Geo-ICT technology push vs. Cadastral market pull

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ABSTRACT

This paper discusses the recent Geo-ICT developments, such as information system modelling standards, database technology, global positioning systems, Internet development, wireless communication and acceptance of geometry standards within general ICT tools and its uses on cadastral systems. Efficient design, development, testing and maintenance of cadastral systems allow the introduction of such systems within acceptable time and budgets. A basic condition for system development is analysis of user requirements. Those requirements can change in time, e.g. because of changes in legislation, governmental policy, new tasks for organisations or technology. It is therefore important to design generic and flexible information systems, e.g. to follow the (data) model driven architecture (MDA).

1. INTRODUCTION

Recent developments in Geo-Information and Communication Technology (Geo-ICT) have given tremendous push toward the development of cadastral systems and geo-spatial data infrastructures (GSDI). Both theoretical and practical developments in ICT such as the ubiquitous communication (Internet), data base management systems (DBMS), information system modelling such as Unified Modelling Language (UML), and global positioning systems will improve the quality, cost effectiveness, performance and maintainability of cadastral systems. Further, users and industry have accepted the standardisation efforts in the spatial area by the OpenGIS Consortium and the International Standards Organisation (e.g. the ISO T211 Geographic Information/Geomatics). This has resulted in the introduction of new (versions of) general ICT tools with spatial capabilities; e.g. eXtensible Mark-up Language/ Geography Mark-up Language (XML/GML), Java (with geo-libraries), object/relational Geo-DBMS including support of simple geographic features.

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It is the first time ever that such a set of worldwide-accepted standards and development tools are available (UML, XML, Geo-DBMS, OpenGIS standards). This creates new perspectives in both the development of new cadastral systems and in the improvement of or extension of existing cadastral systems. At the moment, the first Internet-GIS applications are already operational in a cadastral context. In the near future this will be extended to mobile GIS applications based on cadastral information (sometimes also called location-based services). Imagine the users of mobile phone or personal digital assistant (PDA) such as a civil servant of the municipality, a rea[redacted] estate broker, or a policeman, with their mobile using up-to-date cadastral information for their day-to-day tasks in the field: 'who is the owner of this building?', 'when was this building sold and what was the price?', etc.

On the cadastral market pull side, its new requirements that satisfy users have emerged due to the changes in government policies, legislation, emerging new tasks of the organisations and users, etc. A global overview of such user requirements related to cadastral systems is presented in Section 2 of this paper. In Section 3 an overview is given of recent Geo-ICT developments with a qualitative analysis on cadastral systems. The conclusions of this paper and a proposal on further development of *cadastral* OpenGIS standards are finally given in Section 4.

2. USER REQUIREMENTS

For an inventory of the general user requirements for cadastral systems, the *United Nations/Economic Commission for Europe* (UN/ECE) Land Administration Guidelines (*UN/ECE*, 1996) and UN/FIG the Bathurst Declaration (*FIG,* 1999) give some important and fundamental basic requirements. Furthermore, results from market surveys of the Netherlands Cadastre, have been used for inventory presented at the end of this section.

2.1 UN/ECE Land Administration Guidelines: user needs

The UN/ECE Land Administration Guidelines highlight the importance of addressing user requirements. Before altering an existing system or introducing a new one, it is essential that the requirements of those who will use or benefit from the system are clearly identified. Naylor (1996) relates this to the current market-oriented approach applied to land information. Products and services must certainly satisfy the user needs. The UN/ECE Guidelines state that a user can be anyone who is interested in land matters. A wide variety of user communities will need to be consulted in order to understand their requirements and the constraints under which they currently operate. The assessment of user needs should be made not only at the outset of the development of a new land administration system, but also *throughout its lifetime*. Questions need to be asked about the *categories of data* that will be required in the future. It may be an attractive idea to collect some types of data for some possible use in the future but if it is not necessary to do so at present, then few resources should be allocated for that purpose. A *step-by-step* approach may be more cost-effective.

Further requirements, which are recognised in the UN/ECE guidelines are:

- There will be a need for cooperation over who collects and coordinates data, what technology should be acquired so that *all components of the system are compatible*, how common standards and procedures can be developed, and other system-related decisions.

- *Data protection* has to be covered in a land administration system.
- Are *strata titles* (relating to the ownership of apartments, etc.) to be recognized? This subject has been discussed in a FIG workshop on 3D Cadastres (*Oosterom, P.J.M. van, J.E. Stoter, and E.M. Fendel,* 2001), organised in Delft, the Netherlands. The 3D representation of cadastral data is a typical example of a future need for certain areas in the world.
- The application of new technologies, such as GPS, should be assessed from an economic rather than a technical perspective. Provisions must also be made to accommodate future changes in the network that may occur as a result of technical improvements. These may affect *all coordinate-based systems*. If the coordinates are an essential component of the cadastral system, then the survey technique must be capable of producing these either *directly or indirectly*.
- A key component in any land administration system is the parcel identifier or *unique parcel reference number*. This acts as a link between the parcel itself and *all records related* to it. It facilitates data input and data exchange. Fiedler and Vargas (2001) recognise a technical requirement for cadastral data collection: the need to change the parcel identifier during the data collection process (first related to aerial photographs, later related to the administrative subdivision of the country).
- Orthophotomaps, rectified photomaps, or planimetric maps may be used depending on the user requirements, cost, and timing among other factors.
- *Redundancies* should be avoided.
- The management of an up-to-date land administration system inevitably involves the use of *modern information and communication technology*. It must be able to accommodate new user demands and to take advantage of *new technologies* as they become available. The technology adopted should be sufficiently flexible to meet *anticipated future needs* and to permit system growth and change. In this context, a framework for re-engineering land administration systems is given by Williamson and Ting (2001).
- When data collection starts, it is important that an *updating process* should be installed at the same time. See also Flores Silles, Javier (2001).
- Whilst more and more users require cadastral information that is frequently and quickly updated in real-time, the need to *secure data quality* should not be underestimated. One important aspect here is the management of topology integrated with geometry and other attributes (*Lemmen and Van Oosterom,* 2001).
- There are opportunities for greater cost-effectiveness in areas such as subcontracting work to the private sector; increasing cost recovery through higher fees, sales of information, and taxes; and by *linking* the existing land administration records with a wider range of land information. See also Bogaerts and Zevenbergen (2001).
- The public must understand and accept the level of information that is placed in the *public domain* or else people will find ways to avoid information appearing in the registers. See also Van der Molen (1999, 2000).

These requirements are of a more general nature. Some of them can also be interpreted as conditions for development of stable systems to run for a long time. Here it should be remembered that life-time of data is 50 years or more, of software 10 years or more and of hardware 3 years or more.

2.2 UN/FIG Bathurst Declaration

In the UN/FIG Bathurst Declaration, the importance of ICT for the development of land administration systems is underlined. Information technology will play an increasingly important role both in constructing the necessary infrastructure and in providing effective public access to information. Finally, there must be total commitment to the maintenance and upgrading of the land administration infrastructure. Some of the 'system development'-related recommendations of the Bathurst Declaration are:

- Encourage the *flow* of information relating to land and property between different government agencies and between these agencies and the public. Whilst access to data, its collection, custody and updating should be facilitated at a *local level*, the overall land information infrastructure should be recognised as belonging to a *national* uniform service to promote sharing within and between nations. See also Bogaerts and Zevenbergen (2001) and Williamson and Ting (2001).
- Recognise that good land administration can be achieved *incrementally* using relatively simple, inexpensive, *user-driven* systems that deliver what is most needed for sustainable development.
- Agencies should seek to develop multi-disciplinary, multi-national training courses in land administration and make these available at the local level through the use of modern information technology. Groot and Van der Molen (2000) present similar conclusions as a result of a Workshop on Capacity Building in Land Administration.
- In order to ensure sustainable development of territorial oceans claimed under UNCLOS (United Nations Convention on the Law of the Sea), the United Nations emphasise the need for claimant countries to develop their capability to support effective marine resource administration through the national spatial data infrastructure.

Williamson and Ting (2001) underline the importance of the Bathurst Declaration, as it establishes a strong link between land administration and sustainable development.

2.3 Business requirements: Observations from the Netherlands Cadastre

The information society has become prominently visible over the past few years (*Magis,* 1998). The use of information and communication technology (ICT) for *management, transactions and communication* is becoming increasingly popular. Customers are taking up a much more *directive* role. Organisations are becoming more dependent of each other and are in fact forced to openness (of systems) and exchange (of data). Developments such as *chain-orientation, digitisation* and *new technologies* are leading to the fading of physical product concepts. Information products are becoming flexible combinations of digital data components and additional facilities and services. To be able to operate as a supplier of information products in this changing environment in the long term, an organisation must understand the economic dynamics of information production. Technically, digital information products offer considerably more possibilities *for perfect reproduction and fast, inexpensive and easy distribution.* In addition, it is important to realise that a product does not have the same value to every customer and that as a consequence not every customer is prepared to pay the same price. A pricing policy based on customer-group differentiation is, in the Dutch situation, not feasible (principle for government operation). A pricing policy based on product differentiation is feasible. *Variation* in the product range is possible in many ways: by differentiation in access to the information, for instance (time, place, duration); or by differentiation in the actuality, completeness or extent of detail in the information; or by differentiation in the possibility for the user to download and store the information, to multiply it, print it, or in any possible way edit it. In addition, differentiation is possible in the speed of delivery, in user-friendliness, and in support. The variants can besides be used separately as well as in combination with each other. In view of the specific business characteristics, an information supplier should aim for *standards* (of distribution, exchange and usage) and *product flexibility*.

In the near future, customers want to have access to information *24 hours a day, 7 days a week, at home, in the office, and in the field*. They want to be served in a professional way, through user-friendly tools to information that is timely, up-to-date, reliable, complete, accurate, relevant, if necessary customised, *well-integrated with other relevant data sets of other suppliers*, good value for money by systems that are compatible with the customer's working procedures.

The Netherlands Cadastre's main customer group, the notaries, is becoming more cost-effective. They will have to differentiate their products, deliver their services faster and with higher quality, will have longer opening hours, will have to specialise, have to provide more and clearer information. Citizens want one-stop-shopping (integrated service delivery). And more and more they want to access the information through the Internet. *Electronic conveyancing techniques* such as electronic signatures, encryption, hash values, measures against bit-loss, are applied increasingly. Because the law has to provide legitimacy to the transmission, submission and registration of electric documents, changes in the (land) law are necessary. Expertise to define the new legal prescriptions concerning the authenticity of electronic documents, the certification authorities that are empowered to issue digital keys, is available now (*Van der Molen,* 2001). As land registers and cadastres play an increasing role in the knowledge regarding the legal status of land according to public law (the so-called public encumbrances) as a complement to the status according to private law, the submission and recording of government documents concerning government decisions on land with an effect on third parties, are within reach. This will contribute to the development of *e-government*. Modern *mobile computers* allow updating of (cadastral) maps during the field session and make geometric quality management possible in the field, so that detected errors can be investigated and rectified on the spot. Wireless data communication facilitates the transmission of work files of maps from the field to the office in order to establish an efficient work process. The recording process (throughput) will be improved through internal data communication offering a better integration between centralised and decentralised processes. Workflow management techniques will become applicable, which will have a positive impact on the management of daily fluctuating supply and demand, because an allocation of the workload is possible at the location where the work force is available that very moment. The integration of work processes allows for combining the benefits of centralised IT services and decentralised information management. Not the location but speed of access is important. On the output-side the strategic objective of making the accessibility of land information better, easier and cheaper, will be supported by data communication. A well-organised front office supported by an efficient back office provides a boost in customer-oriented services. Internet services can be applied here. This requires a reflection on opening hours, data quality, liability, data protection and copyright, privacy issues, and pricing policy. Establishing an e-commerce environment will require decisions on to which extent tailor-made land information products are offered, and how payment will be guaranteed. Land administration will become an important basis of establishing a GSDI.

Van der Molen (1999) concludes: users of cadastral information need clarity, simplicity and speed in the registration process. The information must be as complete as possible, reliable (which means ready when required by the users), and rapidly accessible. Finally, the system must be sustainable in order to keep the information up to date.

3. GEO-ICT DEVELOPMENT

Recent developments in Geo-ICT have now important roles for the development of cadastral systems and GSDI surrounding cadastral systems. The developments in ICT in general, and specifically the Geo-ICT can improve the quality, cost effectiveness, performance and maintainability of cadastral systems.

GISs are used within (local, regional, central) governments, utility, and other companies to support their primary business, which often depends heavily on spatially referenced data. Until recently the spatial data management was handled by GIS software outside the DBMS. As DBMSs are being spatially enabled, more and more GISs (Arc/Info, Geomedia, Smallworld, Geographic Microstation) are or will soon migrate towards an integrated architecture: all data (spatial and thematic) are stored in the DBMS. This marks an important step forward that took many years of awareness creation and subsequent system development. Many organisations are currently in the process of migrating towards this new architecture. This is a lot of work and will still take many years. The next step will be the creation of a common GSDI for related organisations; the so-called information communities. This can replace, in the long run, the exchange of copies of data sets between organisations. It requires good protocols, standardisation such as the OpenGIS (*Buehler, K. and L. McKee*, 1998) web mapping specification. But also the role of the Geo-DBMS becomes more important, because not a single organisation depends on it, but a whole community. The main use will be query-oriented (and less update-oriented, only the owner of the data is doing updates, others are only doing queries). This also means that Geo-data derivation (creating new spatial data sets out of existing ones) is an important component that uses advanced class of queries. Here, an essential component for realizing such query processes is the network infrastructure (bandwidth) itself.

In this section, we will first discuss the broader concept of the Geo-Data Infrastructure and relate this to cadastral systems in 3.1. Next, we describe the relevant OpenGIS standards in Section 3.2. This is followed by an analysis of the developments in modelling and structured information transfer (in 3.3). Section 3.4 shortly presents the developments in database technology. Finally, Section 3.5 introduces the concepts and technologies behind the location based services and again relate this to cadastral systems.

3.1 The Geo-Data Infrastructure

During the 5th Geo Spatial Data Infrastructure Conference (*Resolutions*, 5th GSDI Conference, 2001), the following definition of GSDI was agreed on by the GSDI Steering

Committee: "The Global Spatial Data Infrastructure supports ready global access to geographic information. This is achieved through the co-ordinated actions of nations and organisations that promote awareness and implementation of complimentary policies, common standards and effective mechanisms for the development and availability of interoperable digital geographic data and technologies to support decision making at all scales for multiple purposes. These actions encompass the policies, organisational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives". The processes of production, provision, use, maintenance, exchange and sharing of these data are complex in nature. Large data volumes have to be managed using database management technology and geographic information systems (GIS). The managers of geo-data are not only the custodians of cadastres, but also national mapping agencies, geological surveys, soil surveys, ministries, land use planning institutes and large municipalities.

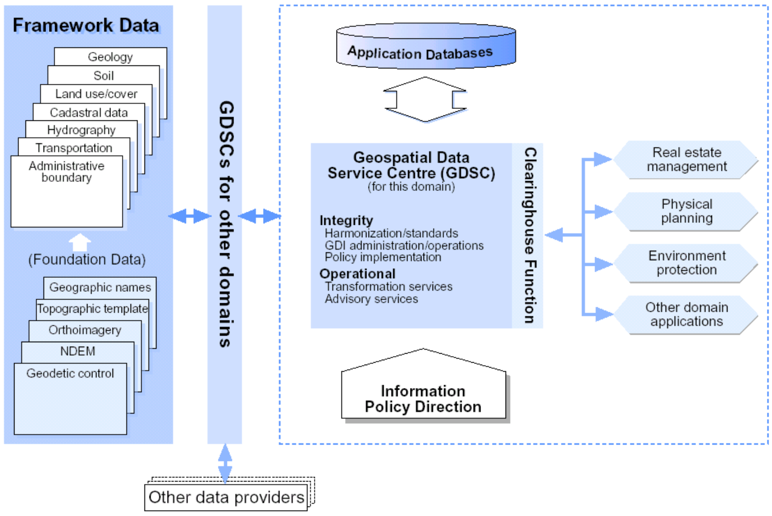

Figure 1: The foundation data for Geo Spatial Data Infra-structures in relation to the Geo Spatial Data Service Centre of the Environment and Physical Planning Domain (source: Groot and McLaughlin, 2000*).*

The success of the Internet in general has shown the power of an open infrastructure. The open standards and the decentralised architecture are responsible for the many free and non-free services. Besides the network infrastructure (wired and mobile), the GSDI (Figure 1) can be seen as composed of three important and quite different types of ingredients (*Van Oosterom et al,* 2000, *Groot and McLaughlin,* 2000):

- *Geo-data sets* in different domains. *Framework data sets* like cadastres, but also coverage data pertaining to soil, land use, hydrography, geology and transportation are all necessary tools of effective government. Framework data provide information on people and the land where they live and work. They supply information on the location of administrative boundaries and of objects like buildings and roads. They provide information on type of soil and pollution, ownership (land tenure), value and use of the land as well as geological information. Framework data/information can help governments to determine how to deal with land in their policies to combat poverty, to achieve sustainable settlement goals and to manage natural resources. A special sub set of geo-data are *foundation data*. This is the fundamental geographical reference for all other thematic application data. Foundation data concern Geodetic Control, National Digital Elevation Model, Ortho Imagery, the Topographic Template and Geographic Names. All these data sets should be well defined with respect to their data model, thematic contents, quality, accuracy, actuality, and so on.

- *Geo-Data Services* in general and the geo-DBMS specifically. The Geo-Data Service Centre (GDSC) harmonises/standardises all data for its application domain. It ensures they are described in a national metadata standard to facilitate the sharing of these resources by other potential users. The GDSC also enforces the information policies that control access, use and planning, in keeping with legislation and overall government policy. The geo-data sets are maintained in geo-DBMSs and are served to users from these geo-DBMSs via networks or traditional means. For these purposes, the DBMS has to support spatial data types and operators (simple analysis and selection-oriented queries), spatial clustering and indexing (for large data sets), and if possible support for advanced analysis (topology-based analysis). Also, temporal support is required in the form of some kind of future standard TSQL (*Snodgrass, R.T., I. Ahn and G. Ariav,* 1994) or in the meantime through some other (non-standardised) means: extension for a specific DBMS or explicitly in the application data model.
- *Interoperability standards* are required to enable the integration of the different data sets and to combine the geo-data processing services. In fact, different organisations and individuals using each other's geo-data sets in a digital environment can be regarded as parts of a distributed computing environment. One of the most obvious examples of this is an internet GIS retrieving *on-the-fly* data from different sources on the internet. To operate in such a heterogeneous world (different types of hardware, operating systems, geo-DBMSs, geo-data sets) interoperability standards at many levels are required.

All three ingredients have different aspects, which can be either technical or non-technical (organisational, financial, legal, etc.).

One of the most time-consuming tasks when implementing a GIS is obtaining geo-data. First, relevant data sets and sources have to be located, then these data sets have to be copied and converted into the local (DBMS of a) GIS. Some reasons why this process is so time-consuming are that it may be difficult to find the data, the data model of the source may be very different from the model implemented by the local system, the supported exchange formats of source and destination are different. To improve this situation, much effort is needed to create a GSDI, which should at least cover the following aspects: *consensus* on the geometric parts of the data model; support for both raster and vector data (including different spatial reference systems); a formal description of the geo-data sets (and geo-processes), that is, metadata standards, covering both the spatial and non-spatial aspects; *access to and query* the metadata and how the result of such a query is returned, this is called catalog services; selection of the geo-data; *format (and transfer)* of the resulting geo-data set. Instead of always copying data sets from one system to another, a new scheme becomes feasible once the above aspects are covered by implementations of geo-standards. This new scheme allows to keep the data at the source, which can then be used all over the world. At the client side, no data management is needed for data originating from other sources. This scheme also allows fair pricing of geo-data, because every time data from the source is used (possibly through a local cache) the user can be charged for this. Currently, in the *full data set copy* scheme the user has to pay for the whole data set, even if certain data (regions) are not used at all (in a certain period). The new *data at the source* scheme allows fairer pricing, both viewed from the vendor's and buyer's points of view.

An early pilot in this area started in 1996 and was called Geoshop (*Berg C. van den et al,* 1997*)*. The following partners were involved: the municipality of Almere, a cable TV company (Casema), and the Cadastre. It was based on the C++ Magma (server) and Java Lava (client) software developed by Professional GEO Systems (PGS); see Figure 2.

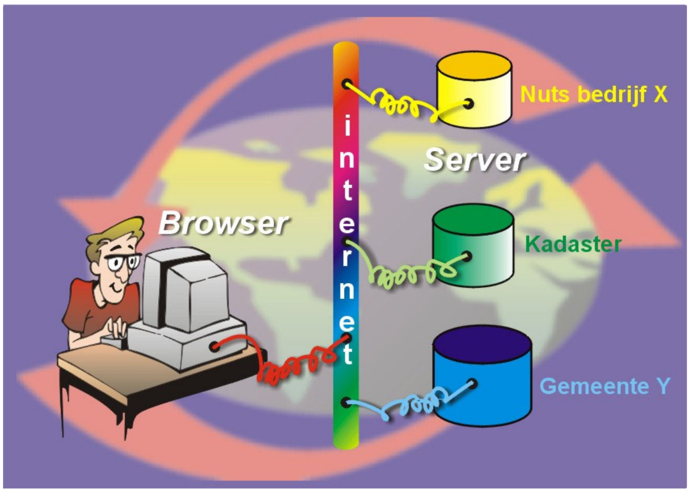

Figure 2: Geoshop example of Internet GIS.

Important characteristics are: access data form multiple and heterogeneous sources (Ingres, Informix, DXF files), raster and vector data at server and client side, client side software platform independent (Java platform). No attempt was made to implement the payment aspects as this was expected to be a more generic issue, also treated outside the GI community. Also, no standards for querying (meta) data and for returning the results were available at that time (1996).

3.2 OpenGIS Standards

The OpenGIS Consortium (OGC) and the official standardisation organisations (ISO and CEN) have addressed several aspects of the interoperating framework. In this section, we will focus on the OGC as they also (re-)use official ISO standards when appropriate. OGC has basically two levels of standards: abstract (comparable to 'official' standards) and implementation standards. Implementation standards describe the exact interfaces (protocols) of a (part of) an abstract standard in the context of a specific distributed computing platform. An overview of the OpenGIS domain can be found in the OpenGIS Guide (*Buehler, K. and L. McKee,* 1998). In Section 3.2.1, the feature geometry data model will be discussed. The next section covers the aspects of metadata and catalog services. Finally, Internet GIS standards are described in Section 3.2.3.

3.2.1 <u>Feature Geometry</u>

The first OpenGIS implementation standard was related to the feature geometry abstract specification. It was called Simple Feature Specification (SFS) and it standardised the basic spatial types and functions. The implementation specification for the SFS are described for three different platforms: SQL (*OpenGIS Consortium,* 1998), Corba, and OLE/COM. Currently, OpenGIS is revising/changing the feature geometry abstract specification to be consistent with the draft standard ISO TC 211 *Spatial schema* (*ISO TC 211/WG 2,* 1999): covering also 3D types, more geometric primitives (curve and surface types), and complex features (topology). What is still missing is the implementation specification of topology for specific platforms comparable to the implementation specification for simple features. What the abstract *feature geometry* and implementation *simple feature* specifications are for the vector model, are the abstract *earth imagery* and the implementation *grid coverage* (*OpenGIS Consortium,* 2000b) implementation specifications for the raster data model.

3.2.2 Metadata and catalog services

With respect to the contents and structure of the metadata, the OGC decided more or less to adopt the work by ISO TC 211 (*ISO TC 211/WG 3,* 1999). Much attention of the OGC has been paid to the related aspect of catalog services (*OpenGIS Consortium,* 2000a), describing how to access the metadata (and also data describing available computing services). This standard can and will be used in realising clearinghouses for geo-information all over the world; e.g., the new NCGI in the Netherlands (*Absil et al*, 1997) will be based on this OpenGIS standard.

3.2.3 Internet GIS

Strongly related to the previous standards, metadata and catalog services are the activities in the area of Internet GIS (or web-mapping). This may be seen as an interactive (and ultimate) form of interoperability as data from multiple sources can be retrieved and combined in the web-browser. However, instead of querying and receiving metadata, now the geo-data itself is queried and received. The OGC has created in this area:

- the implementation specification *Web Map Server Interface* (*OpenGIS Consortium,* 2000d) for the query aspects using three basic functions: GetCapabilities (what is available on the server), GetMap (raster images, graphic primitives or data) and GetFeature_info (fetch attributes), in addition the *Web Feature Server Interface* can be used for updating information and has functions for locking and committing transactions, and
- the recommendation *Geography Markup Language* (GML) (*OpenGIS Consortium,* 2000c) (simple features in XML with XSLT 'stylesheet' for presentation) for vector data transfer.

The query from a client uses the well-known structure of an Internet URL. The OGC has specified the names of the query parameters (e.g., BBOX, LAYERS, FORMAT) and the meaning and allowed values for these parameters. An example of a GetMap query:

```
http://b-map-co.com/servlets/mapservlet?WMTVER=0.9&REQUEST=map&
BBOX=-88.68815,30.284573,-87.48539,30.989218&
WIDTH=792&HEIGHT=464&SRS=4326&
LAYERS=AL+Highway,AL+Highway,AL+Highway&
STYLES=casing,interior,label&FORMAT=GIF&TRANSPARENT=TRUE
```

With respect to the different types of clients OGC has developed a model to compare these clients. See Figure 3: thin clients (which display only raster images JPEG and PNG), medium clients (with graphic primitives WebCGM and SVG) or thick clients (data in the form of simple features XML, that is GML (*OpenGIS Constortium,* 2000c), is processed at the client side).

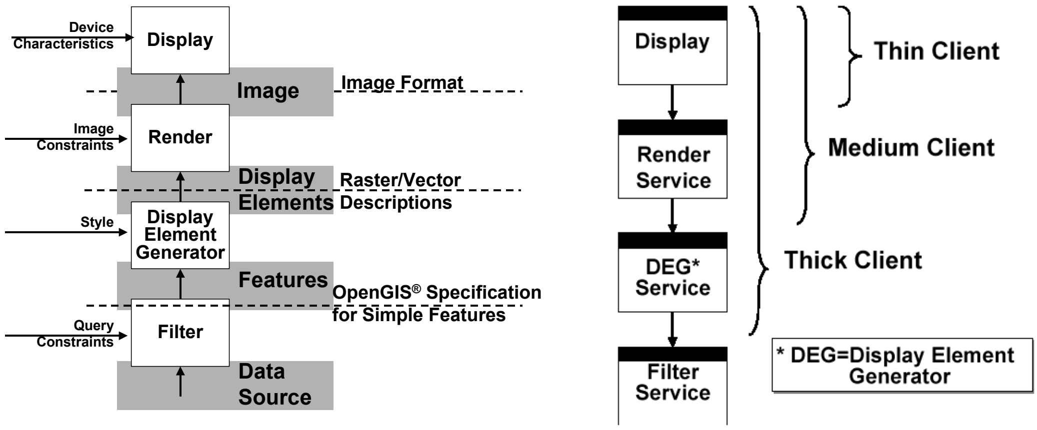

Figure 3: Different levels to exchange geo-information (OpenGIS Consortium, 2000d*).*

It is clear that when a certain process is not executed at the client side, the work has to be done at the server side. For example, generation of graphic primitives from GML data and/or convert graphic primitives into images (rendering). The FORMAT parameter in the query indicates what type of result should be sent back; in the example above a GIF image is requested. This could also have been a request for GML data. Below a fragment of a GML data sets is shown, taken from the domain of topographic mapping (*Vries, De et al,* 2001). The Topographic Service of the Netherlands has enriched a standard topographic map (1:10,000), which was converted into a GML (2.0) prototype by TU Delft. The format and structure resemble the well known HTML format where everything has a begin and an end tag: the whole object (tdn:SpoorbaanDeel), thematic attributes (tdn:begindatum) and geometric attributes (gml:Polygon).

```
<tdn:SpoorbaanDeel fid="TOP10.4200001">
 <tdn:top10_id>4200001</tdn:top10_id>
 <tdn:begindatum>06 Jul 2001 08:08:24</tdn:begindatum>
 ...
 <tdn:verkeersgebruik>Tram</tdn:verkeersgebruik>
 <tdn:aantal_sporen>1</tdn:aantal_sporen>
 <gml:geometryProperty>
  <gml:Polygon srsName="EPSG:7408">
   <gml:outerBoundaryIs>
    <gml:LinearRing>
     <gml:coordinates>
      191008.456,447232.635,0.0 190990.713,447236.938,0.0 190972.849,447239.952,0.0
      190955.904,447235.469,0.0 190940.491,447231.646,0.0 190923.831,447229.355,0.0
      190924.668,447229.093,0.0 190942.211,447223.787,0.0 190944.282,447224.343,0.0
      190957.890,447227.719,0.0 190973.223,447231.776,0.0 190989.103,447229.096,0.0
      191006.570,447224.861,0.0 191008.456,447232.635,0.0
     </gml:coordinates>
    </gml:LinearRing>
   </gml:outerBoundaryIs>
  </gml:Polygon>
 </gml:geometryProperty>
 <tdn:hoogteniveau>0</tdn:hoogteniveau>
</tdn:SpoorbaanDeel>
```

3.3 Unified Modelling Language and eXtensible Markup Language

For the several decades, the different modelling techniques have been employed in the design and development of information systems. Now, we have reached the stage of a world-wide acceptance of a standard modelling language: the Unified Modelling Language (UML) *Booch et al*, 1999). It supports a rich set of graphical notation describing classes, objects, activities, states, workflow, use case, components, nodes and the relationships among them. It provides significant benefits to system designers and organization by building rigorous, traceable and maintainable models, supporting development lifecycle. It is used for modelling both the data aspect (structural) and the functional aspect (behavioural) of information systems supporting both external and internal requirements. Thus, UML models can be used to describe and implement various components and their links of cadastre and land registration systems within the scope of management framework for developing information systems and their business processes (Tuladhar, 2002). There are three most important components in UML: use case diagram to capture external environments (user requirements and behaviours), activity diagram to show how use case can be realized, object model (system behaviours) showing interaction between actors and entity objects, and information model (commonly known as 'class diagram', which resembles the well-known entity-relationship diagrams). Since it is based on object-oriented technology, it can effectively be used to design a generic model. To this end, the simple and generic cadastral system can be developed on the top of Simple Feature Specification (refer to section 3.2.1) using UML.

An international consortium promoting the use of object-oriented information technology is maintaining the UML standard: the Object Management Group (OMG).

eXtensible Markup Language (XML) is the standard for the exchange of structured information and plays an important role in the Internet. Data models can be described within either a Document Type Description (DTD) or, more advanced an XML Schema document (*W3C, 2000a, W3C,* 2000b). XML documents must obey some basic rules: they must be 'well formed' (have corresponding begin and end tags) and 'valid'. An XML document is valid when its structure is conform to the definitions and declarations in the model (given in DTD or XML Schema). The XML, DTD and XML Schema standards are developed and maintained by the world-wide web consortium (W3C). XML Schema has a 'connection' to UML: the data part of the (UML) model can be transformed into the XML Schema (by hand or automatically). Many tools exist to manipulate the XML data and know how to interpret the models. The advantages of XML in general are that it is well readable by humans and machines (in contrast to binary formats), international (support of Unicode for non-western languages), methods to process XML documents are available (e.g. develop an XML Style Sheet Transformation, XSLT to convert a DLM into a DCM), extensible with own parts (using the 'XML Schema' language (*W3C,* 200a and *WC3,* 2000b)). Moreover it is very well supported by all kinds of software in the market (ranging from the web-browser to the DBMS).

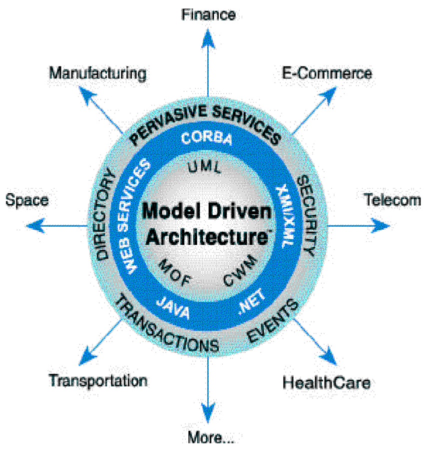

Figure 4: OMG's Model Driven Architecture (from Siegel, 2001*).*

As stated in the user requirements cadastral systems need to be generic and flexible because of the changing requirements over time. Flexible information systems are also one of the main motivations behind the model driven architecture (MDA) also promoted by the OMG (Siegel, 2001). The MDA is based on models of information systems (components) being described in UML. Other advantages of the MDA approach, specifically for today's highly networked, constantly changing systems environment, are: portability, cross-platform interoperability, platform independence, domain specificity, and productivity. Figure 4 shows the MDA in relationship with the different technologies being incorporated (including UML) and the relationship with the different domain specific models.

Now, returning to our specific domain, the spatial or geographic information of which the cadastral data form a sub set. There is a growing demand to distribute the geo-information in a more open transfer format. Geography Markup Language (GML) and its underlying technologies, OpenGIS specifications and OMG and W3C standards, have been introduced above. Now we will show some aspects in a little more detail. Two XML Schemas describe GML itself: the geometry schema and the feature schema. The UML schema belonging to the geometry schema is shown in Figure 5. With version 2.0 the OpenGIS Consortium decided only to use XML Schema to convey the structure of GML files (and not DTD anymore). The GML specification is basically a set of XML Schema documents with element declarations and type definitions plus a hierarchical structure for the relationships between types. In this way the specification offers a framework that can be used by organisations to make their specific XML application schemas for their GML implementations.

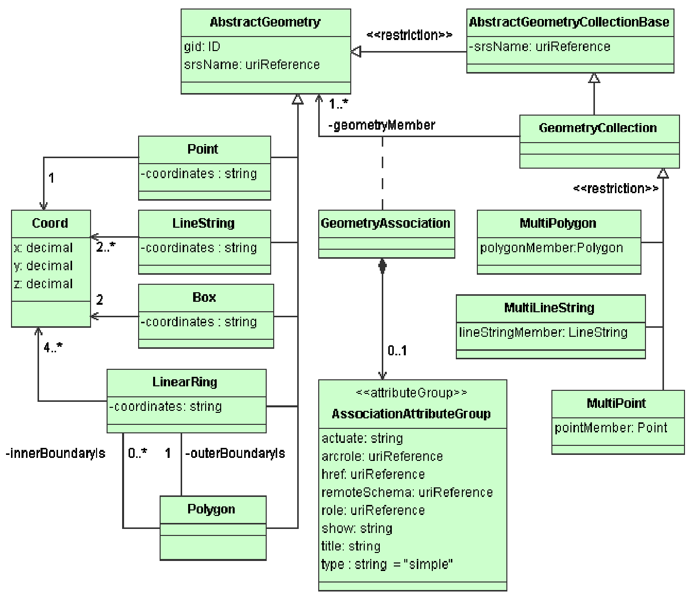

Figure 5: The UML schema of the GML Geometry model taken from (OGC, 2000c).

3.4 Developments in Database Technology

Both developments in hardware and software and in database technology will influence the future development of the Geographic Information Infrastructure. Current extensible DBMSs (*ASK-OpenIngres 1994, ESRI,* 1999) are very well capable of storing spatial data. Also simple queries like zooming in and zooming out can be handled efficiently. However, more complex operations, like map overlay, on the fly generalisation, enforcing correct topology during updates etc., are still not within reach of these systems. New developments in DBMS technology that can help to build a new generation of spatial DBMSs are for example Extensible (Object Relational) DBMSs, Object Oriented DBMSs, and Very Large Memory (VLM) Databases. The current status of the mainstream DBMSs with respect to handling geo-information can be found in the Appendix 2.

3.5 Location Based Services

Mobile information society is developing rapidly as mobile telecommunications moves from second (GSM) to third (UTMS) generation technology. The Internet and its services are coming to wireless devices. Location-based services (LBS) personal navigation are parts of mobile multimedia services. Personal navigation is a service concept in which advanced mobile telecommunications allow people to find out where they are, where they can find the products and services they need and how they can get to a destination. (*Rainio*, 2001).

Figure 6: The transmission senders and the positioning of the mobile phone.

The architecture of LBS consists of components from three different disciplines:

1. positioning of the mobile terminal, either based on the mobile phone network or on a positioning system such as GPS, GLONASS or Galileo;
2. wireless communication network, either based on GSM, GPRS or UTMS;
3. geo-information and geo-services based on GIS technology.

The three disciplines have one thing in common: in one way or the other the concept of location is important.

The supply of services is visible to the users as different service applications, in the background of which can be generic services and technologies, like data management, customer administration, data security, etc. Service applications can support all modes of transport (walking, skiing, vehicles such as the wheelchair, bicycle, motorbike, skidoo, car, taxi, bus, train, ship, plane, etc.). The services can include address, route, timetable, weather, accommodation, restaurant, and other guidance, traffic and travel services, as well as a description of any commercial and public services to be positioned. The nature of the information can be travelling directions, historical and cultural information, programme and event information, official regulations, etc. Safety is enhanced by the automatic transmission of the terminal device's location when making emergency calls. Positioning and the transmission of location data can also be applied with different kind of orders and when trying to locate a lost person, animal or object (*Rainio,* 2001). The use of mobile phones and personal digital assistants (PDAs) is growing rapidly. Wireless data transfer, mobile multimedia and mobile Internet are the main trends in mobile telecommunication. The third generation network, UMTS (Universal Mobile Telecommunication System) will provide 5-10 times more efficient data transfer links (300 kbit/s) than in conventional Internet modem use. Mobile data networks are also being joined by Wireless Local Area Networks (WLAN 11 Mbit/s) and other wireless data transfer systems (Bluetooth 770 kbit/s); although their coverage is limited to one hundred metres. One directional data transfer for digital television and radio offers up to 20 Mbit/s. This could be partly utilised for other data transfer.

4. PROPOSAL AND CONCLUSIONS

In this paper, we have first tried to get an overview of the general user requirements of cadastral systems based on the work done by the UN/ECE and the UN/FIG. This was augmented with user requirements from the Dutch Cadastre. One thing became very clear: cadastral systems are dynamic; they do have to change over time in order to support society in a sustainable manner. With these user requirements in the back of our mind we did analyse the recent Geo-ICT developments in a broader sense, that is, including as information system modelling standards, database technology, positioning systems, Internet development, wireless communication and acceptance of geometry standards within general ICT tools, on cadastral systems. It can be concluded from this analysis that the development and maintenance of the cadastral systems can benefit a lot from the new Geo-ICT and even completely new functions are now becoming possible (e.g. LBS).

However, in spite of the now available standards (for modelling UML), exchanging structured information (XML) and geo-information standards (OpenGIS Simple Features, Web Map servers, GML, etc.), there is still one important aspect missing. This is a standard and accepted base model for the cadastral domain. This should include both the spatial and administrative part and be based on the above mentioned core standards. Within the OpenGIS consortium there are several special interest groups (SIGs) working on generic domain models on which specific applications can be founded by assembling parts adhering to this domain model. The generic domain models itself are based on the core technology models (such as for geometry, time, meta data, etc.). The standardised cadastral domain model should be described in UML schemas and accepted by the proper international organisations (FIG, OpenGIS...). This will enable industry to develop products. And in turn this will enable cadastral organisations to buy these components and develop (and maintain) systems in an even more efficient way. More than two years ago the Technical Committee (TC) of the OpenGIS Consortium tried to set up a 'Land Title and Tenure SIG' without success. This in spite of several other successful domain SIGs within the OGC, such as Telecommunications, Defence and Intelligence, Disaster Management, Natural Resources and Environmental, etc. It is time to join forces between the FIG and the OpenGIS Consortium and start working a standard and accepted cadastral base model. This model can be used in (nearly) every country. Of course, on top of this cadastral base model, parts of the system may be added for specific situations in a certain country. That is, the model can be extended and adapted according to the theory of object-oriented systems.

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Appendix 1: RDBMS Spatial Data Management

This is a summary of a Product Survey published in GIM International, 2002-2 (Editor: Christiaan Lemmen).

Questions	***Answers by*** **Oracle** (Spatial Option), **Computer Associates** (Ingres II, Spatial Object Library), **IBM Informix** (Informix Dynamic Server) and **Sybase** (Adaptive Server Enterprise 12.5, with Spatial Query Server Option)
Supported spatial data types (to be applied direct in SQL)	
Spatial data-types (vector oriented) supported by your RDBMS	For products all spatial data types supported in Simple Feature Specification + circles, arcs, combinations of arcs and lines and rectangles
Spatial data-types (raster oriented) supported by your RDBMS	Not supported, only some ‘output formats’ like jpg, gif, bmp, png, geotiff
Supported spatial data operators (to be applied direct in SQL)	
Could you give an overview of spatial data-operators (vector oriented) supported by your RDBMS	A wide range of (OpenGIS-ISO/SQLMM compliant) spatial operators and functions is available in all products.
Could you give an overview of spatial data-operators (raster oriented) supported by your RDBMS	Not supported, except classical way of storage in Binary Large Objects
Spatial indexing	
Is there a specific spatial index supported by your RDBMS for fast data retrieval	Yes
If answer is ‘Yes’: which spatial index	Support for Quad-tree (most products) and R-tree (most products), sometimes a B-tree is used in a smart way
Spatial data clustering	
Is spatial data clustering supported for better access performance? Spatial data clustering means spatial data storage is organized in such way that spatial objects which are ‘near’ to each other on disk	Not really.
If yes: which method of spatial data clustering is supported	One product uses Hilbert functions
Support in topology	
Is there any support in storage of topologic relationships	Not supported
Is topologic structure management supported to support the realisation of a planar partition (e.g. cadastral parcels) or linear networks	Not supported
Do you support ‘Clementini’ and ‘Egenhofer’ operators	More and more products have support of more and more of these operators.
3D GIS support	
Can 3d GIS be supported by your RDBMS	Support depends on GIS tool
Can 3D coordinates be stored in your data types?	One product supports for 3D storing of lines/points/polygons. R-Tree supports 3D indexing, but no 3D operators. Linear Referencing can be 4D. Other products also support 3D representation but not for all data-types

Do you support spatio-temporal models? E.g.: can you support maintenance of history (reconstruction of the past) with functionality in your RDBMS?	Most products support spatio-temporal models
If yes: could you summarize (max. 100 words) how this is organized	One approach: it works by maintaining versioned tables, which implies a.o. that the version will always be part of the primary key. Workspace Manager can consolidate versions, by tracking changes to handed out copies. Other approach: since these are relational data-types, we can maintain a time attribute as another column in the table containing the spatial data.
Internet-GIS	
Can you support Internet-GIS applications with your RDBMS	Yes
VLM	
Very Large Memory (VLM) is not only important for spatial data management support. But because of the performance of a RDBMS in a VLM environment it is important to know if your RDBMS runs in VLM environment	Yes
Other	
Please give an overview of specific advantages or your product for management of large spatial data sets	A selection of replies: • Coordinate System Support, • Whole Earth indexing. Spatial data can be portioned • Performance • Ease of data management • Storage of Geodetic information
Could you give an overview of strategic partnerships within the GIS industry	Most RDBMS providers have strategic partner ships with GIS suppliers
Is your company a member of the Open GIS Consortium	Yes for one RDBMS supplier, No for others
For which specification is your RDBMS Open GIS compliant	One supplier replies: Several specifications, including: Simple feature specification, Open Location Services, GML 2.0 and WKT (Well Known Text). Other suppliers N/A