2. ESTABLISH BACKWARD CHAIN BY REFERENCE TO PREVIOUS DEED

A document references the previous document, the document with which the transferor had acquired the real estate. If every document reliably contains this information and is checked by the registrar for correctness, then searching backwards through a chain of titles is much simplified. The procedure to check this link is very similar to the backwards search for a title.

8.3. ANNOTATE FORWARD CHAIN WITH REGISTERED DEED

If every document references the previous one, then the registrar can build the forward chain between documents by adding the identifier of the newly registered document next to the text of the previous (referenced) document. This is often done in traditional registries, without specific regulation, just for the benefit of the registry itself. It is a sort of additional index, maintained in the document registry. This simplifies the forward search enormously: references for all later documents exist and they only must be checked.

8.4. CHECK FOR NO ADVERSE TRANSFERS

When the registrar annotates the previous document in the register with the identifier for the newly registered document, he sees all other references to documents registered by this grantor. It is then possible to check if the grantor still holds the right to make the current transfer. The registrar must be allowed to refuse registration of documents, when the grantor has already disposed of the right. For example the registrar may detect, and then must refuse to register, a transfer of ownership if the grantor has already sold the parcel previously and is not owner anymore.

This requires that the transfer is for specific rights on specific parcels, which are identified. In practice, this is no problem, as only a few set types of rights are used and transfers are specific to assure the grantee what he receives. In principle, some legal systems allow enormous freedom in the transfer of rights to land, which, again in principle, makes it impossible for a registrar to check if the grantor has the rights he transfers.

8.5. TITLE REGISTRATION

If the registrar reliably checks the relation of a new document with the previous ones and refuses registration of documents which are not valid, then one must ask

- if something is checked, is the result of the check recorded?
- if the check is negative, what follows?
- if the check is positive and the document registered, does this guarantee the elements checked?

If a registry starts with valid titles (e.g. adjudications from the government) and if for every transfer the relation to the previous document is checked, the identity of the persons involved established, and the reference to the parcel boundary is by reference to the previous document, it is clear that a correct chain of titles exists for each registered document.

The validity of the transfer itself may remain to be assessed. A transfer is often based on a legal contract, and this contract may not be valid. There are several legal reasons why a signed contract is not valid: fraud, error on the side of one of the contracting parties, etc. This may (depending on the applicable law) lead to invalidation of the transfer. Demanding specific forms of contracting, e.g. the assistance of a legal professional, can exclude many of the rules for an invalid contract. Excluded from registration must also be 'conditional' transfer agreements, in which it depends on a future event.

If the registrar does check and refuses registration of invalid documents, the title search need not be repeated and no new assessment of the validity of the title of the last owner is necessary. The registrar can carry professional liability insurance to guarantee his work in the same way a lawyer guarantees his 'title opinion'. In many countries the registrar is a public official and the state guarantees his work. This would come very close to some forms of title registration. In a title registration system, the registrar does not only formally check that a chain of titles is established, but checks also if the transfer of title is effective and may guarantee the new owner his rights.

9. CONCLUSIONS

From the analysis we see that the difference in the operation of a registry of deeds and a title registration system is in the difference when and by whom the assessment of the title chain is executed. In a deeds registration system, the registrar is forced to register any document received. In a title registration system he is charged to examine every document for its relation to the chain of titles and if it effects a valid transfer. The registrar must refuse to register invalid documents.

The checks the registrar has to carry out are for one part formal as shown in the code above. For the other part, he must check the contents of the documents. Are the boundaries of the parcel in correspondence with the previous document? Is the contract valid? etc. These checks must be done quickly so that the registry is reasonably up to date. This is only possible, if the transfers are following a set pattern, and are not subject to extensive interpretation.

9.1. A PROPERTY REGISTRATION PACKAGE

From the specifications here - and some extensions to include special cases not covered here - a generally usable registration system can be built. It shows how the indexes and the diary must be maintained and shows the importance of recording time. The logic of title search coded here gives the simplest case, which must remain extensible to adapt it to particular legal systems.

If such an engine is used for a deed registration system, for example in the USA, then incoming titles can be checked as a help for the registration personnel to catch errors, but deeds which do not conform must be registered, despite the doubts they raise. The title search is then performed each time a client asks for it. Such a registry could quickly give indications who is most likely the owner.

If the same engine is used for a title registration system, for example in central Europe or South America, the incoming documents are checked and registration is refused if they do not conform. The registry can then answer questions about who owns a parcel authoritatively.

The result here shows that the same software can be used in both cases, as the fundamental structure and operations are the same.

9.2. TRANSLATION TO CONVENTIONAL TOOLS

The formalization has led to an understanding of the issues. For implementation, they must be translated to database schemata and queries. The object definitions must be split to factor out inheritance very much the same way the data statement for Document and GeneralDoc are set up here. A relational schema should then be checked for normalization. For query processing a 'computationally complete' language (or a query language with transitive closure) is necessary because the computation of the title search required is recursive [Al-Taha, 1992].

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