Spatial Cadastral Information Systems

The maintenance of digital
cadastral maps

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Declaration

This is to certify that:

(i) the thesis comprises only my original work;

(ii) due acknowledgement has been made in the text to all materials used;

(iii) the thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies, appendices and footnotes.

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Abstract

The management of a cadastral system's digital spatial data has prompted considerable research, generally with a focus limited to the organisation maintaining the cadastral map. The approach of viewing the maintenance of cadastral maps as a system encompassing the entire cadastral industry has not been comprehensively studied and documented. This approach is seen as essential to transform cadastral mapping from its current organisation specific isolation, into a form that is truly interoperable with the processing of spatial cadastral information in a digital environment.

This dissertation documents a research program that is essentially a definition and an analysis and design of spatial cadastral systems with particular emphasis on the Australian State of Victoria. The research substantiates the existence of a spatial cadastral system within the overall cadastral system. A review is presented of the analysis of a number of international, western spatial cadastral systems, and establishes the boundary of the spatial cadastral system. An investigation of system methodologies used in cadastral research and information systems concludes the applicability of the Zachman Framework to structure and document the more comprehensive analysis of spatial cadastral systems. This analysis is undertaken for the spatial cadastral systems of the Australian State of Victoria.

The impacting developments, such as enabling technology, coupled with user requirements and issues relating to existing spatial cadastral systems, provides the basis for the presentation of a range of solution alternatives to manage the spatial data associated with the maintenance of the multipurpose cadastral map in a digital and Internet enabled environment.

Acknowledgements

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List of Acronyms

AAS	Australian Accounting Standard
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
ACTLIC	ACT Land Information System
ANZLIC	Australia New Zealand Land Information Council
AP	Approved Plan
ASCII	American Standard Character Information Interchange
BEV	Federal Office of Surveying and Metrology (Austria)
BRP	Business Process Engineering
CAD	Computer Aided Drafting
CASE	Computer Aided System Engineering
CLID	Crown Land Information Database (LIC NSW Australia)
CRM	Coordinated Reference Mark
DCDB	Digital Cadastral Database
DFD	Data Flow Diagram
DNRE	Department of Natural Resources and Environment
DP	Deposited Plan
ERD	Entity Relationship Diagram
ESTE	Electronic Spatial Transfer Environment (Land Victoria Australia)
FIG	International Federation of Surveyors
GDV	Geographic Data Victoria
GI	Geospatial Information
GIS	Geographic Information System
GPS	Global Positioning System
ICSM	Intergovernmental Committee on Survey and Mapping (Australia)
JAD	Joint Application Development

KMS	National Survey and Cadastre (Denmark)
LATIS	Land Tenure Information System (Eden 1988)
LIC	Land Information Centre (NSW Australia)
LIG	Land Information Group (Land Victoria Australia)
LIS	Land Information Systems
LMRI	Land Management and Resource Information (Land Victoria Australia)
LTO	Land Titles Office
MOLA	Meeting of Officials on Land Administration (Europe)
MOU	Memorandum of Understanding
MPC	Multi Purpose Cadastre
MWC	Melbourne Water Corporation (Victoria Australia)
NRC	National Research Council (America)
NSW	New South Wales
OGDC	Office of Geographic Data Coordination
PALM	Planning and Land Management Group (ACT)
PIP	Property Information Project (Land Victoria Australia)
PSMA	Public Sector Mapping Association (Australia)
RAD	Rapid Application Development
RDBMS	Relation Database Management System
SDI	Spatial Data Infrastructure
SDLC	Systems Development Life Cycle
SDTS	Spatial Data Transfer Standard
SSM	Soft Systems Methodology
UFI	Unique Feature Identification
UK	United Kingdom
UN	United Nations

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"The last thing one knows when writing a book is what to put first."

                        Pascal

Maintaining Digital Cadastral Maps

The geometric description of the individual land parcel is the basis of most modern cadastral systems and the fundamental unit of the cadastral map. In turn the cadastral map is becoming an essential component of a country's spatial data infrastructure. The maintenance of the digital spatial data depicted on the cadastral map, is a requisite activity to ensure efficient operation of a jurisdiction's land-related activities.

This chapter will outline the research problem, the research aim and the approach to investigating cadastral map maintenance. The thesis of this research is that there exists a spatial cadastral system that must be studied in its entirety to ensure that the management of spatial cadastral data and the maintenance of the digital cadastral map are effective, efficient and timely.

The research approach is outlined by a brief summary of each chapter's content and its contribution to the structure of the dissertation. The diagrammatic depiction of chapters outlines

1.1 The cadastre

The cadastre is most simply described as a methodically arranged public inventory of data concerning properties within a jurisdiction, based on a survey of their boundaries (Henssen 1995). From a database perspective, this is a land information system where information is referenced to unique, well-defined units of land, normally referred to as land parcels. The outlines of these land parcels are normally shown on large scale maps, are linked to textual land title registers and provide a spatial reference for other spatial or aspatial, parcel related data.

More specifically the International Federation of Surveyors (FIG) published statement on the cadastre (FIG 1995) defines the cadastre as:

"A Cadastre is normally a parcel based and up-to-date land information system containing a record of interests in the land (e.g. rights, restriction and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, and often the value of the parcel and its improvements."

While the terms cadastre and cadastral system are used interchangeably in the literature, the term cadastre tends to refer to the actual cadastral data, whereas the cadastral system is additionally the collection of organisations (people) and procedures that are associated with the cadastral data.

1.2 The cadastral map

The geometric description of individual land parcels forms the building block of a jurisdiction wide map of parcels known as the cadastral map. For many modern cadastral systems around the world the individual geometric parcel description, the cadastral map and the legal register of rights and interests, forms the information database of the cadastral system. In concert with current technology, this cadastral

map, and hence the geometry of the land parcel, is increasingly stored and manipulated in digital format.

Western European countries have been routinely using cadastral maps for nearly two hundred years. In contrast the Australian land titling system does not have a tradition of cadastral maps (Williamson and Enemark 1996). Nevertheless in common with countries that have a mature cadastral system, all Australian states have developed digital cadastral maps, known as digital cadastral databases (DCDB).

These spatial cadastral databases have entered a maintenance phase that involves both updates and upgrades. The incorporation of all changes to the parcel framework, as a result of land development activities such as land subdivision, is referred to as update. Upgrades are corrections, alterations and adjustments to improve the content and accuracy of this spatial cadastral data. In contrast to the varied paths taken by jurisdictions to develop their present digital cadastral maps, the current problems associated with the maintenance of digital spatial cadastral data are similar worldwide.

1.3   The problems of the cadastral map

Unlike small to medium scale topographic data sets, cadastral maps are dynamic; they must reflect the daily changes in the cadastral framework arising from land development. The map of the land parcels is therefore never finished, as it must be constantly updated to keep pace with the subdivision, consolidation or mutation of land boundaries and the titling processes associated with land development.

In addition to the requirement for an efficient and timely process to keep the cadastral map up to date, there is considerable pressure to increase the accuracy of the cadastral geometry data in line with emerging surveying technology. The ever improving accuracy of new information (new surveys) with respect to current digital cadastral maps, means that more accurate spatial data must be incorporated into the existing cadastral maps that are often of a much lower spatial accuracy and reliability.

Land parcels are complex, geometric features with ties to geographical, historical and legal objects. The process of maintaining the cadastral map must ensure the integrity

of spatial cadastral data and the ability to integrate the spatial data with other land-related spatial and aspatial data sets.

The distribution of the spatial cadastral information must take account of the importance of the currency of the cadastral map that provides the infrastructure component for many Geographic Information Systems (GIS) applications. It is important for utility and local government information systems because most of their business information and transactions are related to the land parcel. Cadastral maps are used as a base for delineating utility infrastructure (water, sewer, power, gas and communications) as well as planning and zoning activities, emergency response, tracking crime, etc. The updated cadastral map, and its impending changes, need be made available to all users, in a timely and efficient distribution process.

1.4   Motivation for research

The above cadastral map issues associated with the upgrade and update (maintenance) and distribution of digital, spatial cadastral data must now be dealt with in a digital and Internet enabled environment. Their solution is perceived to be essential to transform digital cadastral mapping from its current organisation specific isolation, into a form that is truly interoperable with the processing of spatial information in a digital environment with Internet service delivery.

Individual organisations comprising the cadastral system have embraced new technology by introducing digital systems to replace or complement existing internal analogue processes. These well documented, individual, technological advances represent both considerable investments and savings, but other organisations in the cadastral system cannot necessarily fully access the digital data or its associated benefits.

The approach of viewing the maintenance of the digital cadastral map as part of the entire cadastral industry has not been thoroughly researched or documented. Indeed maintenance issues associated with users' digital cadastral map versus the jurisdiction wide cadastral map are treated separately and duplicated, even though the organisations are both part of the same government system (NSW 1999). The lack of an information systems analysis approach to the entire spatial cadastral industry has

maintained duplication of processes and data (albeit digital data) inherent in the superseded analogue systems. This represents an under use of the available technology, prohibits access to data, limits the multipurpose application of cadastral data and inhibits the information infrastructure role of the digital cadastral map.

1.5   Aim of research

Digital cadastral maps are undergoing continual incremental change in terms of their content, accuracy and purpose. The aim of this research is to bring a formal information systems approach to the system that manages the spatial cadastral information that is the basis of these cadastral maps. This involves a number of subsidiary aims, namely to:

- verify and define the spatial cadastral system;

- fully understand the range of cadastral maps;

- conduct an in depth analysis of the spatial cadastral system using suitable analysis methodologies and documentation constructs;

- investigate the alternative models to achieve effective, efficient and timely maintenance and distribution of the spatial cadastral data.

1.6   Research approach

The research approach involves the application of formal systems methodologies to analyse and document a spectrum of western spatial cadastral system with particular emphasis on the spatial cadastral systems of the Australian states of Victoria and New South Wales. This approach takes account of all the organisations, processes, data, etc with spatial cadastral data to maximise the benefits of current technological for a multi-agency, multi-user digital environment.

The cadastral maintenance and distribution alternatives, arising from the systems analysis approach, take into account the current digital and Internet enabled environment within which that cadastral system and the cadastral map exist and operate. The systems methodology is applied in *top down* approach to encompass all the organisations in the defined spatial cadastral system. This is in contrast to other

studies that have concentrated on specific organisations or processes within the cadastral system in essentially a *bottom up* approach.

1.7 Research History

This dissertation represents a part time study over seven years from 1994. The timeframe of this research has coincided with a period of significant economic, organisational and technological change. A time in which organisations within cadastral systems undertook considerable reassessment of their cadastral mapping to accommodate the new ways that spatial cadastral data could be collected, manipulated and distributed. In 1994 most Australian states had just completed the capture of their digital cadastral maps (DCDB). The then economic imperative to recover the cost of DCDB capture, focused custodians on the requirements of the paying users of DCDBs (Wan and Williamson 1995), such as utilities and large local councils. This is in contrast to a current vision that aims to provide access to geospatial information for all users at minimum cost (Land Victoria 1999c).

The research approach required an examination of the institutions that are involved in the collection, verification, manipulation and use of spatial cadastral data. The research was conducted with the full cooperation of the DCDB custodians of both New South Wales (LIC, Land Information Centre) and Victoria (GDV, Geographic Data Victoria now incorporated into Land Victoria). Considerable time was spent visiting councils, utilities and land titles offices in both of Victoria, NSW and Queensland. Throughout the research period, feedback on research progress and findings was sought from these organisations through a regular program of research visits and on site seminars. The involvement in the workshop on DCDBs, involving all Australian states and New Zealand (PSMA, 1996 #11), allowed first hand consideration of the needs and problems of maintaining a nation wide DCDB sourced from independently developed DCDBs.

A critical component of the research was the international fieldwork undertaken in the UK, Austria, Switzerland and Denmark. The main emphasis was research and discussion with experts in GIS research and practice, specifically relating to the creation, update and the upgrade of digital cadastral maps for individual countries.

These experts included Peter Dale (England), Gerhard Muggenhuber and Andrew Frank (Austria), Daniel Steudler (Switzerland) and Stig Enermark (Denmark).

Visitors to the Department of Geomatics at the University of Melbourne provided further research opportunities. These included John McLaughlin (University of New Brunswick Canada), Bill Robertson (former Director-General/Surveyor General New Zealand) and George Benwell (Otago University New Zealand). This spectrum of international experts kindly provided the resource that widened the research focus to include non-Australian and hence non-Torrens Title jurisdictions. This afforded the continual opportunity of discussing and verifying the research against spatial cadastral systems other than those of Australian states.

1.8   Dissertation Structure

A necessary premise for the research aim is to validate the existence and system status of the spatial cadastral system. Chapter 2 defines the context of the spatial cadastral components within the cadastral system, and mindful of the concepts of the multipurpose cadastre, spatial data infrastructure and sustainable development. A crucial outcome of this chapter is that the cadastral system can be clearly divided into a spatial and a textual component, but also that there are a number of spatial components identifiable as subsystems of the cadastral system. This validates the thesis that the maintenance of the digital cadastral map can be analysed as an identifiable spatial subsystem of the cadastral system.

Chapter 3 presents a spectrum of modern cadastral systems to provide an international perspective to the study area. A full appreciation of the spatial cadastral system and specifically the maintenance of the cadastral map necessarily involves consideration of cadastral systems in general. It is not the intention of this research to present the definitive work on cadastral systems, rather a range of cadastral systems are presented in this chapter to give a broad understanding of the systems within which the digital cadastral map is created, maintained and used. Five western cadastral systems are documented using a structured approach to define the boundary of the spatial cadastral system that manages the spatial cadastral data used to maintain the cadastral map. Another outcome of this chapter's analysis is a better understanding of the range

of cadastral maps that support cadastral systems. The commonalities in the high level processes that are instrumental in the maintenance of the spatial cadastral map further substantiate the bounds of the spatial cadastral system.

The documentation of a range of spatial cadastral systems, presented in chapter 3, provides the necessary understanding for discussion of systems analysis and design methodologies undertaken in chapter 4. The focus of chapter 4 is a review of the system methodologies and modelling techniques utilised in the documentation and analysis of cadastral system specifically and information systems generally. This review is undertaken to justify the systems analysis and design approach that structures much of the remainder of the thesis.

The Zachman Framework (Zachman 1987), a structure to analyse, design and document enterprise information systems, is fully described and the application of the framework to cadastral systems and particularly spatial cadastral systems is argued. Additionally chapter 4 gives a useful comparison of what are often considered competing systems methodologies and a considered assessment of how these methodologies may be applied in a complementary approach under the framework.

Building on the understanding of spatial cadastral systems developed in chapter 3, chapter 5 briefly documents the historical setting of Australian cadastral systems and cadastral maps. This provides background for the comprehensive system analysis of the spatial cadastral system of the specific Australian State of Victoria. A similar but less in depth analysis for the Australian State of NSW was also undertaken and is presented in Appendix 1.

The usual single organisation concept of the Zachman Framework is expanded to cover all organisations that constitute the spatial cadastral system defined in chapter 3. The dimensions of the Framework provide a simplifying structure for the description of the Victorian spatial cadastres system. Each dimension of the spatial cadastral system is analysed at the inventory list perspective and the model perspective. This business model perspective uses, where possible, the standard and well documented diagrammatic tools from information systems analysis.

The detail presented in chapter 5 and Appendix 1 is the analysis information derived during numerous research visits to the organisations within the spatial cadastral system for the state of Victoria and NSW over the period of the research. The field research repeatedly conducted at these organisations involved standard systems analysis techniques of observation, seminars and documentation gathering. Where possible published diagrams and descriptions are extracted and classified according to the dimensions of the Zachman Framework.

The impacting developments such as enabling technology and issues arising from user feedback relating to existing spatial cadastral system are presented in chapter 7, using the dimensions of the Zachman Framework as the delineating structure. An increased understanding of these impacting developments and complex issues is achieved by their mapping to the framework dimensions. Addressing the spatial cadastral issues in a dimension specific manner is intended to more accurately reflect in what dimension the solution model should be developed.

Often the financial, regulatory and policy constraints of business are a result of past system and technology constraints. Chapter 7 presents the range of alternatives available to maintain the spatial data associated with the multipurpose cadastral map in an enabling digital and Internet environment. The structure and application of these models is aligned with the spatial cadastral systems of the Australian states and specifically the state of Victoria.

Chapter 8 fully defines a model to manage the flow of spatial data that updates the cadastral map. The design of this update model encompasses the requirements of the spatial cadastral system to digitally progress the spatial cadastral data through the cadastral process and simultaneously the cadastral map maintenance process. The documentation of the spatial cadastral update model is structured using the six dimensions of the Zachman framework.

Chapter 9 presents a summary of the conclusions from each part the study. The criteria of efficient, effective and timely management of the spatial cadastral data are reviewed within the six Zachman system dimensions. The application and success of the Zachman Framework for this thesis is reviewed. Lastly opportunities for further research are discussed.

In reading the thesis each chapter is prefaced by a short chapter overview. This overview is intended to convey the aim of the chapter, a brief indication of the chapter's content and the primary conclusion of the chapter. Figure 1.1 is a diagrammatic summary of the structure of the dissertation.

Figure 1.1   Dissertation summary

1. Introduction

outlines the cadastral maintenance problem, the aim of the research and the approach of this thesis

2. Spatial Cadastre?

substantiates the existence of the spatial cadastral system within the context of western cadastral systems

3. Cadastral Systems

overview of western cadastral systems to define the spatial cadastral system and understand the range of cadastral maps

4. Structured Approaches

consideration of structured systems approaches for cadastral information systems research and justification of the Zachman Framework

5. Structured Analysis

inventory and model based documentation of the analysis of the spatial cadastral system of Victoria, Australia under the Zachman Framework

6. Issues

classify requirements and impacting developments associated with the management of the spatial cadastral data

8. Update Model

documents a conceptual model for cadastral map update in a digital environment

7. Maintenance Models

presents a range of dimension specific spatial cadastral maintenance models with particular emphasis on possibilities for the Australian states

9. Conclusion

summary of the chapter conclusions, review of criteria for management of spatial cadastral map within the dimensions of the spatial cadastral system, assessment of the application of the Zachman

"*Cadastral systems are not ends in themselves.*" (UN-FIG 1996)

The Context of Spatial Cadastral Systems

This chapter aims is to show the context of the cadastral map within a jurisdiction's cadastral system. While this highlights aspects of cadastral maps that have their origin in a nation's cultural and fiscal history, this chapter's purpose is to show that the cadastral map and its maintenance is a distinct subsystem of a cadastral system.

This chapter reviews the literature pertaining to cadastral systems, their analysis and conceptual modelling. These multipurpose cadastral models depict cadastral systems as fundamentally consisting of a spatial and textual component, with the spatial component (the spatial cadastral system) constituting subsystem within the context of the cadastral system.

This chapter's examination of cadastral system models highlights the accepted separateness of a cadastral map and its maintenance. This accepted separateness legitimises this thesis' research focus on the maintenance of the cadastral map as

separately examinable subsystem of the cadastral system.

2.1   Historical perspective

The origins of fiscal cadastres that support a system of land valuation, and land tax can be traced to Egyptian times (Dale and McLaughlin 1988). On the other hand juridical cadastres, information systems that underpin the legal registration of land in support of land transactions are far more recent. Over time many of these cadastral systems have evolved beyond their primary purposes to provide the basis for general land administration systems (Ting and Williamson 1999). Therefore for any jurisdiction, the current cadastral system is a unique product, evolved from its initial design function in a manner that is specific to the cultural and social history of the jurisdiction within which it has evolved. This proposition is reinforced in the paper *Understanding Cadastral Maps* (Williamson and Enemark 1996), which details the development of the cadastral systems and the cadastral maps of Australia and Denmark.

Evolving differences and subsequent incompatibility of cadastral data sets can extend to specific jurisdiction levels within a single nation. A workshop for digital cadastral databases (DCDB) for New Zealand and the Australian states concluded that:

"The considerable diversity between different DCDBs came as a surprise to some and reinforced that jurisdictions have different cadastral systems, different title registrations systems and different methods of maintaining and updating their DCDBs." (PSMA 1996)

Fuller historical overviews of cadastres can be found in the book *Land Information Management: An introduction with special reference to cadastral problems in Third World Countries* by Dale and McLaughlin (1988), while Williamson's Ph.D. thesis, *A Modern Cadastre for New South Wales* (Williamson 1983), provides background information on some additional western cadastral systems. Readers will find country or state specific histories are offered by many authors when describing the current status of their jurisdiction's cadastral systems: Denmark (Williamson and Enemark 1996), Austria (Höflinger 1993), Germany (Hawerk 1995), Australia (Williamson and Enemark 1996), Australia, Queensland (Cook 1994), etc.

These authors indicate that present day western cadastres have their genesis in 19th Century Napoleonic Europe. These cadastral systems, and their supporting maps, have evolved significantly different roles within each of their juridical cadastral systems, indeed the changing role of the cadastre is itself a significant research area (Ting and Williamson 1999). Irrespective of their historical, social and cultural underpinnings, and their technical differences, the cadastral data within these cadastral systems fulfil wider roles than were originally intended. It is now recognised that an effective cadastral system is the basis for an efficient real estate market and fundamental for an efficient system of sustainable land use management (UN-FIG 1996).

2.2   Development of cadastral models

The examination of the development of cadastral models over the recent years is undertaken to determine the context of spatial cadastral data within cadastral systems. The documentation of the context of the cadastral map within cadastral systems will ensure that the latter sections of this research, dealing more specifically with cadastral map maintenance, will properly account for all the intended uses and users of the map data.

The utilisation of the cadastral map with respect to legal registration of land, ranges from the maps being charting or index maps for other legal instruments, to the maps being the legal determination of the land parcel boundary (legal cadastre). Recent theoretical perceptions of cadastral systems provide the temporal track that depicts the initial formal recognition of multipurpose cadastres, to the cadastral map being recognised as an essential infrastructure component within sustainable development (UN-FIG 1999). Dale (1979) depicted a model of the cadastre from a systems or holistic viewpoint. Figure 2.1 shows the connections between the broader uses and users of cadastral data. While this model heralds the multipurpose role of the cadastre, multipurpose was more precisely defined by the American National Research Council (NRC 1980).

Dale's system view depicts both the multi-user view of the cadastre and the central role of the cadastre. The holistic system view generates a model of the cadastre that incorporates data (e.g. legal cadastre), activities or functions (e.g. land development),

and the organisations or people involved (e.g. lawyers). In addition he has attempted

Figure 2.1 shows a triangular diagram with apex labeled (planners) LAND and base corners (lawyers) and (public). The base is labeled LAW, Courts, GOVERNMENT, professions, PEOPLE. The left side shows Land Use, LAND TENURE, administration. The right side shows Land Development, LAND ECONOMY, money. A circle in the centre labeled CADASTRE is divided into multipurpose cadastre, legal cadastre, and fiscal cadastre. Outside influences HISTORY, TECHNOLOGY, EDUCATION point to the upper left.

to show the outside influences on the system (e.g. technology).

Figure 2.1   A Systems View of the Cadastre (Dale 1979)

Apart from the different types of cadastres Dale further depicted the cadastre as containing quadrants that represent the surveying activities of demarcation, adjudication, survey and description.

2.2.1   Cadastral data models

With the development of centralised digital information systems in the late seventies and early eighties, theoretical, data focused models were presenting themselves to position cadastral systems within Land Information Systems (LIS). Large LIS were envisaged to integrate (and centralise) all land related data for specific regions. A definition for an LIS adopted by the International Federation of Surveyors reads:

"A Land Information System (LIS) comprises the systematic compilation of all the relevant data of a region with respect to soil and ground as a basis for legal actions,

administration and economy as aids in the planning and development for the maintenance and improvement of the standard of living." (Andersson 1981)

The integration of data, with the cadastral map as the central base map in these LIS, demonstrates the multipurpose and centralised view of the spatial cadastral data as depicted in Figure 2.2. In analogue cadastral systems the cadastral map has long been used as a charting or index map to other cadastral information and legal instruments. In the 1980s, a critical observation was the recognition of the role of the digital, cadastral parcel as a fundamental unit of the data models associated with LIS; additionally there was a recognition of the multipurpose use of the cadastral data to service the information needs of the public and private sector, and individual users.

Figure 2.2   Integrated LIS (after Dale 1979)
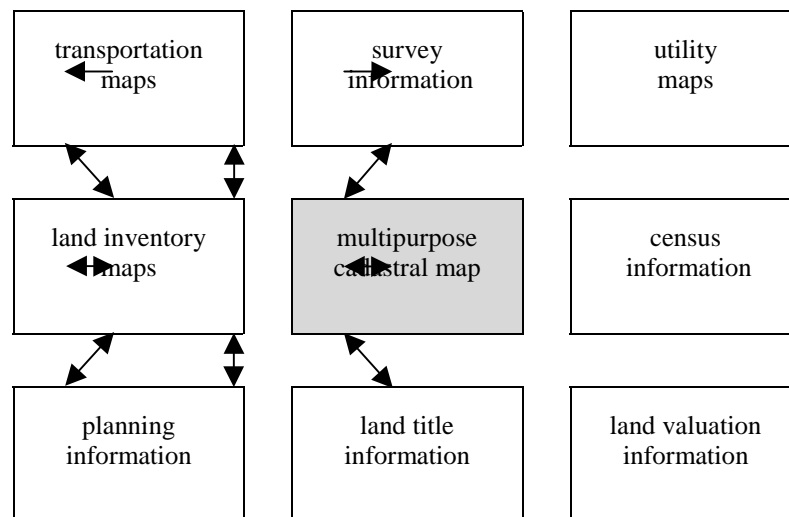
The report by the American National Research Council (NRC 1980) presents a conceptual model that depicts the components of the multipurpose cadastre. The structural diagram in Figure 2.3 is an early data model that identifies the cadastral data (along with topographic maps and the geodetic framework) as infrastructure. It clearly shows the interdependency of the spatial data, spatial data ranging from the geodetic framework to the cadastral overlay data (e.g. utility asset information), a required interdependency of spatial data to achieve the integration depicted in Figure 2.2.

The NRC model of Figure 2.3 provides the basis for other conceptual models for the cadastre, a number of which are presented in the latter part of this chapter (Eden 1998 and Williamson 1983).

Figure 2.3   Components of a Multi-Purpose Cadaster (NRC 1980)

Title & Fiscal Records	Administrative Records	Natural Resource Records	Other Land Records

Linkage Mechanism

Cadastral Overlay

Base Maps

Geodetic Reference Framework
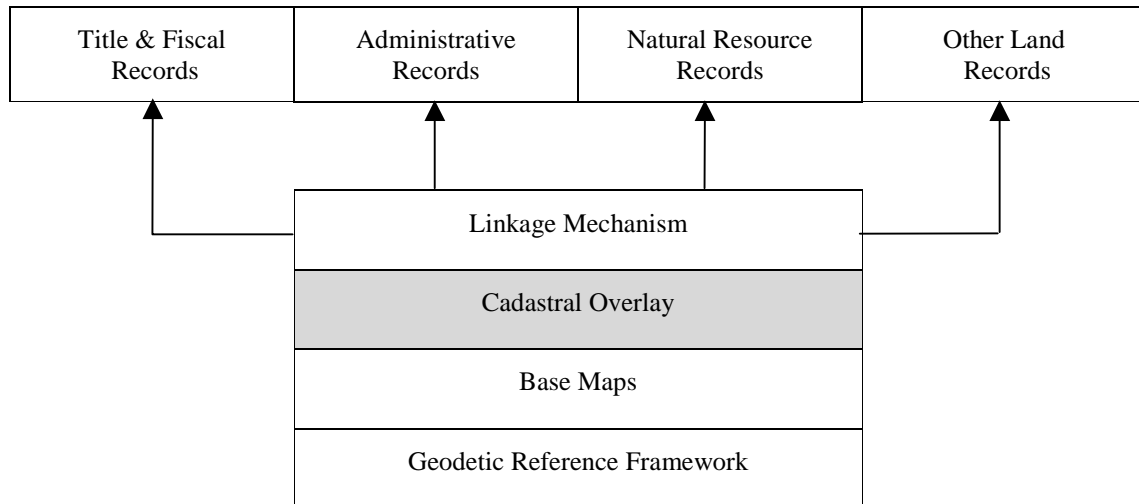
The goal of most of these data models was the integration of varying types of land-related data to provide truly comprehensive land information systems. Consistent with centralised computing and the pre-Internet era, the conceptual models, and the subsequent information systems, needed to be bounded to ensure their successful implementation.

2.2.2   Cadastral organisational models

For the interpretation and comparison of the cadastral models presented it is necessary to understand the different possible dimensions of the systems. Figure 2.1 is a holistic, view of the entire cadastre, while Figure 2.2 and 2.3 are more data focused.

In his thesis, *A Modern Cadastre for New South Wales*, Williamson (1983) developed a model of a cadastral system emphasising the organisational structures (see Figure 2.4). An abbreviation of Williamson's conceptual model is depicted in Figure 2.4. (The original full model expands the cadastral database to detail the data and functions of this component.)

In this model the cadastral database organisation, with its primary functions of cadastral surveying and title registration, maintains the ownership data and parcel data of the system. This cadastral database provides the foundation of a centralised land information system, which manages all the data in the overall information system.

Figure 2.4   Conceptual Model of a Cadastral System for NSW (Williamson 1983)
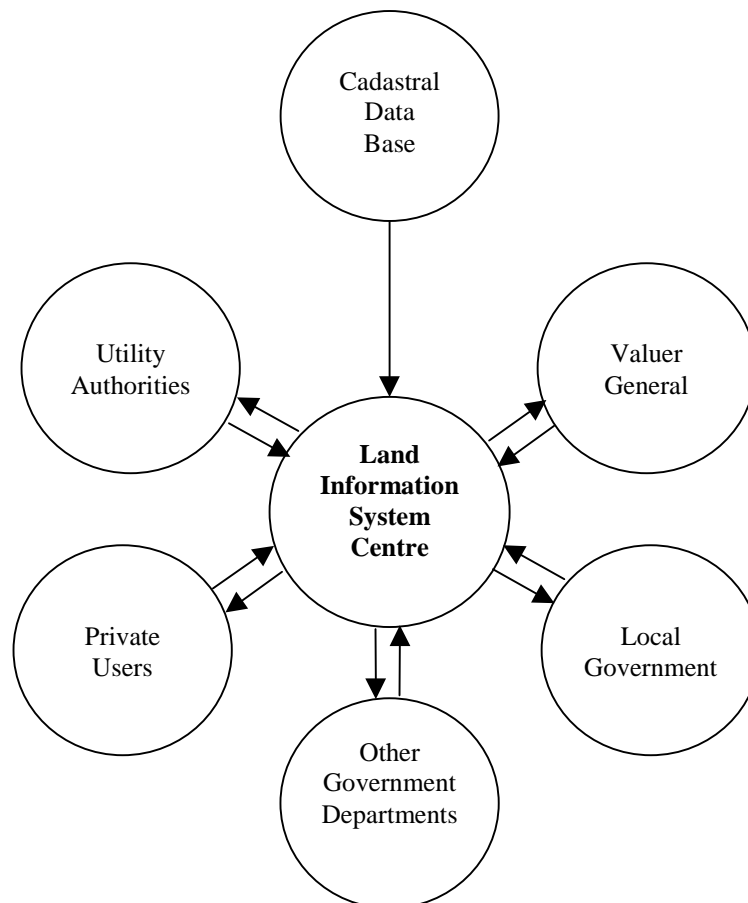
Two characteristics of this conceptual model are important to note. First the up-to-date cadastral data is distributed to other organisations, providing the spatial reference for their information systems. Cadastral information in digital format had moved from being in support of the land titling system to a wider multipurpose role. Second the data maintained by each of the users is linked back to the LIS Centre for distribution to other users. The model proposes a two-way information flow, with the LIS Centre as the information broker and the unique lot and plan number of the cadastral parcel as

the method of linking and integrating the data. Digital Cadastral information had moved to an infrastructure role that facilitated sharing of data across organisations.

If account is taken of their data or organisational focus, any two models may not necessarily be incompatible. The dimensions of the system (data, organisational, functional, etc) are important aspects of a comprehensive analysis. This concept of a system dimensions to ensure comprehensive systems analysis is examined in later chapters of this study using the Zachman Framework (Inmon, *et al.* 1997).

2.2.3   *The cadastre and sustainable development*

In addition to the functions associated with land tenure, Enemark (1998) sees the purpose of the cadastral systems as necessary infrastructure to assist in the management of land and land use, to enable sustainable development and environmental improvement. Specifically Enemark presents a concept of the cadastral system as a basic infrastructure component to support the different business systems in the area of land administration. Enemark (1998) cites these systems as:

- Land Tenure Systems –to secure legal rights in land;

- Land Value System – to levy tax on market value of land;

- Land Use Control System – to enable land use planning;

- Land Development System – to enable regulation of land development.

Figure 2.5 depicts the role of the cadastre as a basis of these land business systems. Enemark sees the design and operation of these business systems leading to efficient land markets and effective systems of land use administration. Efficient and effective operation of these business systems was cited as the basis of a sustainable approach to economic, social and environmental development.

The cadastre within the triangle, with apex labels of land use, land tenure and land value, signifies the multipurpose role of the cadastre to provide the link between these business systems and their data.

2.3 Context of spatial cadastral systems

The models of the cadastral systems reviewed demonstrate the changing concepts of the cadastre. Concepts that represent cadastres that have moved beyond their conceived primary function and restricted usage. The models reflect the infrastructure role of cadastral data by depicting it as the basic or central component. The parcel based data and its identifiers provide the necessary means by which other geo-information is linked. Figure 2.5 shows this relationship for land business systems.

Figure 2.5   Conceptual Model for sustainable development (Enemark 1998)

LAND TENURE

CADASTRE

LAND VALUE   LAND USE

SUSTAINABLE DEVELOPMENT
ECONOMIC —— **SOCIAL** —— **ENVIRONMENTAL**

LAND USE

CADASTRE

LAND TENURE   LAND VALUE

EFFICIENT LAND MARKET   EFFECTIVE LAND USE ADMINISTRATION

LAND TENURE	LAND VALUE	LAND USE	LAND DEVELOPMENT
TITLES MORTGAGES EASEMENTS	ASSESSMENT OF LAND VALUE	POLICIES AND SPATIAL PLANNING	CONSTRUCTION PLANNING AND PERMITS
SECURE LEGAL RIGHTS	COLLECTION OF PROPERTY TAX	CONTROL OF LAND USE	REGULATION AND IMPLEMENTATION

CADASTRE

IDENTIFICATION OF LAND PARCELS

REGISTER & MAPS

THE ROLE OF THE CADASTRE
TO FACILITATE AN EFFICIENT LAND MARKET AND EFFECTIVE LAND USE ADMINISTRATION

Eden (1988) describes the cadastral system as providing a *core* of information for a multipurpose cadastre. The multipurpose usage of cadastral data is reflected in the use of parcel based information systems by a variety of users not necessarily directly involved in the cadastral system or land administration. Non-land related business

systems include such business systems as vehicle dispatch and monitoring systems, state and national census collection, etc.

The digital nature of the cadastral data has promoted new users and enhanced its usage by traditional users. In the report, *Land Information Vision for Victoria,* Williamson (1996) provides an exhaustive list of both traditional and potential new users and uses of land information for which the cadastral data is regarded as a basic component. The scope of the present and potential users of the cadastre clearly identifies the extent of the multipurpose usage of cadastral data. Current land administration systems are still primarily focused on cadastral data, and structured to suit 19th Century paradigms of land markets and newly industrialised societies (Ting and Williamson 1999).

2.4   Cadastral system components

The literature and the models presented often use the terminology of cadastre, cadastral systems, cadastral data and cadastral maps interchangeably. It is not always sufficiently clear whether the authors are referring to the entire cadastral system or specific cadastral components.

Fundamental to this study is that the maintenance of the cadastral map can be viewed as a separately examinable subsystem within the overall cadastral system. The models presented indicate that the cadastre consists of a number of components such as land register, maps and survey data. For the purpose of this study it is essential to identify the spatial subsystems of a cadastral system and specifically to identify the maintenance of cadastral map as a subsystem of a multipurpose cadastre. The cadastral map that fulfils not only its fiscal and juridical requirements but also the requirements of sustainable development. For the purposes of identifying these separately examinable subsystems, the cadastral system will be reviewed by examining data and organisational dimensions.

2.4.1   Cadastral data components

In Figure 2.5 the cadastre has the components of register and maps. The FIG statement on the Cadastre (FIG 1995) describes a cadastral system as containing a record of legal interest in a land parcel and a geometric description of that land parcel. Eden

(1988) describes these two components of a cadastral system using the terminology of spatial data, and textual data.

In defining the domain of cadastral systems Henssen (1995) uses the term land recording to describe the two complimentary components of land register and the cadastral map.

Henssen (1995) defined the cadastral map as:

"The outlines of the property and the parcel identifier normally are shown on large-scale maps which, together with registers, may show for each separate property the nature, size, value and legal rights associated with the parcel."

The land register Henssen defined as:

"Land registration is a process of official recording of rights in land through deeds or as title on properties. It means that there is an official record (land register) of rights on land or of deeds concerning changes in the legal situation of defined units of land."

This reflects the situation in Europe where the register is separate from the *cadastre*. The register of legal property information is often termed the Land Registry or the Germanic term *"Grundbuch"* (land book). This land register records the ownership, legal rights, restrictions and responsibilities relating to each individual land parcel.

The workshop on the objects (components) in the *cadastre* by MOLA (Meeting of Officials on Land Administration, Oslo 1997) was an initiative of the Economic Commission for Europe. The paper by Wolters (1997) presented at this workshop, lists components of the Danish *Cadastre* as:

1. the register of parcel information;
2. the register of control points;
3. the individual surveys relating to parcel boundaries;
4. the cadastral map.

The register of parcel information contains amongst other textual data the property number, the area, and plot details if the parcel consists of more than one plot (Enemark

1987). In Denmark this textual register of parcel information exists in addition to the Land Register.

This geodetic framework is an infrastructure component for the survey and mapping activities of a nation. The register of control points is a necessary adjunct to the cadastral system, to ensure that the parcel survey information is tied to the geodetic framework of the jurisdiction, and hence ensure the spatial compatibility of individual surveys. While control points are essentially spatial (point) information, their textual attribute information is easily stored in aspatial computer databases.

The individual surveys relating to parcel boundaries are often termed subdivision plans or measurement sheets. These contain the necessary survey information to fully describe the geometric attributes of the parcel and the rigorous mathematics to assure the integrity of the parcel's dimensions and its position on the earth's surface. These plans are normally stored physically or digitally (scanned plans) or the actual survey measurements are entered into a survey database from which, amongst other things, the geometric description of the individual parcel can be generated.

The individual cadastral surveys provide the basis of the cadastral map. Where the cadastral map is a survey accurate representation of all land parcels, the map is in effect, a continuous cadastral survey plan (Höflinger 1992). This is the case in some European cadastral systems where the geometric description of the land parcel for the purposes of the land title has always been held as a map. This type of cadastre has also been referred to as a coordinated cadastre (Williamson and Hunter 1996).

In some jurisdictions, such as in the Australian states, there has not been a history of cadastral maps and recent digital cadastral maps have been digitised from the best available non-contiguous, paper maps (Williamson and Enemark 1996). The emphasis was for these cadastral maps to show an up-to-date, complete and topologically correct cadastral framework. This cadastral map, where each parcel corner is an approximation of the surveyed coordinates, is often termed a graphical cadastre.

The above descriptions are not intended to define the cadastral system, rather they serve to explore the spatial and textual components of cadastral systems. The textual component of cadastral systems consists of one or more registers, but more

importantly the spatial component has three distinct elements. Dale (1988) identifies the three spatial elements of a multipurpose cadastre as the *geodetic network* providing the spatial framework for *survey plans* and large scale *maps*.

The following two models further substantiate the separateness of these three spatial components. In his thesis *Modelling for Land Information System Development in Australia and in particular Queensland,* Eden (1988) proposes a model for a Land Tenure Information System (LATIS). LATIS, as depicted in Figure 2.6, is proposed as a subsystem within Eden's concept of the multipurpose cadastre and in which separate reference is made to the three spatial components of the cadastre (shaded portions)

Figure 2.6   Conceptual Model of a LATIS for Queensland (Eden 1988)
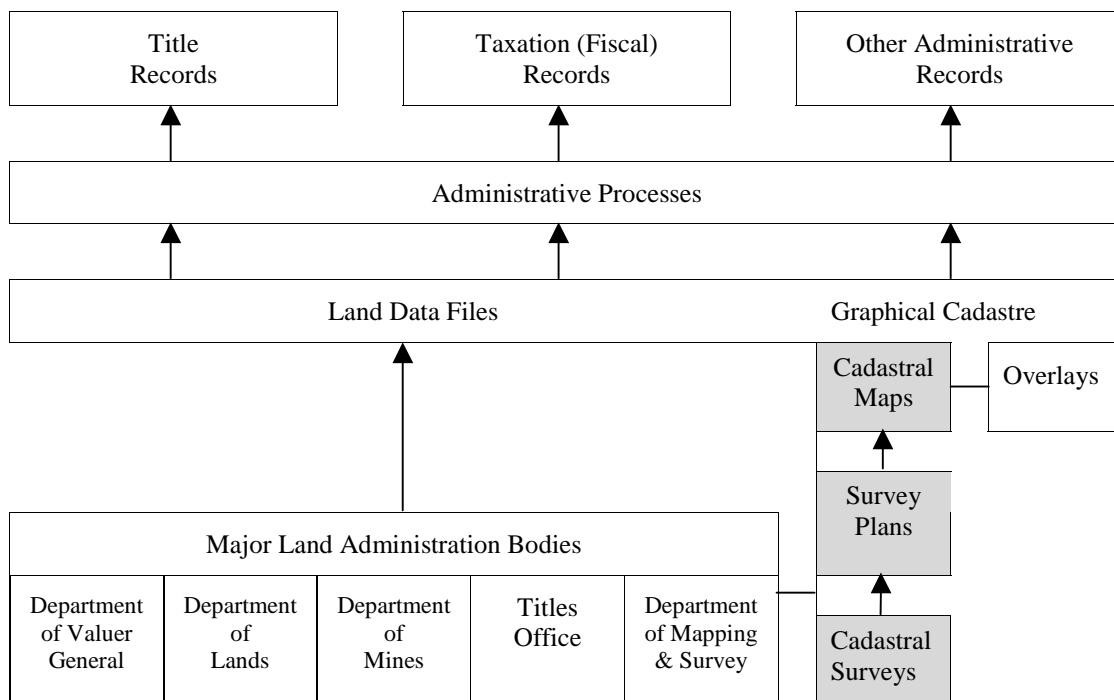
In Figure 2.6 the Survey Plans and Cadastral Map components are grouped under the *Graphical Cadastre*. The geodetic framework component is less clearly identified. In the extended multipurpose cadastral model for Queensland (Eden 1988), the Cadastral Surveys component is linked to a system of monuments provided by the geodetic framework. The Land Registry component is the Title Records.

A similar set of spatial components is diagrammed by Toms *et al.* (1987) when discussing the conceptual model for a cadastral and Land Information Systems for the Australian State of South Australia. The relevant portion of this parcel based system is reproduced in Figure 2.7, the shaded portion again depicting the spatial components.

Figure 2.7   Cadastral portion of a larger LIS (Toms*, et al.* 1987)

Digital Cadastral Data Base	Land Registration System
Cadastral Survey System	Conveyancing System
Geodetic Reference Framework	
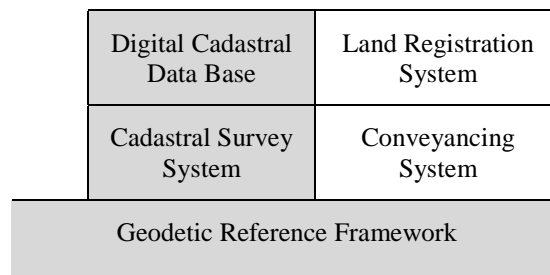
This separateness of the cadastral map component is consistent across the Australian states, where the digital, state wide cadastral map is a relatively new product and was not specifically created to support the land registration process of each state's titles office. In Australia the cadastral map is known as the Digital Cadastral Database (DCDB). This is largely in the recognition of the fact that the first state wide cadastral maps were created in the late 1980s and early 1990s as digital maps.

Not only does the cadastral system consist of distinct components, their separateness can be further substantiated by the different organisational structures that have evolved to maintain each component.

2.4.2   Cadastral organisational components

The organisations that maintain the different components of the cadastral system have evolved, in some cases, over hundreds of years. These organisational structures are specific to each jurisdiction's cultural, social and legal history. As an example, the systems approach adopted by Eden depicts a model (Figure 2.6) that incorporates the five major departments in the Australian State of Queensland concerned with land administration (also associated data and processes).

Generally the land register is textual and handled either by the local courts, or a title's office, specifically created to administer the legal transfer of land and maintain appropriate legal instruments. The spatial components of the cadastre are normally

under the governance of the jurisdiction's survey and mapping organisations. These may be separate departments within a single government. England probably provides the best example of the division of the spatial and textual components, both from a data and organisational viewpoint. The system of title registration is the domain of Her Majesty's Land Registry, while the supporting spatial component in the form of large scale topographic maps are the exclusive function of Ordnance Survey (Dale 1976).

In their report *The Establishment of a Coordinated Cadastre for Victoria,* Williamson and Hunter (1996) concede the institutional separateness of the components of the cadastre by recognizing the need for their coordination. They strongly recommend that a single authority coordinate the maintenance and quality assurance activities of all title registration, land transfer, cadastral surveying and mapping functions.

The creation and maintenance of Australian DCDBs was undertaken by either the survey and mapping organisations of each state, or a structure within government was created to coordinate the creation of the DCDB. These digital cadastral maps are updated by the registered survey plans released by Titles Office. The Torrens Title system means that the individual survey plans fall under jurisdiction of the Land Titles Office, where the geometric parcel description forms part of the land register.

The brief review of organisations involved in the cadastral system gives further credence to the concept of three separate but closely related spatial systems The Australian Capital Territory, has both the most accurate spatial cadastral data and an integrated organisation structure responsible for spatial cadastral data (PSMA 1996). Under this organisational structure, Williamson (1987) proposed that even in a digital environment for the cadastral data there would be separate databases for the cadastral map, the survey plan detail and the supporting geodetic framework information.

2.5   Conclusions

The cadastral process of any country can be viewed as a system; in fact the literature inevitably refers to a jurisdiction's cadastre as a cadastral system. These cadastral systems are depicted as having textual and spatial information; a geometric description of the land parcels, linked to the textual records or registers describing the nature of interests and ownership of the land parcel.

The models presented support the concept of the spatial cadastral subsystem, within the overall cadastral system. The computerisation of textual cadastral information closely followed the introduction of large computer databases in the late nineteen seventies and early eighties. This textual information and associated manual systems were obvious candidates for computerised non-spatial (aspatial) databases. Clearly the textual cadastral information was seen to constitute a computertisable subsystem, further substantiating the concept of the spatial cadastral subsystem.

Closer examination of the components that can make up a spatial cadastral subsystem actually reveals a number of interdependent components. The spatial components are the survey control points, the cadastral survey plans and the cadastral map. While recognising the interdependence and possible duplication of function, two factors indicate that these cadastral components constitute subsystems of the cadastre:

- When the data dimension of the cadastral system components are examined, the textual land register and the spatial components (the cadastral map, the survey plans and the geodetic framework) exist as individual information repositories, albeit not all are necessarily present in all cadastral systems.

- The organisational dimension of the cadastral systems indicates that traditionally the responsibility of the individual cadastral components is spread across a number of organisations within government. There is a trend to bring these organisational components together (Kaufmann and Steudler 1998), nevertheless, even when the organisations are merged or coordinated, the components while integratable are treated separately. The separate operation of managing these components of the cadastral system while obviously being part of the overall cadastral system is the standard definition of a subsystem.

The cadastral map is a separate component able to be studied as a bounded subsystem in support of or utilised by the cadastral system. The separateness is not only important for this research but also to allow the cadastral map to fulfil its multipurpose role and to be used as a spatial infrastructure component.

The conceptual models in this chapter portray the separateness, yet interdependence, of the spatial cadastral components in a hierarchical or dependency model. This

separateness, yet interdependence, of the cadastral components could also be represented as an interaction, as depicted in Figure 2.8.

Figure 2.8   Interaction of cadastral components
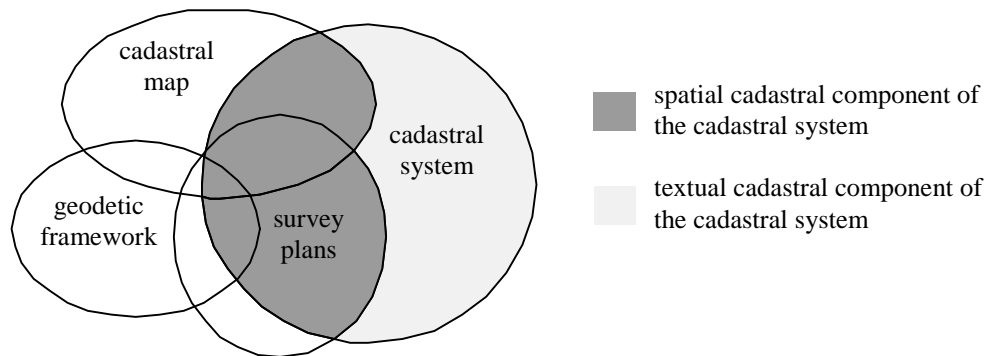
In Figure 2.8, the cadastral map constitutes a component of the spatial information of cadastral systems. This form of diagramming allows some observations about the conceptual level of overlap or interaction. Where the cadastral map is not the legal description of the parcel this spatial component is a less tightly integrated subsystem of the cadastral system.

The absence of a cadastral map in the Australian Torrens Land Title System would mean that the cadastral map is largely external to the cadastral system. Conversely, where the cadastral map is a representation of the legal parcel boundary, each of the three spatial components, while being possible separate subsystems, will be more tightly bound or integrated with each other and the cadastral system.

The models examined in this chapter represent some of the concepts of cadastral systems in western countries. These cadastral systems are shown to increasingly operate in a digital environment and need to evolve to respond to the opportunities offered by technology to service the information needs of society. The cadastral data is depicted to be multipurpose, to service a wide range of users and innovative uses outside it traditional land tenure role. The recognition that cadastral data is able to facilitate the integration of a broad spectrum of digital information in any jurisdiction has promoted the concept of cadastral data as an infrastructure data. The models show that cadastral data must contribute to spatial data infrastructure, to facilitate the integration of data and support spatial information business systems critical to

sustainable economic, social and land development. This study is undertaken with the recognition that the cadastral system's data serves a multipurpose and infrastructure role.

3

It is always a mistake to assume that what works in one country, will necessarily work in another.
(Dale 1995)

The Spatial Cadastre and Cadastral Maps

The purpose of this chapter is to review and document a number of cadastral systems to gain an understanding of the spatial cadastral component, identified in Chapter 2, specifically the cadastral map and its maintenance process.

A number of modern, western, cadastral systems are examined to define the spatial, cadastral subsystems that support the maintenance of the cadastral map, a map that is increasingly a digital cadastral map. The analysis highlights the organisations, processes and data that constitute the spatial cadastral subsystems. The consistent documentation across these cadastral systems provides a basis for the high level definition of spatial cadastral systems and the examination of a range of cadastral maps and processes that are instrumental in the maintenance of spatial cadastral data.

A high level understanding of cadastral maps and their maintenance processes is fundamental for defining the boundaries of the spatial cadastral system, and provides an international perspective

3.1   Introduction

Understanding and modelling the spatial cadastral system is an important phase in the research aim of eventually formulating models for the maintenance of spatial cadastral data. The starting point for detailed analysis of a system is the identification of the system boundary. This phase is common to the information system development life cycle, is specifically a requirement of traditional information system development and also the modern practice of Business Process Reengineering (BRP) (Covert 1997).

The aim in this preliminary stage is a high level review and documentation of a spectrum of existing, western spatial cadastral systems. This spectrum of systems is provided by England, Denmark, Austria, and of two Australian states. These will give an empirical understanding of what constitutes a spatial cadastral system.

This high level country review is the product of standard information systems analysis. The analysis procedures involved reading published documentation, visits to the jurisdictions, and interviews with key personnel within the cadastral organisations and wider cadastral system, and finally verification of the documented analysis by key personnel from each jurisdiction.

3.2   Modelling cadastral map maintenance

The previous chapter concluded that the spatial cadastral data component of the cadastral system constitutes a bounded subsystem. What information then should be included in the high level comparison of spatial cadastral systems?

The analysis focuses on understanding the organisations (people), data and processes that are involved with the spatial data supporting the cadastral systems and the maintenance of the cadastral map product. Specifically, a focus on the information flow associated with the spatial cadastral data produced by changes in legal boundaries often associated with land development. These changes result in

incremental changes in the cadastral map that must be distributed to the users of that map.

3.2.1   Structured documentation

The documentation of this international analysis is presented in a consistent high level format to facilitate the preliminary analysis and comparison. The documentation for each jurisdiction begins with background information of the jurisdiction and its cadastral system followed by an analysis of the spatial component as follows:

- the digital map;

- role of the map in boundary identification;

- spatial data produced by survey;

- spatial data flow;

- customers of the digital map.

The flow of spatial data concentrates on the survey data associated with the subdivision process that results in changes to the cadastral map. While not the only spatial data used to update maps supporting the cadastral systems, it is representative of the processes involved. The flow of spatial data is depicted using a Data Flow Diagram (DFD). DFDs are traditional analysis and documentation techniques used in information systems and fulfil the requirements of this preliminary analysis.

3.2.2   Data Flow Diagrams (DFD)

A DFD is primarily an analysis tool that can be used to depict system data flows and the processes enacted on that data. Importantly it shows the information boundary of the system. DFDs are simple, free format and use a limited number of symbols to show the relationship between data and processes.

Figure 3.1   Notation for Data Flow Diagrams (Gane and Sarson 1979)
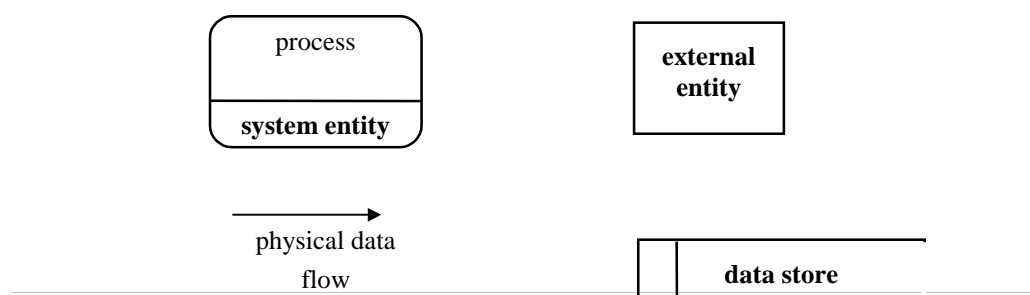
Figure 3.1 illustrates the DFD notation to be used in this thesis. A rectangle is used to represent an entity external of the system. It is a source or destination of data flows into or out of the system. The rounded rectangle represents a process that transforms the physical data in some manner. An arrow shows the pathway along which data may pass. The rectangular open ended shape represents a data store that could be any filed data but is now generally interpreted as a database.

DFDs are constructed in a structured top-down methodology. The first step is to produce a diagram of the system's interaction with its environment. This is generally termed the context level DFD (or level 0 DFD) and shows the system in context with its surroundings. The context level DFD is decomposed into a level 1 DFD that defines the system processes at its next level of detail. Subsequent lower level DFDs are constructed that decompose these system processes until the system is defined at its most elemental level. The entire set of DFDs are termed a levelled set (Burch 1992).

3.2.3   Standard cadastral map context level DFD

The models for the maintenance of the cadastral map place the boundary of the spatial cadastral system around the custodian of the cadastral map. Strict application of DFD modelling to the maintenance of the cadastral map would result in a context level DFD as follows:

Figure 3.2   Context level DFD for cadastral map maintenance
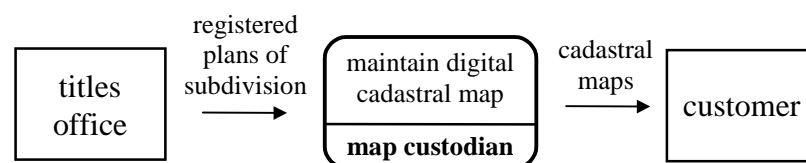
This however would not show the initial creation process of the digital cadastral data by the surveyor, the other institutions influencing that data, and the intermediate customers of the new spatial cadastral data. For this reason in documenting the different cadastral systems in this chapter, data flows between traditionally perceived external entities are shown. Examination of these external entities provides the basis

to redefine the boundary of spatial cadastral system. Nevertheless the context level, spatial data flow representation of cadastral systems documented in this chapter, is more formal than the spatial data flow diagramming initially utilised by Effenberg and Williamson (1996), and conforms more closely to the Gane and Sarson notation (Gane and Sarson 1979).

A deficiency of the data flow diagrams, as presented, is that they do not show the iterative nature of some cadastral data flows and process, for example where spatial data may be resubmitted a number of times before approval is granted. This omission is not critical to the depiction the incremental flow of spatial cadastral information. Indeed, for the purposes of comparison across the spatial cadastral systems, the exclusion of iterative data flows serves to exclude unnecessary detail. Nor should the diagrams be interpreted as a linear process. In many jurisdictions the surveyor may be required to submit spatial data along with other legal instruments, to many organisations in the cadastral process at specified times.

3.3   Western cadastral systems

To fulfil this chapter's purpose of defining, analysing and comparing spatial cadastral systems the question arises as to which countries or jurisdictions should be examined.

Cadastral systems around the world tend to be categorised according to their method of land title registration. Henssen (1995) defines land registration as the process of officially recording rights in land through deeds or as title on property. Based on this definition, Henssen gives an arbitrary classification of cadastral systems based on the differences in the laws relating to land registration and the subsequent spatial cadastral information that supports these land registration laws.

Henssen cites three land registration groups as listed below. Not surprisingly the method of land registration will impact on the supporting or resultant spatial cadastral product. The spatial data generally associated with each group is included in the following land registration grouping:

- The English group - England, Ireland, Nigeria. This group makes use of large scale topographic maps to assist where necessary with the textual description of the property consistent with General Boundaries (Dale 1976).

- The Torrens group, - Australia, New Zealand, some parts of Canada and the USA, Morocco, Tunisia and Syria. In the land registration process individual or island surveys of the parcels or subdivisions are utilised without the specific requirement for a map. Cadastral maps are however utilised for charting and indexing purposes.

- The German/Swiss Group, – Germany, Switzerland, Austria, Sweden, Denmark, Alsace-Lorraine, Egypt, Turkey Thailand and Korea. These have the parcel based cadastral maps as an inherent component of the cadastral system.

Henssen (1995) makes the point that these groups have the same land registration principles but differ mainly in procedure. This procedural difference is significantly demonstrated by the difference in the associated spatial cadastral data. In addition Williamson and Hunter (1996) have differentiated spatial cadastral data on the basis of accuracy and level of integration of the spatial data with the jurisdiction's entire cadastral system. This means that a classification of cadastral maps cannot be based solely on the land registration grouping, since there is a variation in the accuracy of the map within each of the land registration groups listed above.

Based on the land registration grouping from Henssen (1995), and additionally the accuracy considerations suggested by Williamson and Hunter (1996), the following jurisdictions are reviewed and documented to provide the range spatial cadastral systems that support western cadastral systems:

- UK - no cadastral map, but large scale topographic maps;

- Australia (Victoria and New South Wales) - graphical cadastre;

- Denmark - controlled graphical cadastre;

- Australia (Canberra ACT) - survey accurate cadastre;

- Austria - legal survey accurate cadastre.

3.3.1   UK

This overview concentrates on the cadastral system of England. The cadastral system of Wales very much mirrors the cadastral system and Land Register of England. The Scottish system has some parallels with England and Wales, but in distinct contrast has evolved in an environment where land records have always been in the public domain. In England, the data in Her Majesty's Land Register has not been available for public access until as recently as 1990, and even then some data cannot be disclosed without the landowner's permission (Dale 1995). Nonetheless, large scale topographic maps produced by the UK mapping authority, Ordnance Survey, support all three systems.

The digital map

The spatial component of the Land Register consists of extracts or copies of large scale Ordnance Survey topographic maps. The map scales vary around the country:

- Urban (1:1250 scale) city and large town areas;

- Rural (1:2500 scale) smaller towns, villages and developed rural areas;

- Moorland (1:10000 scale) mountain, moorland and some coastal areas.

Figure 3.3 shows a portion of a title from the Scotland Land Registry register (Scotland 1997). The underlying map depicted is an Ordnance Survey topographic map (1:1250). The level of boundary detail is typical of this scale of map and for the UK in general.

Role of the map in boundary identification

Under the *General Boundary Principle* the property is described in relation to physical features. There is no formal cadastral map or survey plan required to support the Land Register system. The topographic maps give a clearly defined accuracy and representation of the real world physical features, which are sometimes adopted as boundaries.

The map is only one of many resources used to establish existing property boundaries. The general boundaries system in UK means that existing physical boundary features

in nature take precedent, *"pegs are paramount to plans"* (Dale 1995). The topographic map would be utilised where reference is made to physical features in the associated property deeds (with or without plans). The graphically defined Land Registry Plan (derived from deeds if the property is registered) is outlined in red ink on extracts of the topographic map to graphical accuracy standards (Figure 3.3).

Figure 3.3   Extract of land certificate in Scotland (Scotland 1997)
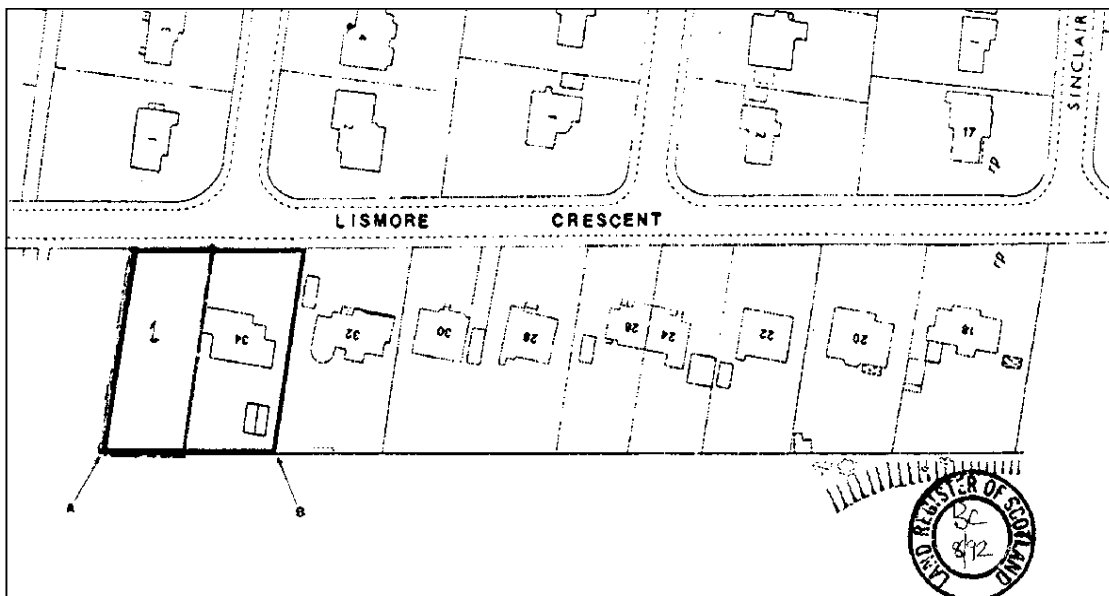
Spatial data produced by the survey

Land surveyors in England are not licensed or registered and no legal requirement exists for a surveyor to be involved in the subdivision process. Plans, if produced in the subdivision process, are associated with the deeds and are used to define the general property boundary. The content and accuracy of these plans are determined by the available Ordnance Survey topographic map data. Where these are insufficient to determine the boundary, a new topographic survey could be requested from Ordnance Survey. Ordnance Survey topographic maps therefore provides a legal basis for the description of the property boundary.

Spatial data flow

The spatial subdivision plans, which might be produced, are approved in the planning process and normally kept with the property deed. New boundaries are either associated with existing physical features or are suitably marked in nature with the expectation of new physical features (house wall, fence, etc) being erected. This part of the spatial data flow is depicted in Figure 3.4. The dashed line indicating that a survey may not always occur.

Figure 3.4 Flow of spatial property boundary data in England
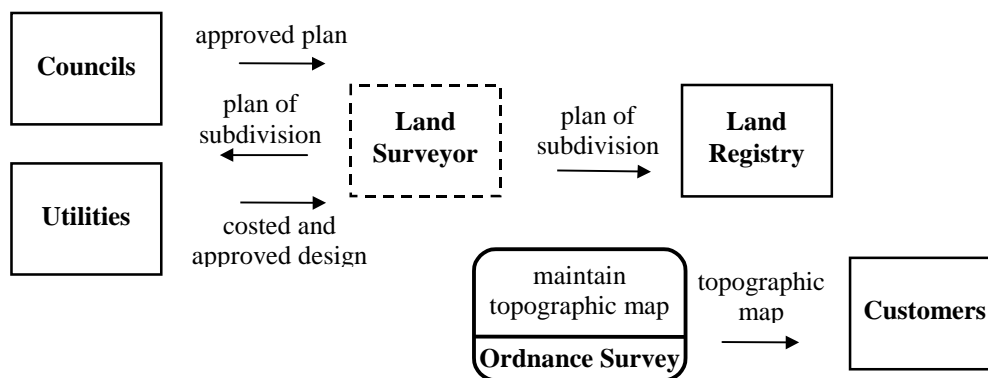
At some future date, normally dependent on physical activity and normal cycles of topographic map maintenance, Ordnance Survey would survey these new and other changed physical features to update the digital topographic map base. Figure 3.4 demonstrates the independence of this data flow from the subdivision process.

Customers of the digital map

The customers of these large scale topographic maps include the depicted external entities in the spatial data flow. The Land Registry generates boundary data or title plans by outlining the property in red on extracts of the Ordnance Survey topographical map to a graphical accuracy based on the deed information. The survey measurements or plans produced in the subdivision process are utilised to assist in the generation of the graphically accurate Land Registry Plan as depicted in Figure 3.4. Only in exceptional circumstances are measurements recorded on the Land Registry Plan and there is no official record of the precise measurement of area (Dale 1995).

The topographic map is an essential component of evidence to establish existing boundaries, that it is extensively used to assist in the interpretation of the textual general boundary description.

The absence of a parcel polygon in the digital topographic map base means that customers seeking to set up a property based GIS must utilise data from local councils, Ordnance Survey, Land Registry and Valuation Office to generate parcel or property polygons (Yeoman and Musgrave 1997).

3.3.2   Australia - Victoria

Historically the Departments of Lands or Office of Surveyor General within each Australian state administered the Crown land and managed the jurisdictions' surveying and mapping infrastructure. The individual state Land Titles Office (LTO) had responsibility for the titles and deeds associated with all freehold or private lands. The Land Titles Offices were only ever concerned with individual land transactions supported by individual or island cadastral surveys. Not only has each Australian State and Territory developed its own, somewhat different Torrens based cadastral system, but each lacks a European style cadastral office providing a complete cadastral record, which could be used for land administration purposes (Williamson *et al.* 1997).

In Victoria the jurisdiction wide custodian of the cadastral map was the Office of Geographic Data Coordination (OGDC). The rural and metropolitan digital maps were developed separately and were independently managed until combined in 1996 under OGDC. OGDC was not directly associated either the Office of the Surveyor General or the Land Tiles Office. Recently all these bodies have come together under the one government Department and marketed as Land Victoria.

The digital map

In common with other Australian states the digital cadastral map of Victoria—termed the Digital Cadastral Data Base (DCDB)—was digitised from paper maps, which in turn had been compiled from individual cadastral survey plans. In rural areas the source maps were generally at a scale of 1:25000 and 1:2500 in towns, for the

metropolitan areas scales ranged from 1:5000 to 1:200 (Effenberg and Williamson 1997). The digital boundaries are therefore represented at a graphical accuracy, with the accuracy of the scaled boundary coordinates being about ±0.5 millimetres at map scale (e.g. ±12.5 metres for 1:25000). Figure 3.5 is a extract of this graphical DCDB.

Figure 3.5   Extract of the Victorian DCDB

Role of the map in boundary identification

Victoria's digital cadastral map is a graphical representation of the legal cadastral framework; it plays no role, either survey or legal, in the identification of parcel boundaries. The original survey plans deposited at the Land Titles Office are used to verify boundaries. Up to the 1970s and early 1980s, subdivisions of private lands were charted in Land Titles Offices on cadastral index maps of low spatial integrity. These maps were often copied from approximate valuation maps and were frequently used by other authorities such as local government and utilities (Williamson *et al.* 1997).

Spatial data produced by the survey

A licensed cadastral surveyor must survey any changes to the legal cadastral framework, to a prescribed survey accuracy and practice. The survey plans contain boundary dimensions, which may or may not be tied into control or local reference markers. The survey plan also includes spatial data for easement and road reserves.

Spatial data flow

The council must approve the plans of subdivision generated by the surveyor, before the surveyor is able to deposit the subdivision plans for the titling process. The council in turn has a number of referral bodies, including the utilities, upon which its final approval is dependent. In practice the surveyor often forwards the plans of subdivision directly to the utilities to hasten the council approval phase. The custodian of the digital cadastral map updates the *approved* digital cadastral map after the plans have been registered at the titles office.

Figure 3.6   Data flow for the State of Victoria, Australia.
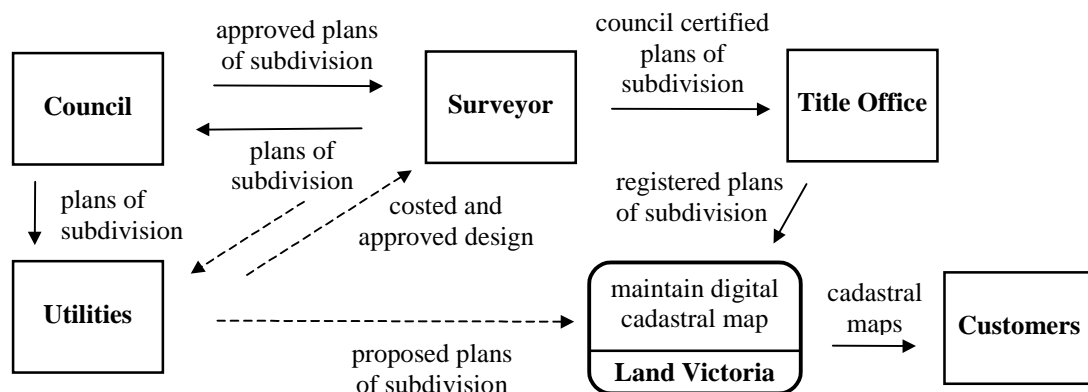
Some plans of subdivision are forwarded to the custodian of the digital map at council planning stage and incorporated into the digital map as *proposed* to become part of the approved digital cadastral map after title registration.

Customers of the digital map

Councils and utilities use the digital cadastral map as a reference map for their assets, with many choosing to maintain their own digital cadastral maps from the information submitted at the planning stage. The Titles Office is a potential customer of the digital

map for parcel indexing purposes. The inclusion of street addresses and road centre lines in the digital cadastral map allows a derived product to be utilised by emergency dispatch services. Increasingly there is a demand for a national digital cadastral map, which requires an expensive process of combining current disparate state digital maps. The digital cadastral database of the whole of Australia produced for the 1996 Census was a one time compilation of discrete and disparate data sets from each of the Australian states (PSMA, 1996).

3.3.3   Denmark

From its beginning the Danish cadastre consisted of two parts, the cadastral registers and the cadastral maps. These cadastral maps were village centred and depicted the property framework to a graphical accuracy and with no ties to local or national control network. Modern cadastral surveying in Denmark is done to a high local accuracy with most cadastral surveys connected to state control points and since 1934 linked to the national geodetic network (Enemark 1994).

The digital map

The country wide digital cadastral map, based on the national grid network, was completed by 1997. The digital map is essentially a controlled digitisation of the old analogue *island* maps of individual village areas surveyed by plane table at the scale of 1:4000, not based on any local or national control network. An extract of the Danish cadastral map is shown in Figure 3.7. The national control points and connected cadastral surveys formed the *skeleton* digital map (urban 40%, rural 20%). These are designated points in the cadastral map and are annotated with circular points as shown in Figure 3.7.

The remaining digitised cadastre was inserted into the *skeleton* map by transformation often using the digital topographic map as control. These are the intersection points in Figure 3.7 that have no annotation. These boundary coordinates range in accuracy from a few centimetres, in some urban areas, to several metres in some rural areas.

Figure 3.7   An extract of the cadastral map of Denmark (Enemark 1999)

Role of the map in boundary identification

A licensed surveyor compares the legal survey information (cadastral map and legal survey measurement sheets) to the monuments, occupations, fences, etc, and has the responsibility for resolving any discrepancies. Where there are no useful legal survey measurements, the cadastral map, which was in use at the time of establishing the boundary, must be used as the main information for boundary determination. The digital cadastral map is deemed graphical even where the coordinates of the boundary points represented in the digital graphical cadastral map have been derived from survey measurement sheets. The graphical boundaries in the digital cadastral map may have been distorted during the digital map production process or subsequent update. Boundary point coordinates in the digital cadastral map therefore may not be used for the calculation of legal distances, parcel areas, etc (Enemark 1994).

Spatial data produced by the survey

Licensed surveyors accurately position new parcel boundaries, normally connected to the national control grid and presented as legal survey measurements sheets. The process of determining existing boundaries requires private licensed surveyors to take into account the information from cadastral maps and these measurement sheets.

Spatial data flow

When land is to be subdivided or boundaries changed landowners must apply to a private licensed surveyor for the necessary legal surveys and the preparation of documents. These are the necessary documents submitted as an application to the National Survey and Cadastre – Denmark (KMS) for updating the cadastral register and the cadastral maps. The application must contain a copy of the cadastral map showing the alteration of the boundaries, measurement sheets showing the new boundaries, documentation proving legal rights and showing the approval of the future land use according to local planning and land use regulations.

Figure 3.8   Spatial cadastral data flow for Denmark
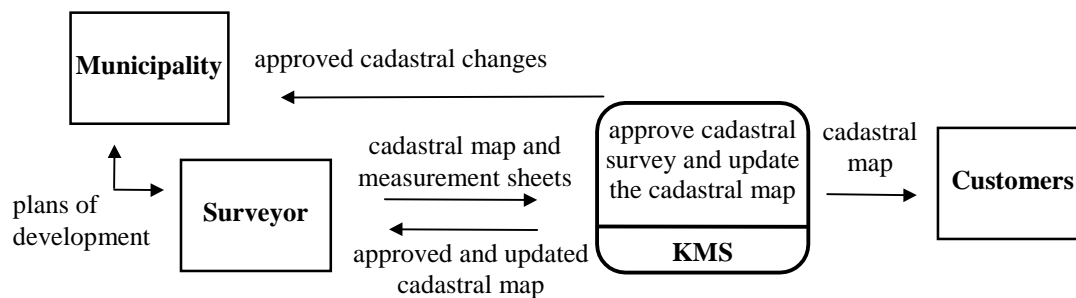
The KMS approved and updated cadastral map is returned to the private licensed surveyor and also forwarded to the municipality to update the property tax register, and to the local Land Registry Office to update the Land Book. Survey information or cadastral maps are obtained from a local private surveyor or KMS.

Customers of the digital map

Denmark's cadastre provides the basic infrastructure for managing economic interests in land and supports environmental and development interests (Enemark 1992). The cadastral map is part of a Danish *Coordinated Information System,* where the linkages between land information subsystems are achieved by unique *Cross Reference Register* (Enemark 1994). The customers are found within both the private and public sector: estate agents, lawyers, engineers, architects and local, regional and national government authorities.

3.3.4   Australia –Canberra, Australian Capital Territory

The Planning and Land Management Group (PALM) within the Department of Urban Services is responsible for all land use, planning, development, building approval and land information for the Australian Capital Territory (ACT). ACTMAP is the major Land Information System used for planning and land management within the ACT Government. The ACT Land Information Centre (ACTLIC), a section of PALM, is the ACT Government's agency for surveying, mapping and land information.

In line with other ACT government bodies PALM performs the dual roles of local council and state government. In support of these roles and functions ACTLIC, in addition to cadastral map base, maintains all the required spatial information such as street addresses, building footprints, building names, all administrative boundaries, road centre lines and kerbs, survey control, two metre contours, water features and utility information (PSMA 1996). ACTMAP's primary fundamental data layer is the network of land parcel boundaries that make up the ACT cadastre. Further information about ACTLIC within the ACT Government and online cadastral map data are available at *http://www.palm.act.gov.au/actlic/*.

The digital map

The cadastral map is referred to as the Cadastral Base of ACTMAP and is a fully coordinated urban cadastre. There are in excess of 105,000 urban parcels held at survey accuracy (PSMA 1996), a small number of rural parcels are held at varying lower orders of accuracy, with the remainder being national park. The urban cadastral information is held in two layers, the planning layer and the final accurate and registered layer. The spatial cadastral data is always current and updated for inquiry purposes each day.

Figure 3.9 shows a part of the map information of the ACT as sourced from *http://www.palm.act.gov.au/actlic/*. The right portion shows the cadastral component, while the left part gives an indication of the level of integration of the cadastral map with topographic information.

Figure 3.9   ACT cadastral map online (http://www.palm.act.gov.au/actlic/*)*
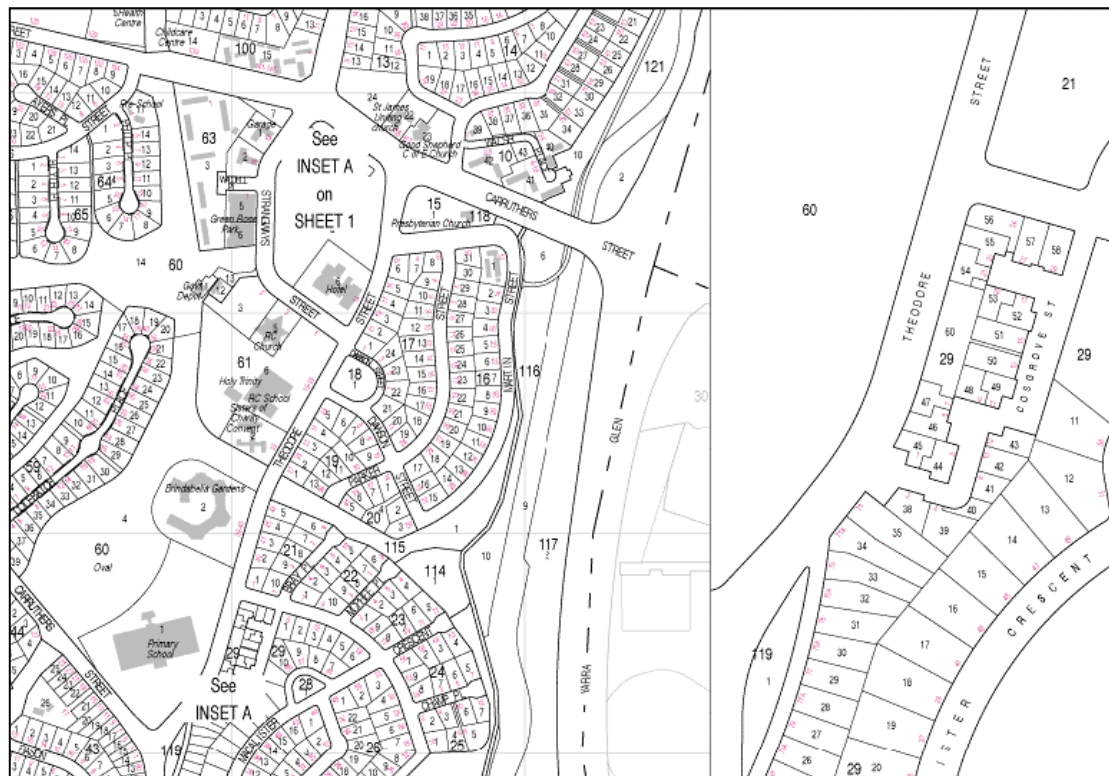
Role of the digital map in boundary identification

The accurately positioned Coordinated Reference Marks (CRM) positioned every 150 metres along every street in Canberra allow the surveyor to fit the real world subdivision to the cadastral map to within ±3 centimetres relative to the nearest CRM. The cadastral map base is a fully coordinated urban cadastre but despite considerable discussion there appears to be no moves to develop a legal coordinated cadastre.

Spatial data produced by cadastral survey

Depending on the size of the subdivision the licensed surveyor cadastral survey will (by completion of subdivision construction) produce survey control, survey accurate subdivision plans, computation sheets and kerb based CRM

Spatial data flow

The dual nature of the ACT Government (local and state) means that the ACTLIC Section receives the spatial data from the developers shortly after planning approval has been obtained. As a result the *state* government function of the ACT receives the spatial data relating to the approved plan (AP) up to 18 months before the Deposited Plans (DP) are finally lodged for title registration at the Titles Office (Figure 3.10).

Figure 3.10   Flow of subdivision data in the ACT of Australia
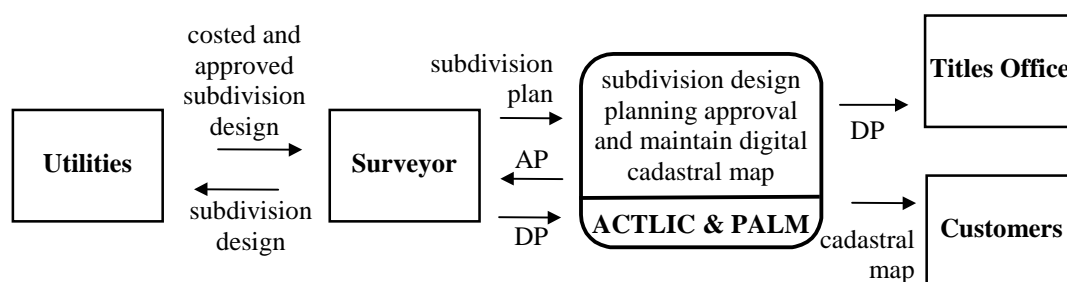
This means that the Cadastral map has two classifications of data, namely planning data (proposed layer) and final accurate data. The names refer more to the data accuracy provided by the surveyors, with many surveyors supplying accurate data from the outset of subdivision planning. All parcel data within the cadastral map must be *accurate* before the Deposited Plan can be registered at the Titles Office.

Customers of the map

The nature of the ACT government means that the office maintaining the cadastral map deals at a local council level with the private surveyors and also fulfils the state function of cadastral map maintenance. ACTMAP is the core cadastral data set used by all the ACT government and utility companies that operate LIS/GIS systems, with direct access to the cadastral map details both at the planning and registration stages. As well as providing a centralised land information collection and integration point for the ACT Government, ACTMAP data is distributed widely throughout the ACT Government and private enterprise.

3.3.5   Austria

In common with other central European cadastres the Austrian cadastre was established for taxation purposes, although the concept of using maps and cadastral records for other government purposes was envisaged and implemented in the cadastral systems from the beginning (Hawerk 1995). Land use classification and land area formed the initial basis of the taxation system and remain major elements of the current digital cadastral map.

As with other cadastral systems within this group the cadastre exists as two parts, and generally held in separate organisations. The *Grundbuch* (Land Register) is part of the local courts and under the administration of the Ministry of Building and Technic. This Register is 100% digital. The spatial component consists of a database of coordinates and the cadastral map, which is administered by the local survey offices under the control of the Austrian Federal Office of Surveying and Metrology (Bundesamt für Eich- und Vermessungswesen - BEV). The number of local survey offices was reduced from sixty-eight to forty-one as of the first of January 1998 (Schennach 1998).

The digital map

The digital cadastral map is derived from the cadastral maps produced in the late nineteenth century (1856 –1883) (Schennach 1998). It is a survey accurate cadastral map of the legal parcel boundaries as depicted in Figure 3.11. The digital map shows the survey accurate spatial data to define land use boundaries, with the main categories being building (hatched building footprint) garden (Q), farm (Ln), etc, to facilitate land use area calculations. The boundary point notation references an integrated database of coordinates for all border and survey control points.

The digital map is fully integrated with the aspatial land register (*Grundbuch*) and the database of coordinates for all border and survey control points. The legal digital map is approximately 60 to 70 percent complete and is created and maintained by local survey offices with the centrally stored Austria wide legal cadastre held by the Federal Office of Surveying and metrology (Höflinger 1993).

Figure 3.11 Digital map example for Austria (BEV 1991)

Role of the map in boundary identification

The subdivision documents and the associated database of control and border points is the legal parcel boundary. The digital cadastral map is a survey accurate representation of all current spatial documentation pertaining to boundaries. The database of boundary points is integrated with the cadastral map. It is the role of the

surveyor to ensure that subdivision surveys accords with the proceeding documents and with the legal cadastral map. If the boundary in nature differs to the boundary in the cadastral map, the surveyor is required to involve parties to that boundary in order to survey the new agreed boundary. The surveyor submits these measurements and appropriate legal agreement documents to authorise the change to the current legal digital cadastral map and database of control points.

Spatial data produced by the survey

In the past surveyors were licensed for specific areas, this is no longer the case under European Union membership. A licensed surveyor conducts the cadastral surveys to accurately and legally define the parcel boundary and designated land use boundaries. All cadastral survey data is tied to an extensive national control network.

Spatial data flow

Surveyors base their subdivision survey plan on measurements extracted from the central database of boundary and control points. The plans of subdivision are deposited at the local survey office where they are held for a maximum of two years awaiting legal approval. After approval the subdivision plan is entered into the legal digital cadastral map at each of the local survey offices. This digital information is further checked and integrated into the legal cadastre at the federal survey office. This flow of spatial data is depicted in Figure 3.12.

Figure 3.12 Data flow for spatial data in Austria
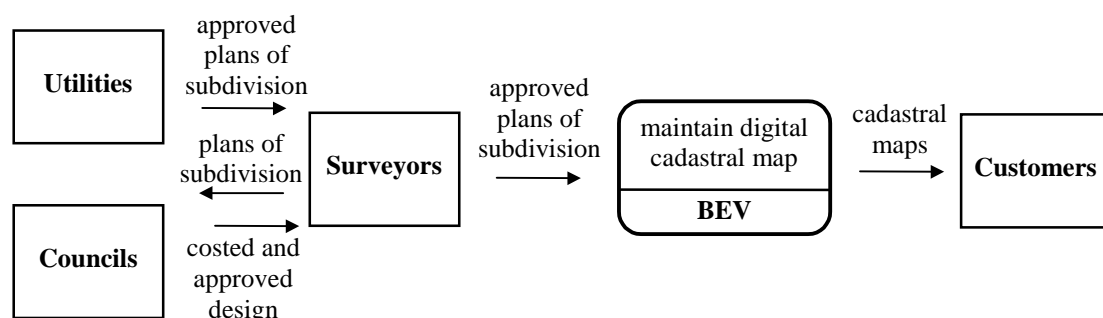
The local survey office holds all the analogue subdivision information. It undertakes the incremental creation of the digital map before being centrally verified. Some of this work is contracted out to the surveyors by the survey office (Schennach 1998).

Customers of the digital map

Information in the digital cadastral map, the land register and the database of control points are open to public access at any of the local survey offices at minimal cost (Twaroch and Muggenhuber 1997). Larger quantities of data can be delivered on the preferred electronic medium. Since 1984 a videotex system has given direct access to surveyors, the legal profession, councils, banks and others (Höflinger 1992).

3.4   Review of cadastral maps

The intent here is to review the cadastral maps that are the output of the spatial cadastral systems analysed in this chapter. The cadastral maps documented vary not only across, but also within, the land registration groups suggested by Henssen (1995). The level of integration of the map with the land registration process is reflected in the accuracy and legal status of the map's cadastral boundaries. This accords with the views of the differing coordinated cadastre defined Williamson and Hunter (1996). The following is a general summary of these different maps.

3.4.1   Topographic maps

While this is not a cadastral map it is clear that this type of map is utilised by and supports aspects of cadastral systems that are based on the general boundary principle. Topographic maps depict the physical features of the landscape that can be used to identify property boundaries under the general boundary principle. The scale therefore has to be sufficiently large to map features such as fences, building corners, walls and hedges, etc. The accuracy is directly related to the scale of the topographic map.

The legal status of the map derives from its accurate record of the physical landscape at the date of survey. As depicted in Figure 3.13 this spatial information may assist in the interpretation of the textual description of the property.

Figure 3.13   Cadastral role of the topographic map

The map however is not formally used in the process of land registration. The topographic map is updated completely independent of the land subdivision and land registration processes but practically is often updated beyond the normal update cycle in response to land development.

3.4.2 Graphical cadastral maps

These digital cadastral maps have generally been digitised from the best available paper maps. The capture priority for the digital cadastral map was to represent the framework of all the legal land parcels of the jurisdiction and to keep this representation up to date. In contrast to entering all the survey measurements this is a rapid capture method, but at the expense of accuracy.

The accuracy of the jurisdiction wide cadastral map can vary greatly depending on the accuracy of the source maps and the digitising process. In Australia some analogue property maps created by water utilities were large scale (e.g. 1:400) while charting maps used in Titles Offices had low spatial integrity. In general there is a significant decline in accuracy from metropolitan areas, to urban areas, to rural areas. For example, in some graphical cadastral maps of the Australian states the absolute accuracy may vary from greater than ±25 metres in rural areas to a relative accuracy of less than ±0.5 metres in metropolitan areas (Effenberg and Williamson 1996).

To increase the multi-purpose status of these maps they are generally topologically enhanced and include additional spatial data not specifically relevant to the cadastral process. The update of the graphical cadastres is usually at the post title stage via access to registered subdivision plans.

The controlled digital cadastral map is a combination, at initial creation, of survey accurate coordinates from survey plans and graphically accurate data from paper maps. Jurisdiction wide, survey accurate data, tied to survey control, is used to create an initial skeleton of the digital cadastral map. This is then filled in with the available digitised cadastral data.

The accuracy depends on which type of data is referenced. The survey accurate data is differentiated from graphically accurate data both in display and data processing.

Updates to the map may or may not be part of the cadastral process but use survey accurate plans created by the cadastral process. In the update procedure new survey data takes precedence over the existing digitised data. Only graphically accurate points (digitised points) may be manually changed, while only survey accurate points are utilised in any survey adjustment procedure to integrate new survey data.

The legal status of the map depends very much on the status accorded by the cadastral system to the survey accurate coordinates within the cadastral map. For instance in the case of Denmark, from which this classification is derived, the parcel area calculated by the survey accurate coordinates within the map, is not constituted to be the legal area. The inherent inaccuracies of the graphical cadastral map, means that no legal status has been associated with these recently emergent digital maps in relation to the legal definition of boundaries.

3.4.3   Survey accurate cadastral maps

In the survey accurate cadastral map the coordinates determined by survey are used to define the digital parcel boundaries. This requires a state coordinate system and sufficient density of control, along with the necessity of additional control as large areas are opened for subdivision. This is termed a fully coordinated cadastral survey system and is the most common understanding of a coordinated cadastre (Williamson and Hunter 1996). The digital cadastral map update is tied closely to the land subdivision process and the cadastral system ensuring the continued integrity of land registration. The derivation from survey data means that the boundary coordinate accuracy, in urban areas, should be ±0.03 metres or better, with respect to the nearest survey control; generally the level of accuracy decreases in rural areas.

At any point in time, the digital map might comprise, the three levels of accuracy described above. This results from the maintenance process applying new legal survey accurate data to the initially captured map. It is then necessary to ensure that sufficient metadata exists to document the accuracy of the individual parts of the cadastral map and to ensure that the update procedure does not corrupt that accuracy. Clearly there is a trend towards survey accurate cadastral maps (Williamson and Hunter 1996). This accuracy trend and the role of the individual survey plan are reflected in Figure 3.14.

Figure 3.14   Trend in graphical cadastres
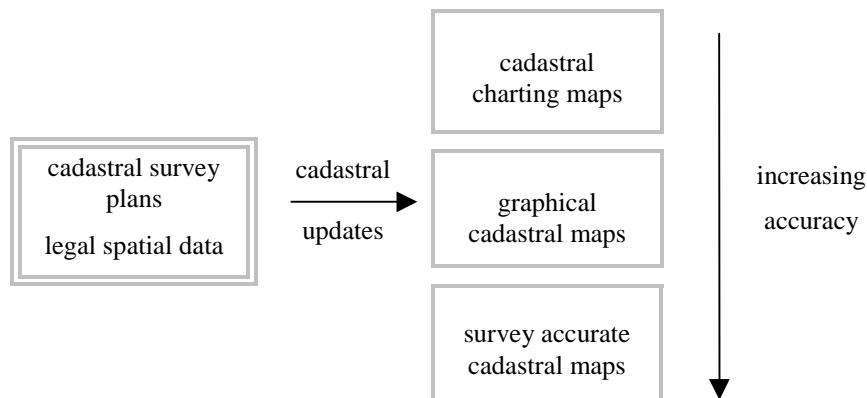
Even for cadastral maps that are completely survey accurate and for all practical purposes, the coordinates in the digital cadastral map are the true coordinates, the digital map does not constitute the legal cadastre. This may be for two reasons, first, the digital map may not been accorded the same legal status as the survey plans from which it was derived. Second, the boundary principle in use may accord legal significance to occupation boundaries and not the survey accurate map.

3.4.4   Legal cadastral maps

Here the survey accurate cadastral map is accorded legal significance (Williamson and Enemark 1996). The legal representation of the boundary is the digital cadastral map. The update of the cadastral map is now a legally essential and integrated process within the cadastral system. This is represented in Figure 3.15.

Figure 3.15   The legal cadastral map
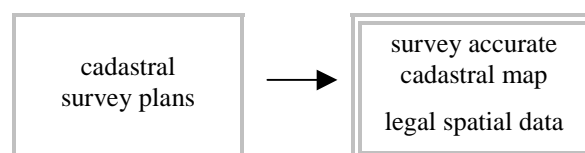
The survey accurate, legal, cadastral map may require an associated accuracy in topographic map, particularly where topographic features are included in aspects of legal rights, such as water access rights.

In their discussion of the levels of maturity of survey infrastructure, Todd *et al.* (1999) suggest levels of maturity of the cadastral map are determined by the associated survey infrastructure that must exist to support the more accurate cadastral mapping. They suggest a further type of cadastral map, the *reinstated cadastre*. The levels of maturity are presented as follows (Todd *et al.* 1999):

1. graphical cadastre;

2. upgraded graphical cadastre;

3. survey accurate cadastre;

4. reinstated cadastre;

5. legal cadastre.

Irrespective of the nomenclature, the maturing of cadastral maps is consistent with the trend towards survey accurate cadastral maps.

3.5   Defining the spatial cadastral system

An examination of the spatial product has shown that there is a range of maps associated with or in support of cadastral systems. The five data flow models, however show a consistency in the external entities that are involved in the cadastral systems. While the external entities are similar, the processes they individually enact in the creation and maintenance of spatial cadastral data vary significantly.

In order to define what should be the spatial cadastral system boundary, each of the external entities and the cadastral map update process is revisited to summarise the possible processes which each undertakes. This summary across the different cadastral systems provides the basis for identifying the boundary of the spatial cadastral system and the high level processes involved in the production and maintenance of spatial data.

3.5.1   The cadastral or land surveyor

The role of the surveyor differs with both the eventual purposes of the cadastral map and organisational structure within the cadastral system. The following specifically details the possible spatial data responsibilities of the cadastral surveyor.

The spatial cadastral data originates with surveyors who are increasingly generating the cadastral data in digital format and with the high accuracy afforded by current survey technology. The surveyors' role varies from possibly no involvement to the almost direct inclusion of the surveyor's survey data into the cadastral map. The surveyor is increasingly required to include survey control and can also be required to place control where required. The surveyor is contracted to create portions of the digital cadastral map in Austria where an incremental creation process is under way.

In Austria, Denmark and many other Northern European countries, the surveyor holds the initial legal responsibility for land dispute resolution. These resolution powers cover areas such as boundary discrepancies, the correct legal interpretation of old survey information, subdivision planning permission, etc (FIG 1995). As a consequence, the surveyor is expected to submit boundary changes to the cadastral map, normally for direct inclusion, along with the necessary legal instruments to the local courts.

The FIG Statement on the Cadastre (FIG 1995) gives a comprehensive list of the possible responsibilities of the surveyor across different cadastral systems. Specifically the statement indicate that the surveyor may be responsible for:

- cadastral surveying;

- survey examination and recording;

- land valuation;

- land use planning;

- management of digital survey information;

- land dispute resolution.

This amalgamated list is consistent with the observations within the five jurisdictions modelled. Each of the listed responsibilities, whether the responsibility of the surveyor or another cadastral system entity, has a spatial cadastral data component dependent on the cadastral survey data generated by the surveyor.

The surveyors' processes and spatial data are subject to scrutiny in a number of different ways across the jurisdictions examined. Firstly, by having checking

mechanisms as part of the processes of subsequent cadastral system entities. In countries such as Australia, Germany and Switzerland the title's body employs surveyors to check and reject, if necessary, the spatial data (subdivision plans) presented by the cadastral surveyor. Secondly, in some jurisdictions, the surveyor is directly employed by another cadastral system entity (council or cadastral map custodian). In some jurisdictions quality control is assured by virtue of the final legal responsibility for the spatial data resting with the surveyor.

3.5.2   The local councils

In most instances the local council, municipality or its equivalent, is charged with enforcing local planning and land use regulations. Since planning approval is always sought prior to the formal subdivision survey, the local councils have access to spatial data often many months before application is made for land title registration. Generally the spatial data is restricted from further entry into the cadastral system until the councils approve the plans to ensure that they adhere to all applicable planning and land use regulations. In addition, local councils are generally required to seek and receive approval from utilities and other legally nominated referral bodies.

In general local government administers land at the property level. This means that the spatial data submitted to the local council, for planning purposes, might differ significantly from the subsequent parcel based, spatial data presented for land title registration.

3.5.3   The utilities

The inclusion of utilities and other referral bodies in the spatial data flow diagrams is open to argument. In most cases they are legal referral bodies whose approval must be received before the council will signature the surveyor's plans. This council's signature or approval stamp indicates compliance with all necessary planning and land use regulations for registration purposes.

The utilities significantly influence the flow of spatial cadastral data because of their role in the costing of specific utility infrastructure to accommodate the land development. The surveyor may submit either a number of optional plans or a number

of iterations to an original plan to ensure the most cost-effective subdivision design that will accommodate the necessary utility infrastructure. While the utilities are council referral bodies, surveyors frequently submit planning spatial data to both the councils and other referral bodies simultaneously to speed up the planning approval process.

Water utilities, particularly in Australia, were often forerunners in the digital cadastral map product and indeed their data formed the basis of many Australian state cadastral maps. These institutions, charged with accurately mapping their underground assets, have a great interest in survey accurate, multipurpose cadastral maps. In spite of the availability of jurisdiction wide cadastral maps, many utilities worldwide often maintain their own cadastral maps, justified by either their business needs for specific spatial data or the perceived deficiencies in the state digital product. On the other hand they can also partnership the state digital cadastral product, both in financial and maintenance aspects.

Many utilities and councils input the planning data for their own cadastral maps particularly if the cadastral map is a post title product divorced from the planning process. Whether the planning cadastral data they enter goes on to update their own version of the cadastral map, or is discarded, is dependent on the perceived accuracy of the jurisdiction wide cadastral map and ease of incorporating spatial update at a later date.

3.5.4   The land registry or titles entity

The processes of the title's body may vary from no involvement in the spatial data and merely granting title on the basis of spatial data previously verified by another entity; to the titles body undertaking a rigorous survey check of the surveyor's subdivision measurements and planning approval status. In all cases the titles body, or its decentralised court equivalent, is usually the custodian of the land register or land book holding the ownership and legal rights relating to the cadastral parcel, and its processes define the completion of the legal process of the cadastral system.

In the case where the cadastral map defines the legal extent and boundaries of the parcel, the currency of the digital map may be measured in months and years. In many

cadastral systems the titles body and the custodian of the cadastral map are the same institution operating in close cooperation to minimise duplication.

3.5.5   The cadastral map custodian

The necessity for a base cadastral map to support the jurisdiction wide spatial data infrastructure has led either to the tasking of existing institutions or the formation of a new body to undertake the creation and custodianship of a state or national digital cadastral map. Once created and marketed the national digital cadastral map is increasingly required to fulfil a multipurpose role. Stewardship of the jurisdiction wide cadastral map means applying standards to the spatial data in the update and upgrade procedures and maintaining the content and accuracy of the jurisdiction wide cadastral map to ensure that it meets its intended legal or spatial infrastructure requirements.

The creation and maintenance of the cadastral map may be performed either in a centralised or decentralised manner by either the custodian or its offices, or is contracted out to a third party. The maintenance process may be pre or post title registration but is rarely conducted at the planning stage.

3.5.6   The spatial cadastral system

Irrespective of the initially intended function of the cadastral map within the complete cadastral system, or its evolved current function, the spatial cadastral system that supports the production and maintenance of the cadastral map can now be viewed as a more encompassing system. The input is a request for land development and the eventual output is the distribution of the cadastral map to users. The DFD diagram Figure 3.16 depicts this is redefined boundary of the spatial cadastral system.

Figure 3.16   Context Level DFD for the spatial cadastral system.
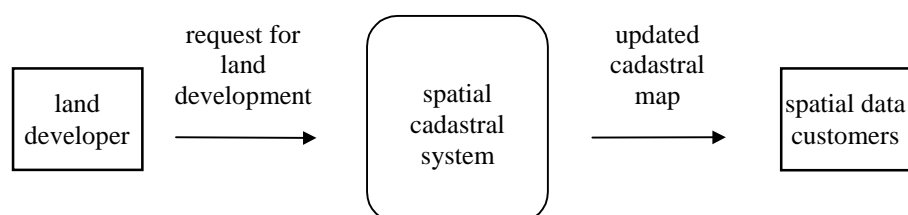
In the paper *Basic Principles of the Main Cadastral Systems in the World* by Henssen (1995) cited earlier in this chapter, Henssen contents that:

"Around the world, there are different categories of title registration systems, which do have the same principles but differ mainly in procedures."

Henssen's stance is based on his observations of cadastral systems as a whole. In contrast, from a spatial cadastral subsystem viewpoint the processes or procedures enacted within the spatial cadastral system are surprisingly generic, albeit enacted by different entities within the spatial cadastral systems. These high level processes within the spatial cadastral system independent of the organisational or individuals that perform them, provides the basis for later theoretical models.

3.6   Conclusions

The jurisdictions chosen for study in this chapter reflect the differing western land registration procedures defined by Henssen (1995). This spectrum of western cadastral systems serves to demonstrate that the cadastral map continues to evolve to meet specific jurisdictional requirements while still fulfilling its primary role of supporting the cadastral system. A range of cadastral maps became evident and are reiterated below

1. graphically accurate cadastral map;
2. controlled graphical cadastral map;
3. survey accurate cadastral map;
4. no cadastral map but large scale topographic maps;
5. survey accurate cadastral map with legal status.

The large scale topographic map and the survey accurate legal cadastral are grouped together to reflect the legal nature of the spatial data they represent. There is really no implied correspondence with the above list and land registration systems. The Torrens system for instance is not dependent on any cadastral map but could possibly operate more efficiently as the cadastral map status moves towards a greater accuracy.

It should again be noted that in line with the concepts of maturity levels (Todd *et al.* 1999), at any point in time, a jurisdiction's cadastral map may be composed of differing accuracies within its spatial extent. Importantly though, the map or the spatial extent under consideration must be classified in terms of the least accurate elements within that extent, unless accuracy metadata is available for smaller spatial extents or spatial objects.

A review of both the custodian of the cadastral map as well as what are generally regarded as external entities highlighted a number of consistent spatial data flows apart from the inputs and outputs to the cadastral map custodian. Indeed there appears to be no radical difference amongst the reviewed systems, in the way spatial data moves through the land development process to eventually update the cadastral map.

The review of these cadastral systems and their supporting map clearly indicates that the spatial cadastral system that supports the maintenance of the map cannot be studied independent of the depicted external entities which may not or may not interact directly with the map custodian. The spatial cadastral system is therefore defined to encompass the external entities represented by the surveyor, the utilities, the councils, the titles body and the custodian of the map.

The technique of data flow diagrams, as used in information systems analysis, provided a modelling tool to analyse the spatial cadastral systems of a number of jurisdictions, albeit at a very high level. While this affords the opportunity of providing an understanding of the spatial cadastral systems, DFDs alone, with their emphasis on data and processes, would not be sufficient for a more in depth study of spatial cadastral systems. The next chapter therefore seeks to explore systems analysis techniques that would provide a methodology for comprehensive and structured study of the spatial cadastral system of the Australian State of Victoria.

4

Systems Methodology and Documentation

The aim of this chapter is to justify a methodology for the analysis and documentation of spatial cadastral systems. The methodology should provide the structure for spatial cadastral systems analysis and documentation, and to simplify the presentation of a range of alternative improvements to spatial cadastral systems that are within the scope of the research.

This chapter reviews a number of system methodologies and modelling techniques utilised in the documentation and analysis of cadastral systems and information systems generally. The Zachman Framework is presented as a structured approach for the analysis, documentation, and development of complex information systems.

The Zachman Framework has application for spatial cadastral systems by offering the opportunity to comprehensively analyse and document the spatial cadastral information system. It is able to incorporate other methodologies utilised in information systems research, in a structure that decreases complexity.

4.1   Systems methodology

The research methodology, as outlined in chapter 1, recognises the need to apply a formal systems methodology to the maintenance of the cadastral map. It is therefore necessary to select a methodology that is in keeping with the research aim of confining the study to the spatial cadastral system but remaining cognisant of the entire cadastral system and its users. Ideally what is required is a methodology or framework that provides a comprehensive and in depth analysis of the specific areas of interest, but recognises the impact of other aspects of the organisation or industry.

This thesis has already applied formal analysis methodologies in terms of the use of conceptual models and high level data flow diagrams. In chapter 2 the conceptual models were presented as a means of defining the cadastral systems in terms of its data, and sometimes its organisational components, in support of the concept of a spatial cadastral subsystem. Chapter 3 utilised data flow diagrams and a uniform set of headings to document and understand the spatial cadastral systems of a number of western jurisdictions in terms of data, processes and organisations. This high level documentation and comparison provided a means of defining and understanding the spatial cadastral system.

This chapter initially explores some of systems methodologies that have been applied to cadastral systems and GIS. More traditional information engineering methodologies are also briefly reviewed. This investigation should lead to a better understanding of what aspects of the cadastral system are being modelled in these methodologies, and will substantiate the most appropriate systems analysis and documentation methodology to apply for the purposes of this thesis.

4.2   Conceptual modelling of cadastres

The conceptual models of the cadastre presented in Chapter 2 have been developed over a number of years to diagrammatically capture what constitutes a modern cadastral system. Authors of these conceptual models (Eden 1988, Williamson 1996, Enemark 1998) have attempted to include all the data and contributing organisations, and their linkages to the users of the information. These conceptual models have

provided a basis, in chapter 2, for this research to expand the notion of what constitutes the spatial component of cadastral systems. However, these conceptual models provide a limited structure within which current cadastral systems can be analysed or how spatial cadastral information can be managed more efficiently and effectively across the cadastral industry.

Miller (1992) comments that many of the conceptual models of cadastral systems are data centric; they basically and constrictively define the cadastre as a data set containing a textual and graphical component. Miller contends that:

- While conceptual models have been expanded over time to address specific jurisdictions, they have only really expanded to include data considered to comprise a cadastre;

- The conceptual models have largely remained one dimensional, consisting of a variety of definitions expressed in terms of data.

To allow a modern cadastre to develop into an information system, Miller advances a definition of the cadastre based on a management information system by Sanders (1988). Miller proposes a system concept of four dimensions:

- Data (Information);

- Control mechanism;

- Business;

- Research and Product Development.

These dimensions form the core radial sectors depicted in Figure 4.1. Miller argues that it is only with the consideration and application of these dimensions, that a modern cadastre can develop into an efficient information system, delivering quality data and services to meet the present and future needs of all its customers.

This four dimensional conceptual model, for defining and understanding the cadastre and specifically the cadastral information system, broadens the scope of the conceptual model of the cadastre to include a range of other, non data specific, organisational functions. The four dimensions of this conceptual model for the cadastre begin to overcome the data centric criticism of other models.

Figure 4.1   Conceptual model of a four dimensional cadastre (Miller 1992)
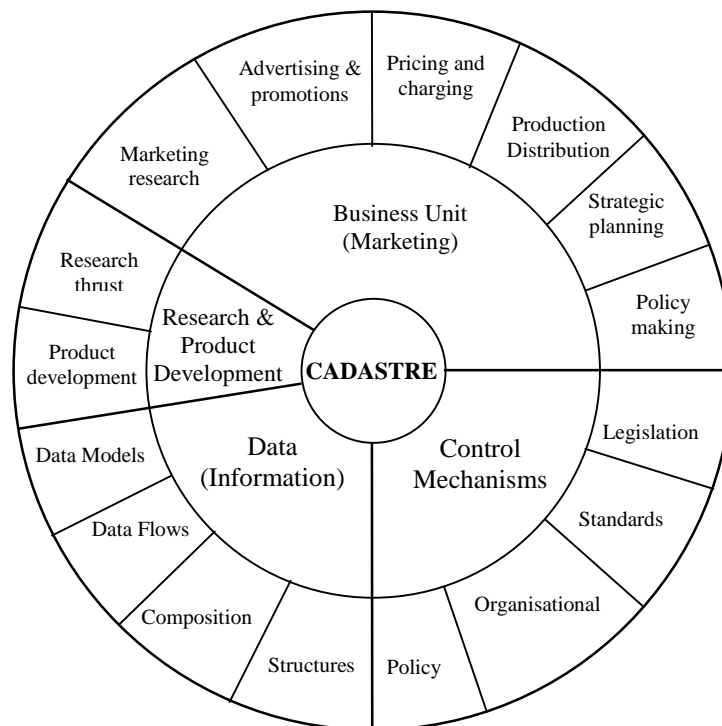
This model could be used to analyse spatial cadastral systems, where each component within each dimension of the model could be populated by an audit of the spatial cadastral system. Missing abstractions of any of the four dimensions would not limit the model since more components could presumably be added. The addition of another ring to the exterior of the model could also allow a further refinement or decomposition of the components of each dimension. While this extension is possible, the already considerable variation in the levels of abstraction of the components makes further refinement arbitrary. A limitation of this model is that it does not describe the relationship between dimensions, or the information flow between them. Miller (1992) recognises this limitation of the conceptual model and addresses this in the same paper by presenting an additional model for the cadastre, a high level functional model of the dimensions of the cadastre.

The data centric criticism of conceptual models is also raised by Coleman and McLaughlin (1997) whose primary focus is the Spatial Data Infrastructure (SDI) and specifically Global SDI. They highlight a common problem associated with the understanding, conceptualising and modelling of information systems and information

infrastructure. Conceptual models proposed for cadastral systems and conceptual models proposed for SDI suffer the same concentration on data, resulting in a modelling that emphasises data component relationships.

Some conceptual models for cadastres expand to include technology, data network and institutional components. While these approaches begin to show non-data specific components, they still only show linkages and fail to increase the understanding of how these components genuinely overlap (Coleman and McLaughlin 1997).

The paper by Coleman and McLaughlin (1997) focuses on the concepts and understanding of SDI. However, the contribution that the authors make is that modelling and design of information systems must not be limited to data components. There is a need to include the organisations that are involved and the perspective from which the information system is viewed. Conceptual models, presented in chapter 2, fail to meet these modelling requirements. The observations offered by Coleman and McLaughlin (1997) are not valid only for SDI or global SDI but should also be taken into account for spatial cadastral systems that provide the data integral to SDI.

Importantly the paper by Coleman and McLaughlin (1997) define five perspectives to structure the discussion of the *bigger picture* of a system:

- A data perspective, reflecting the data interrelationships and the data maintenance tasks;

- A technology perspective, dwelling on the contributions of technology in the operation and understanding of the spatial data;

- An institutional perspective, which looks at the issues from the viewpoint of the inherent responsibilities, constraints, etc, of the respective organisations involved;

- A market driven perspective emphasising demands associated with the dissemination of products and return on investment;

- An application driven perspective where the information systems data sets are seen in terms of user specific applications (functions).

These perspectives are aimed towards a more inclusive understanding, design and evaluation of SDI, but are equally applicable to other information systems.

4.3 Beer's Viable System Model

Based on his analysis of organisational structures Beer (1984) developed a Viable System Model that incorporates the essential conditions for adequate sustainable and purposive operation of the organisational system. In his dissertation *A Cybernetic Approach to Land Management Issues*, Cook (1994) argues for the application of the Beer's Viable System Model as a framework to develop a description of the Australian State of Queensland's cadastral surveying system.

This model reflects the origins of system thinking from the biological sciences, the requirement to transcend the perspective of individual analysts and the need to encompass the *bigger picture* in the development of organisational structures. The organic origin of the Viable System Model is reflected in the five subsystems and the associated functions that are needed to sustain organisational viability. These subsystems and functions are tabulated in Figure 4.2.

Figure 4.2   Components of Beer's Viable System Model (Cook 1996)

Function	Major thrust of activity	Description of activity
Sub-System 1	Production	Operations that fulfil the purpose or primary operation of the organisation.
Sub-System 2	Coordination	Coordination of the separate operations of Sub-System 1 into a coherent overall production process. This includes arriving at voluntary agreements on production standards and practice.
Sub-System 3	Control	A residual function to manage aspects of current production that are otherwise unmanageable. It identifies problems of control not identified by routine reporting in Sub-System 1 or coordination functions in Sub-System 2. It includes sporadic auditing functions aimed at identifying potential for synergy in existing operations.
Sub-System 4	Intelligence	Research and development into new technological, political and market conditions affecting the operating environment to identify future directions of the organisation.
Sub-System 5	Policy	Arbitration between the demands of the present and the future. A source of authority and responsibility for the operation of the system as a whole.

Cook (1994) perceives the Viable System Model as a general conceptual model of an organisation's management information system, such as the cadastral surveying and mapping organisation of Queensland. The model maps how an organisation processes information to manage its affairs and remain in business (Cook 1994).

A central theme of the Viable System Model is that *every viable system contains and is contained in a viable system* (Beer 1984). In the application of this model by Cook (1994) to the Cadastral Surveying and Mapping Organisation, the Digital Land Boundary Information is defined as an operational subsystem within Sub-System 1 of Beer's Viable System Model. The purpose of this defined system is to

"...provide land parcel and boundary data in electronic format as a spatial referencing element in computerised land information systems."   (Cook 1994)

This model and its application to cadastral systems highlights two noteworthy factors. First, it reinforces the contention of this thesis that the maintenance of the digital spatial cadastral map constitutes a subsystem in its own right. Second, the dimensions of the system under examination are expanded into a total organisational context, in a similar way to the dimensions of Miller's (1992) cadastral model.

The recursive application of Beer's Viable System Model to the spatial cadastral system would appear to offer an organisational description of the spatial cadastral system and some insight into its viability. The system decomposition tool, afforded by this recursive model is consistent with most systems approaches that enable understanding and description of complex organisational structures or systems through decomposition of the high level modelling.

4.4   Case Study methodology

The case study methodology has been applied to studies of specific cadastral system, particularly to culturally based cadastral systems attempting to integrate land market principles. The standard definition of a case study is that it is an investigation of a specific system or phenomena from which generalisations are drawn and applied (Evans 1995). A case study is a basis for generating hypotheses as distinct from a study from which conclusions are directly drawn (Onsrud, *et al.* 1992).

In *Using the Case Study Methodology for Cadastral Reform* (Williamson and Fourie 1998) Williamson uses an anthropological classification to increase the analysis rigor. The *big picture* is procured by a *setting* analysis. Lower levels of detail are studied in a drill down process for the specific aspects of the cadastral systems. The limited case

study areas are derived from the *setting* analysis, in response to hypotheses to be tested or questions to be answered.

The stated purpose of the case study methodology is as the examination of phenomena for the primary purpose of research, rather than system implementation or improvement (Onsrud*, et al.* 1992). Given it is a methodology for research and increasing understanding means it does not provide a mechanism to develop cadastral information systems. Extensive background research or derivation of the *setting* of the information system, by whatever analysis techniques, will improve the possible success of the system being developed. The case study methodology provides no means by which this information can be incorporated into an information system development methodology.

Drawing on his experience with cadastral reform in a number of jurisdictions ranging from Thailand, Australia and New Guinea, Williamson (1998) proposes a waterfall methodology inclusive of the case study to arrive at changes to cadastral systems. These subsequent steps are depicted in Figure 4.3.

Figure 4.3   Methodology for Cadastral Reform (after Williamson and Fourie 1998)
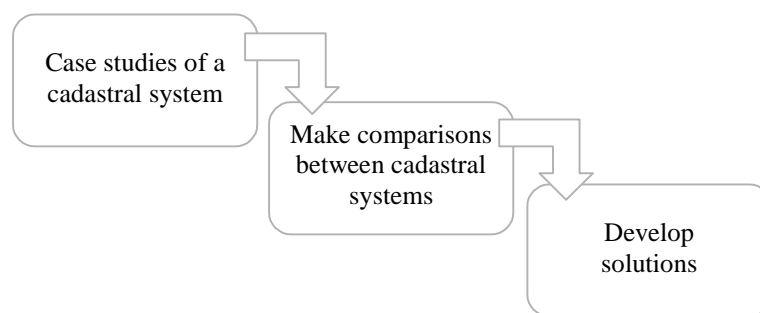
From this diagram it is evident that the case study methodology is a research or analysis tool that in itself cannot construct solutions for cadastral systems.

4.5   *Traditional Information Engineering*

The traditional Systems Development Life Cycle (SDLC) is a set of sequential techniques that facilitate the recording and analysis of an existing system to generate a set of requirements that define the functional and technical characteristics of the new

system. These are the basis for the subsequent steps of system design, construction, implementation and testing. The system analysis and design tools pioneered by this methodology and referenced in many computer systems teaching texts are still utilised extensively today.

Included among these tools are flowcharting techniques (Gane and Sarson 1979) first introduced by John Von Neumann in 1945. Flowcharts concentrate on the processes performed by a system and the necessary data inputs and subsequent process outputs. Entity-relationship diagrams are for the graphic notation of data entities and their attributes. The techniques of Object Oriented programming attempt to combine the data and the processes that are performed on them, in order to constrain data operations to maintain data and functional integrity.

The techniques and tools mentioned above are essentially pre-programming documentation that traditionally focus on the system's data and processes with great clarity. The potentially powerful methodology of SDLC is effective for its intended application but has often been justifiably criticised for not being sufficiently cognisant or responsive to the wider corporate needs.

The phases of this methodology, with its formal, sequential, completion schedules, was the forerunner of information engineering. Information Engineering provides a set of rigorous, interlocking techniques, which build on business, data and process models to provide a comprehensive method of maintaining information systems.

The four major steps of this disciplined engineering approach to application system development are summarised by Inmon *et al.* (1997) as:

- Planning, to define the scope of the problem or opportunity;

- Analysis, to define what the solution needs to do;

- Design, to specify how the solution will be developed;

- Construction, to actually build and implement the solution.

The subsequent emergence of CASE tools represents the Computer Aided System Engineering software that evolved to support these system development activities.

The weakness of the traditional structured systems approach, and information engineering, has been documented as follows:

- Lack of user involvement resulting in new systems and changes that do not reflect what is needed or feasible (Crinnon 1991);

- The formal documents of systems analysis, such as flow charts, data flow diagrams and entity relationship diagrams, are specific data and process documentation and design tools without a wider business and user perspective (Inmon *et al.* 1997);

- The emphasis on data and process fails to adequately recognise the other dimensions of the system (Inmon *et al.* 1997);

- The traditional SDLC lacks the ability to incorporate changing organisational objectives and requirements indicative of large organisations (Crinnon 1991).

SDLC in its various forms is a good basic model for any methodology. Extensions to traditional Systems Development and Information Engineering have attempted to address the weaknesses of the methodology and take advantage of the new technology (Hoffer et al 1999). Rapid Application Development (RAD) and Prototyping address the problem of slow development cycles and Joint Application Development (JAD) address the need for a more inclusive, business wide systems methodology.

For the most part these extensions are not seen as changing the foundation of Information Engineering (Inmon *et al.* 1997). The failure of traditional systems engineering to cope with anything other than well-structured problem situations prompted a rethink of the systems approach (Checkland and Scholes 1990).

4.6 Soft Systems Methodology

The initial stages in the provision of information systems within organisations have very little to do with computer system components and more to do with a rethink of the information needs of an entire organisation. Checkland (1988) refers to traditional structured systems methodologies that concentrate on the project life cycle (SDLC) as *hard systems* that are biased towards solving problems that are clearly defined. Hard systems thinking concentrates on a *means-to-an-end* framework, the *how-to* of computer systems problems. In contrast *soft systems* highlights *what-to-do* with the

organisational concerns, irrespective of whether or not they are directly related to computer systems.

Soft Systems Methodology (SSM) offers a systemic rather than a systematic approach to information provision and processing systems. The methodology defines real and system world activities, a differentiation unique to this methodology. The system world activities provide a mechanism to establish ideal systems that can be compared with the real world systems to highlight possible changes (Patching 1990). The generation and subsequent comparison of a *could be* system to the real world *as is* system provides a mechanism for directing future action.

Patching (1990) summarises the strengths of the Soft Systems as follows:

- provides a set of guidelines to help comprehend complex situations and identify potential improvements;

- many of the actions taken by an analyst using soft systems methodology are conventional fact finding activities;

- encourages an iterative process of viewing the situation from a number of different viewpoints or perspectives;

- makes an explicit distinction between *real-world* and *systems-world* activities;

- models systems in a more open method, attempting to account for human activity and surrounding environmental influences;

- enables a participative approach to establish debate about possible improvements to complex organisational problems.

The soft systems methodology can be viewed as a precursor to SDLC methodologies described earlier i.e. as input to the planning and analysis stages. The tools and processes of SSM are designed to capture the total complex system and incorporate all viewpoints or perspectives. These tools and the concept of the Rich Picture have a role to play in deriving conceptual models. The Rich Picture in SSM (Patching 1990) attempts to document all aspects (people, data, hardware, software and procedures) considered pertinent in order to understand the *bigger picture* of an organisational system. The generation of the Rich Picture is a people intensive, brainstorming process that attempts to capture all perspectives relating to the problem situation.

Conceptual models are then derived from this pictorial documentation of the system through a *"Root Definition"* phase (Checkland and Scholes 1990). The methodology of the Root Definition is designed to fully express the following for a specific perspective or world view (Effenberg 1994).

"A system owned by (**Owner**) *and operated by* (**Actors**) *to achieve* (**Transformation**) *subject to* (**Environment**) ….."

The expansion of conceptual cadastral models to increasingly include more components appears to complement soft systems thinking and its initial high level, all-inclusive pictorial documentation. SSM must be considered as a high-level organisational analysis process, a basis for deriving conceptual models and structuring the action to be taken to address organisational needs. This methodology has been used successfully in a GIS context (Effenberg 1994). Here the research focus was on an organisation's requirement for, response to and policy on temporal spatial data.

4.7   Zachman Framework

The methodologies described have been applied to cadastral information systems to extend the context of the cadastral system and at the same time to simplify the description of that system. Given the benefits of the above methodologies, what is required is an architecture that allows appropriate, proven methodologies to be utilised for specific aspects of the cadastral information system.

Described in another way, a framework that provides a balance between a system wide view, a contextual view specific for subsystems and the pragmatic view related to specific subsystem implementations. The Zachman Framework would appear to offer some of these qualities; it has been described as providing:

"..a taxonomy for relating the concepts that describe the real world to the concepts that describe an information system and its implementation."   (Sowa and Zachman 1992).

Drawing on the experiences and accumulated knowledge of engineering and manufacturing industries, Zachman (1996) proposes a framework which he describes as a logical structure for classifying and organising the descriptive representation of

information systems, and also more broadly to manage and develop organisational systems. This framework is considered equally applicable to an object, information system or organisation with the characteristics of a good classification system that allows for abstractions intended to simultaneously (Zachman 1996):

- simplify understanding and communication;

- clearly focus on independent variable for analytical purposes;

- maintain a disciplined awareness of contextual relationships.

Zachman's premise for an information system framework is derived from engineering principles. Figure 4.4 depicts the framework for the production of an engineering object.

Figure 4.4   Simple framework

	material	function	geometry
owner			
designer		full object description	
builder			

Completing the matrix of cells formed by the rows (perspective) and columns (dimensions or abstractions) achieves a full description of the production object.

"*A framework for information system architecture*" (Zachman 1987) describes the application of this concept to provide an architecture for information systems. The simple framework from Figure 4.4 has been expanded for an organisational system by increasing the number of perspectives and substituting data, function and network for the object dimensions. These dimensions are very much the *what, how* and *where* interrogatives of information systems.

The additional interrogative primitives of *who, when* and *how* were envisaged by Zachman in his original paper and were formally expanded in a later paper (Sowa and Zachman 1992). The resulting framework for a comprehensive description is a matrix of five perspectives and six dimensions as diagrammed in Figure 4.5.

Figure 4.5   Framework for information system architecture (Zachman 1987)

	Data (what)	Function (how)	Network (where)	Organisation (who)	Schedule (when)	Strategy (why)
Scope/Objective (planner)						
Business Model (owner)						
Info System (designer)						
Technology Model (builder)						
Detailed Models (subcontractor)						

full description of the information system

The Zachman Framework is intended to allow description and communication of complex organisational concepts in simple cells or units, while comprehensively and contextually mapping all organisational issues. Instead of replacing other information analysis and documentation tools and techniques it provides an architecture within which they can all be accommodated.

The depicted matrix is variously referred to in the literature as *"A framework for information system architecture"* (Zachman 1987), *"A framework for enterprise architecture"* (Hay 1996), *"Enterprise Information architecture"*, *"Enterprise Architecture"* or most simply *"The Zachman framework"* (Inmon *et al.* 1997). This nomenclature reflects somewhat the expanded uses of the framework, in this thesis the framework will be referred to as the Zachman Framework. The actual naming of dimensions and perspectives also varies; the nomenclature adopted by this thesis is consistent with Hay's (1996) documentation (see Figure 4.6).

4.7.1   Dimensions

Dimensions represented by columns in the Zachman Framework build on the concept of breaking down the description of an object. The isolation of these descriptions (and perspectives) is fundamental to the framework to constrain the complexity of the

object, information system or organisation. The following is a summary of the types of descriptions for the same information system object:

- **Data**   For information systems the modelling of data;

- **Function**   A descriptive or diagrammatic representation of the input-process-output concept;

- **Network**   In this dimension the focus is on connections between components of the information system. Client server technology, the Internet and the Intranet are new factors to consider for information systems;

- **Organisation**   The basic model for this column could be viewed as people-process-people. The organisational infrastructure for work allocation, authority and responsibility. Work allocation is not concentrated on or to be confused with process;

- **Schedule**   The temporal primitive of when events occur in the system. This relates to the currency of data and impacts on the level of resource commitment required to meet the shorter duration for specific event cycles;

- **Strategy**   A representation of objectives and strategies. It is from this dimension, that rules and constraints for the operation and design of the system are derived.

<div align="center">after (Zachman 1987) and (Sowa and Zachman 1992)</div>

While the above dimensions describe the same information system each serves a different purpose. Their descriptions are unique and explicitly do not say anything about the other dimensions, in fact only assumptions can be made from one about the other (Zachman 1987).

4.7.2 Perspectives

The rows of the framework reflect the different players involved in systems development process and the concept of different descriptions or abstractions of the same object in reality. The following is a brief summary of the perspectives applied to information systems:

- **Scope/Objective**   The planner as an outside observer. A completed row fully defines an organisation's direction and business purpose;

- **Business** The owner's perspective defines the nature of the business giving rise to models of the business that define its structure, function, organisation;

- **Information System** A more rigorous description of the business compared to the row above, resulting in system models with a perspective coincident with information systems analysts;

- **Technology** The builder must interpret, redraw and adapt the designer's system models to present technology models which take into consideration the opportunities and constraints of technology and tools of information system building;

- **Detailed representation** This is the detailed representation of each dimension where parts of the system are built or enforced without being concerned with the overall structure or context.

after (Hay 1996) and (Sowa and Zachman 1992)

An important aspect of the *perspectives* is that each brings a different set of constraints to the system. The builder will impose technology constraints while the owner will focus on usage and policy constraints. These constraints are additive in that constraints of the lower rows are added to the model of the higher row. The existence of inconsistent constraints must be carefully monitored to ensure that no gaps in expectations exist, and if necessary, to initiate dialog between the different perspectives (Sowa and Zachman 1992).

4.7.3 Cells

The application of this architecture requires the framework cells to be populated with descriptors, models and methods to ensure comprehensive documentation and understanding, facilitating efficient construction and correct operation. The basis of the framework is that this architecture attempts to incorporate the accumulated knowledge and experience from architecture and manufacturing to information systems and organisational information management. The framework therefore, is equally applicable to house design, product manufacture (Zachman 1987), information system development or a data warehouse application (Inmon *et al.* 1997).

In applying the framework to information engineering and the process of system development it is obvious that some cells may not have representations available (Hay 1996). In contrast some cells may have poorly developed models or methods while no good techniques may exist for some other cells. Figure 4.6 represents the population of the Zachman Framework for information system documentation and development.

Figure 4.6   Zachman Framework for information systems (Hay 1996)

	Data (what)	Function (how)	Network (where)	Organisation (who)	Schedule (when)	Strategy (why)
Objectives / Scope	List of things important to the organisation	List of organisational processes	List of sites organisation operates	List of organizational units	List of business events	List of business goals
Model of Business	Entity relationship diagrams	Business physical data flow diagram	Logistics network (nodes, links)	Organisation chart, roles skill sets and security	Business master schedule	Business plan
Model of Information System	Data model (fully normalised)	Essential data flow diagram	Distributed system architecture	Human interface architecture	Dependency diagram, entity life history	Business rule model
Technology Model	Data architecture mapped to legacy data	System design: structure, and pseudo-code	System architecture (hardware, software)	User interface (how the system will behave); security design	"Control flow" diagram	Business rule design
Detailed Represen-tation	Physical data storage design	Detailed program design	Network architecture	Screens, security architecture	Timing definitions	Rule specification in program logic

4.7.4   Integrity rules

As with other systemic approaches the Zachman Framework has rules that are designed to preserve the integrity of the framework. The following is a précis of these rules derived from Inmon *et al.* (1997) and Sowa and Zachman (1992):

1. **Dimension importance** All dimensions are equally important. There is no natural order to the dimensions in the framework that would imply a data or function driven approach. While a specific solution alternative in any dimension has the capacity to impact other dimensions, this doesn't elevate its importance, but may suggests its consideration early in the design process

2. **Dimension simplicity** Each dimension represents an abstraction of the real world corresponding to the interrogatives of *what, how, when, where, who* and *why*. For each dimension there exists a connector or relationship that provides a basic unique model, which is valid for all perspectives. For example the *what* or data dimension a basic model would be data entity–relationship–data entity.

3. **Dimension uniqueness** It is essential for a classification scheme that there can be no ambiguity. Therefore the basic model for each dimension must be unique.

4. **Perspective uniqueness** Each perspective is unique, driven by the difference in constraints of each perspective and the cumulative nature of these constraints.

5. **Cell uniqueness** A consequence of the previous two rules. A corollary is that different techniques and representations are appropriate for each cell.

6. **Cell necessity** The integration of all cells in a row represents a complete depiction of reality from that perspective. All six dimensions of that perspective must be developed to get a *complete picture* of that reality.

7. **Logic recursiveness** There are two types of recursiveness. First, version recursiveness as exemplified by the current or *as is* framework compared to the planned or *to be* framework. Second, decomposition recursiveness addresses the levels of detail that is not consistent with perspectives, i.e. an individual system as a subset of an organisation framework.

4.8   Zachman Framework and cadastral modelling

"The Zachman framework differs from traditional methodologies in that it is, in actuality, not a methodology. It is a classification scheme for the deliverables from a methodology."   (Inmon *et al.* 1997)

The practitioners of the Zachman Framework contend that the framework is consistent with other existing techniques and methodologies and their deliverables can be mapped to the framework. The thesis therefore revisits each of the methodologies discussed in this chapter to consider how they map to the Zachman Framework.

4.8.1   Conceptual models

The framework cell necessity rule states that the aggregation of all cells in one row constitutes a complete model from that perspective, i.e. an abstraction of the same reality from a defined perspective. Conceptual models therefore represent a summation and diagramming of Zachman Framework cells, conversely Zachman Framework cells should be derivable from conceptual models. This represents a two way mapping between framework cells and conceptual models.

The framework provides an insight into both the content and deficiencies of conceptual models. Conceptual models for cadastral systems can be analysed in terms of whether they are a full or partial summation of a specific row and whether multiple perspectives have been included (a summation of both rows and columns). The data centric criticism can now be interpreted as concentration of the *data* dimension.

The more general management information model offered by Miller (1992) while rightly showing that many conceptual models of cadastral systems lack all the dimensions defined by the Zachman Framework, is in itself only a subset of the dimensions of the framework. The four dimensions of Miller's model and their abstractions are, in the context of the Zachman Framework, a mixture of perspective and dimension. A comparison with the perspectives offered by Coleman and McLaughlin (1997) indicates a mapping into the dimensions of Zachman Framework.

4.8.2   Beer's Viable System Model

Like the Zachman Framework, Beer's Viable System is also a logical framework that provides a mechanism to break down and understand complex organisations. The subsystem structure postulated by Beer's model does not to map to the Zachman Framework as each subsystem has the elements of both dimension and perspective. The subsystems structure of Beer's Model combined with its recursive decomposition property provides a complement to Zachman Framework in identifying organisational systems for which the frameworks can be constructed. Beer's Viable System does not, at any level of recursion, incorporate methodologies to construct information systems.

Cook's (1994) application of Beer's Viable System Model is as an audit mechanism of an existing system to appraise its current and future viability. It identifies those components that are universally true of viable organisational systems whose presence or absence is an indicator of the organisation's future viability. A viability audit process may provide a complement to Zachman Frameworks for proposed systems.

4.8.3 Case study methodology

In the context of the Zachman Framework and the way in which the case study methodology has been used in cadastral systems the *setting* cannot be equated with *the big or complete picture.* Rather, the initial stage of the case study methodology provides the background information or historical and social context for the particular system being analysed or developed. This information is necessarily not directly mappable to the framework but provides some of the essential knowledge relating to constraints within the perspectives of Zachman Framework, constraints for cadastral systems, which may well be social.

The framework, however, dictates an even more rigorous approach to the case study methodology in the respect of studying specific areas of interest. The framework defines all the dimensions that must be addressed in a comprehensive study. The levels of complexity gathered in the case study research could be mapped onto the appropriate framework perspective utilising the best descriptor tools available, be they textual or diagrammatic.

4.8.4 Information engineering

In information engineering terms the process of building an information system is described as the system development life cycle, defined by the staged processes of analysis, design, construction and implementation. Mapping of the deliverables from these stages to the Zachman Framework requires the sequential progression down the columns of the framework (Inmon *et al.* 1997). This sequential mapping is depicted by Figure 4.6 and also shows how each of the five perspectives of the Zachman Framework is dependent on its predecessors, serves a different purpose, provides a different product, and is subject to different constraints (Inmon *et al.* 1997).

Information engineering is additionally about the system development process to achieve deliverables and the tools and techniques to progress between stages or perspectives (arrows in Fig 4.7). This is highlighted by the implementation process, which delivers the functioning system, absent from the Zachman Framework but included in Hay's (1996) fully populated framework.

Figure 4.7   Sequential nature of Zachman Framework

	what	how	where	who	when	why	
Scope/Objective (planner)	information to define basic scope						⎫ Analysis
Business Model (owner)	information about the system and its usage						
Info System (designer)	information about the abstract system						⎬ Design
Technology Model (builder)	information about system construction and assembly						⎫ Construction
Detailed Models (subcontractor)	information for component construction and assembly						⎭ Implementation

Moving down the columns of the framework charts the movement between perspectives. This transition carries the risk of correctly understanding the language and representation of the preceding perspective and correctly addressing the constraints of the subsequent perspective. In fostering dialogue between perspectives a number of tools and techniques may arise which are abridged or hybrid version of the actual cell representation (Inmon et al. 1997).

The Zachman Framework is a not a replacement for the methodology of information engineering. The framework models the necessary equal importance of all the dimensions of an organisation's system. In particular, the incorporation of dimensions that must be developed in conjunction with the traditional data and function dimensions of an information system.

4.8.5   Soft systems methodology (SSM)

SSM provides an iterative and people intensive methodology to derive conceptual models of organisations or systems. In the context of the Zachman Framework, the

Rich Picture phase is then a compilation of perspectives and dimensions, or if the participants are carefully chosen the perspectives within selected dimensions. The *Root Definition* phase is where a viewpoint or perspective is selected and modelled for further study, resulting in conceptual models that can be mapped to the framework.

SSM is also heralded as a precursor methodology to traditional systems analysis, therefore, it is not surprising that SSM both complements and maps to the Zachman Framework. It provides a mechanism for:

- dialog within one dimension but across perspectives;
- obtaining a complete picture or conceptual model for one perspective of the Zachman Framework from which the dimensions can be populated.

SSM however in its classical form must be able to progress beyond the requirements definition to the design of the computing support (Kawalek and Greenwood 1998) The Zachman Framework and SSM therefore have a complementary relationship in that SSM is an analysis mechanism to populate the rows and columns of the framework (albeit at the higher perspectives) and the framework classification property can be used to define viewpoints and perspectives for SSM.

4.9 Conclusions

The appropriateness of traditional information systems development methodologies and their modelling techniques to spatial information systems has been substantiated in GIS research (Benwell, 1991) and demonstrated in the documentation of spatial cadastral systems (Marwick 1998). The Zachman Framework's ability to absorb the deliverables from variety of system methodologies used in the study of cadastral information systems makes its utilisation appropriate for this thesis' spatial cadastral system research. Additionally, the Zachman Framework allows for the structured consideration of the complete spatial cadastral system at the analysis perspectives and more detailed documentation of specific dimensions using formal information systems techniques. This allows concentration on the dimension under consideration while separately and in a structured manner addressing impacts on and from other dimensions. This is consistent with the aim of the research, to study the maintenance of the spatial cadastral data within the context of the jurisdiction's cadastral systems.

The primary contribution of the Zachman Framework is its recognition of all the components that contribute to design and development of a complex information system. These components are classified into a matrix of unique perspectives and dimensions. The logical framework classification of all documentation relating to a system provides a greater understanding of those existing information systems.

The classification property of the Zachman Framework means that it is not inconsistent with existing information methodologies or analysis techniques. Specifically for the methodologies used in cadastral system research and development, the Zachman Framework:

- gives an insight into the completeness of the conceptual models when viewed as an aggregation of the Zachman Framework cells;

- imposes additional rigor on information engineering and case study analysis methodologies by highlighting dimensions and showing that perspectives generate different models which are in fact abstractions of the same reality;

- maps the documentation deliverables from other information system methodologies to the cells of the framework, providing not only a complete system description but also a better understanding of what the methodology is attempting to accomplish;

- positions Soft Systems, Beers Viable Systems and aspects of the case study methodology as complementary or precursor processes for information system design and development.

The Zachman Framework refers to an organisation or business (Zachman 1998) albeit large and complex organisations. The intent of this research is to apply the construct of the Zachman Enterprise Information Architecture to encompass the multiple enterprises or organisations that contribute to the maintenance of the spatial cadastral map. Zachman has written little in this regard but basically the question is whether multiple frameworks are constructed, or a single, expanded framework is constructed to model the multiple organisations of an industry (Zachman 1999).

The analysis of the spatial cadastral system could be undertaken by constructing separate frameworks for each of the organisation within the defined spatial cadastral

system. In this fashion the examination of the same cells would highlight what is the same and what is different. In the design phase the cells that are essentially the same could then be made common (e.g. the spatial cadastral data model). The alternative is to extend the boundaries of the definition of the organisation to include the spatial cadastral industry. In this approach it is harder to differentiate what is and is not common. However, the concept of integration can be leveraged to highlight things that should be common.

This research adopts the latter expanded definition of the spatial cadastral system as identified in chapter 3. This approach amalgamates the high level perspectives of the differing frameworks for the external entities identified in the DFD in Chapter 3, to produce a jurisdictional spatial cadastral framework.

5

Spatial Cadastre of Victoria

Chapter 5 analyses and documents the spatial cadastral system for the Australian State of Victoria; a system amongst whose products is a graphical cadastral map. The dimensions of this analysis accords to the Zachman Framework as outlined in chapter 4, and significantly for the spatial cadastral system as defined in chapter 3.

Some initial historical information is presented to provide the context or setting of the spatial cadastre in Victoria. The analysis of the spatial cadastre covers both the scope and system model perspective of the Zachman Framework. The scope perspective provides an inventory list for each of the six dimensions with an associated clarification of terms. The framework's model perspective utilises where possible the formal diagrammatic tools of information engineering.

This chapter provides a complete and at the time of writing, an up-to-date documented analysis of the spatial cadastral system of Victoria. The application of the Zachman Framework to classify this analysis, and its documentation is unique to

5.1 Introduction

The intent of this chapter is to document a high level analysis of the spatial cadastral system for the Australian State of Victoria. This formal analysis is structured by the dimensions and perspectives outlined by the Zachman Framework. The material presented represents the outcomes of standard systems analysis research namely the observation, interviewing and documentation research, of the peoples and organisations in the spatial cadastral system of Victoria.

The chapter is framed into two main parts. Firstly, the historical background of the cadastral system for Victoria provides the setting within which the current spatial cadastral system was developed and now operates. The second part of the chapter deals with an analysis of the Victorian spatial cadastral system. This analysis corresponds to the first two perspectives of the Zachman Framework as described by Hay (1996), but with the organisation and strategy as the initial dimensions. Figure 5.1 depicts what is essentially the analysis stage of information engineering.

Figure 5.1   Analysis perspectives of the Zachman Framework

	Organisation	**Strategy**	**Data**	**Function**	**Network**	**Schedule**
Scope / Objectives	Inventory of organisational units	Inventory of business goals and strategies	Inventory of data important for spatial cadastre	Inventory of spatial cadastral processes	Inventory of locations where the system operates	Inventory of spatial cadastral events / cycles
Model of the System	Organisations showing roles, skills and security issues	State DCDB strategy	Data Entity Model	System data flow diagram	Organisational and data links	Schedule for spatial data transfer

5.2 Historical context of cadastral systems

For completeness the following sections 5.2 and 5.3 revisit and expand on the background documentation for Australian cadastral systems presented in chapter 3.

In common with other cadastral systems, Australian cadastral systems are a product of their histories. In particular the influence of the historical settlement of the Australian states and territories and the development of two separate institutional arrangements for the administration of crown land and freehold land (Williamson*, et al.* 1997). On the one hand the Departments of Lands, or Offices of Surveyor General, administered the ever decreasing crown lands (as a result of rapid alienation) as well as managing the jurisdictions' surveying and mapping. The Surveyors General controlled licensing of cadastral surveyors and the carrying out of Crown land surveys (Williamson and Enemark 1996). Surveyors General have also had the responsibility for compiling cadastral overlays for topographic maps, particularly over the last forty odd years, and in most cases, the creation of digital cadastral maps or Digital Cadastral Data Bases (DCDBs) over the last fifteen to twenty years.

On the other hand Land Titles Office (LTO) has had responsibility for maintaining records of cadastral surveys associated with the ever increasing freehold or private lands, now comprising the majority of land parcels in Australian states. The LTOs have usually been responsible for examining individual cadastral survey plans of freehold lands. The LTOs primary concern was with individual land parcel transactions in support of the freehold land market. Australia thus lacks a cadastral map that could be used for land administration purposes (Williamson*, et al.* 1997).

5.2.1 Australian cadastral maps

This background to Australian cadastral maps extensively references the paper *Understanding cadastral maps* by Williamson and Enemark (1996)

Up to the 1970s and early 1980s, subdivisions of private lands were charted in Land Titles Offices on index maps, which had a low spatial integrity. These maps were often copied from approximate valuation maps and were frequently used by many other authorities such as local government and utilities. There was major duplication in maintaining these base maps with as many as twenty to thirty different base map series being maintained in each state. These maps were rarely if ever kept up-to-date. The integrity of the cadastral system however was based on the individual accurate

cadastral surveys and plans kept in the Land Titles Offices and those relating to Crown land kept in the Department of Lands or Offices of Surveyors General.

The large digital mapping data sets have their origin in the early to mid 1980s. The typical technique for establishing state based digital cadastral maps was to fit the best available cadastral survey plans together onto a topographic base map using control surveys and physical features as control in a graphic *rubber sheeting* technique. In rural areas the source maps were generally at 1:25,000 scale, while the metropolitan areas were sourced from paper map ranging scale from 1:5,000 up to 1:200. In urban areas, field surveys and survey control was used to a much greater extent with typical scales being usually 1:500 to 1:4,000. The resulting paper cadastral map base was then digitised to establish the DCDB of the majority of Australian states.

The derivation of DCDBs from paper cadastral maps means that cadastral boundaries are represented at a graphical accuracy. Large variations in the accuracy of the coordinates of boundaries are possible with the accuracy of the scaled boundary coordinates in most Australian state and territory systems being about ±1 mm at map scale (e.g. ±25 m at a map scale of 1:25,000) (Effenberg and Williamson 1997).

A very significant feature of the Australian digital cadastre is its full digital coverage across all the eight states or territories of Australia. A spatial cadastral coverage developed independently by each of the eight states or territories, each having a number of significant differences and similarities. Each Australia state maintains its own state DCDB for which the individual data content and management is accounted for by a number of historical, political and economic reasons (Williamson*, et al.* 1998). The digital cadastral map of Australia is a one time compilation of discrete and disparate data sets of each the Australian states and territories (PSMA 1996).

5.2.2 *The cadastral map of Victoria*

The mid 1980s through to early 1990s saw the capture of a state wide digital cadastre become the key mandate for each of the Australian states (Mooney and Grant 1997). Victoria established the Office of Geographic Data Coordination (OGDC) in 1992, under the department of Finance, to ensure the state achieved the projected benefits of

a state wide digital cadastre. The *GIS Strategy Report* (Tomlinson Associates 1993), commissioned by the Victorian Government reinforced the extent of these benefits.

Urban digital cadastral maps were initially captured and maintained by utility authorities responsible for water, sewerage and drainage. Metropolitan water utilities have maintained cadastral maps to manage their underground assets since the late 1800s. Melbourne Water Corporation (MWC) originally captured and managed their state's metropolitan cadastral map. The MWC's cadastral data set became the basis for the Victoria's mandated DCDB. The DCDB was therefore state and specifically metropolitan focused. The initial capture of the DCDB for Victoria was completed in the mid 1990s. Whilst there are some areas in the state that lack completeness Victoria can rightly claim to have state wide coverage (Land Victoria 1998a).

These water utilities' spatial cadastral data sets represent a large portion of the land parcels in the state of Victoria. The Victorian metropolitan cadastral map base comprised nearly 70% of Victorian freehold land parcels and includes most of the state's subdivisional activity (OGDC 1995). Collectively NSW and Victoria have the majority of legal land parcels in Australia (Wan and Williamson 1995).

For Victoria, two separate DCDBs were being developed in the late 1980s, the DCDB of Metropolitan Melbourne, owned by a government business enterprise, the Melbourne Water Corporation (MWC), and the rural DCDB, managed by a State agency called Survey and Mapping Victoria. By early 1994, OGDC identified strategic needs to acquire, on behalf of the State of Victoria, the controlling interest in the metropolitan DCDB from MWC. In May 1994, an establishment agreement was signed between OGDC and MWC to bring the metropolitan and rural databases together under government ownership, to develop a truly state wide DCDB (Jacoby and Marwick 1997). Later in 1994 the Geographic Data Victoria (GDV) was created under OGDC to manage this state wide digital cadastral map (Williamson *et al.* 1997).

The management, maintenance and distribution of the Melbourne metropolitan DCDB was contracted out on 1 July 1995 to Dataflow Pty Ltd (the government owns the data set but does not hold a copy). The maintenance of the whole Victorian State DCDB was then contracted out at the end of 1996 to Dataflow.

5.3 Organisation dimension

5.3.1   Scope/Objectives Perspective

The dataflow flow diagram presented in Figure 3.6 defines the organisations that represent the spatial cadastral system of Victoria. These are described as follows:

- Survey offices, specifically cadastral surveyors;

- Local government bodies, most often referred to as local councils. (Shire is an increasingly less used term for predominately rural areas);

- Referral authorities. In the approval process councils have a statutory obligation to refer all plans of subdivision to a number of organisations for either noting or approval. The organisations of specific interest are the utility authorities, namely those authorities responsible for water supply and sewerage (water utilities) the power supply authorities, etc;

- LTO. In common with all Australian states Victoria has one centralised LTO in Melbourne for all land registration dealings;

- Cadastral map (DCDB) custodian. Consistent with the Victorian government purchaser provider policy (Williamson*, et al.* 1997), the maintenance of the DCDB is contracted out to private enterprise. The private company Dataflow is currently contractually required to provide all the resources necessary to ensure the proper management and continuing improvement of the Victorian DCDB. The Land Information Group, as part of Land Victoria, and in its capacity as purchaser, is responsible for the maintenance guidelines and their ongoing review;

- Customers of the spatial cadastral data. It is necessary to clearly differentiate the one distinct group of customers. Supply side customers refers to those organisations that are involved in the subdivision process and consequently have access to the plans of subdivision at the planning stage. (The terminology of a *supply chain* is used in the report by Watt (1998)). While these customers represent about one third of Land Victoria's customer base, they are the major customers by data volume, and subsequently by revenue.

  In the absence of a proposed layer to represent spatial cadastral data at the planning stage, non supply side customers only have access to spatial cadastral data at the

post title registration stage, either from the DCDB custodian as DCDB updates or as paper copies of registered plans from the titles office.

5.3.2   Model perspective

For a specific business, a model for this dimension would be an organisational chart. In attempting to model a collection of independent businesses for this perspective the thesis will document the spatial cadastral skills and roles of organisations (people) within the spatial cadastral system.

Surveyors:
- survey skills to conduct cadastral surveys, asset surveys, etc;

- CAD skills to produce digital subdivision plans;

- considerable local survey information and knowledge;

- interaction with councils, utilities and LTO to whom the surveyor must supply specific spatial information, often in a variety of hardcopy and digital formats;

- must be a registered cadastral surveyor to sign subdivision plans submitted to local councils and the LTO.

Local councils
- skills to interpret subdivision plans to assess compliance with planning regulations;

- GIS and survey knowledge to incorporate proposed subdivision plans, and to plan and map council assets;

- council signature on plan of subdivision to enable LTO lodgement.

Utilities
- GIS and survey knowledge to digitally incorporate proposed subdivision plans, and to plan, map and cost infrastructure assets.

Land Titles Office
- survey skills to examine plans for title registration;

- validate signatures of councils and surveyors.

Land Victoria (Dataflow)
- GIS and survey knowledge to update and upgrade cadastral map;

- distribution techniques for incremental updates.

Other cadastral map customers
- ability to incorporate updates to their portion of the DCDB.

5.4   *Strategy dimension*

The spatial cadastral system is composed of organisations that are specifically involved in the flow of spatial information, either for the maintenance of the state wide cadastral map, or by virtue of their involvement in maintaining a digital cadastral map for their area of interest. The strategy dimension of the framework is intended to focus on the business objectives and strategies of a composite of these organisations. This presents some difficulty given that a number of these organisations may perceive their business strategy as being incompatible with others of the spatial cadastral system. It is the intent of this research to be aware of the impacting business goals of each organisation within of the spatial cadastral system. It is however, not within the scope of the research to reconcile these strategies for specific cadastral jurisdictions.

5.4.1   *Scope/Objectives Perspective*

The strategy dimension at this perspective will inventory the business goals and strategies of each of the organisations as they pertain to the spatial component of their business and impact the maintenance of spatial cadastral data.

Surveying offices
Besides meeting the requirements imposed by utilities and councils to submit proposed plans of subdivision in a digital format, cadastral surveyors have a limited interest in the maintenance of a graphically accurate, jurisdiction wide, cadastral map. While there is pressure on the surveying industry to participate in emerging spatial data infrastructures (Williamson 1997) the traditional cadastral surveying profession would contend that they:

- have a requirement to hold database of survey measurements and submitted plans for their areas of operation;

- believe that they hold a competitive advantage in retaining their own digital data, given their fears that survey data may be made available to other surveyors for the cost of a search fee (Hayes 1997);

- willing to contribute to a spatial cadastral system that processes subdivision plans from the planning stage to title registration in the cheapest and most efficient manner (Elfick and Fryer 1992);

- require a return for participation, changed business processes, and contributing to maintenance of jurisdiction wide spatial data;

- are limited customers for graphically accurate DCDBs given their own database of survey measurements and local knowledge.

Local councils

In common with other Australian states, Victorian councils have or are developing Asset Management Systems in order to comply with the accounting requirements for local government, as laid out in the Australian Accounting Standard (AAS27). AAS27 requires councils to audit and value their assets right down to street furniture level. GIS and the DCDB have provided the means to administer and maintain these local council assets. Indeed some councils have embarked on capturing their own cadastral databases both before and in spite of the availability of the state wide DCDB. This is evidenced by the then Victorian Maryborough City Council, who completely recaptured a digital cadastre for its area, to support its administration, planning and engineering functions based on the perceived inadequacies of the state DCDB (Bryning 1994). In contrast some councils have not adopted a GIS to facilitate their operations. The following summarises possible council based business strategies.

- A willingness to participate in mechanisms to provide effective and efficient land development to promote investment in the council's jurisdiction;

- Implement GIS with DCDB backdrop to meet accounting and funding requirements as set out in AAS27;

- A willingness to contribute in DCDB upgrade programs for their locality;

- An interest in reconciling their property DCDB against the parcel based DCDB;

- Capture their own spatial cadastral data to meet local requirements;

- Maintain their own version of cadastral map via proposed plans of subdivision submitted for certification, perhaps even insist on digital lodgement;

- Accept state DCDB in exchange for update information as proposed for instance under Land Victoria's property project (Jacoby and Murray 1998).

Utilities

The requirement to engineer and administer assets, particularly underground assets, means that utilities were often the pioneer users of GIS and in many cases developed their own property based cadastral maps which provided the basis for the state wide cadastral maps.

The larger and more densely populated water authority regions have maintained cadastral maps often at a greater accuracy than the state DCDB for the same region. In Victoria, where Melbourne Water has been spilt and corporatised, the changed business goals have resulted in differing mapping requirements. There are of course residual agreements in place for them to access and supply to the Victorian DCDB.

Similar to local councils, utilities also have a range of business goals and strategies related to the mapping and planning of their assets. These are summarised below:

- A business need to maintain a property based DCDB, with information supplied from proposed plans of subdivision, generally submitted in digital format for large subdivisions;

- The maintenance and distribution of its spatial cadastral data seen as both an asset and potential income source;

- The creation and maintenance of the spatial cadastral data not seen as a core business activity of the water authority;

- A number of both legacy and up-to-date systems deemed to rely heavily on the current digital, spatial data and considerable system and data issues involved with changeover to state DCDB.

Land Titles Office

In the past the Land Titles Offices of Victoria and has operated separate to the state mapping agencies. The need of the DCDB to reflect the legal cadastral fabric means that Land Victoria (Dataflow) needs to obtain copies of the registered subdivision plans from the LTO as quickly as possible. In Victoria this is via the hardcopy of the registered subdivision plan.

The following would reflect the strategy issues for the Land Titles Offices in terms of the spatial information represented by the subdivision plans:

- An existing ability to profitably administer its functions using a computerised index of scanned subdivision plans (raster images);

- Possible cost/benefit of maintaining a survey accurate digital cadastral database (LTO 1998);

- Utilise graphical DCDB for title search and indexing;

- A business objective to reduce the time and internal cost of land registration.

DCDB custodian

Land Victoria has published a policy statements relating to the provision of spatial information, namely:

"Geographic Information to be consistent, accurate, reliable and current, and to be on-line, easily accessible to any part of Victoria and available anywhere, anytime by anyone."   (Land Victoria 1997b).

A number of subsidiary and often undocumented objectives need to follow to support these policy statements:

- Homogeneous cadastral map – the concept of all users in the state using the same cadastral map maintained by the state custodian. This homogeneous aspect is seen as providing spatial infrastructure;

- Minimise duplication – not only in the sense that the there are not multiple maintainers of the spatial cadastral data, but to prevent multiple cycles involving the re-entry of spatial information from hardcopy computer plots;

- Multipurpose – both ensuring that the content of the cadastral map contains multipurpose data (e.g. parcel and property data) but also of a format, currency and accuracy suitable to the users;

- Interoperable – the spatial cadastral data can integrate both aspatial and spatial data sets (e.g. coherence with topographic data).

Customers of spatial cadastral data

While the strategy of the supply side customers has been elucidated, the expectation is that other customers will have content and delivery requirements. Increased usage and awareness will add to the pressure for a truly multipurpose cadastre, which will

subsequently pressure the content and maintenance of the spatial cadastral map. This is evident in both NSW and Victoria where user demands have changed the content of the digital map from its original land parcel specification. In particular in Victoria, Land Victoria's contract with emergency dispatch customers has resulted in an emphasis for the inclusion of property and address information.

5.4.2   Model perspective

The strategy dimension at this perspective, involves considerable rationalisation of the business strategies of the individual organisations that impact the maintenance of the state wide digital cadastral map. The task of accommodating the differing business focuses of individual public and private entities represents a political endeavour that is clearly outside the scope of this research. Notwithstanding that the strategic dimension potentially has significant impact on the maintenance and distribution of spatial cadastral information, this study will limit itself to the following strategy documentation provided by Land Victoria in support of its activities to promote a spatial cadastre that meets the needs of all users.

Land Victoria Vision
- All Victorians will be able to access and use the Geospatial Information (GI) they need (Land Victoria 1999c);

- The state wide property based DCDB is to provide integration and distribution of all state government land related information to service government and the community (O'Keeffe, 1998).

Strategic Objectives (Land Victoria 1997)
The overall objectives of the Strategy are to establish, maintain and improve:

- Awareness - Public awareness of GI, its use and benefits;

- Access - On-line, easily accessible GI about any part of Victoria and available anywhere, anytime by anyone;

- Affordability - GI priced to encourage, not discourage its use. Access to GI will not be limited by price;

- Quality of GI - Consistent, accurate, reliable and current GI;

- Integration of GI - Seamless integration with aspatial data sets;

- Use of GI - GI tools will be readily available. Victoria will have a GI literate, GI aware community, able to use GI tools and techniques to make decisions with the overall aim of maximising the total value of Victoria's investment in GI.

These have been reinforced in the Victorian Geospatial Information Strategy for 2000 (Land Victoria 1999c), but in terms of infrastructure information rather than GI.

5.5   Data dimension

Observation of the differences in the cadastral maps between Europe and Australia, or even the cadastral maps of the Australian states, clearly shows that there is no agreed content for the cadastral map, let alone a consensus on data models (PSMA 1996). The current and future content of the digital cadastral map is ultimately determined by a careful consideration of the current and intended use of the digital cadastral map. That the cadastral map is also based on the cultural, social and economic history of that jurisdiction, is reinforced in a paper by Williamson and Enemark (1996). While the cadastral map is a product to service the often unique processes of a jurisdiction's cadastral system, it is increasingly expected to meet the requirements of multipurpose spatial cadastral data.

The major spatial data update source for the digital cadastral maps for Victoria is the plan of subdivision lodged by the surveyor to the LTO. The data and process centric nature of information systems development means that the data dimension of the state wide, digital, cadastral map is well documented. Complete Australia wide, state specific descriptions can be found in the report on the 1996 DCDB workshop (PSMA 1996). Also World Wide Web based information sites specific to Land Victoria provide up-to-date information about the available digital cadastral products.

5.5.1   Scope/Objectives perspective

The following is an inventory and definition of the spatial and aspatial data normally associated with western cadastral maps (see chapter 3). The digital cadastral map data content for Victoria are contained within this larger listing.

Spatial data:

- **Parcel boundaries** – The graphical cadastre maintained by Victoria means that the parcel boundary is a graphical depiction of the parcel's relative position. The digital parcel coordinates are not the actual coordinates, nor are there any direct references to the survey coordinates that created the parcel boundary.

- **Property boundaries** – Generally a property consists of one or more legal land parcels. The initial presence of property boundaries, rather than parcel boundaries in the DCDBs, reflects the water utility source of much of the spatial cadastral data. While there is a renewed interest in property boundaries for the multipurpose cadastre, the water utilities and councils were and generally are only interested in rateable properties, i.e. property boundaries The Victorian metropolitan cadastre was property based while the non-metropolitan DCDB was parcel based. Land Victoria is currently attempting to capture and maintain both property and parcel boundaries for the entire state wide cadastral map.

- **Building footprint** – The outline of building footprints is not part of the DCDB. Some footprint outlines are being included to overcome interpretation problems in large parcels occupied by many dwellings or having multiple council or utility access points, such as retirement villages and shopping centres.

- **Occupation boundaries** – Representing all land occupation boundaries such as roads, railway lines, parks, crown land, etc, these are often not covered by legal title. In Victoria over 40% of land is crown land comprising National Parks, reserves and Crown leases. The fundamental origin of the digital cadastral map areas was however from the freehold boundaries. Victoria is continuing to upgrade the deficiencies of the spatial data in this area.

- **Easements or right of ways** – In Victoria, drainage and sewerage easements, relevant to metropolitan water authorities, are maintained along with some major transmission and pipeline easements.

- **Cadastral administration boundaries** – The nature of the centralised state wide cadastral system means that the cadastral boundaries are only relevant at state boundaries, with no cadastral administration boundaries internal to the state.

- **General administration boundaries** – These include postcode, administration boundaries such as local government, suburb, electoral, etc. In Victoria, these

boundaries are the responsibility of other government departments and therefore are not maintained in conjunction with the cadastral map.

- **Land use boundaries** – These are land use category boundaries for buildings, garden, agriculture land, forest etc; these have never been a feature of Australian cadastral maps.

- **Roads**– Victoria has derived a road centreline spatial data set from the cadastral street boundaries. This dataset is now maintained in conjunction with the DCDB.

- **Other sub parcel data** – Includes other spatial data to reflect three dimensional ownership, e.g. high rise ownership or parcels above tunnels. In addition other legal ownership instruments, such as strata titles, result in sub parcel spatial data.

Aspatial data:
- **Parcel identifier** – A unique identifier to link to spatial cadastral data to the aspatial databases or attribute data. Victoria has recently implemented unique identifiers for all points, lines and polygons.

- **Survey identifier** – A unique reference to the original subdivision plan that created the parcel and was lodged and registered at the LTO. A *lot on plan* notation identifies individual parcels on subdivision plans. The DCDB holds this information but early software utilised in digital cadastral map capture for Victoria meant that this information was only held as annotated text in digital map. This is now also held as an attribute of each parcel.

- **Street names** – These are an essential part of the lodged survey plan and are transferred to the digital cadastral maps.

- **Street address** – Usually associated with the property rather than the parcel, allocated by the local government body. The capture of these addresses is a priority for the Victorian digital cadastral map.

- **Accuracy indication** –Victoria does not have accuracy indicators directly associated with the individual data elements. Metadata supplied with the digital spatial data reflects relative accuracy associated with the hardcopy map scale from which the spatial data was originally captured. The accuracy is for acquisition by digitisation, traditionally 1mm at map scale, i.e. ±25 metres for hardcopy source maps at 1:25,000 scale.

Proposed data:

This refers to subdivision plans submitted to local government and utilities by the surveyor for planning purposes, but not yet registered by the Land Titles Office. In Victoria, the metropolitan DCDB captured proposed plans of subdivision. The rural DCDB had only ever held the legal parcel fabric at a post title registration stage.

Historical data:

In the past each update of the DCDB meant that the previous subdivision structure was deleted. Storing spatial data in relational databases makes historical data easier to retain, but still difficult to integrate and allow temporal investigations. Victoria typically retains some temporal spatial data. The recent introduction of unique feature identification (UFI) for all points, lines and polygons allows incremental updates of the DCDB to be distributed in text format and a history of changes to be retained.

Spatial data examples

Figure 5.2 shows a portion of the DCDB obtained from Dataflow. The diagram has been modified to highlight the update data derived from the subdivision plan shown in Figure 5.3. Figure 5.3 shows the plan of subdivision, P.S.400592, as produced by the surveyor for lodgement at the LTO, and from which the DCDB was updated (plan orientation has been altered). The emphasis of the DCDB update procedure is to maintain the relative accuracy of the map, this may result in the loss of absolute accuracy as the whole subdivision may be moved and *fitted* to the current cadastral map. Note the inclusion of address information not present on the subdivision plan and of course the generation of the road centreline.

Figure 5.2   Portion of DCDB updated with PS 400592

Figure 5.3   Plan of Subdivision PS 400592

5.5.2   Model perspective

There will be different data models for each of the organisations involved in the spatial cadastral system. In line with the business strategy for a homogeneous DCDB, Land Victoria in its capacity as custodian of the state wide spatial cadastral data has an interest in generating a data model that encompasses the needs of all its users. Practically, this means a data model (or a subset thereof) implemented for the state digital cadastral map to meet user data needs for less than state wide extents.

Victoria has implemented a data model based on unique identifiers for all graphic elements (points, lines and polygons). The model depicted in Figure 5.4 has been published by Jacoby and Marwick (1997) on behalf of Land Victoria. This is not an ERD as defined by systems software design. It is included here as an example of an abridged model that fosters understanding between the scope perspective and the more rigorous modelling perspective of ERDs (Sowa and Zachman 1992).

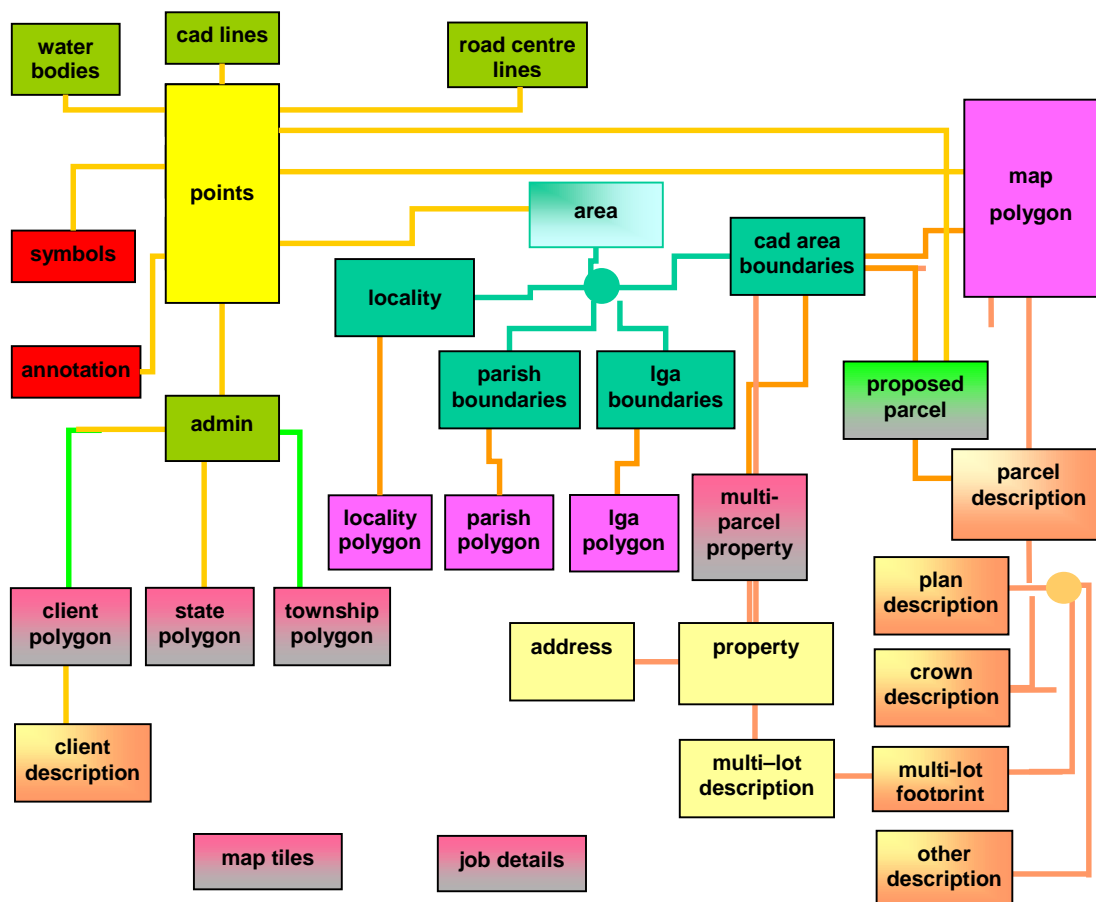**Figure 5.4**   Cadastral framework model (Jacoby and Marwick 1997)

Figure 5.4 is an abridged Entity-Relationship diagram, showing entities, but not fully defining their relationships. A formal ERD is depicted in Figure 5.5 using the following standard convention.

- data entity

- cardinality symbols

    - 0 to many

    - 1 to many

    - 0 or 1

    - exactly 1

The data model represents the primitive components of the data contained in the Vicmap Digital Property. Polygons are used to represent formally bounded area features such as parcels, properties and administrative areas, e.g. Parishes, Local Government Areas (LGA), etc. Lines are used to represent the boundaries defining area features, they also provide the graphical definition of linear features such as easements, road centre-lines. Points are used define the extent of all lines, and to locate symbols.

The data dictionary applicable to the Vicmap Digital Property data model entities represented in Figure 5.5 can be found in the Vicmap Digital product description (DNRE 2000).

The data model contains a number of entities that cannot be updated or sourced from the traditional plans of subdivision. These data entities include:

- property information where a property may contain a number of parcels;

- property address information;

- administration boundaries, such as local government, parish, etc;

- topographic elements such as road features and water bodies.

This impacts on other dimensions of the spatial cadastral systems such as new data flows to source property and address information from local government.

Figure 5.5 Vicmap Digital Property Data Model (after DNRE 2000)
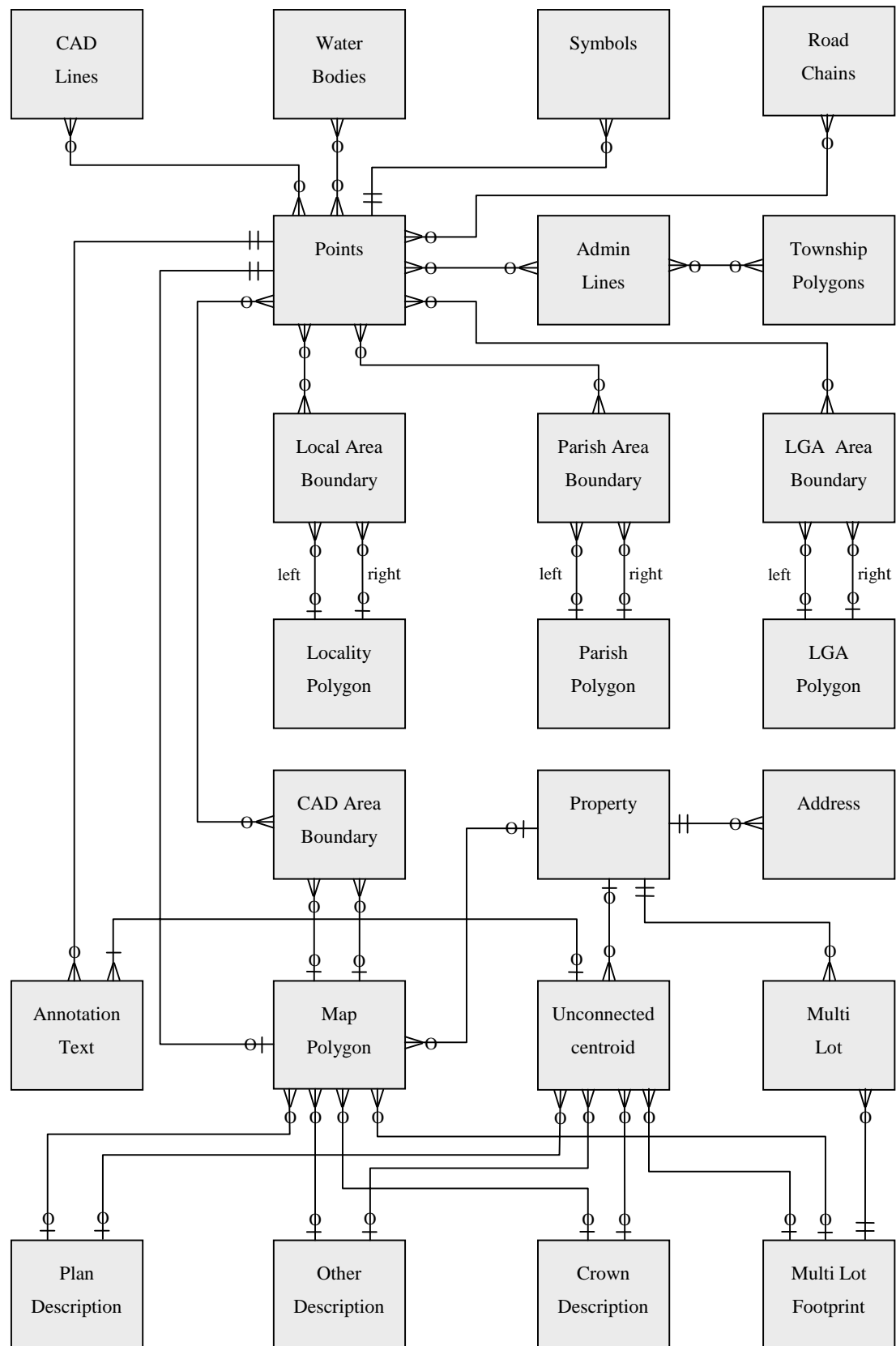
5.6 Function dimension

5.6.1 Scope/Objectives Perspective

Under the framework guidelines the documentation of this dimension is a listing of the functions associated with the spatial cadastral system. Specifically, for the purposes of this research, the functions that result in a change of either status or content of the spatial cadastral map. In effect, this listing is the first stage of expanding the context level DFD for the cadastral system presented in Figure 3.16.

Within this scope the following is the list of identified processes for the spatial cadastral system:

- Spatial representation of subdivision for planning approval;

- Creation of the cadastral survey plan for subdivision;

- Distribution of the proposed plan of subdivision;

- Approval of the subdivision plan;

- Lodgement of subdivision for title registration;

- Survey examination of plan of subdivision;

- Distribution of registered plan of subdivision;

- Maintenance of the DCDB;

- Distribution of spatial cadastral changes.

These spatial cadastral processes are more fully explained as follows:

Spatial representation of subdivision for planning approval
Planning approval must be sought from the local government authority. This may often only involve a rough sketch of the proposed subdivision to convey development intent and assess compliance with planning regulations.

Creation of the cadastral survey plan for subdivision
As clearly depicted in the data dimension, the cadastral survey information originating from the surveyor is the basis for the spatial data that will construct the subdivision plan (see Figure 5.3). The survey plan provides the necessary spatial information to update the digital cadastral map.

Distribution of the proposed plan of subdivision

Upon receipt of plans of subdivision, local councils have a statutory obligation to refer these plans to a number of referral bodies for noting and approval. This generally involves mailing photocopied subdivision plans to the appropriate referral authorities. The surveyors will often submit their plans to some of the referral bodies at the same time, or prior to them being submitted to the councils, with the intent of speeding up the approval process. The water authorities in particular, with their background in cadastral mapping, have demanded that surveyors digitally lodge large subdivision plans to secure even greater efficiency (PSMA 1996).

Land Victoria, the custodian of the cadastral map, is not amongst the organisations to which local government must refer subdivision plans. Acquisition of proposed or pre-built subdivision plan information for preliminary update of the DCDB would require that the information be sourced at this planning stage, often months before the subdivision plan is lodged at the LTO.

Victoria, as a result of its association with the Melbourne metropolitan water utility, is able to secure subdivision proposal plans for the metropolitan area on a twice weekly basis (PSMA 1996). These are lodged in a digital format to the water authority for all subdivision plans comprising greater than ten lots.

Approval of subdivision plans

The local council is charged with enforcing local planning and land use regulations; the local council must formally approve the subdivision plan. The council's approval is dependent on the responses from the statutory referral bodies that include authorities responsible for water, gas, electricity, sewerage telecommunications, etc. The approved plan, bearing the council signature, is termed the certified plan, and is returned to the surveyor for submission to the land registration body.

Australian state cadastral map custodians have initiated a number of investigations and trials to assess the feasibility of acquiring proposed plans of subdivision from local councils at plan certification stage, i.e. after the local council approval of the subdivision plan.

The Property Project, undertaken by Land Victoria in 1998 (Jacoby and Murray 1998), attempts to acquire proposed plans of subdivision from all councils in the state

of Victoria. The Property Project seeks to source the following information from all councils (Jacoby and Murray 1998):

- Plans defining rateable properties as distinct from legal land parcels;

- New and amended street addresses;

- New and amended road names;

- New and amended council property reference numbers with corresponding street address information.

Lodgement of subdivision for title registration

The hardcopy plan of survey, approved by local council, and other legally supporting textual and legal documentation, is required to be lodged with the titles office to initiate the land registration process. At lodgement, the plan of survey is registered, becomes a legal document and becomes available for public perusal.

Survey Examination of plan of subdivision

The role of the government in guaranteeing land title means that the LTO for both Victoria and NSW employ surveyors to check the correctness of cadastral surveys. The island nature of cadastral surveys requires that prior to the examination of any new cadastral survey plan all adjoining plans need to be collated. Examination of the spatial cadastral data therefore involves checking that the new survey information is consistent with all registered plans surrounding the new subdivision.

A full survey examination ensures that:

- land in the plan agrees with stated references to title and locality details, and existing easements are correctly depicted;

- all existing boundaries are correctly defined;

- common boundaries with existing parcels have been adopted;

- the plan is mathematically correct;

- the land in the plan is wholly within and includes the whole of the land denoted by the subdivider's title;

- new easements are correctly defined;

- all survey markings and connection to survey control are correct;

- all statutory requirements have been met.   (LTO 1998)

This examination process is largely conducted by hand on hardcopy plans. The nature of this survey examination has changed over the years, as a result of the reduction in the number of examining surveyors being employed, the requirement to fast track land registration, and the impact of technology. There is a growing trend for the plan examination to concentrate on those spatial aspects that verify the consistency with adjoining land parcels, leaving the internal integrity and correctness of the subdivision plan the responsibility of the individual surveyor.

Distribution of registered plan of subdivision

An important consideration in the update processes of the cadastral map is that of user access to the new spatial data. That is, the boundary of the spatial cadastral system is defined such that the process of distribution of the spatial cadastral data to users is included in the system. The flow of spatial cadastral update information finishes, not with the update of the DCDB, but with the ability of the user to update their copies of the spatial cadastre.

The LTO provides a service that allows customers to receive copies of all newly registered plans of subdivision usually in hardcopy format. This is a critical update source for the DCDB, as most changes to the spatial cadastral framework must pass through the LTO. Councils, utilities and other bodies, with access to the subdivision information at planning stage, will be customers of this LTO service to note any changes between to the proposed and legal plans of subdivision. Further, those organisational maintaining their own versions of the DCDB, will need to reflect any such changes in their own spatial databases.

To ensure the integrity and completeness of the DCDB other data sources such as government gazettes, parish plans, etc are consulted to capture all boundary data. Some states quote that up to 40% of current cadastral update activity is outside the current subdivision process (PSMA 1996). While the cadastral activity that is not required to pass through the LTO is generally easily identified, it is often difficult to capture the related survey data.

Maintenance of the DCDB

The term maintenance is increasingly used as an encompassing term for both the update and upgrade of the cadastral map. The terms update and upgrade while often used in relation to the DCDB need to be clearly defined. The following is the classification of these two different processes as used by this research.

Spatial update of the digital cadastral map essentially refers to those processes that ensure that all new and existing legal subdivisions are recorded, i.e. the cadastral map is up to date.

Specifically this will include:

- recording all new legal subdivisions. Given the post title nature of DCDB this involves the inclusion into the DCDB of the registered subdivision plans distributed by the LTO. Where spatial data has been previously sourced from the proposed plan, this data will need to be amended to reflect both changes as a result of the plan examination process and the change of status of the subdivision from proposed to legal;

- sourcing and recording changes in these spatial or aspatial components subject to change. Administrative boundaries, building footprints and street names and address are subject to change and therefore require maintenance;

- ensuring map completeness including recognised backlog or holes in the map still incomplete from the capture phase, particularly areas of the map that have not been revisited since capture due to little or no subdivisional activity in those areas. This would also encompass the capture of boundary information relating to non freehold land such as Crown land, etc;

- inclusion of a proposed or planning data layer to secure spatial cadastral updates at the planning stage, before the land registration process is completed.

The graphical nature of the spatial cadastre means that new subdivision plans cannot always be incorporated directly into the existing DCDB. The following reflects the procedure policy used by Victoria to incorporate spatial updates, and ensure that, at the very least, the current spatial accuracy of the DCDB is maintained.

- **absolute accuracy:** extensive updates containing spatial data of greater accuracy by virtue of survey control or more accurate collection is placed into the DCDB in its correct position and existing data is then adjusted to fit the new data**.**

- **relative accuracy:** updates are entered with their absolute accuracy and then moved to best fit within the existing parcel fabric. In order to maintain the correct survey dimensions of new spatial data, some adjustment of the existing spatial fabric may need to occur.

- **graphical accuracy:** this may occur for either of two cases. Firstly for simple updates where an existing parcel is simply divided into two. Secondly and more importantly where the absolute and relative accuracy methods would cause too large a movement in the existing parcel fabric.   (Ranshaw 1995)

The obvious spatial upgrade activity associated with the digital cadastral map is an increase in the accuracy of the spatial data, an increase in the accuracy of all or part of the map content. Beyond this obvious process the following is a more comprehensive list of activities that should also be included in the discussion of upgrades to the digital cadastral map:

- Increase in the spatial accuracy of all or any part of the cadastre;

- The inclusion of more survey control and measurements;

- The alignment of the spatial cadastre with topographic features;

- Changes in spatial data models to introduce (or delete) entities e.g.

    ~ property boundaries,

    ~ building footprints or other land use identifiers,

    ~ street addresses,

    ~ specific aspatial attributes;

- Generation of topological database structures for the spatial data;

- The inclusion of a historical layer to allow verification of new parcel creation;

- Unique identification for all spatial entities.

Many of the latter cadastral upgrades mentioned above can be achieved in the process of changing the software and/or the hardware platform of the digital cadastral map.

The inherent translation or migration processes associated with these platform changes often provides a cost effective means of upgrading aspects of the digital cadastre.

Distribution of spatial cadastral changes

The distribution of updates to the DCDB that reflect all changes as a result of the subdivision process and specific upgrade projects, has always been a major focus of the cadastral map custodian in Victoria. Considerable effort has been allocated to meet the diverse range of user mapping technologies, data requirements and geographical extents. The updates to the DCDB are made available in a range of digital formats and supplied to the user as follows:

- Hard copy plots of specified areas;

- Whole file replacement for predefined areas or map sheets or the whole of the state. The custodians of the DCDB offer customers a complete or *refresh* copy of the DCDB for their area of interest;

- Predefined tiles, the Victorian Metropolitan DCDB, is able to be delivered as a bulk replacement of any of the 2,800 predefined tiles that have changed (Hesse and Jacoby 1995);

- Incremental update, a mechanism to deliver only changes to the customer's portion of the DCDB since the last update delivery. Victoria has implemented an incremental update procedure that requires clients to take an initial copy of the DCDB followed by ASCII file updates of all subsequent changes consistent with the customer's original copy (Jacoby and Marwick 1997);

- Mirror sites, Victoria has attempted to implement the concept of mirror sites for either internal customers or specific customer research projects. Here the customer's spatial database is a site external to the custodians, all spatial cadastral updates are applied as an automated process each night, week or at other specified times. This requires customers to have similar or predetermined hardware and software and the maintenance of communication technology.

The distribution of the DCDB to customers requesting multi state coverage would require a third party to join the data sets from a number of states.

The function dimension processes are largely in chronological order. A number of the processes, which involve approval or costing, can possibly undergo a number of iterations to ensure that the subdivision meets regulations or allow subdivisions to be redesigned to achieve more cost effective infrastructure costs.

5.6.2   Model perspective

The model presented in Figure 5.6 is again a hybrid model presented on behalf of Land Victoria by Jacoby and Marwick (1997). The use of unconventional symbols makes this diagram potentially confusing unless presented in the context of attempting to foster understanding between traditional systems modelling and the previously presented scope perspective.

Figure 5.6   Information flow for DCDB maintenance (Jacoby and Marwick 1997)
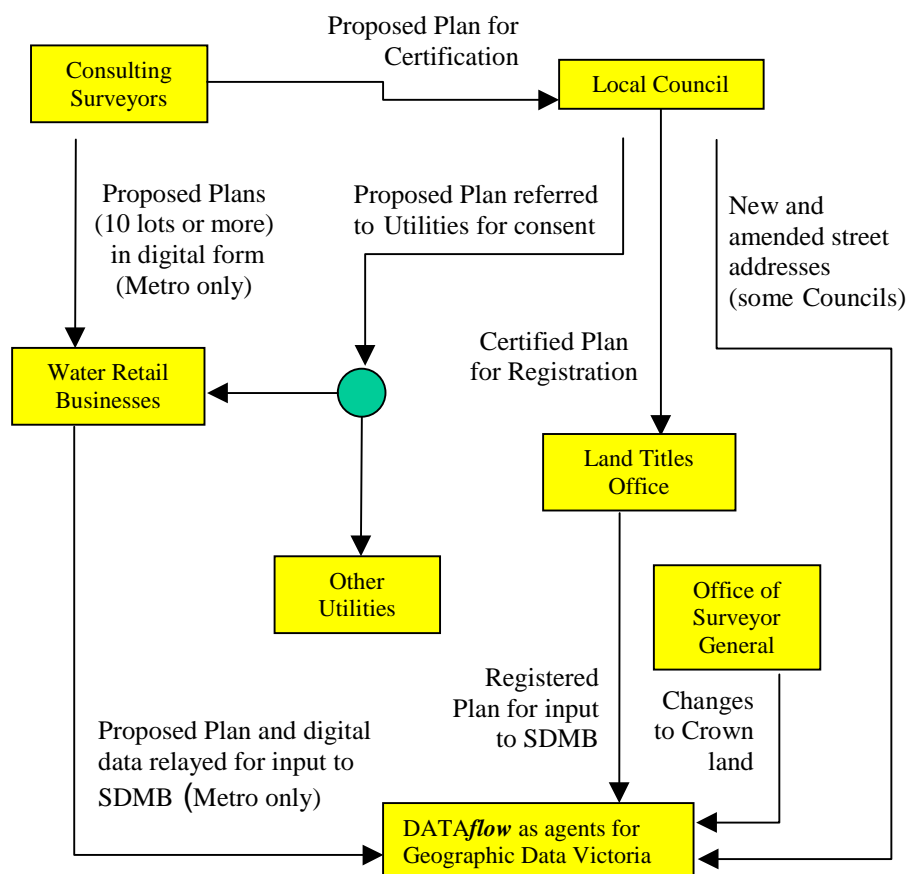
The formal level 1 DFD for the Victorian spatial cadastral system is presented in Figure 5.7. This is the decomposition of the level 0 DFD presented in Figure 3.16.

Figure 5.7   Level 1 DFD for Victorian spatial cadastral system
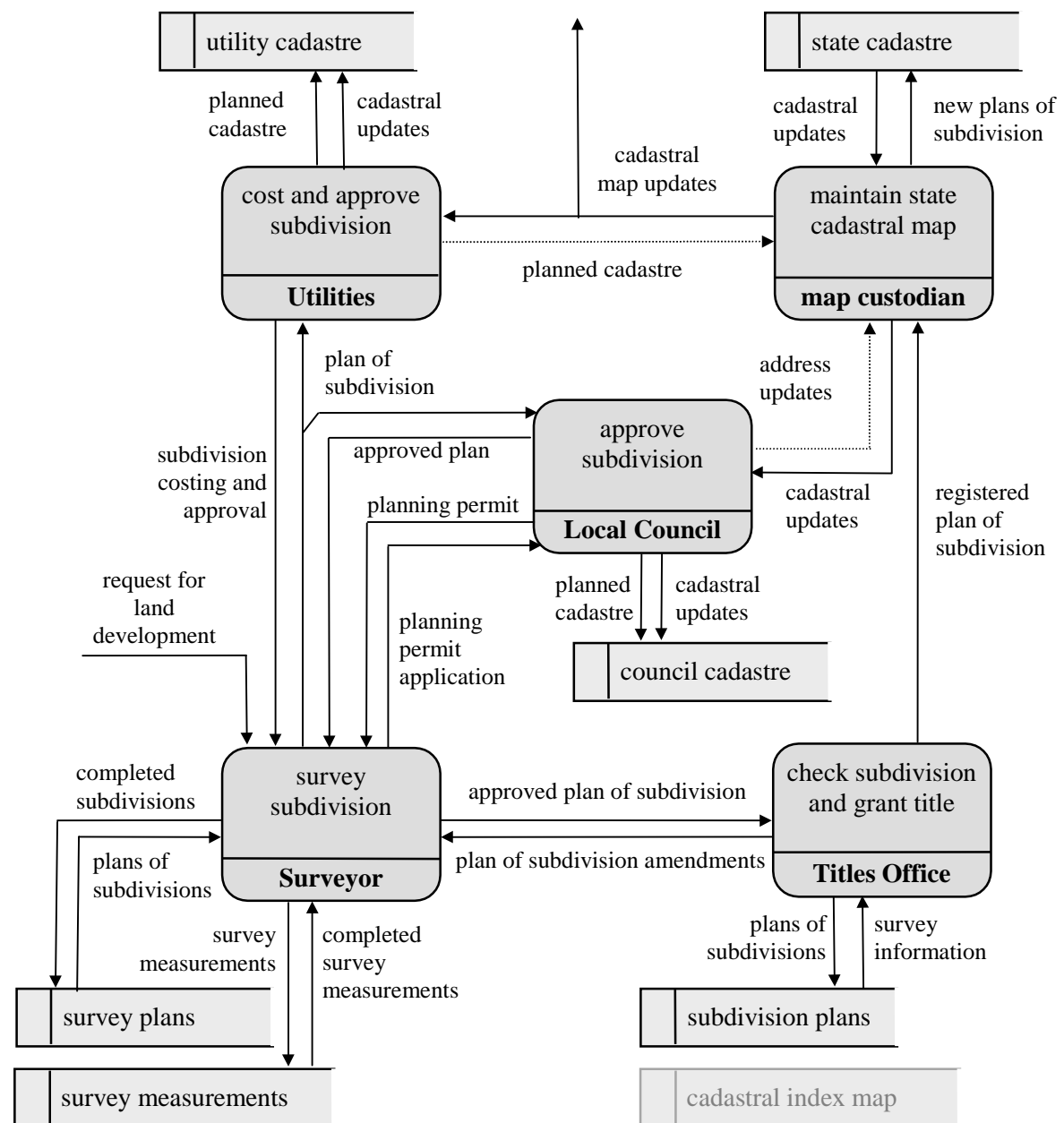
In his thesis *A Prototype System for the Digital Lodgement of Spatial Data* Hayes (1997) gives comprehensive documentation of the processes that are enacted within councils and the LTO. This would then represent the next level of the DFD decomposition. The processes for the Australian State of Queensland appear to have substantial similarities with the processes across all Australian states.

5.7   Network dimension

5.7.1   Scope/Objectives Perspective

The inventory of locations where the spatial cadastral system operates, and where digital or hardcopy versions of spatial cadastral data reside in its passage from the surveyor of the subdivision, to the spatial updates distributed to the users.

- Field surveyors;

- Survey offices across the state submitting their data to a number of councils and utilities;

- Local government. In Victoria there are 78 local government authorities, of these 26 are in metropolitan Melbourne, 10 are rural city councils, with the balance being rural or shire councils;

- Utilities. In Victoria there are four power utilities, three metropolitan water authorities and fifteen urban water authorities;

- LTOs. One centralised office located in state capital, Melbourne;

- Cadastral map custodians: this is now the Land Information Group within Land Victoria, with the actual maintenance of the Victorian DCDB out sourced to Dataflow, a private company located in suburban Melbourne.

As we move from the surveyor to the custodian of the cadastral map, the geographical extent increases. As an example, while the LTO has state wide responsibility, the power utilities divide the state into four, while the councils divide the state into 78 areas with correspondingly smaller areas of interest.

5.7.2   Model perspective

No formal models are documented for this cell of the Zachman framework. The network model for the Victorian spatial cadastral system in Figure 5.8 was constructed to highlight the method by which data is transferred between organisations enacting the spatial cadastral processes and the independent uptake of technology by participating organisations.

Figure 5.8   Network of organisational information systems
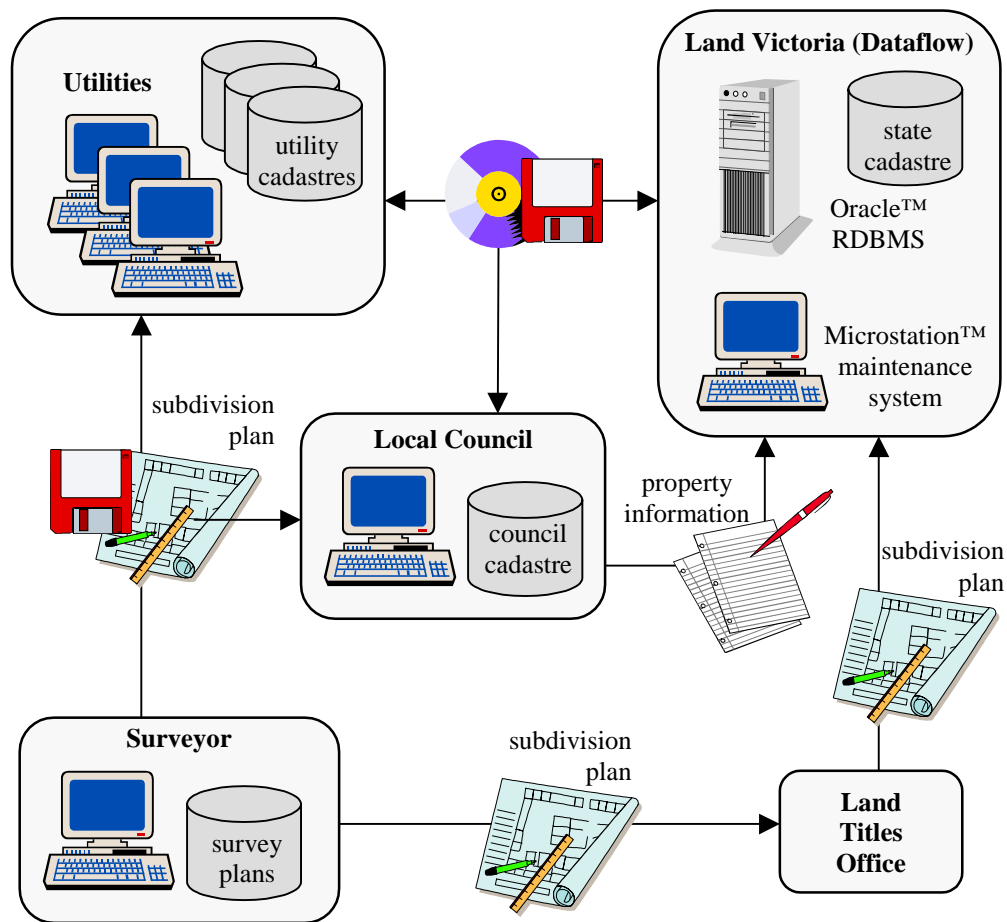
The following should be noted in relation to the above network model:

- Many surveyors utilise a CAD system for preparation of subdivision plans;

- The existence of some digital information, but no digital transfer of spatial information between institutional entities;

- While not all local councils necessarily have a GIS, all have computerised property and rating systems;

- Most utilities digitally map their assets against a cadastral map.

5.8   Schedule dimension

The emphasis of the time dimension of the framework is to identify those events that are necessarily subsequent to or prior to processes identified earlier under the function dimension. These are events, which do not necessarily change the spatial data, but

events that signify the progression of the spatial cadastral data through the cadastral system.

5.8.1   Scope/Objectives Perspective

The inventory of events depicts the progression from the request for land development to the user of the cadastral maps receiving updates to their copy of the cadastral map.

- Prepare development application with preliminary spatial data;

- Lodge development application with local government;

- Local Government planning approval granted;

- Surveyor conducts detailed survey and prepares plan of subdivision;

- Surveyor lodges survey plan with local Government;

- Survey plans referred to specified authorities;

- Approval gained from referral bodies, utilities, water authorities etc;

- Approval of subdivision plan by local councils (Plan Certification);

- Preliminary titles office approval of survey plan (NSW only);

- Survey plan forwarded by metropolitan water authorities to cadastral map custodian for entry into proposed layer of the cadastral map.

- Lodgement of cadastral survey information to the LTO;

- Survey plan approval and title registration;

- Registered plan distributed by LTO to customers including state DCDB custodians;

- Update DCDBs;

- Distribute updated state DCDB to users on request or at predetermined intervals.

5.8.2   Model perspective

The list above is roughly in chronological order and reflects the end on end nature of the progression of spatial data from the surveyor to the custodian of the cadastral map. The purpose of Figure 5.9 is to clearly show the times involved with the process from land development and subdivision, through to the update of the digital cadastral data by the spatial data customers. While accurate at the time of writing these times are subject to change with newer technology or changing regulations

Figure 5.9   Schedule of spatial data to update user DCDB
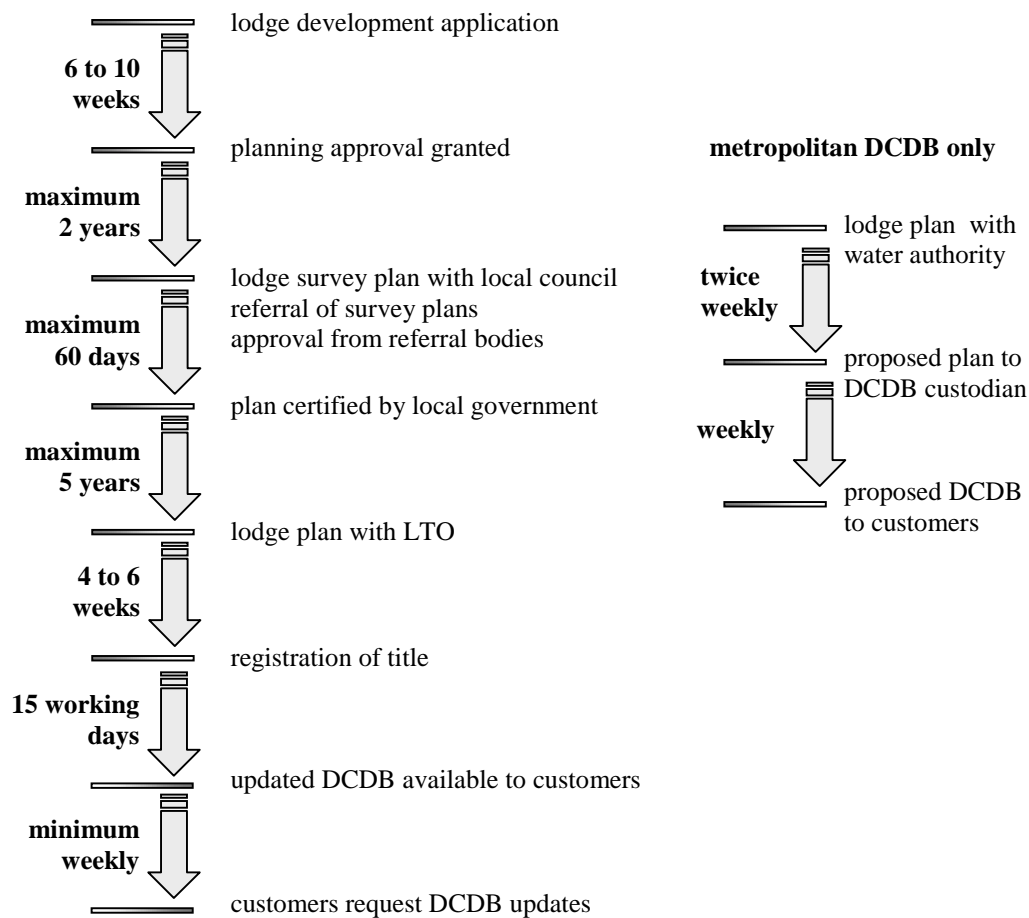
By way of explanation, the fifteen working days, from the legal registration to the updates being available to DCDB users has two components. Firstly, five days to progress the plans of subdivision from the LTO to the maintainer of the DCDB, (DataFlow). Secondly, ten days to integrate the plan into the DCDB. Updates are generated weekly for the water authorities. Updates are planned to be generated fortnightly under the new regime of incremental updates.

The times in Figure 5.9 represent a sequential process, a number of mechanisms exist to speed up this schedule such, as the concurrent lodgement of development application and subdivision plan. Additionally, the schedule of times does not take into account delays arising from the need for corrections or requests for more information for the submitted planning or subdivision applications.

5.9   Conclusions

The background information presented at the beginning of this chapter provided, in the case study terminology, the *setting* for the spatial cadastral system of Victoria. The dimension structure of the Zachman Framework has afforded a comprehensive analysis and documentation of a multi-organisational spatial cadastral system. The dimension descriptions have concentrated on the maintenance of the spatial cadastral map. The maintenance update process is part of the well structured and rigorous subdivision process making the analysis process far easier. The upgrade process, when not integrated with the daily update process, is far more ad hoc and piecemeal. The upgrade process is normally the result of specific partnership between the DCDB custodians and supply side customers to enhance specific portions of the DCDB and its documentation is therefore less formalised.

The inventory list, as the documentation descriptor for this scope perspective, has proved more detailed than expected. This is a direct result of the requirement to not only provide an inventory but also to define each component. This inventory analysis of the spatial cadastral system is a necessary step to proceed to diagrammatic analysis or design perspectives.

The business model perspective of the Victorian spatial cadastre has drawn out the specifics of some of the diverse documentation that exists within the spatial cadastral industry. Additionally, diagrammatic representation has been generated for the previously undocumented dimensions of network, function and schedule.

In applying the Zachman Framework for the multi-organisational spatial cadastral information system, a number of observations are pertinent. First, the order of presentation of the dimensions; logically the strategic dimension is recognised as being the first dimension that should be considered in the design process. The subsequent order of dimensions is the basis of considerable current research. In this chapter's analysis framework of multiple organisations and to enhance readability, the organisation and strategic dimension are reviewed first. Also the top two rows or perspectives of the framework are documented at the same time, again to enhance

readability and also to be more consistent with traditional top down information system development.

Second, in the application of the cell uniqueness rule of the Zachman Framework (Inmon *et al*. 1997) the information overlap across dimensions has sometimes been difficult to exclude. This requires continual and careful consideration of whether these information overlaps represent dimension amalgamation, are impacting factors from other dimensions, or perhaps, whether a rethink is required of the documentation descriptor utilised for a particular cell. As an example the spatial data object represented by the subdivision plan has a content (data dimension) and is processed (function dimension) at specific locations (network) for defined periods of time (schedule dimension).

Third, this analysis of the Victorian spatial system is snapshot in time. This will mean that the dimensions may not be synchronized or may actually be in conflict. This would naturally be expected of a dynamic system, as the technical dimensions catch up with strategic direction, or may indicate an implementation issue where perhaps the data may not be valid for a required function. The strategic direction for property representation in the cadastral map, while the current spatial cadastral data and update process have a parcel focus, presents such a dimensional inconsistency. While this analysis would be expected to highlight these issues, it is not the intention to reconcile the inconsistencies across system dimensions.

And last, a criticism that the application of the Zachman Framework seems to artificially force documentation into specific cells with some subsequent confusion. This however, appears to be in contradiction to the principle of breaking a system into its components or dimensions to simplify analysis and increase understanding. The absence of formal cell descriptors, or their deficiencies, may be more at fault. The clarity engendered by pertinent and well documented diagrammatic techniques, such as data flow diagrams, would support this observation.

6

Review of Developments and Issues

This chapter documents the current developments and changing requirements that pertain to the maintenance of digital cadastral maps. Particular reference is made to the jurisdiction wide cadastral maps or DCDBs of Australian states.

The six system dimensions of the Zachman Framework provide the structure to catalogue these developments and requirements. Within each of these six dimensions there exist a number of impacting developments such as enabling technology and new concepts and practices. A review of the changing requirements is therefore preceded by a consideration of the developments.

The understanding of the developments and complex issues impacting the spatial cadastral system and specifically digital cadastral maps is enhanced by their disciplined mapping to the system dimensions of the Zachman Framework. This provides the basis for the next chapter's discussion and development of dimension specific solution alternatives for the maintenance of the digital cadastral map.

6.1   Introduction

Cadastral systems are not static, indeed they must continue to evolve to meet the changing economic, environmental, and cultural needs of society (UN-FIG 1999). These changing user requirements and unmet user needs, coupled with technological developments, give rise to a range of issues relating to spatial cadastral data. The intent of this chapter is to review these impacting developments and issues with particular emphasis on graphical cadastral maps, especially the DCDBs of the Australian states of NSW and Victoria.

The system dimensions of the Zachman Framework are utilised to structure this review, but more importantly, to categorise the analysis findings thereby providing a basis for the solution models discussed in the following chapter. The documentation structure for the current chapter is depicted in Figure 6.1

Figure 6.1   Zachman documentation structure

	Organisation	Strategy	Data	Function	Network	Schedule
	Impacting developments Issues	....	....	....	....	....

The coverage of these developments and issues is undertaken at the perspectives associated with system analysis and design, as outlined in chapter 4. From a system viewpoint the review of developments is consistent with an examination of factors influencing the system as depicted for instance in Figure 2.1. Issues arise not only from the consideration of unmet user requirements, but also the changing role of each of the organisations that are the spatial cadastral system.

This analysis must necessarily take into account the constraints associated with the more detailed design and construction perspectives of the framework. Further, the design process must also be aware of new enabling technology that has the potential to remove existing constraints. This is in agreement with the Zachman description of

dimension constraints (Zachman 1996), which states that models at the higher perspective must take into account the constraints imposed by the lower perspective.

Specific developments and issues potentially span a number of dimensions; thus there needs to be a benefit for making the additional effort to classify developments and requirements into the above dimensions. The benefits are, first, that the complexity of the spatial cadastral system requires a structured approach to ensure a complete documentation. The six system dimensions provide a simplifying structure within which to document and understand these developments and requirements. Second the dimensions allow an examination of the requirements in isolation, by clearly determining to which dimension the requirement and hence the solution pertains. This is a precursor to the additional and more complex problem of assessing impacts of proposed models on other system dimensions.

6.2   Organisation

The developments and issues for this dimension are confined to the organisational infrastructure that supports the maintenance of cadastral maps and the distribution of spatial maintenance tasks and responsibilities for the cadastral map.

6.2.1   Impacting developments

Viable solutions for homogeneous cadastral maps and multipurpose usage have emerged for jurisdictions such as Canberra ACT, where the geographical extent and the organisational infrastructure are small (PSMA 1996). There is considerable expectation that similar solutions are possible for larger jurisdictions, such as Victoria and NSW, two states that encompass the majority of land parcels in Australia and consequently have more complex spatial cadastral systems. The survey and title automation project in New Zealand is a current initiative to achieve such an integrated and homogeneous cadastral map (Bevin 1999).

Technological advances and related efficiency expectations are impacting all supply side customers and increasingly requiring them to participate in the digital spatial cadastral system. Surveyors are required to generate coordinated digital survey plans that can be more easily incorporated into digital cadastral maps. Utilities and all local

councils are becoming more active customers of an up-to-date digital cadastral map as they embark on GIS related information systems to administer their geospatial assets and property related services. While utilities were often in the vanguard of digital mapping they are now increasingly required to justify their involvement in maintaining their own copies of digital cadastral maps (NSW 1999).

6.2.2   Organisational issues

In most Australian states a centralised organisational structure was created for the initial capture of the jurisdiction wide digital cadastral map. These structures while remaining centralised have evolved into smaller maintenance structures. In the case of Victoria, spatial cadastral maintenance has been defined as a function capable of being out sourced (Jacoby and Murray 1998). This organisational structure is continuing to evolve, as supply side organisations are included in the maintenance process. While a centralised structure may have been most appropriate for data capture, decentralised or distributed concepts are beginning to be considered for future cadastral map maintenance (Jacoby and Murray 1998).

Economic rationalism and the downsizing of government have meant that governments are reviewing funding where duplication exists in the maintenance of the cadastral information. This is reflected in a report advocating a whole of government approach to cadastral mapping in particular, and mapping in general, for the state of NSW (NSW 1999). A report prompted by the possibility of that state maintaining a graphical state wide cadastral map, while the Land Titles Office was independently proposing to develop a survey accurate cadastre to facilitate automated survey plan examination (LTO 1998).

The micro-economic reform, and ensuing smaller government, has meant a convergence of government bodies to eliminate duplication of spatial cadastral maintenance. An obvious target for organisational merging has been in jurisdictions where the custodian of the cadastral map is not associated with land registration and both organisations undertake mapping functions. Structural reorganisation is not necessarily feasible for a spatial, cadastral industry comprising a number of government, semi government and private bodies.

There is also a move for much wider cadastral reform to include cadastral survey practices, as well as the bringing together of titling and cadastral mapping functions (Williamson and Hunter, 1996). The impact of technology means a changing role for the surveyor. There is growing trend for LTOs to move away from plan examination, with the expectation that the licensed surveyor will fully exercise the responsibilities the license imposes (Houghton 1995). A strict quality assurance program accompanies the reduction in plan examination. The Licensed Surveyor is made responsible for the production of quality data for the registration of title, and their assistance in the cadastral map maintenance process is encouraged. The existing duplication of the cadastral map indicates that the skills required to maintain a cadastral map exist across the spatial cadastral system.

6.3   Strategy

The strategic issues and developments of the spatial component of cadastral systems are not easily isolated from cadastral systems and other government mapping responsibilities. It is not within the scope of this thesis to consider these wider strategic issues. The strategic developments and issues reviewed are constrained to those that most directly impact maintenance of cadastral maps.

6.3.1   Impacting developments

In Australia and other western countries, economic rationalism and micro-economic reform results in a re-evaluation of the goods and services delivered by government. For jurisdiction wide cadastral maps the essence of these economic developments is the resultant level of commitment (invariably financial) for digital map maintenance, funding for spatial data upgrades and the pricing policy for access.

Victoria is regarded as having aggressively embraced the concepts of economic rationalism (Williamson *et al.* 1997). The important outcome for the digital cadastral map is the restated commitment by government to be responsible for its maintenance. The Geospatial Information Strategies Victoria for 1997 – 2000 (Land Victoria 1997b) and 2000-2003 (Land Victoria 1999c) confirm this commitment to the *State*

Framework Information where the digital cadastral/property information is cited an as integral component.

The economic benefits of up-to-date, state wide cadastral maps have been documented (Tomlinson Associates 1993, Price Waterhouse 1995). The more recent development of firmly casting the cadastral map as part of the spatial data infrastructure for economic development, and indeed sustainable land development, ensures funding commitment to its maintenance, irrespective of its role within the cadastral system (UN-FIG 1999).

Further, the recognition of the cadastral map as necessary infrastructure component to encourage the development of other spatial business systems, has seen a significant review of the pricing and hence accessibility to spatial cadastral data. This pricing development is reflected in strategies that promote increased usage of the digital spatial data through minimisation of costs associated with the customer's data purchase and delivery (Land Victoria 1999c). This is a reversal of the previous policy for the recovery of costs associated with the initial and ongoing data capture.

The other aspect of economic reform is the philosophy of *user pays*. In the context of the cadastral map, this means that the cost of upgrading the cadastral map may not be borne by government alone. The cost is either sourced from the customers of the cadastral map contributing to specific upgrades or a levy on the land development (NSW 1999).

6.3.2   Strategic issues

The pricing policy of the jurisdiction wide cadastral map has not always been structured to promote usage and discourage duplication. The application of the concepts of user pays, or cost recovery, to the digital cadastral map has important consequences. Pricing spatial, cadastral data to recover the cost of capture of the digital map has resulted in under usage of the cadastral data and creates financial barriers to the development of spatial business systems. Additionally, with newer technology, it can be feasible for customers to recapture and maintain cadastral maps for their particular areas rather than purchase the digital data and its updates.

The objective of a homogeneous, jurisdiction wide cadastral map means that the map must be multipurpose (Williamson and Enemark 1996). The property information, street declaration and urban boundaries are all the province of local government, but necessary for the construction of the multipurpose cadastral map. The recognition that local government is both a significant user and provider of spatial information means that the custodians of cadastral maps are moving towards strategic alliances, and partnerships, with councils, to source specific information, to access data earlier and to encourage use of the jurisdiction wide cadastral map (Land Victoria 1999c).

In jurisdictions where the map is closely tied to the land registration system, particularly where the cadastral map underpins the integrity of the land registration, the source of funds for cadastral mapping is secured in that land registration process. The recognition of the strategic or infrastructure status of the cadastral map is essential to ensure continued funding for its maintenance. The association of the cadastral map with other infrastructure data sets, both spatial and aspatial, increases pressure on the cadastral map to become interoperable with the other aspatial data sets and coherent with other spatial data sets, such as the topographic map.

The emergence of the concept of SDI and the casting of the cadastral map as a fundamental spatial data set provides the strategic reasoning to fund cadastral map maintenance. The role of government is therefore seen as supporting the generation of a number of fundamental data sets that in turn allow development of other businesses. In Victoria this has been in terms of considering the digital cadastral map as *Framework Information* around which other key business information can be created and maintained (Land Victoria 1999c). The physical asset information of utilities is considered the key business information that builds on the cadastral *framework information*.

The acceptance of the cadastral map as part of the spatial data infrastructure does not necessarily extend to the commitment of additional expenditure for cadastral upgrades. It has been asserted that data quality is a question of research to determine what the market requires and what the market is prepared to pay (Van Der Molen 1996). Experience in Victoria and NSW indicates that cadastral upgrades are unlikely to be paid for by government. This has led to custodians of cadastral maps seeking

partnerships with supply side customers to improve the accuracy of specific areas of the map, that is, upgrades are funded on the *user pays* principle.

The increased use of the digital cadastral map within government, for such activities as planning, emergency dispatch, etc, means that demands are placed on the map content, accuracy and currency, but provides a further source of maintenance funding.

6.4   Data

The data dimension describes *what* is maintained in the jurisdiction wide cadastral map. Changes to the data models and the technology of spatial data storage and manipulation, are manifested as altered functions to maintain data content and possible institutional rearrangements to ensure access to this new or additional data.

6.4.1   Impacting developments

The developments impacting the data dimension are, data content within the concepts of the multipurpose cadastre, and new technology associated with the storage and manipulation of spatial data.

Multipurpose cadastre

The significant factor for data content is the multipurpose usage of the cadastral information, and specifically for this research, the cadastral map. The current multipurpose requirements could not have been envisaged by the late eighties agenda of producing a digital graphical representation of the legal cadastral fabric.

The impact of these multipurpose requirements is reflected by three separate developments. First, that the cadastral map be coherent with associated spatial data such as topographic data. Coherence represents a requirement for accuracy upgrade. Second, the necessity for spatial data to integrate with aspatial data sets. Third, the inclusion of additional spatial data content into the definition of the cadastral map. Spatial data integration and new spatial data entities both necessitate the inclusion of additional data into the cadastral map and its consequent maintenance.

Additional data, often considered for inclusion, can be broadly grouped as either sub parcel data, super parcel data or physical features.

The sub parcel data includes:

- strata title (spatial separation of ownership within one legal parcel);

- surveyed building footprints;

- third dimension for multistorey ownership, tunnels under houses, etc;

- unique parcel identifiers to link to aspatial data sets.

The super parcel information might include:

- properties, where properties can be an amalgamation of adjacent or non-contiguous legal parcels;

- street address associated with property;

- boundary information for cadastral districts, suburbs, etc.

In the absence of large scale topographic maps physical features appearing in cadastral maps include:

- road features, the road centreline, multiple roadway representation and road kerbing;

- other transport features such as rail;

- drainage features such as rivers, lakes and sea shores;

- representation of building footprints.

Technology

A significant technological development for data storage has been the emergence of relational databases that store spatial data and aspatial attributes in the same database. This is in contrast to most Computer Aided Drafting (CAD) and some GIS software packages that store spatial and aspatial data in separate databases. The flexibility of relational databases, such as multiple representations of physical features, the abolition of the layer concept for data management and truly seamless databases, are therefore available to spatial data.

Object Oriented software and programming tools are significant developments to handle the processing of spatial data and specifically the maintenance of spatial cadastral data (Hesse and Williamson 1993). Object Oriented GIS handle data associativity issues, incremental upgrade and spatial data integrity far more effectively and efficiently than conventional CAD and non-Object Oriented GIS software.

6.4.2   Data issues

Definition of the cadastral map

A cadastral map product only supporting a land titling process has proved deficient for the spatial cadastral data to fulfil a spatial data infrastructure role (NSW 1999). The requirements for the cadastral map to be interoperable and coherent with other land related, data means that what defines the cadastral map is evolving. The changing data content of the cadastral map impacts users; users may need to reengineer their systems to accommodate the changed delivery content of cadastral map updates.

The noted disparity of the cadastral data models for different states within a country (e.g. Australia (PSMA 1996)) highlights the difficulty of defining a consistent cadastral map data model. Disparate state data sets will remain until agreement is reached on what actually represents or constitutes the national cadastral map. Without this agreement it will always be difficult to either generate a nationwide digital cadastral map from individual state data sets; to subdivide the individual jurisdiction wide cadastral maps for possible decentralised maintenance; or in fact for users to be confident of the future content stability of the cadastral map.

In the development of national and international data sets, by far the biggest issue is the ability to combine data sets. Current SDI research must also define what cadastral data is truly infrastructure. A spatial data infrastructure definition suitable for specific local spatial systems, and provide the basis of state, national and regional cadastral maps (Rajabifard*, et al.* 1999). Cadastral map custodians must still, however, ensure that their data is integratable with other related data sets. The definition of the cadastral map must therefore meet both horizontal and vertical integration requirements.

Spatial data accuracy

The issues relating to the demand for increased accuracy in the cadastral map can be categorised as follows:

- The demand for increased accuracy as a consequence of higher accuracy of the spatial data collected by users (e.g. asset data), which is subsequently associated with the cadastral map.

- The requirement for coherent integration of cadastral data with other existing, jurisdiction wide, spatial data, most commonly topographic data and increasingly the road network database.

- The general accuracy of the cadastral map in an area being inconsistent with the economic significance of the land in that area (Ranshaw 1995).

- The need for a survey accurate cadastral map to allow for automated survey plan examination (LTO 1998).

- The expectation that survey data should remain at its captured accuracy, without attenuation, in its progress through the subdivision process (Hayes 1997).

Any significant change in the accuracy specification of the cadastral map will impact other dimensions of spatial data maintenance. Greater spatial accuracy significantly alters update processes, indeed even limited spatial upgrades impact on users of the cadastral map, in terms of data associativity (Wan and Williamson 1994a).

Data associativity

Data associativity can be defined as the association between features in different layers in a layer-based LIS/GIS (Wan and Williamson 1994b). The reference to layers has its origins in CAD systems. A more current definition defines associativity as the spatial relationship between spatial objects derived from two different data sources (Scheu, *et al.* 1999).

An example of these objects would be the parcel in the digital cadastral map and an underground utility service line in an assets database. If, in the maintenance process, parcel objects shift in the cadastral map, every user, utilising the digital cadastral map

as a spatial reference for their asset information, may need to move their associated spatial objects. An upgraded, and consequently shifted, boundary in the digital cadastral map may result in the subsequent incorrect position of the asset object, the asset may, for example, appear on the incorrect side of a boundary. The asset data must be repositioned to maintain its spatial integrity.

6.5 Function

The functions of cadastral map maintenance involve the separate processes of update, upgrade and distribution. The exact definition of these functions is largely determined by the requirements or enabling technology of the other framework dimensions of the spatial cadastral system. That is, the *"how"* of digital cadastral map maintenance is dependent on the *"what, who, when, why and where."*

6.5.1 Impacting developments

The impacting developments are largely consequent of other system dimensions. The main development arising from the past ten to fifteen years of experience of digital spatial data maintenance, is the continued high level of duplication of both the maintenance function and the digital cadastral data.

The perceived deficiencies of the spatial data maintenance, of even survey accurate cadastral maps, has prompted users to either recapture portions of the cadastral map in their geographical area, and/or to maintain their own versions of the cadastral map. This inevitably leads to considerable duplication of function and the existence of duplicate copies of the digital cadastral map. The economic costs of this duplication represent the main driving factor for more efficient cadastral maintenance and a more timely distribution of the changes.

6.5.2 Function issues

Function issues are structured under the headings of update, upgrade and distribution. There are however some legacy issues relating to the initial creation of the cadastral map that impact all functions. Broadly these legacy issues arise from the initial

purpose of the digital map, the map source data, the method of digital data capture and residual legacy information systems (software and hardware).

Updating the cadastral map

A major issue is the numerous occasions that spatial data is re-entered from digitally derived hardcopy in the processes of planning, land registration and cadastral mapping. This is particularly evident in the post title update of the cadastral map, as is the case in most Australian states. One estimate is the plan of subdivision may be digitised between five to ten times and the parcel/property details entered ten to twenty times (DNRE 1997).

The reasons for duplication within councils and utilities are twofold. First, planning authorities have the survey data, often well before the custodians of the jurisdiction wide cadastral map. For planning purposes and subsequent asset management it is easier to enter the spatial data at this stage. Second, councils and utilities can consider changes to the cadastre that impact their spatial assets (associativity) at the earliest possible time. In the absence of planning data within the cadastral map many councils and utilities maintain their own cadastral maps. Custodians, however, still have the responsibility to maintain the state or jurisdiction's entire cadastral map.

Duplication of input results in duplication of the update process when the new spatial data is merged with existing spatial cadastral data. Ultimately property owners fund the duplication of maps across utilities, councils and government. For the state of NSW an estimated 2.5 million dollars is being spent collectively by the utilities to maintain duplicate, but independent, versions of the cadastral map within their jurisdictions (Watt 1998). A homogeneous, jurisdiction wide parcel and property map, maintained without duplication and obviously in conjunction with the supply side customers, would achieve significant savings for participating organisations and subsequently the individual property owners (DNRE 1997).

The merging of survey plans with a graphical cadastral map is a subjective update process. A subjective methodology for updating the existing graphical cadastres has a twofold effect. First, even in a homogeneous update situation, survey accuracy is lost when the survey data is entered and *fitted* to the existing cadastral fabric. Secondly,

where the update process is duplicated across organisations, two portions of the same spatial cadastral extent will vary over time.

Economically, a water authority may consider the additional overhead of maintaining the cadastral data is marginal to the necessary overhead of maintaining its own associated asset data in relation to the cadastral map. This is particularly so if the associativity problem is handled manually and further justified if the utility has data exchange relationships with the councils within their jurisdiction, that provides for a two way flow of cadastral data (Caldow 1999).

Upgrade of the digital cadastral map

GIS users of the digital cadastral map are now increasingly demanding greater accuracy. Ten years ago these GIS users were content with a graphical accuracy consistent with digitising from paper maps (about ±2-4m in urban areas to ±20m or more in rural areas). These same users are now demanding coordinate accuracy of the order ±0.3m or better in urban areas (Williamson and Hunter 1996).

In the current economic climate the custodians of graphical digital cadastral maps find it difficult to embark on expensive upgrade programs. The Victorian yearly maintenance costs have been quoted as A\$14 per changed parcel (Jacoby 1996).

Graphical cadastres are generally updated from survey accurate plans. The concept that a graphical cadastral map can be incrementally upgraded with each new update (each new subdivision entered) has a number of specific problems:

- The cadastral map must have metadata or specific annotation for all spatial data to ensure that updates do not degrade accuracy, particularly where manual updates are applied to previously upgraded areas;

- Custodians prefer to maintain the relative accuracy rather than the absolute accuracy when updating to reduce the associativity problem for users (Wan and Williamson 1994a);

- It is invariably necessary to include spatial data for a map area much greater than represented by the extent of the new subdivision, to achieve a meaningful upgrade and maintain the integrity of the cadastral fabric (Enemark 1987);

- Upgrade issues often reference surrounding original survey plans, local knowledge or even resurvey to achieve an accurate resolution;

- The time frame for an upgrade via update policy. In NSW it was estimated that it would require 40 years of new cadastral survey update information to impact more than 60% of the cadastral map (LIC 1998);

- Some Australian states quote up to forty percent of current cadastral update activity is outside the subdivision process (PSMA, 1996). To ensure capture of all cadastral boundary mutations, a variety of data sources must be consulted. While the cadastral activity that is not required to pass through the land registration process is generally easily identified, it is often difficult to capture the related survey data.

Evidence to disassociate the update and upgrade processes is the outsourcing of the maintenance of the cadastral map in the state of Victoria. The difference between update and upgrade processes is contractually explicit, indicating that while updates and upgrades may be done simultaneously they are two distinct problems and remain two independent spatial cadastral processes.

Distribution

In the past, user update requirements were met by the delivery of the entire cadastral map, or any of the maintained subsets of the cadastral map. These subsets were the predefined blocks, tiles or divisions usually associated with the underlying file structure of CAD systems initially used to capture the cadastral map.

Users of cadastral maps are therefore faced with accepting complete new versions of files where changes have occurred. Cadastral map customers in Australia reported difficulties with this *whole file replacement* distribution method (Wan and Williamson 1995). Without a method of comparison with the current version of the cadastral map the customers are unable to differentiate updates from upgrades in the delivered *update*. This method effectively hides spatial data changes from the users potentially exacerbating the associativity problem.

Supply side customers, such as councils and utilities, represent the main users of cadastral data, if not numerically, certainly in data quantity. GIS technology dictates

that these customers have a current copy of the cadastral fabric upon which to register their own geographical asset information. There is little doubt that the spatial data associativity will remain a major problem until the accuracy of cadastral maps are upgraded to the level demanded by customers with critical underground assets. In the meantime many of these customers will be able to construct a business case to update and maintain their own cadastral map.

The lack of data transfer standards has meant that custodians of the cadastral maps have invested resources to create marketable, vendor specific formats. The conversion process can therefore be viewed as a value adding process capable of generating funds to recover costs of data capture.

6.6   Network

It is apparent from preceding chapters that the spatial cadastral system is a network of independent organisations, each processing the spatial data that eventually updates the jurisdiction wide cadastral map. Figure 6.2 shows the organisations of this spatial cadastral network and the status of spatial data that are enacted between them. The context of developments and issues in the network dimension are associated with the way organisations of the spatial cadastral system interact.

Figure 6.2   Spatial cadastral network for Australian states
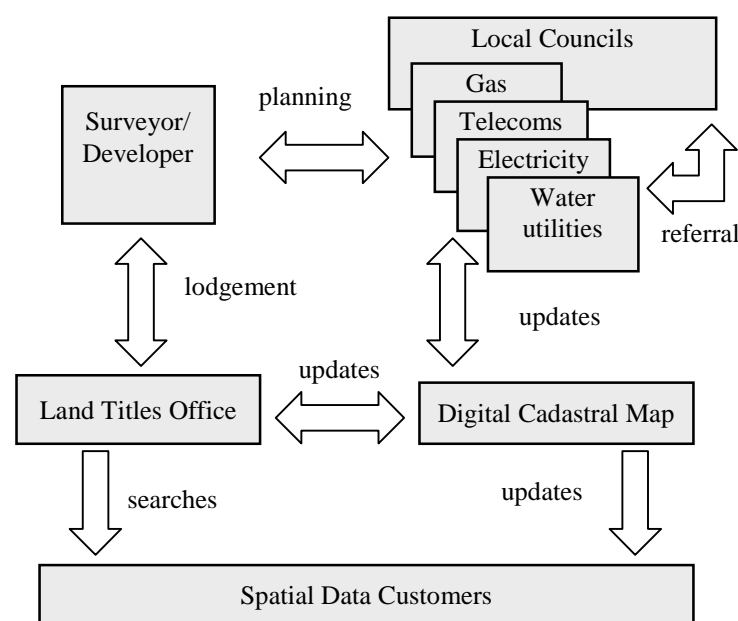
This structure, with small variations, could describe a number of western cadastral systems where the digital cadastral map is updated as a post land registration function. The dataflow diagrams of the spatial cadastres presented in chapter 3 reinforce this structural similarity. Also a paper on incremental update mechanisms by Scheu *et al.* (1999) derives a similar network structure for the German State of Berlin.

6.6.1   Impacting development

The impacting developments on connections between components of the spatial cadastral subsystems arise not only from developments in computer and communication technology but also with the convergence of these technologies, most conspicuously represented by the World Wide Web (WWW) on the Internet.

Internet

Despite the appearance of Figure 6.2 the flow of spatial data through the cadastral network system is substantially linear. The dataflow diagrams of chapter 3 and the documentation of the schedule dimension in chapter 6 attest to this linear approval process. This has resulted in an end on end cadastral process or in the terminology of the Internet the data is *put* to successive organisations. The philosophy of the Internet however is more of a *get* nature. In a digital environment approval authorities would be electronically notified to *get* specific data made available on the Internet by other organisations.

The capabilities of the Internet also apply to Intranets. Intranets provide secure and restricted environments with all the technological potentials of the Internet. These potentially provide ideal environments for the passage of spatial cadastral data that is not public information.

Computer technology

Client/Server computing is seen as the replacement technology for centralised mainframe computing. Client/Server architecture allows for logically centralised but physically distributed databases or data sets. This technology allows reconsideration of the past centralised information system models, but implemented in an incremental and distributed manner. For instance, multiple servers could accommodate the receipt,

storage, distribution and tracking of information such as digital survey plans. These servers have sophisticated operating systems which can control user access to specific data, facilitate auditing of access and modifications to data, and are able to automate event/trigger actions such as emails when certain files change status.

Most digital maps were first captured using CAD software. While these systems limited the geographic information processing, current networked CAD workflow software has many features that could be utilised in the processing of plan information across the spatial cadastral network.

Current CAD software packages (e.g. Intergraph™, AutoCad™) have implemented workflow capabilities that pertain to spatial data:

- Electronic drawing *markup* or *redlining* features used in combination with revision control. Changes that need to be made to drawings can be electronically marked up using redlining tools, making it easy to communicate and track spatial modification and associated comments. These modifications can be made across computer systems. Changes themselves cannot be altered, every redline action is traceable and restorable, but the person who made the revision cannot change the drawing, effectively giving insight into the history of a drawing.

- Version management tools to track changes to within drawings.

- Comparison tools to highlight any spatial data differences between two digital drawings.

- *Brief Case* technology facilitates the review, change and approval process between users. *Brief Cases* are an electronic version of regular briefcases, in which can be placed drawings, memos, word processing documents and e-commerce transactions for electronic transport. Additionally there is the ability to compress and/or password protect/encrypt the data before dispatching the *Brief Case* via the Internet.

Networked workflow practices in CAD systems are proven technologies that should be taken into account for the digital transfer and approval of survey plans.

6.6.2   Network issues

The network issues for the spatial cadastre are categorised under the headings of hardcopy spatial data transfer, and spatial data availability

Hardcopy spatial data transfer

In many jurisdictions the digital cadastral map maintenance has been superimposed upon an existing survey system to register land titles. Private and public agencies in the spatial cadastral system have utilised enabling technology to collect, manipulate and present either cadastral or asset data. Digital survey data is not transferred digitally but rather used to create hardcopy plans to meet the requirements of the subdivision process (Hayes 1997). A subdivision process that explicitly requires hardcopy survey plans to be submitted simultaneously with other legal instruments.

The organisations within the spatial cadastral system recognise the benefits of digital inputs to their processes (LTO and SGD 1998), (PSMA 1996). However the uptake of technology by individual organisations within the cadastral industry has resulted in each imposing their own uncoordinated requests for digital data in a variety of formats (DNRE 1999). While some data is available in digital format, Australia represents one extreme where the digital cadastral map or DCDB is updated using the analogue spatial data information made available subsequent to the land registration process i.e. at the end of the cadastral process.

Of further issue in the transaction of update data, is consideration of the actual size of these updates and their relative quantity. In discussion with both NSW and Victoria it was noted that the majority of update tasks originating from the subdivision process, are for one and two lot subdivisions (OGDC 1995).

Survey plans containing amendments to only one or two parcels in the cadastral map can be reliably and economically handled by sourcing the data from hardcopy plans. Where these types of plans represent the majority of updates, digital submission must be carefully evaluated. As a past example, and specifically for planning purposes, the Victorian metropolitan water authority for greater Melbourne required digital lodgement of spatial data, but only for subdivisions of ten lots or more (PSMA 1996).

In an electronic environment the hardcopy spatial data transfer is sometimes referred to as walking the information between organisations that make up the spatial cadastral system. A digital format for the spatial data is only half the solution, without efficient transfer mechanisms, digital data is effectively walked through the cadastral network.

Spatial data availability

Figure 6.2 is a network model where maintenance of the digital cadastral map is excluded both physically and temporally from the subdivision process that generates the changes to the digital cadastral map. It is this exclusion that gives rise to spatial duplication and data availability issues affecting the maintenance and distribution of the cadastral changes. The availability issues in reference to Figure 6.2 are as follows:

- Planning data, submitted by surveyors to councils for approval, are not available to the custodian of the cadastral map and technically not available to the referral authorities until forwarded by the councils.

- Local Councils and referral authorities need to check their planning data against cadastral updates, or newly registered plans, to confirm possible spatial changes during the registration process. This is also true for cadastral map custodians intending to hold planning data.

- Where the cadastral map custodian does not hold planning data, updates to the cadastral map are only available after plan registration.

- Non supply side customers are not availed of spatial changes until they receive cadastral updates from the map custodian unless they source all newly registered plans from the titles body.

- Local councils hold cadastral data, such as street names and property details; these are not always available on registered survey plans.

6.7   Schedule

The actual *when* of updating a cadastral map representing the legal parcel boundaries is immovably subsequent to the legal registration process. Of interest to this dimension, however, are times for processes, times between processes and subsequent overall timings that relate to the maintenance of the spatial cadastral data.

6.7.1 Impacting developments

In tandem with newer technology there is an expectation that processes can be accelerated and that digital data transfer times are measured in seconds. The spatial cadastral system is not excluded from the expectation of faster land development approval, land registration and the reflection of these changes in the cadastral map.

6.7.2 Schedule issues

The actual approval times for spatial data within the cadastral systems affect the time span for the spatial data to reach legal registration and become part of the cadastral map. As stated previously, where customers do not have access to planning data, the updates received post title, could have been in the cadastral system for an indeterminate time (up to a maximum of two years). While decreasing the duration to legally complete land development may lead to a more efficient land market, for utilisation of the multipurpose cadastre, the duration is not as important as actually having knowledge of and access to the spatial planning data.

Cadastral map custodians quote their data being current to within 5 to 10 working days of title registration. This currency may not be reflected in the user's copy of the cadastral map. The supply of updates to customers is generally negotiable and subject to individual contractual arrangements. For whole file replacement these times are typically 6 to 12 months, however, there are other update delivery times of interest.

For the Victorian Metropolitan DCDB, updates are able to be delivered to Melbourne water utilities, on a weekly basis, a bulk replacement of any of the 2,800 predefined tiles that have changed (Hesse and Jacoby 1995). At the other end of the spectrum a national customer requesting multi state coverage may require a third party to join the disparate spatial data sets from a number of states. In the instance of the Australian Bureau of Statistics (ABS), this is notionally a four yearly occurrence (PSMA 1996).

A graphical cadastre is easily maintained within ten days of title registration, whereas, a survey accurate legal cadastral with more requirements for aspatial integration and spatial coherence will require considerably more time to update, trading to some extent accuracy for currency.

6.8 Conclusions

This chapter mapped the developments and issues for the maintenance of cadastral maps to the six system dimensions of the Zachman Framework. While specific developments often impact across dimensions, disciplined mapping to the framework provided a much clearer context for understanding. The distinction between *process* and *network* is very relevant and assists the research aim of canvassing dimension specific solution models. In a more data and process centric analysis, the issues and impacts relating to *organisation* and *strategy* dimensions are usually not considered. Their inclusion, however, highlights their significant impact on the operation of the spatial cadastral system, and their driving role in the selection of dimension specific solution alternatives.

This chapter has made particular reference to the DCDBs of Australian states to highlight current, digital cadastral map issues, requirements and impacting developments. Nevertheless research observation indicates that these are the same factors facing the custodians of digital cadastral maps around the developed world, despite their varied paths to digital cadastral mapping.

The fact that Australia has a full digital cadastral coverage of its states and territories cannot be understated. The wide availability of digital cadastral data has without doubt been a major contributing factor in the growth of GIS and the subsequent pressure for a more accurate and more accessible cadastral maps. The liability of these first generation cadastral data sets is that there are significant difficulties associated with the maintenance of graphically accurate, digitised, cadastral maps. Jurisdictions that have survey accurate cadastral maps while being spared accuracy upgrade pressures, are facing equivalent issues in respect of multipurpose usage and update and distribution in a digital and Internet environment.

The overarching, strategic objective, for any jurisdiction, is to maintain a current and homogeneous cadastral map that fully meets the daily needs of the data originators and all customers of the cadastral map. The next chapter discusses alternative solutions, within each spatial cadastral system dimension, that seek to meet these user requirements.

Spatial Cadastral Maintenance Models

This chapter presents a range of models for cadastral map maintenance. These models will be explored within each of the system dimensions of the Zachman Framework with emphasis on the spatial cadastral systems of Australia.

This chapter draws on the spatial cadastral systems analysis documented in previous chapters, current improvement strategies and published research to present a range of options available for cadastral map maintenance. The Zachman Framework facilitates dimension specific models, which take advantage of impacting developments and address the developments and issues presented in the previous chapter.

The Zachman Framework allows the design and presentation of simpler dimension specific models for spatial cadastral maintenance. Specific jurisdictional factors pertaining to the cadastral map would determine the overall spatial cadastral maintenance model generated from the alternatives presented.

7.1   Introduction

The impacting developments and issues raised in the previous chapter are the impetus for a range of improvement strategies undertaken by the custodians of cadastral maps. This chapter draws on the spatial cadastral systems analysis of previous chapters in this thesis, current improvement strategies and published research to present the range of possible models for the management of the spatial cadastral data that underpins cadastral map maintenance.

The Zachman Framework is utilised to classify and simplify the many models available and allows for initial evaluation of dimension specific alternatives. This is a necessary prelude for constructing a composite conceptual model that meets the needs of specific jurisdictions.

7.2   Strategy

A jurisdiction's strategic direction determines all other dimensions of the spatial cadastral system and the cadastral map maintenance model. The intention is not to explore and compare strategic directions; rather to present alternative models within each Zachman dimension whose selection is determined by the jurisdiction's strategy.

It is however worth noting that financial considerations have consistently driven cadastral map creation and maintenance, prompting the following observations:

- The land registration system has always been a source of government revenue. The close association of the cadastral map with the land registration process can ensure a source of revenue for cadastral map maintenance.

- There are no technical barriers to the upgrading the cadastral map to a desired accuracy, however, upgrades are expensive. Cost recovery techniques include a land registration tax (Bevin 1999) or partnership with supply side users.

- The pricing policy of the cadastral map is the major determinant of usage and whether there is a duplication of spatial cadastral data capture.

- The production and currency of a multipurpose cadastral map is increasingly seen as the provision of government infrastructure, to facilitate indirect financial returns (Land Victoria 1999c).

7.3   Organisation

7.3.1   Organisational relationships

The previous chapter noted that where organisations are corporately integrated, more significant integration of data is fostered and duplication is reduced. A number of organisational relationship changes are being contemplated in Australia:

- The cadastral map custodian, government owned mapping organisations and utilities, and significantly the LTO, are being brought closer together. Bringing these bodies under a single ministerial or departmental control facilitates a whole of government perspective (Land Victoria 1999c, NSW 1999).

- Amalgamation of the LTO and the cadastral map custodian (NSW 1999).

- The custodians of the cadastral maps are recognising the role of, and entering into relationships with, supply side customers for the maintenance of the cadastral map. These relationships are intended to foster a two-way flow of spatial cadastral maintenance information and are exemplified by the Property Information Project (PIP) in Victoria (Land Victoria 1998a) and imperative in NSW for Memorandums of Understanding (MOU) (NSW 1999).

7.3.2   Organisational maintenance models

In defining models for the maintenance of the jurisdiction wide cadastral map, organisational restructure is not the focus. Modelling here attempts to focus on the organisations on the supply side of the digital spatial cadastral environment that could update the cadastral map. As noted previously, supply side organisations have the skills to undertake digital cadastral maintenance, and many already do so.

The assumption for the models presented here, is a cadastral map custodian whose mandate is to ensure a jurisdiction wide cadastral map. The intent therefore is to present each possible organisation within the spatial cadastral system that is able to participate in the update of the jurisdiction wide cadastral map. Each of these alternatives will impact at least the organisational processes (function), changed and new data flows (data) and a differing role for the map custodian. These cross dimensional impacts are outlined for each organisational alternative presented.

Jurisdiction map custodian

This model normally results where the digital cadastral map maintenance is superimposed on a system essentially designed for land registration. This means that the agenda for spatial information content and format is set by the land titling system. The dataflow is represented in Figure 7.1 with the rounded box indicating the organisations enacting the spatial maintenance process. The post land registration maintenance by custodian is primarily dependent on the spatial information submitted by the land surveyor to the Land Titles Office, for the purpose of land registration rather than cadastral map maintenance (arrow 1 Figure 7.1). The surveyor's data is a parcel view of the spatial cadastre to enable granting of title to each land parcel.

Figure 7.1   Custodial cadastral map maintenance model
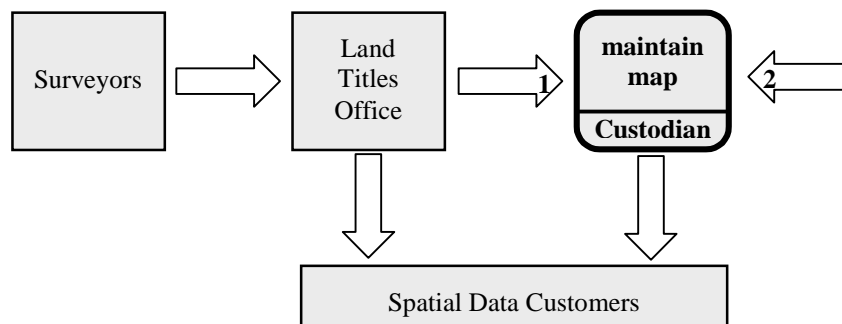
Land development activity not processed through land titles must also be acquired. To ensure the map is complete, arrow 2 in Figure 7.1 denotes any additional information required by the spatial maintenance process. For a multipurpose cadastral map additional data, such as street address, property data and planning data must be sourced from the other supply side organisations.

Land Titles Office

Figure 7.2 again represents a maintenance model for the digital cadastral map, where the custodian utilises the land registry to make updates from all survey information submitted for land registration.

The motivation for the land registry office to undertake cadastral map maintenance is that the map will be a survey accurate, parcel based digital map, that can be used to verify the correctness of subdivision plans submitted for land registration (LTO 1999). This is an Australian-centric view where the Land Titles Office has a history of individual survey plan examination, in the absence of a survey accurate map.

Figure 7.2 Maintenance model based on Land Titles Office
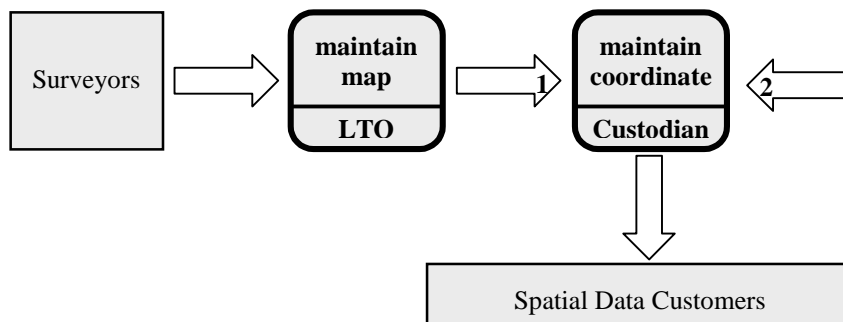
As with the previous model it will be necessary to capture additional information to ensure that the cadastral map is complete. Significantly, the land titles office has the ability, in its role of granting title, to set the spatial data input agenda and therefore possibly maintaining a multipurpose cadastral map. Where this is not achieved the custodian would still have to undertake the additional data gathering role (arrow 2 Figure 7.2) described in the previous model. Additionally, the custodian would need to play a maintenance role for rural areas of low land value and minimal cadastral activity, where a survey accurate spatial data capture may not be economically viable.

This model is in contrast to the European concept of Cadastral Offices where up-to-date maps are not held, but rather legal instruments contain unique links to the parcel in the cadastral map. In Australia, the European model is approximated in the ACT, where the custodian maintains a survey accurate cadastral map and generates the title plan for the purposes of the Land Titles Office (see ACT chapter 3).

Utilities

Utilities are normally both subdivision approval referral organisations and customers of the spatial cadastral system. They generally maintain a cadastral map component for asset inventory while not involved in the cadastral titling process. Where a utility divides the jurisdiction into geographic regions, a number of utilities could undertake the maintenance of the digital cadastral map on behalf of the cadastral map custodian.

The utilities have access to a parcel view of the cadastre, while maintaining a property view in order to facilitate their asset connections and billing processes. That is as an existing task they maintain the spatial data pertaining to a multipurpose cadastre, often

independent of the custodian. Their role in the subdivision approval process means access to the planning data (unregistered subdivision data) and they are able to insist on spatial data format and drive content.

Figure 7.3   Utility maintenance model
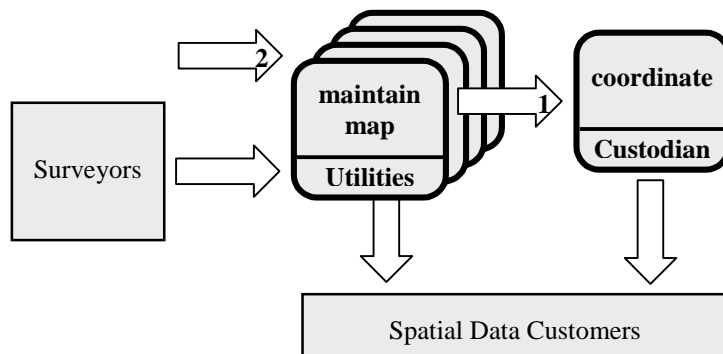
The role of the custodian here is to coordinate the decentralised maintenance of the cadastral map to ensure the integrity of the jurisdiction wide cadastral map. The water authorities represent ideal utility candidates to undertake this maintenance and supply incremental updates to the custodian (arrow 1 Figure 7.3).

The custodian may have to additionally compensate the utility to maintain a more multipurpose cadastre (e.g. both a parcel and property view) or to maintain the cadastre in areas where the utility may not have assets. The utility will need to access the post title plans of subdivision to migrate the spatial data from proposed status to legal status. These inputs are represented by arrow 2 in Figure 7.3.

In this model there are two types of spatial data customers. The decentralised maintainer would service those customers whose data requirements are within their spatial extents. The custodian would service customers who require data for larger geographical extents than maintained by the utility.

Local councils

The council centred model is the same as the utilities model except local councils replace the utilities. There are two noteworthy differences in the models not evident from Figure 7.3. First, there are a greater number councils than utilities, for example in metropolitan areas of Australia one water authority may encompass twenty to thirty

local councils. In rural areas, water authorities may wholly or partially encompass perhaps five to eight local councils. Second, the local councils do not have sufficient underground assets that provide the imperatives to use and maintain a digital cadastral map for asset planning and maintenance.

Surveyor model

The model presented in Figure 7.4 is where the surveyor is responsible for the maintenance of the cadastral map as part of his land surveying activities. This decentralised, remote maintenance model has the processes of gathering, maintaining and onward distribution of the cadastral map updates resting with the creator of the spatial cadastral data. Licensed survey bodies (surveyors or smaller pseudo cadastral offices) undertake all the processes of the spatial cadastral maintenance subject to prescribed standards in conjunction with a process of quality control and audit.

Figure 7.4   Surveyor based maintenance model
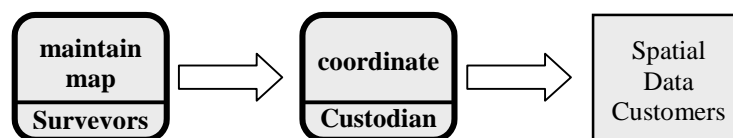
In Austria, where the survey accurate legal cadastral map is a recording of the surveyor's measurements, the surveyor is responsible for supplying the updates to the cadastral map (see chapter 3). A surveyor based model offers great potential in Australia, when taken in conjunction with the trends in other dimensions of the spatial cadastral system. Where the cadastral map is a graphical cadastre the surveyor would need to additionally produce the cadastral map geometry.

Implicit in this model is the role of the custodian of the cadastral map in coordinating the input represented by the proposed cadastral changes from all surveying activities. This should include any surveying activities that impact on the cadastral map, not just those surveying activities that result in a submission to the land titles office. While the number of surveyors is difficult to determine, both Victoria and NSW report that a small number of surveyors represent the bulk of subdivision activity.

Composite model

It is possible to achieve the maintenance of the cadastral map with a composite of the above models. Provided the custodian of the jurisdiction wide cadastral map undertakes a coordinating and agenda setting role. The imperative is to ensure that the jurisdiction wide cadastral map is comprehensively maintained. This may, for example, mean that for a specific jurisdiction, the metropolitan area may be maintained by a large water authority while some rural areas may be handled by a few surveyors while low cost land areas with little land development, may need to be maintained by the map custodian.

7.4 Data

Models considered address the requirements and impact of:

- the definition of the cadastral map to more easily maintain super or sub sets of a jurisdiction's cadastral map;

- the alternative methodologies for incorporating additional data to fulfil the multipurpose cadastral map concept;

- spatial data opportunities with new database technology.

7.4.1 Definition of the cadastral map

In common with other state based cadastral systems world wide, the upgrade of the spatial cadastral data model has, in Australia, been on a state by state basis with no standard adopted to more easily generate national data sets. The reality for Australia is that there are still currently eight different cadastral spatial data sets, all with different standards and accuracies (PSMA 1996). Shared ownership of data sets at state borders is one method of beginning to formulate a national capability.

In countries where disparate state based cadastral maps exist, national cadastral data models for the specification of digital cadastral databases are required. In the absence of a specification, the derivation of a national cadastral data model requires both an overseeing body and a co-operative methodology. In Australia, an initiative by the Intergovernmental Committee on Surveying and Mapping (ICSM) resulted in a National Cadastral Data Model (ICSM 1999) derived as follows:

- Each jurisdiction supplied their entity relationship data models;

- A draft model which aimed to accommodate each jurisdiction's model (ICSM 1996) was prepared and published;

- Each jurisdiction reviewed the draft, and suggested changes were incorporated in the final data model (ICSM 1999).

This resultant model was a compromise model of eight jurisdictions. However, it is expected that each jurisdiction, while not adopting this model, will adapt their DCDB to be able to populate this data model, in the interest of more efficient spatial data transfer and facilitate easier production of a national cadastral map.

7.4.2   *Additional multipurpose data*

To address the multipurpose issue, the addition of data to an existing cadastral map can be simply achieved by including the data in the cadastral map. That is, the new data becomes an intrinsic part of the cadastral map, by either enlarging the data model or existing spatial data is remodelled to represent multiple features (e.g. parcel boundary is also a property boundary). Road centrelines (derived from parcel boundaries), property boundaries and street addresses are examples for Victoria of spatial data being added to the data model.

Alternatively, the new spatial data is a separate database, but integrated with the existing cadastral map. This solution increases the integration and coherence requirement of the cadastral map. The Danish *Coordinated Information System* (Enemark 1997) is an example of this approach where an extensive cross referencing system allows separate development and maintenance of new databases that can integrate with the cadastral map.

Street addressing provides a good example of these two alternatives. Under the first alternative, the street address is an aspatial attribute of the property and is spatially attributed to the property polygon via its centroid. There are a number of potential shortcomings to this approach, not the least of which is that the address capture and maintenance will be reproduced in many maps such as large scale street mapping and numerous aspatial databases containing addresses. The postal service in Australia as part of its *FuturePOST* program (Australia Post 1999) has constructed an aspatial

database of the nation's postal addresses to facilitate bar coding of mail for more efficient sorting and distribution. This represents a major duplication if the same addresses are to be additionally captured for cadastral maps.

In the Australian context, the legal survey plan, which is the major source for cadastral updates, does not always carry address data. The inclusion of address data in the cadastral map may require new data inputs. New data items not only impact sources for data input, but also constitute additional ongoing data maintenance and considerable data capture to fully populate the existing database.

Alternatively the street address can be regarded as a spatial entity that exists as an independent database (Lind 1997). Increasingly many publications quote the street address as separate data sets (NSW 1999) (Land Victoria 1999c) but do not clarify the separateness.

The concept of a separately maintained address database could be as follows:

- a textual data base of address records;

- the address point is associated with a spatial object such as the mail delivery point or building or property entrance;

- each address has an associated unique XYZ coordinate;

- the Z coordinate offers solutions to multi-storey situations;

- some address content such as town, post code and state does not need to be stored with each address and can be computed by a *point within closed boundary* algorithm;

- database access, search and update is facilitated by the Internet;

- addresses can be easily sorted into geographical areas.

This solution offers a multipurpose alternative to simply adding to the data content of the cadastral map, but is not necessarily simple to implement. The existence of a master national address database even if not easily integrated with spatial data sets would provide the ability to cross check addresses from cadastral maps (Christensen 1997) or provides an additional source of address update information.

7.4.3 Database Technology

The advent of new relational database technologies (RDBMS) allows custodians of cadastral maps to restructure the data models derived in the CAD based software environment. Specifically there is a trend towards *spatial server* technology where the spatial data and GIS software are independent.

RDBMS facilitates significant improvements in the maintenance of spatial data:

- The jurisdiction's cadastral map is in a single database that is a truly seamless spatial database without underlying file divisions.

- RDBMS provides a structure to hold relationships between all entities in the cadastral map, allowing the spatial data to be topologically structured. A single cadastral line can denote both a property and parcel boundary (Marwick 1998).

- The complex migration to new technologies justifies the reconsideration of the cadastral map's content and the possible redesign of the data model.

- Allows unique identification of all spatial and aspatial database entities and time stamps. This facilitates incremental updates delivery and version control.

Some jurisdictions have generated survey measurement databases independent of the state cadastral map. Newer technologies allow digital survey measurements to be retained by either the newly generated survey databases that are integrated with state DCDBs, or original boundary geometry generated in the update input process can be retained. These data may later be used to upgrade the spatial accuracy of the map

7.5 Function

In the maintenance function of the jurisdiction wide cadastral map it is important to differentiate between update and upgrade. While updates and upgrades might progress simultaneously, different procedures need to be put in place to facilitate each.

7.5.1 Update function

Models to improve the update function are covered from two distinct viewpoints. First, from the viewpoint of the cadastral map custodian, and second, from the spatial system view, derived from the jurisdictional studies in chapter 3.

Cadastral map custodian view

The cadastral map custodian's view of the update function is depicted in Figure 7.5.

Figure 7.5   Custodian spatial update view
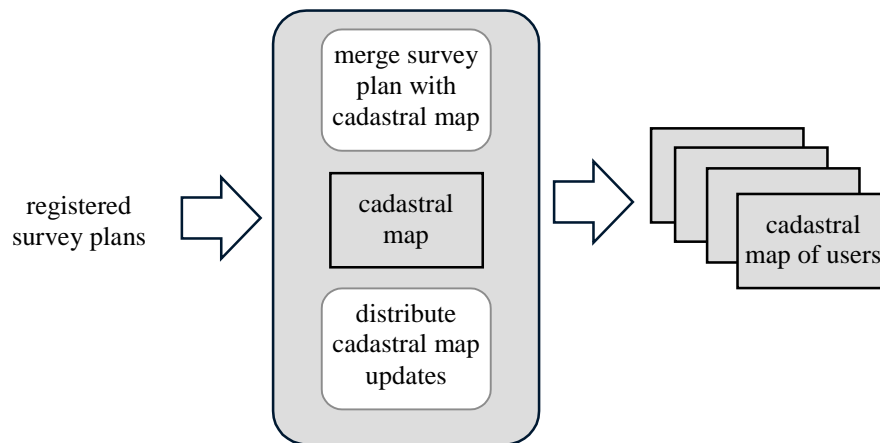
The input is provided by the survey plan. If this plan is digital there is the capacity to eliminate the task of entering the spatial data, but may add the functions of translation and assessment. If the survey data is acquired at the planning stage, proposed update geometry for the cadastral map can be generated, to ensure rapid final map update.

The custodian's actual update procedure involves merging the survey data with the cadastral map. For existing digital cadastral maps, these procedures are unlikely to change, except in response to a significant change to the cadastral map, such as increased accuracy. For the graphically accurate cadastral map, the update process is a predefined and ultimately subjective process. For a survey accurate map the update could be automated and accepted subject to acceptable error levels (Elfick 1995).

To protect current accuracy content, custodians must embark on rigorous metadata programs. At a minimum, metadata for specified portions of the cadastral map need to be implemented, to agreed standards. In Australia this is undertaken as outlined in the ANZLIC Metadata standards (ANZLIC 1996). This metadata currently only reflects the accuracy of source maps from which that portion of the digital data was derived.

The next level is for metadata to document and therefore protect the more accurate cadastral data at a spatial object level. In its simplest form this is a binary distinction

between survey accurate points and graphically accurate points. This is exemplified in the controlled cadastral map format of Denmark (Enemark 1994).

A far more complex metadata scenario is possible where the spatial data is held in relational databases. Not only could each point in the spatial database have its own metadata but could be multiply held at predefined accuracy ranges. This allows both a graphical map point and a survey accurate boundary point to be retained concurrently.

From the custodian's view, the output is the distribution of updated cadastral map to the customers. Rather than whole or partial file replacement, incremental updates, via text files are generated. These files indicate only those parcels the have changed. Incremental updates become possible as custodians implement data models with unique feature identification to point level (Dominguez, *et al.* 1994). Incremental updates have only recently been introduced in Victoria, the state of Queensland has for some time offered updates on the basis of an 'xy' change file, but in an esoteric file format (PSMA 1996). The delivery of incremental updates represents a significant improvement in the distribution of spatial cadastral data (Jacoby 1996).

The overheads for incremental updates are both for the custodian in the extraction process and the user in integrating these updates. From the user's viewpoint, the delivery of incremental updates has the potential to significantly alter their own update processes. Incremental updates allow users to process only changed spatial data and manually or automatically resolve possible associativity problems.

The delivery of incremental updates might not allow users to differentiate between update and upgrade information (new parcel boundary as distinct from a parcel boundary that has shifted). The paper *Incremental Update and Upgrade of Spatial Data* (Scheu *et al.* 1999) canvasses a number of methodologies to minimise the effects of spatial upgrade (shifting of reference objects). These solutions rely on the custodian of the digital cadastral map supplying additional information when the spatial position of objects are upgraded, and requires users of the data to implement software to take advantage of the shift information.

Incremental updates are still evolving and while they represent an important step they also introduce their own set of problems, not the least of which is a transfer standard.

The technology of the Internet offers the promise of some real data distribution and collection solutions. The development of web based spatial data display solutions is, however, still a long way from a solution that delivers current and changed spatial cadastral data to the users GIS system.

Spatial cadastral system

These generic, high level processes occurring within spatial cadastral systems are firstly, the creation of the spatial cadastral information, normally by a surveyor. This is the spatial data that is eventually used to update a digital cadastral map. Secondly, the spatial data produced by a boundary change or the subdivision process is subject to planning and land use regulations, a process normally conducted by the council or municipality in consultation with the relevant utilities. Finally, the application of standards to the spatial cadastral data, for legal verification purposes and to conform to cadastral map requirements.

Figure 7.6 depicts the spatial cadastral system DFD with input and output entities and the high level system processes. The model deliberately disassociates internal system processes from spatial cadastral system organisations that may currently enact them. The blank portion of the process depicts this disassociation.

Figure 7.6   Update functions for spatial cadastral systems
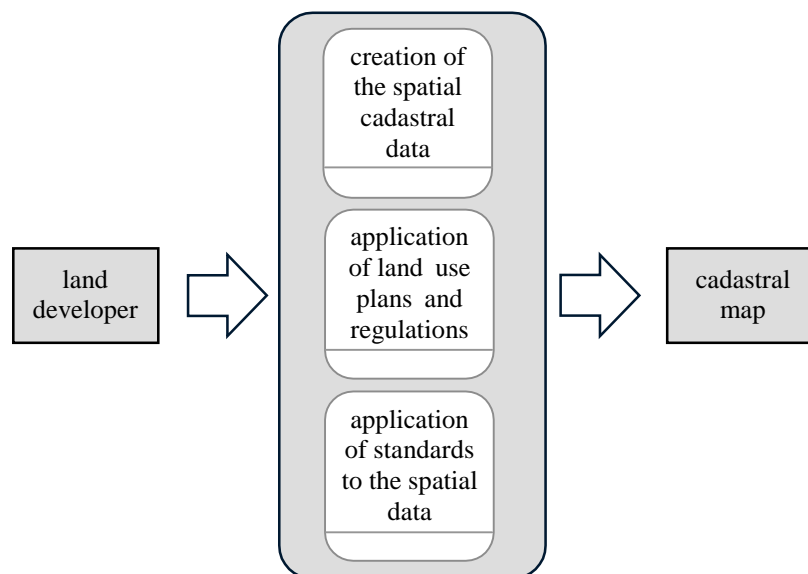
Current and future technology will influence the implementation of these three high level processes, both in how the processes are implemented and what organisations are involved in the implementation. The following defines the three spatial cadastral processes of this model in a digital environment.

Creation of spatial cadastral data: The survey plan provides the spatial data to update the digital cadastral map. It should only be necessary to create the digital spatial cadastral data once. This spatial data can be held in a single spatial database to reflect *as surveyed* or *as fitted* in relation to the cadastral map and tagged to denote the status of the spatial data, i.e. planned, proposed, legal, etc.

Application of land use plans and regulations: The process of confirming that the proposed subdivision meets necessary local and jurisdictional regulations is often spread across a number of organisations within the spatial cadastral system. Internet technology allows for relevant land use plans and regulations to be current and freely available to all organisations, whether or not they are part of the cadastral system.

Application of these land use plans and regulations need not be a centralised process. It is possible to electronically signature digital plans to identify their origin. It is also feasible to digitally signature, confirm compliance with regulations, and to authorise the change of status of spatial cadastral data from, for example, from certified to legal.

Specified areas of the cadastral map could be locked against land development by electronically preventing a change of status for any survey plans falling inside those areas. Such locking could either be predefined as permanent or temporary.

Application of standards to spatial data: Application of standards to spatial data occurs in three areas: the application of quality controls to the survey data; a check of the legality of the subdivision plan; and the application of standard procedures and quality control to ensure the correct maintenance of the cadastral map.

The use of survey regulations and the licensing of surveyors achieves the first standard. Second, to ensure that the subdivision is legally within its stated boundaries, an automated pre-approval process is possible. New subdivision measurements can be entered and the acceptability of this spatial data can be computed (Elfick, 1995).

Alternatively, more responsibility and liability for the legal correctness of the spatial data could be accorded to the surveyor. Last, licensed organisations or individuals accessing or manipulating the digital cadastral map data for maintenance purposes can always be monitored, restricted and audited.

In the spatial cadastral system view there is still the equivalent need to distribute spatial cadastral updates to external cadastral map users. Spatial update distribution and access opportunities for supply side users are discussed in the network dimension.

7.5.2 Upgrade function

The following are optional methods by which spatial upgrades can be achieved:

- recapture entire cadastral map at a higher accuracy;

- recapture specific areas within the cadastral map;

- upgrade through controlled update.

Automated adjustment procedures for cadastral upgrade are not discussed except to observe that the success of these procedures for large areas of graphically accurate spatial data has proved inconclusive. The high local integrity or cadastral fabric of the graphical cadastres is generally not able to be maintained (LIC 1998).

Recapture entire map

Many cadastral maps, digitised in the late eighties and early nineties, have proven to be difficult to upgrade in an incremental manner. Arguments can and are made that a need exists for the total recapture of the digital cadastral map from survey plans in order to create a survey accurate and possibly a coordinated cadastre (Bevin 1999, LTO 1999, Williamson and Hunter 1996, Elfick 1995).

Undertaking a recapture program sourced from original survey plans is extremely labour intensive, and will span a number of years (Bevin 1999). Additionally it needs to be recognised that economically, the map will always have regions of varying accuracy. Rural and mountainous areas (e.g. the Western Lands of NSW, or the mountainous regions of Austria) do not have the same economic value as the metropolitan areas. Regions with low land value and/or with little cadastral activity do not economically justify a survey accurate recapture. The recapture of the New

Zealand spatial cadastre, under the *Survey and Title Automation Project,* has been restricted to the urban and peri-urban areas (Bevin 1999).

Recapture specific areas

Custodians of DCDBs in Australia are seeking to partner with supply side customers particularly councils to upgrade specific areas of the cadastral map. The intent is to recapture or resurvey, low accuracy areas in the cadastral map that are subject to land development or change There are however some important considerations when upgrading spatial data in specific areas:

- A suitable methodology for including the more accurate spatial cadastre which is still surrounded by less accurate spatial data.

- Understanding that the resultant shift in a large number of cadastral parcels will impact all users, especially with respect to the associativity issue.

- The requirement for adequate survey control, either by increased density of survey control or the use of Global Positioning System (GPS) based methodology (Bevin 1999).

- A comprehensive assessment of the costs, not the least of which is the cost of expertise and specialised software (Bevin 1999).

Where duplicate digital map subsets exist, the more accurate can be incorporated into the jurisdiction wide cadastral map. This requires a comprehensive assessment of both data sets, in addition to the above considerations.

Controlled update

This is represented by the Denmark model reviewed in chapter 3, which begins with a survey accurate skeleton cadastral map into which the graphically accurate cadastre and new survey accurate update data is included. This represents the correct survey practice of working from the *whole to the part*. The addition of survey accurate areas to an existing graphically accurate cadastral map can be represented as upgrade via a controlled update, but means working from the *part to the whole*. Both controlled update methods require:

- new surveys tied to the survey control to achieve spatial upgrade integrity;
- an appreciation that cadastral boundaries will be upgraded;

- a metadata process to allow differentiation of spatial data accuracy and to protect upgraded spatial data;

- specified update procedures to ensure survey data and graphically accurate data are treated differently.

7.6 Network

The enabling technology of the Internet means that the current spatial cadastral activities will be undertaken in a digital environment. This digital spatial cadastral environment depicted in Figure 7.7 is both Internet and E-commerce enabled.

Figure 7.7   Digital maintenance network of the cadastral map
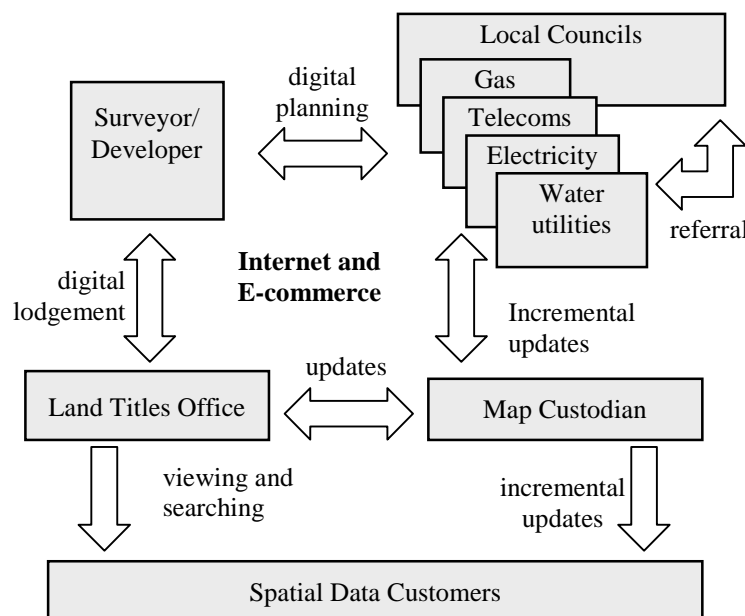
An Internet enabled spatial cadastral system means that while there is a necessary temporal sequence for spatial data, the planning data is available when the surveyor enters it into the system. Potentially, spatial data customers can access data from all organisational entities within the spatial cadastral system. E-commerce relates to the payments or credits involved with spatial data transactions being electronically completed at the time the spatial data is transferred.

The absence of a data flow between the surveyor and the map custodian reflects the current absence of a organisational relationship. The plan of subdivision must

formally enter the planning phase to be of interest to the cadastral maintenance process. This implies that the surveyor's spatial data, for update purposes, will reach the custodian of the cadastral map via the planning authorisation organisation.

7.6.1 Improvement strategies

Moving to the digital environment has been an incremental process. Each organisation within the cadastral system has utilised technology to improve and reengineer their business processes to service departmental or intradepartmental needs. These now seek to improve external transfers. Adoption of digital data transfers, digital lodgement and proposed layer concepts are representative of improvement alternatives. If these proceed in isolation of the entire spatial cadastral system they potentially generate inefficiencies and duplication.

Digital data transfer

NSW, and to a lesser extent Victoria, has implemented the concept of mirror sites for either internal customers or specific customer research projects. Here an external database site has all of the cadastral updates for a day applied as an overnight batch process. While this is efficient for a small number of sites that maintain similar or predetermined hardware and software, it is not a viable solution all users state wide.

The promise of the Internet to offer real data distribution and collection solutions, was demonstrated by a prototype developed by Polley and Williamson (1999). The functionality of the prototype includes the following spatial data transactions:

- downloading of portions of data from WWW servers for local* manipulation (* the user's own computer);

- uploading of local data for comparison with WWW sourced data;

- submission of local data for updating of external digital data sets, e.g. digital lodgement or maintenance of cadastral maps.

To enable users to download data sets with knowledge of the exact data content some custodians are embarking on basic clearinghouse structures. That is WWW servers that contain metadata about spatial data and its physical location. This metadata in turn contains hypertext links to enable users to download digital data onto their own computers (Nerbet 1996).

The Victorian WWW site GI Connections (*www.giconnections.vic.gov.au*) is a first stage clearinghouse example (Phillips *et al.* 1999). It provides metadata with regard to contact information, data set information and web based purchase details.

Digital lodgement

Digital lodgement has been investigated for a number of years. These investigations focused on the digital transfer of survey plans to improve the operations relating to the administration of boundaries and the registration of land (Hayes 1997, Falzon and Williamson 2001). Digital lodgement is seen as one solution to make the surveyor's information more accessible and also to minimise the number of times the cadastral subdivision survey information is printed to hard copy and again entered into another computer system.

In essence, digital lodgement has been viewed as requiring the surveyor to prepare and submit digital copies of the survey plan. While many cadastral map custodians in conjunction with the land registration bodies have been investigating alternatives, the associated signatures and legal instruments have been major issues. The research by Hayes (1997) developed a prototype for digital lodgement from the perspective of the private surveyor. The e-plan concept of electronic plan lodgement (LTO and SGD 1998) can also be viewed at the WWW site–*www.lto.nsw.gov.au*–for the NSW Land Titles Office (LTO).

The above demonstrates not only the validity of the digital lodgement process, but also reinforces the potential for creating a spatial environment, albeit only a partial implementation of the digital, cadastral environment. Digital lodgement is a reality and occurs in some jurisdictions for title registration (DOLA 1994), and also with utilities for planning purposes (PSMA 1996). These digital transfers, however, are not always coordinated, particularly where the spatial cadastral industry is large and the constituent organisations are insular.

Proposed layer

In recognition of the dual role of councils and utilities as both customers and contributors of the cadastral data (Figure 7.3) the custodians of the DCDB are maintaining or are moving to capture a proposed plan of subdivision as part of the cadastral map data model. This is a clear recognition of the fact that once the

subdivision plans have been registered, the planning authorities have already utilised or incorporated the data. There is a perception that the lack of this information is the main cause for the fragmentation and duplication of cadastral data sets. In the Australian ACT, where the cadastral map custodian acts in both a state and council role, the proposed layer has always been maintained (Williamson 1987).

The model indicates that to include the proposed subdivision plan information in the DCDB requires that the information be sourced at planning stage, either from the surveyor, councils or utilities. Victoria, with its close association with metropolitan water utilities, maintains a proposed layer for its metropolitan jurisdiction, complete with access to digital plans for subdivision of greater than ten lots.

The presence of planning cadastral data in the cadastral model assumes that survey planning data can be accessed by the custodians of the DCDB. In turn this cadastral planning information must be accessible, to at least all supply side customers, to avoid possible duplication. Access to planning data, by all spatial cadastral organisations, in a timely and economical method, is a fundamental requirement to achieve a more homogeneous state cadastral map. Methods to facilitate this access are discussed further in the network dimension and the next chapter's proposed conceptual model.

7.6.2   Network models

Traditionally the cadastral map is created and maintained by the custodian of the jurisdiction wide cadastral map in a centralised manner as reflected by the majority of cadastral systems reviewed in chapter 3. The lack of an obvious central organisation in Figure 7.7 suggests decentralised maintenance models need to be considered.

Centralised model

This structure relies on the information being forwarded or requested by the custodian of the cadastral map and the approved spatial data being returned to the other organisatios or customers of the cadastral system. The data flow diagrams from chapter 3 show the implementation of a number of centralised models. The basis for a centralised model is generally in the context of central control, central approval, the perceived specific requirements of individual businesses and for the efficiency and quality of the single jurisdiction wide cadastral map.

The Victorian cadastral map custodian has attempted to address the network issues and encompass the concepts of digital lodgement, proposed layer and cadastral map maintenance within the one centralised vision. Figure 7.8 depicts this maintenance vision that is proposed to be tested under the auspices of the Property Information Project (PIP) (Jacoby and Murray 1998, Land Victoria 1998b).

Figure 7.8 Network model for DCDB (Jacoby and Murray 1998)
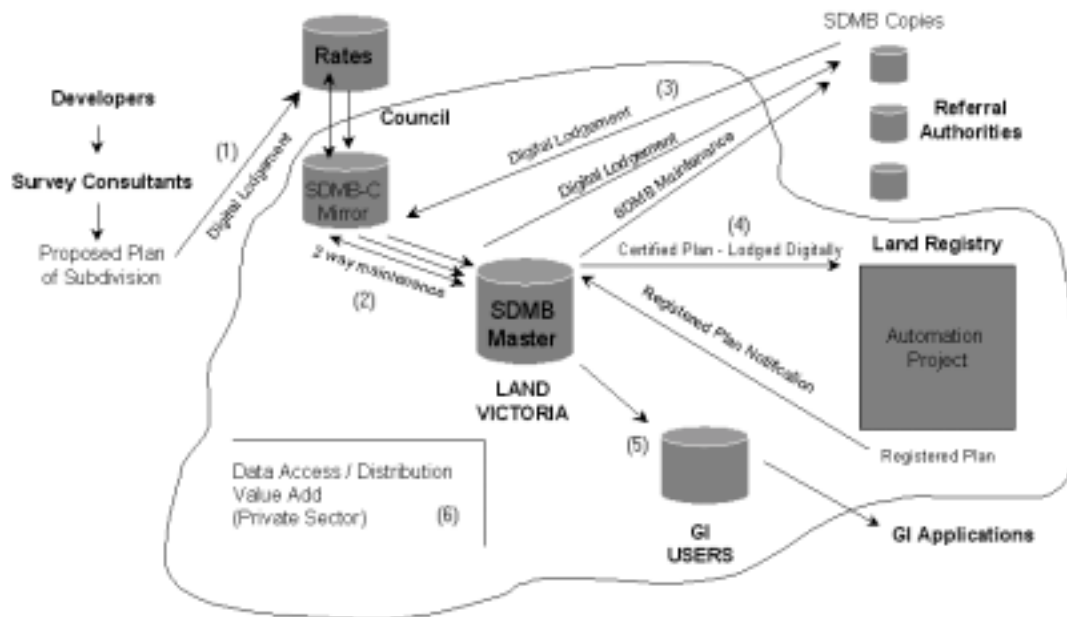
The concept is intended to function as follows (Jacoby and Murray 1998):

1. All survey plans are submitted to councils in digital format;

2. Councils forward the digital plans to Land Victoria DCDB custodian;

3. Land Victoria will update the cadastral map using the information sent by council and electronically send proposed updates back on a regular basis;

4. Referral authorities will be notified of and have access to proposed plans;

5. Any required changes to the proposed plan are electronically notified to the surveyor. New digital versions of the plan will then be lodged at council and again forwarded to Land Victoria;

6. After council certification the plan will then be lodged electronically at Land Registry;

7. Once the survey plan is registered and approved the cadastral map base is modified accordingly;

8. Users will hold their own copies of the cadastral map in their area of interest and will receive updates as required.

Decentralised models

The legitimate objective of maintaining a homogenous jurisdiction wide digital cadastral map does not necessarily dictate a centralised maintenance model. Any organisation or individual viewing, maintaining and down loading or up loading the digital cadastral data need not know where and on what hardware and software platform the digital cadastral map resides. In addition, the concept of distributed databases negates the necessity of an entire database or digital cadastral map residing at a single (central) location.

Fundamental to the feasibility of decentralised maintenance models are digital transfer formats, the Internet technology for access to the cadastral map and the role of the custodian of the cadastral map as a coordinator to ensure the integrity of the jurisdiction wide cadastral map. This affords the opportunity to consider totally decentralised or remote maintenance of the digital cadastral map where the processes of spatial cadastral maintenance are undertaken by organisations other than the central custodian.

Decentralisation of cadastral maintenance can be classified as:

- regional maintenance;

- remote maintenance;

- spatial data theme.

Regional maintenance: The jurisdiction wide cadastral map may be divided into regions based on utility, local government or cadastral boundaries for the purposes of cadastral map maintenance. In effect the maintenance of the digital cadastral map is undertaken regionally on behalf of the cadastral map custodian.

The Austrian cadastral system is an example of a regional model where the cadastral map maintenance is divided into geographical areas (see chapter 3). The federal

survey office has more than fifty individual decentralised offices that handle the creation of the digital update data for digital cadastral map for their cadastral areas.

In Australia there are a number of precedents for decentralised maintenance. This includes recent inclusion of the spatial cadastral data from a rural and urban water authority to replace existing inferior data in the Victorian DCDB (Caldow 1999). In NSW, the Sydney metropolitan DCDB was initially sourced from the Sydney metropolitan water authority, who has continued to duplicate the maintenance undertaken by the cadastral map custodian (Watt 1998).

Remote maintenance: Current communication technology means the maintenance of the cadastral map need not necessarily occur at a centralised location and can be conducted with the same apparent centralised connectivity but at remote locations. The entry of new parcel information and manipulation of the cadastral map can be done at remote locations, by perhaps the surveyor, with structured access to the current digital cadastral map. The essential point here is that the cadastral map need not be distributed geographically to decentralise its maintenance.

To ensure the integrity of the jurisdiction wide cadastral map the role of the cadastral map custodian is then to:

- coordinate the maintenance;

- produce or assemble the current, jurisdiction wide cadastral map as necessary;

- set standards and quality control;

- possibly undertake maintenance for specific portions to ensure completeness.

Spatial data theme: Subject to increased coherence of the spatial data components of the multipurpose cadastral map, there is scope to divide the maintenance of the map by spatial data theme. This maintenance could be undertaken by organisations other than the cadastral map custodian. Spatial themes that provide this opportunity are the:

- parcel based cadastral map;

- property boundaries coherent with the parcel base;

- property addresses;

- transport networks such as road and rail;

- easements;

- administration boundaries.

These spatial themes are often quoted as separate data sets in discussion of fundamental data sets or infrastructure data (Land Victoria 1999c). The singular business requirement for a specific spatial data theme is often the cause of cadastral map duplication. An example of this is the contrasting need for properties by councils and utilities and the focus on the land parcels by the LTOs.

There is scope to construct a composite of the above maintenance methodologies, each casting the custodian of the cadastral map into slightly different roles. The decentralised models offer the advantage of effectively capturing the cadastral maintenance data at the planning stage and to link spatial cadastral upgrade with any kind of local development. Continual spatial upgrade is likely to be more acceptable where users perceive immediate knowledge and benefits of the spatial changes.

7.7 Schedule

Improvement strategies for this dimension revolve around reducing times for internal processes, times for inter processes data transfers (see network dimension) and reducing overall time by paralleling process that are currently sequential.

Process times

Specifically, for the actual update of the cadastral map, the move to digital input and output is aimed at reducing the internal process time by not repeating time consuming input processes. To decrease the time for the update process the cadastral map custodians need access to digital planning data. This allows proposed updates to be held in the digital cadastral map. Once the survey plan is registered the proposed update can merely be *dropped* into the current cadastral map, subject to any spatial modifications in the title registration process.

An additional process focus is the emergence of software to automate time consuming and labour intensive task of survey plan examination. The temporal efficiency of this is dependent on both digital survey plans and also a survey accurate digital cadastral map that retains survey measurements. This has proven successful in trials by the

NSW LTO (Elfick 1995). Another approach is to reduce or eliminate survey plan examination by making the legal correctness of the survey plan the responsibility of the surveyor (Hayes 1997).

Parallel processes

The movement and approval of spatial data from the surveyor to the update of the cadastral map is essentially an end-on-end process. Time reduction can be achieved by placing sequential events such as survey plan referral and approval in parallel.

Rather than waiting for the referral process to be enacted by the councils as part of the approval process, the surveyor will directly submit plans to the other referral bodies such as utilities. This allows these authorities, at referral, to simple reply to council since they will already know the status of the proposed plan. For survey plan examination, the Land Titles Office could accept plans of survey, after council approval, to allow for preliminary approval prior to official lodgement when all the necessary legal instruments for title registration are eventually submitted.

7.8   Conclusions

This chapter has canvassed a number of alternative approaches that may be used to maintain the cadastral map within the defined spatial cadastral system. It has not been the intent to formulate a specific model but to present the alternatives available. The Zachman Framework has provided the classifying structure for these models and forced a focus on each dimension or aspect of the spatial cadastral system's maintenance of the cadastral map.

The Zachman Framework facilitates the focused exploration and design of dimension specific models for spatial cadastral maintenance. These models can be addressed in isolation, but with the awareness that any particular model may have significant impacts on other dimensions of the spatial cadastral system. Whether any individual dimension based model is applicable to specific jurisdictions is primarily dependent on the historical, cultural, social and economic setting of that entire cadastral system. These factors dictate much of the spatial cadastral strategy dimension that provides the rules and constraints for the design and operation of the other dimensions of spatial cadastral system.

A Spatial Cadastral Update Model

This chapter seeks to establish a fully defined model to manage the flow of spatial cadastral data that updates the cadastral map. This in contrast to the previous chapter where a range of models for the management of the spatial cadastral data, were explored within each Zachman dimension.

The design of this update model encompasses the requirements of the spatial cadastral system to digitally progress the data that is created by the surveyor, through the planning and registration process, to eventually update the cadastral map. The documentation of this design of the spatial cadastral update model is structured across the six dimensions of the Zachman framework.

The overarching strategic requirement to negate the duplication of spatial cadastral data, means that the conceptual model must be firmly based on the network dimension. At the same time the model makes the spatial cadastral data accessible, as required, to all organisations within the spatial cadastral system.

8.1　Setting for spatial cadastral update

The concept is for an update model that encompasses the spatial cadastral system as described in this thesis and uses the technology of the Internet. The model which is fully defined by each of the six dimensions of the Zachman framework is intended to meet not only the requirements of the custodian of the cadastral map, but also the needs of all the supply side users of the cadastral map. The model, while streamlining the subdivision process, will supply the necessary data to update the cadastral map.

In the design process the strategy dimension is visited first since it imposes the rules and constraints for design and subsequent operation of a system (Sowa and Zachman 1992). The specifics of this update model implements the subdivision processes associated with the jurisdiction of an Australian State such as Victoria or NSW.

8.2　Strategy

The previous chapter has indicated feasibility of the following strategic directions for cadastral map update:

- The spatial cadastral data that updates the cadastral map need only be entered once;

- The surveyors as the initiator of the changes to the cadastral map should supply this spatial data;

- Supply side customers are able to add additional information to this digital data; for instance councils suppling address information for new subdivisions.

The following are strategic directions to implement a spatial update model in a digital environment and ensure that spatial data is not duplicated:

- Digital mechanisms are used to *signature* certification, lodgement of survey plans for registration and plan examination;

- The custodian of the cadastral map has access to all planning spatial data that impacts the cadastral map;

- To participate in the process supply side customers will have access to the cadastral map and associated survey and control data;

- A proposed cadastral map or proposed layer is not maintained but rather the existence of development activity is flagged / annotated /denoted in the actual areas of the cadastral map. This will allow users to be aware of development and if necessary access the proposed cadastral geometry or the survey plan on the plan server.

These strategic requirements direct where the update of the cadastral map should occur. This means that the primary design is in the network dimension of the Zachman Framework, which will therefore determine the basis of the update model. The other dimensions are required to fully describe and support the update model. The documentation highlights the operation and impact of the design process across the cells of the Zachman dimensions.

8.3 Network

The strategic direction is the implementation of the spatial data flows associated with the cadastral processes in a digital Internet enabled environment. The basis of the digital plan server is that the surveyor uploads spatial data, with the progression of the plan through the cadastral system denoted by the change of the plan's status and depicted by the plan server's four boxes. The diagrammatic concept of this model is presented in Figure 8.1.

Figure 8.1 is the complete network, with a single database where the survey data continually resides until the cadastral map is updated post title registration. Depending on functionality, required access is facilitated by: Internet software such as web browsers for read-only access; file transfers facilities for uploading and downloading data; and remote terminal emulation for status manipulation. Jurisdiction size, or implementation strategies, may require one or more of these plans servers; however distributed plan servers would be largely invisible to most participants.

This model is in contrast to network of organisational information systems depicted in Figure 7.7, where simply digitally enabling the current environment and processes results in a number duplicates of the spatial data and numerous data transfers.

Figure 8.1   Plan server model for update of the digital cadastre
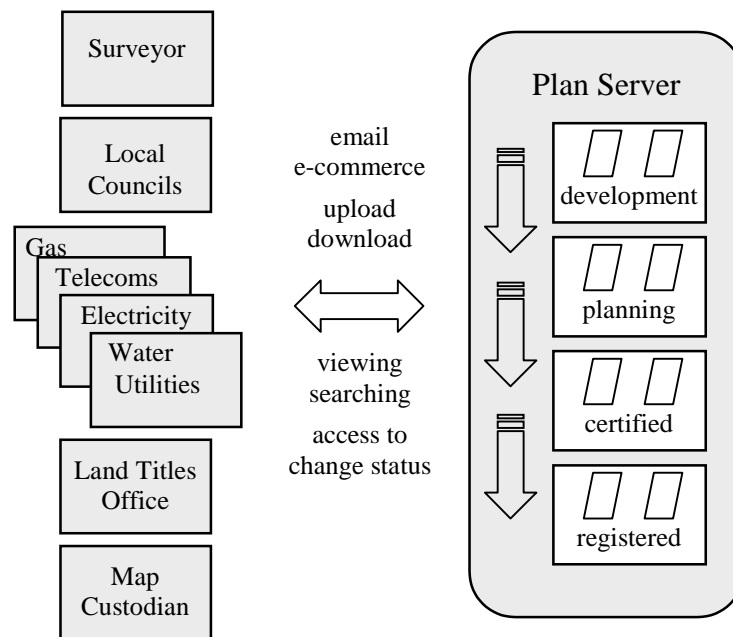
Clearly, there is opportunity for a number of organisations or individuals to take advantage of the spatial data available on the server. The decision, as to whom should have access to the spatial data and at what stage, and whether an Internet or Intranet environment is maintained will need consideration. These factors, however, do not alter the model's functionality to provide an efficient and timely digital mechanism to update the digital cadastral map without duplication of digital spatial data.

8.4   Organisation

This model for the progression of spatial cadastral data from the surveyor to the custodian of the cadastral map envisages the following roles and responsibilities.

Surveyor:
- uploads spatial data such as plan of subdivision to the plan server;
- able to reload modified plan as required, but at development and planning stages only;
- responsible for version maintenance of development and planning data;
- controls which individual or organisation is able to access development data;
- notifies land title office to when certified plan is to be processed.

Council:

- changes plan status from development to planning;

- changes plan status from planning to certified.

Utilities:

- access and process the proposed plan on notification;

- mark up changes or comments on plan at the server.

Land Registry:

- access plan and process on notification;

- change plan status from certified to registered.

Custodian:

- access and process plan at certification stage;

- verify plan after registration and integrate into cadastral map;

- retire registered plan.

Plan Server:

- trigger email notification on plan status changes;

- log plan events and access for audit purposes;

- ensure security and limit access to enforce above responsibilities.

In the plan server environment triggers can be utilised to automate a number of responsibilities. For example, a change by the council of plan status from development to planning would initiate electronic notification to all referral bodies.

The responsibility for tasks such as who generates the graphical map geometry associated with the plan, and how raster geometry might be produced are flexible within this model and not critical to its viability.

8.5   Schedule

The following chronicles a subdivision scenario for the model:

- surveyor uploads necessary spatial for development purposes;

- the data at this stage is surveyor confidential. The surveyor decides which other organisations are notified that data is available for processing, for costing purposes etc;

- surveyor notifies council seeking planning approval and the plan becomes *public;*

- surveyor receives electronic notification of development approval;

- surveyor submits data necessary for plan certification;

- geometry for cadastral map could be generated at this time;

- council and all referral bodies receive electronic communication indicating data requiring attention;

- referral bodies comment and *markup* plan. The surveyor may need to upload new spatial data;

- subject to referral responses, council certifies plan by changing status of plan;

- surveyor packages the certified plan, which he is now unable to change, along with an e-commerce transaction, and notifies land registration organisation;

- after the plan examination process the land registry changes status of plan to legal plan;

- map custodian updates cadastral map with from proposed data which has previously been *fitted* to the cadastral map;

- after a specified time the registered plan is archived;

The above does not depict where iteration occurs, but this repetition of steps are easily accommodated within this model.

8.6   Function

The digital creation of spatial data is a once-only process by the surveyor. At the time that the surveyor submits the plan for certification, the necessary geometry to update the cadastral map could also be generated. While the custodian of the cadastral map could do this, there are benefits if the surveyor undertakes this task at the local level.

The proposed spatial data is now available for use by all organisations within the spatial cadastral system. Signatures are replaced by the giving the approval organisation the exclusive rights to change status of plans, e.g. only a council can change the status from planning to certified, and similar exclusive authority would

apply for surveyors and the land titles office. The update process is completed when the plan reaches the registered status. The responsibilities and timing of this progression is documented in the organisation and schedule dimension respectively.

Subject to any changes since the proposed plan stage, the custodian would merely *"drop"* the proposed plan into the cadastral map. Those users wishing to take daily updates could be notified of and download either the graphical data, or an accompanying incremental update file, posted by the map custodian.

8.7 Data

For cadastral surveys impacting the cadastral map the following types of spatial data might be submitted to the plan server:

- approximate survey design for planning approval;

- survey plan for title registration;

- proposed geometry for cadastral map update, that is the how the survey geometry and the graphically accurate cadastral map might be changed to accommodate the new survey data.

These plans would normally be expected to be in digital vector format. The current process requires hardcopy prints of the plan at various stages. Distribution of digital vector data may be seen as infringing either intellectual property rights or conceding value added data. Where there is requirement to distribute plan data, the vector data can be automatically converted to a less spatial intelligent raster format. This is depicted in Figure 8.1 by multiple plans at each status level.

Additional textual data such as legal instruments might also be included in the transition of plans from one status to the next. For example an associated e-commerce transaction may include the necessary fee for plan certification or land registration.

This update model does not specify the data content. This will obviously be dependent on the actual data required for the land subdivision process, It does however assume that changes to the cadastral map can be derived form this subdivision data as

supplied by the surveyor and added to by other supply side organisations (address and property data normally supplied by councils).

8.8   Verification of update model

This concept of the spatial plan server has been the focus of combined research with myself and both NSW (LIC) and Victorian (Land Victoria) custodians of the cadastral map. Also with the Land titles Office in NSW in their consideration digital lodgement options (LTO and SGD 1998). As part of the research methodology my findings along with the plan server concept were formally presented to each of the above bodies. Their feedback has been incorporated into the update model. These presentations and subsequent feedback reinforced the technical viability of the spatial cadastral update model. Considerable difficulties were raised with respect to cooperation across the organisations comprising the spatial cadastral system, particularly where these organisations have a history of independence and functional duplication.

The thesis was undertaken within the Cadastral Research Group headed by Professor Ian Williamson within the Department of Geomatics at The University Melbourne. Many of the technical aspects of this concept and their viability were demonstrated in conjunction with master's projects arising from this group. These included:

- Suitability of Internet Technologies for Access, Transmission and Updating Digital Cadastral Databases on the Web (Polley, Williamson & Effenberg 1997);

- Spatial Data Infrastructures Concepts (Phillips, Williamson, & Ezigbalike, 1999);

- The A Multi-Purpose Cadastre Prototype on the Web. (Sam Majid 2000).

8.8.1   ESTE Implementation

Land Victoria (Land Information Group) has adopted many of the above concepts in initiating the Electronic Spatial Transfer Environment (ESTE) project (Land Victoria 1999a). The scope of the ESTE project is limited to the currently paper based certification and referral process. Land Victoria as the custodian of the cadastral map is facilitating this project as it benefits from access to proposed plans of subdivision

(digital or analogue). Figure 8.2 depicts the flow of data within the scope of ESTE concept.

Figure 8.2   Scope and data flow for ESTE (Land Victoria 1999a)
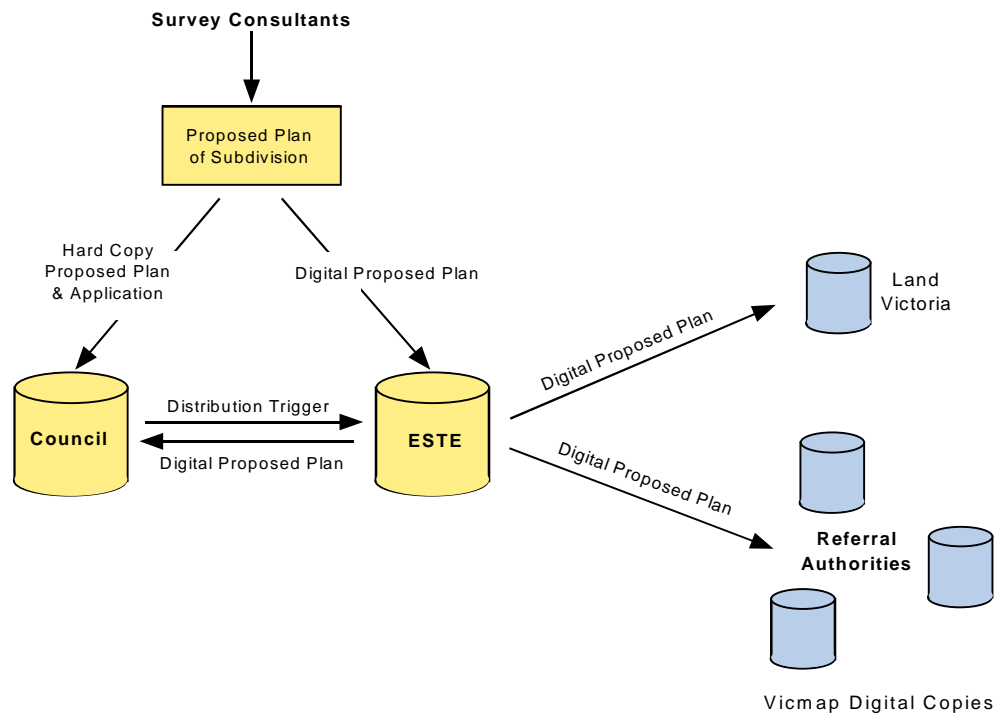
ESTE is an attempt to trial a digital environment without impacting the cadastral current process. This is reflective of the fact that Land Victoria is not part of the legal land development process. To this end it is attempting to develop agreed formats for usage and transfer of digital spatial data and develop procedures for certification and approval in a digital environment. The ESTE project is rightly seen as an initial and ongoing forum to discuss and identify future developments for spatial cadastral data.

The current scope of the ESTE project is based the concept of a *central electronic notice board* (Land Victoria 1999b) implemented as a web document server. The ESTE document (Land Victoria 1999b) gives an insight into the detailed implementation design, not covered Figure 8.2. Therein is documented the ESTE aim of limiting the organisations involved in this model to minimally impact the current business process of plan certification referral.

This approach, however, mimics an analogue process without taking advantage of the digital management and approval of spatial cadastral data envisaged in the more comprehensive conceptual update model derived in this research and depicted in Figure 8.1. Indeed the number of copies of the spatial data actually envisaged in Figure 8.2 fails to address the important issue of spatial data duplication.

8.9 Conclusions

The conceptual model presented in Figure 8.1 was derived from some the possible alternatives proposed in the previous chapter. This model shows how the spatial cadastral system can operate in a completely digital environment. While directed at the Australian spatial cadastral environment, the model, nevertheless, has application in other spatial cadastral systems given the similarities documented in chapter 3 of this dissertation.

The conceptual model importantly demonstrates that, in a totally digital environment, there will be no need for central approval. The spatial cadastral data flow can be based on standards and processes of quality control that should, ideally, exclude time delays and duplication; and provide the basis of an efficient and timely method of maintaining a digital cadastral map.

The conceptual update model for the cadastral map should not be isolated to the land registration process. The model presented clearly shows that any and all land development or land registration leading to a change in the cadastral fabric, must be included to maximise the digital advantages. Indeed the Plan Server concept allows greater efficiency in the all land development by integrating the cadastral map in the land development process, irrespective of the role of the cadastral map within the cadastral system.

9

Real knowledge is to know the extent of
one's ignorance."   Confucius

Summary and Conclusions

The objective of this chapter is to document the major findings from the research in terms of the aims and the approach outlined in chapter 1.

The research approach has resulted in many of the chapters in this dissertation making a number of important observations and conclusions about the spatial cadastral system. This chapter summarises these observations and conclusions.

A review of each of the dimensions of the spatial cadastral system is undertaken to highlight their individual contribution to the effective, efficient and timely maintenance of the cadastral map.

The application of the Zachman Framework, to not only to spatial cadastral systems but also utilising a single framework construct for a multi-organisational system constitutes a major focus of this research design. The application and success of this framework for this thesis is reviewed.

Lastly further research opportunities arising from this thesis's spatial cadastral system definition and research are discussed.

9.1 Summary of chapter conclusions

The research approach adopted required a definition and a better understanding of the spatial cadastral system, as a subsystem of cadastral systems. A structured and comprehensive analysis of a specific spatial cadastral system allowed the formulation and presentation of spatial data maintenance alternatives. This meant that defining the spatial cadastral system, its boundaries and the application of the Zachman Framework to spatial cadastral systems form major components of this research. The following provides a summary of the key observations and conclusions that resulted in each phase of the research.

A review of cadastral models in chapter 2 portrayed the separateness yet interdependence of the spatial cadastral components within the cadastral system. It was also concluded that there are a number of subsystems to the cadastral system, one of which was clearly the spatial cadastral system supporting the cadastral map. This substantiated the underlying thesis of this research that the cadastral map, and its maintenance, is a separate component able to be studied as a bounded subsystem within the cadastral system. Indeed it was shown that even where a jurisdiction's land titling and cadastral mapping organisations are merged, the maintenance of the cadastral map is a separate operation within the larger organisation.

Chapter 3 provided the international *setting* for the investigation of cadastral maps, their maintenance and their use. Cadastral maps were found to range from the graphically accurate maps of Australia, through to the national, survey accurate, legal cadastral map of Austria. A review of these spatial cadastral systems found significant similarities with respect to the organisations involved, the processes applied to the spatial cadastral data, and the spatial data transfers. The spatial cadastral system was defined as beginning with the request for land development and ending with the customer's request for updates to their copy of cadastral map from the jurisdiction wide cadastral map custodian.

Chapter 3 also served to highlight the complexity of the spatial cadastral subsystem. A complexity which makes difficult the detailed analysis and documentation of high level design alternatives for spatial, cadastral systems. Chapter 4, therefore, reviewed

a number of information system methodologies and documentation techniques used in cadastral system research and information technology practice. The Zachman Framework's ability to absorb a variety of often competing information system methodologies, was demonstrated to be most consistent with the primary aim of this research; the study of the maintenance of the cadastral map within the context of a jurisdiction's cadastral system.

Chapter 5 uniquely applied the concept of the Zachman Enterprise Information Architecture to analyse and document the group of organisations, or industry, that represents the spatial cadastral system of the Australian State of Victoria. This approached amalgamated the high level perspectives of the possible differing frameworks for spatial cadastral organisations to produce a jurisdictional spatial cadastral framework.

The list based documentation structure of chapter 5 provided the inventory and definition of spatial cadastral systems, a required preliminary, analysis task before the more diagrammatic analysis presented in the modelling perspective. The unique application of the framework to the spatial cadastral system highlighted the diversity, and scarcity of system-wide analysis documentation. Diagrammatic models were presented for the previously undocumented spatial cadastral system dimensions of function and schedule.

Chapter 6 mapped the impacting developments and issues relating to the maintenance of digital cadastral maps to the six dimensions of the Zachman Framework. The issues were mainly seen as arising from unmet user requirements often associated with technological advances. This classification of the issues clearly showed that the legacies of the first generation of digitised cadastral maps are significant maintenance difficulties. While jurisdictions with survey accurate cadastral maps are spared accuracy pressures, they face equivalent issues in respect to digital data duplication, capture and distribution of updates, and multipurpose usage of spatial cadastral data.

Solutions to these issues in the spatial cadastral system must be established in the same digital and Internet enabled environment from which they arose. Chapter 7 reviewed and developed a number of solution alternatives within each of the Zachman

Framework dimensions. The specific solutions adopted to improve the maintenance of the cadastral map will be unique to a jurisdiction.

The conceptual model presented in chapter 8 was derived from the alternatives proposed in chapter 7. That model showed how the spatial cadastral system might operate in a completely digital environment. The conceptual model importantly demonstrates the use of the Zachman Framework to facilitate a complete model specification, given the strategic drivers of an efficient and timely method of maintaining a digital cadastral map without spatial data duplication.

9.2   Meeting the maintenance criteria

The multipurpose cadastre, envisaged twenty years ago, pioneered the concept that spatial cadastral databases provided the necessary data upon which land information systems were built. The current concept of the multipurpose cadastral map is as spatial infrastructure data and multipurpose usage. This concept, often termed interoperability, means that the cadastral map contains the necessary linkage mechanisms to allow its integration with other aspatial data sets, and that the map is coherent with other spatial, infrastructure data.

This research of the spatial cadastral system was undertaken cognizant of this concept of the cadastral map. The research has achieved the primary aim of defining the expanded spatial cadastral system, bringing a formal systems approach to the analysis an existing system and the formulation of new models to manage the spatial cadastral maintenance process.

The following are conclusions from the analysis and design of spatial cadastral systems undertaken in this research. Each dimension of the spatial cadastral system is revisited to assess its impact on the effective, efficient and timely maintenance of the digital cadastral map. It is these criteria in relation to the models presented that enable the spatial cadastral data to fulfil the infrastructure role that enables responsible management of present and future land development.

9.2.1   Strategy

The objective of the cadastral map custodian is to maintain a current and homogeneous map for its jurisdiction to fully meet the daily needs of the data originators, the title registration process and all customers of the cadastral map. To efficiently meet this objective will involve considerable utilisation of current technology and Internet concepts to gather and deliver proposed and actual updates of the cadastral map in a timely and effective manner.

In the implementation of this cadastral map objective, it is important to strategically define *maintain.* Implementing responsibility for the maintenance of the jurisdiction wide cadastral map could mean either being responsible for its maintenance or actually conducting the maintenance. The latter implies that the custodian undertakes the maintenance task, while the former means the custodian ensures the maintenance is undertaken, possibly by third party organisations.

The latter is the situation in Victoria, where the maintenance task has been outsourced to a single organisation. Economies of scale aside, this concept could be further extended to actually decentralise the maintenance task with the custodian putting in place mechanisms to assemble a whole or part current cadastral map as required. Strategic factors such as sustainable development and the need to involve supply side customers for timely spatial data access may be the drivers for decentralised models for cadastral map maintenance.

9.2.2   Organisation

The increasing tendency for cadastral map custodians to foster organisational relationships with supply side customers is recognition that the maintenance of the cadastral map is a spatial cadastral industry problem, and not merely an input/output problem for the cadastral map custodian. The research analysis shows that a number of supply side organisation can and do maintain spatial cadastral information independent of the cadastral map custodian.

To minimise duplication, a maintenance model that does not involve the surveyor or at least the digital data submitted by the surveyor at planning stage, does not meet the

criteria of efficiency. A maintenance model that does not involve all supply side organisations, removes the responsibility for the cadastral data from the organisation or individual that has the greatest influence on its creation and the best knowledge of the reality that it models.

9.2.3   Data

Meeting user requirements of content and accuracy are fundamental to the effective maintenance of the cadastral map.

There are no technical barriers to increasing the accuracy of the cadastral map, however, a number of observations are pertinent:

- A survey accurate map is required to serve the requirements of an automated plan examination process.

- It is difficult to justify the expense to the public of a wholesale accuracy upgrade of all spatial cadastral data.

- Physical boundaries approximate to legal boundaries in graphical cadastral maps. The difference between occupation and legal boundary will highlight significant associativity issues as greater map accuracy is achieved.

- Customers mapping their assets to physical boundaries will find the requirement for maps that depict the occupation boundary, as distinct from the cadastral map that depicts the legal boundary.

- Customers recognise an additional need for large scale technical or topographic maps that show fence lines, building footprints, footpaths, kerbing, driveways, etc, to properly plan and manage their assets. Utilities with underground assets may require three dimensional mapping in heavily built up areas.

- Associativity will remain an issue since upgrades or changes to specific spatial cadastral objects will continue to occur.

To meet the needs of multipurpose usage, the content of the cadastral map is undergoing incremental change. For effective management of the update process, it is essential that the cadastral map be clearly defined, that is, clearly define what is the

infrastructure component of the cadastral map. This is critical to enable the cadastral map to support national, international and global spatial data infrastructure initiatives, and to support subsets of the cadastral map for decentralised maintenance models. In addition to this vertical component, there is a need to define the content of the cadastral map for the horizontal component that ensures the cadastral map data effectively integrates with other data sets, particularly other infrastructure data sets.

Effective cadastral map maintenance requires access to *proposed* changes to the cadastral map. This however does not mean the maintenance of a centralised *proposed* cadastral map. It can be implemented by simply denoting in the cadastral map that an activity such as subdivision has been initiated in specific land parcels. This notation provides the necessary network link to a spatial data server, to view, down load or verify the status of this cadastral activity.

9.2.4   Function

Efficient exploitation of the digital environment requires access to spatial cadastral data in digital format at the first possible opportunity. Subsequent processes should be reorganised to take advantage of this digital data. The corollary is that it is inefficient to superimpose digital data on processes that have developed over many years to handle analogue data. The analysis of the spatial cadastral systems showed that the update of the cadastral map consists of essentially three broad processes. These processes are the creation of the spatial data, the application of planning regulations, and the conformance of the spatial data to standards. To achieve maximum efficiency, processes subsequent to the creation of the digital survey data, must be reorganised to maximise the usage and accuracy of this data. The digital environment must be utilised to refine and allocate these processes without duplication.

The concept that graphical cadastres can be upgraded in an incremental manner, through the update process, has not been substantiated in the Australian context. At best only the initial capture accuracy is sustained. The concept of degrading survey accurate data to graphical accuracy in the update process is ineffective. This is prompted by a requirement to minimise the impact of the associativity issue and an inability, in the distribution of updates, to differentiate between new boundaries and old boundaries that have moved.

9.2.5   Network

The initial creation of digital cadastral maps was generally undertaken in a centralised organisational structure. There are, however, fundamental process differences between the past creation and the current maintenance of digital cadastral maps, not the least being the significant technology and communication advances. The Internet and its software represent a digital and distributed data environment, with a range of data access possibilities. This digital environment enables decentralised maintenance models that meet the criteria of efficiency and timeliness and allows devolution of responsibility for the cadastral data to producers of that data.

Internet technology enables users to explore data from various sources without regard to their actual location. The digital cadastral map, along with other infrastructure data, will be stored in various databases owned and maintained by different companies or departments of government. The spatial data produced by the surveyor will be tracked and managed in this environment as it moves from planning to title registration before finally updating the cadastral map.

Future Internet developments will provide mechanisms to distribute and access the digital cadastral map. In an Internet environment the necessity to store individual copies of the digital cadastral map on a physically different computer will be negated and the transfer of update information will be superfluous. There will be a continuing need for the transfer of incremental upgrade information as specific spatial objects in the cadastral map are upgraded (move). The associativity problem will exist and become more serious in a digital environment that uses the cadastral map as spatial infrastructure to uniquely link spatial data stored in distributed databases.

9.2.6   Schedule

Improvement in the schedule dimension for the update and distribution of spatial cadastral data are influenced by a digital environment to manage and track the survey data through the spatial cadastral system. The Internet, the WWW and email have the potential notify spatial cadastral organisations of the requirement to process data and virtually eliminate inter-process times. Further computer audit trails can accurately monitor the time to progress spatial data to its next status.

Paralleling processes or eliminating duplicate processes can achieve a reduction in the time for the survey plan to reach the stage where it officially updates the cadastral map. Access to the proposed survey data for earlier registration approval, and also update of the cadastral map, is an example of parallel processing. An example of eliminating duplicate processes would be elimination of plan examination, relying instead on the surveyor licensing procedure and a quality assurance process.

9.3   Review of Zachman Framework

The Zachman Framework has been used extensively in this research, both to define the spatial cadastral research and to structure the dissertation. An assessment of the benefits and shortcomings of its application in this research is therefore undertaken. The utilisation in this research of the Zachman Framework in conjunction with the tools and techniques of information systems, has four main features:

- the unique application of the framework to a multi-organisational system represented by the spatial cadastral system. This is distinct from its documented application to, at the most, a single organisation or enterprise;

- the first time that the concepts of the Zachman Framework have been applied specifically to spatial cadastral systems research;

- the use of the framework to simplify and ensure completeness of the analysis of spatial cadastral systems;

- a reinforcement that the framework is able to accept and drive the documentation deliverables of traditional systems analysis and design.

In uniquely applying the Zachman Framework to a multi-organisational spatial, cadastral system, only the top two rows or perspectives have been considered. These perspectives are normally associated with the stages of traditional systems analysis and design. Framework cells of spatial cadastral organisations were amalgamated to produce the analysis of each dimension of the spatial cadastral system. The research shows that this approach was successful at the system analysis perspectives. The organisation specific dimensions such as *strategy* begin to highlight the limitations of attempting to expand the Zachman Framework to accommodate multi-organisational enterprises. For the strategy dimension and for lower implementation perspectives,

individual frameworks will need to be constructed to accommodate organisational specific business rules and implementation technology.

The six, system dimensions detailed by the Zachman Framework have considerably directed the research. In the analysis phase the documentation of each dimension ensured a complete but simplified description of the complex spatial cadastral system. The order of presentation of dimensions differs from the Zachman's structure and basically covers the organisation and strategy dimensions first to enhance readability. The analysis of the spatial system at a point in time means the dimensions may not be synchronized or indeed actually be in conflict. This would naturally be expected of a dynamic system as the technical dimensions catch up with strategic direction, or perhaps indicates an implementation issue where the data may not be valid for a required function.

In summarising the issues and requirements of spatial cadastral systems, the Zachman Framework provided an architecture of perspectives and dimensions to validate assumptions, and address impacts across dimensions. In designing spatial cadastral maintenance models, alternatives can be developed in specific dimensions, in the knowledge that assumptions will be validated and supported in other dimensions.

The use of the framework to structure documentation has at times been challenging, and certainly time consuming. The documentation may appear to be almost artificially generating repetitive documentation for some framework cells. In this regard there are two, relevant factors. Firstly, the traditional information systems approach is to document a specific dimension such as data or function and move rapidly down the perspectives or columns of the framework. The approach of concentrating on specific dimensions is often at the risk of an incomplete system description and subsequent inconsistencies. In contrast, this dissertation deliberately dealt with all dimensions constrained within the combined perspectives of business scope and model; that is, all dimensions of the spatial cadastral system were documented at the same time and to the same level of detail. This, therefore, could be viewed as essentially a *grid-processing* problem; the dissertation could perhaps have been constructed by dealing with all perspectives within each dimension. This dimension specific approach is

partially adopted in chapter 5 and could be fully affected by reading only the individual dimensions across chapters 5 to 9.

The second factor relates to the lack of standard documentation models for some framework cells. The non-information systems specific dimensions such as strategy or organisation fall into this category. The lack of clarity may therefore lie with the documentation of specific cells of the spatial cadastral system, where clear diagrammatic models have not been available.

In conclusion the system dimensions of the Zachman Framework provided comprehensiveness and simplification to the analysis and design of an information system such as the spatial cadastral system. While the framework is difficult to apply to multi-organisational systems the concept of system dimensions remains an important factor in breaking down complex systems and ensuring completeness of description. Perspectives provide the basis for understanding the differing documentation of the same reality.

9.4   Future research

A number of projects have implemented portions of the envisaged digital environment for the spatial cadastral system. The ESTE project (Land Victoria 1999a), Polley's WWW spatial transaction prototype (Polley and Williamson 1999) and Hayes' work on digital lodgement (Hayes 1997). Each recognises the partial nature of their solution. Equally their research and this thesis confirm that there are no technological barriers for a more comprehensive digital environment for spatial cadastral data.

There is a need to implement a digital environment, as envisaged by this research. An implementation trial of the business processes of plan approval, plan certification, and e-commerce fee transactions The implementation of this digital model in a regional, decentralised manner by perhaps an organisation already duplicating the maintenance of the cadastral map allows for a number of integration and map assembly issues to be tested. Critically, an implementation that uses the spatial data management models of this research, to take full advantage of the digital environment, and to reengineer the business processes of spatial cadastral systems.

This research has modelled only a component of the cadastral system. Many researchers have attempted to model land administration systems, but most have focused on the area of the cadastre and confined themselves to specific dimensions, such as data or organisation. There is considerable scope, to not only apply the concepts of the Zachman Framework architecture to entire cadastral systems, but to use the Zachman Framework to develop a coherent approach to modelling land administration systems. Modelling spatial cadastral systems is an important first step, but it is cadastral systems and land information systems that hold all information about tenure, value and land use. Modelling these is an essential prerequisite to re-engineering these systems to meet current needs.

9.5 Conclusion

The systems approach of viewing the maintenance of the digital cadastral map as part of the entire spatial cadastral industry has resulted in a number of new concepts for the management of spatial cadastral data. The resultant system solutions, particularly the conceptual update model, maximise the capabilities of digital data and the enabling technology of the Internet. The effectiveness, efficiency and timeliness of these models have been critiqued by continual research interaction with the organisations responsible for cadastral maps in Victoria and NSW. The plan server concept represents a system model that encompasses these criteria and its applicability has been verified by the adoption of its concepts by Land Victoria.

This research has applied a structured systems approach to spatial, cadastral systems, to comprehensively document all its system dimensions. The documentation of spatial cadastral systems and the development of digital cadastral map maintenance models, under the Zachman Framework, fills a gap in the understanding of cadastral information systems, and provides a basis for future research.

Appendix 1: Spatial Cadastre of NSW

This appendix documents the spatial cadastral system that maintains the cadastral map, for the Australian State of NSW.

Victoria and NSW have a common cadastral history and have evolved similar cadastral and spatial cadastral structures and processes. Reflecting this similarity much of the documentation in this appendix for NSW is essentially as described for Victoria in chapter 5, and is substantially reproduced here for documentation completeness.

This appendix highlights the commonality and differences between the spatial cadastral systems of Victoria and NSW. This affords an opportunity for future research into the differences between two systems that have evolved from a recent common history.

A1.1   Introduction

This appendix provides a comprehensive, high level documentation of the spatial cadastral industry for the Australian State of NSW current at the time of writing. This analysis is structured by the dimensions and perspectives outlined by the Zachman Framework. The appendix is framed into two main parts. First, the historical background the development of the digital cadastral map NSW providing the setting within which the current spatial cadastral system now operates. The second part deals with an analysis of the spatial cadastral industry at the highest perspective of the Zachman Framework, the scope/objective perspective. The documentation of the scope of the spatial cadastres follows the structure of the Zachman Framework with the cell descriptor as described by Hay (1996) and depicted in Figure A1.1.

Figure A1.1   Scope perspective of Zachman Framework

	Organisation	Strategy	Data	Function	Network	Schedule
Scope / Objectives	Inventory of organizational units	Inventory of business goals and strategies	Inventory of data important for spatial cadastre	Inventory of spatial cadastral processes	Inventory of locations where the system operates	Inventory of spatial cadastral events / cycles

A1.2   The development of the DCDB in NSW

In NSW, the capture of a state wide digital cadastre fell to the Office of the Surveyor General as part of the function of the government mapping agency, the Land Information Centre (LIC) in Bathurst NSW. Sydney Water Corporation (NSW) originally captured and managed their state's metropolitan cadastral map. This digital property based data became the basis for NSW State DCDB.

In 1986 NSW finalised a report on the input specifications and user requirements of the New South Wales Graphic Database. The following brief account of the capture of the DCDB for NSW references unpublished internal documents from LIC in Bathurst.

In 1988 the LIC commenced the collection of the DCDB by digitising data from existing maps, compiled from parish and town maps ranging in scale from 1:2000 to 1:100000. Recognising the need to accelerate completion of the DCDB, the NSW State Government allocated finances to LIC to establish a panel of eight private contractors. These contractors tendered for DCDB capture work issued by the LIC. Digital cadastral data, with a property focus, was acquired from Sydney Water and Hunter Water and transformed to meet the specifications of the DCDB.

The accelerated capture program by different contractors is recognised to have resulted in many errors and omissions. Errors, which are highlighted when development occurs, or other spatial data is integrated with the DCDB. The DCDB has undergone a number of upgrades as a result of specific enhancement projects. Many of these errors were located and rectified as a result of the detailed investigation and verification processes required by the Crown Land Information Database (CLID) project. Currently, Urban Addressing and Rural Road Naming projects in LIC are generating more upgrades to the DCDB as road names are validated from Local Council records. The DCDB was completed by LIC in February 1994, nine months ahead of schedule. LIC continues to control and undertake all update and upgrade activities related to the state DCDB.

The NSW DCDB is a complete, state wide cadastral data set, which in addition to the legal framework contained in the parcel layer, has seventeen layers of topologically aligned ancillary information. Additionally the DCDB was specifically designed and captured to reflect the legal parcel framework of the State of NSW, to ensure that the DCDB was integrated with the LTOs Integrated Titling System. The capture of the DCDB for New South Wales was completed in the mid 1990's. Whilst there are some areas that lack completeness, NSW can claim to have state wide coverage (Watt 1998).

A1.3   *Organisation dimension*

The following lists and defines the organisations involved in the spatial cadastral industry or enterprise of NSW:

- Survey offices, specifically cadastral surveyors;
- Local government bodies, most often referred to as local councils.

- Referral authorities, such as those authorities responsible for water supply and sewerage (water utilities) and the power supply authorities, etc;

- LTO, this office is the sole organisation that deals with land registration;

- The LIC has responsibility for the acquisition, maintenance and provision of cadastral information for the State of NSW. This is carried out in conjunction with its other responsibilities for topographic, aerial photography, survey control and natural resource information.

- Customers of the spatial cadastral data. Supply side customers (Watt 1998) numerically represent well over one third of the customers for LIC and the majority of customers by data volume, and subsequently by revenue.

A1.4   Strategy dimension

The strategy dimension attempts to list the business goals and strategies of each of the organizations related to the spatial component of their business and pertaining to the maintenance of spatial cadastral data.

Surveying offices

Other than meeting the requirements imposed by utilities and councils to submit proposed plans of subdivision in a digital format, cadastral surveyors have a limited interest in the maintenance of a graphically accurate, jurisdiction wide, cadastral map. While there is pressure on the surveying industry to participate in emerging spatial data infrastructures (Williamson 1997) the traditional cadastral surveying profession would contend that they:

- have a requirement to hold database of survey measurements and submitted plans for areas of operation;

- would believe that they hold a competitive advantage in holding such digital data, given their fears that survey data may be made available to other surveyors for the cost of a search fee (Hayes 1997);

- have a willingness to contribute in spatial cadastral system that processes sub division plans from the planning stage to title registration in the cheapest and most efficient manner (Elfick and Fryer 1992);

- require a return for participation, changed business processes, and contributing to maintenance of jurisdiction wide spatial data;

- are limited customers for graphically accurate DCDBs given their own database of survey measurements and local knowledge.

Local councils

In common with other Australian states, NSW councils have or are developing Asset Management Systems in order to comply with the accounting requirements for local government, as laid out in the Australian Accounting Standard (AAS27). The following therefore summarises possible council based business strategies.

- A willingness to participate in mechanisms to provide effective and efficient land development to promote investment in council area;

- Implement GIS with DCDB backdrop to meet accounting and funding requirements as set out in AAS27;

- Willing to contribute in DCDB upgrade programs for their content of the DCDB;

- An interest in reconciling their property DCDB against the parcel based DCDB;

- Capture their own spatial cadastral database to satisfy local requirements;

- Maintain their own version of cadastral map via proposed plans of subdivision submitted for certification, perhaps even insist on digital lodgement;

- Accept state DCDB in exchange for update information.

Utilities

The requirement to administer assets, particularly underground assets, means that the water utilities have largely pioneered DCDB in NSW and provided the basis for the state wide cadastral map for NSW. Sydney Water has continued to maintain its own property based DCDB in parallel to the state DCDB administered by LIC.

Similar to local councils, utilities also have a range of business goals and strategies related to the mapping and planning of their assets. These are summarised below:

- A business need to maintain a property based DCDB, with information supplied from proposed plans of subdivision, submitted digitally for large subdivisions;

- The maintenance and distribution of its spatial cadastral data seen as both an asset and potential income source;

- The creation and maintenance of the spatial cadastral data not seen as a core business activity of the water authority;

- A number of both legacy and up-to-date systems deemed to rely heavily on the current digital, spatial data and considerable system and data issues involved with changeover to state DCDB.

Land Titles Office

In the past the Land Titles Offices of NSW have operated separate to the mapping agency (LIC). The need of the DCDB to reflect the legal cadastral fabric of the state means the LIC needs to obtain copies of the registered subdivision plans from their LTO as quickly as possible. In NSW, this is now via the scanned images.

The following would reflect the strategy issues for the Land Titles Office in term of spatial information represented by the subdivision plans:

- An existing ability to profitably administer its functions using a computerised index of scanned subdivision plans (raster images);

- Possible cost/benefit of maintaining a survey accurate digital cadastral database (LTO 1998);

- Utilise graphical DCDB for title search and indexing;

- A business objective to reduce the time and internal cost of land registration.

DCDB custodian

The LIC in NSW have published policy statements relating to the provision of spatial information to their respective states. The relevant statement for the maintenance of the spatial cadastre is:

"NSW (LIC): Provide equitable local access to spatial data through appropriate means and ensure consistent, accurate, reliable and current data services to meet community needs." (LIC 1999)

A number of subsidiary and often undocumented objectives follow to support this policy statement:

- Homogeneous cadastral map as a basis for providing spatial infrastructure;

- Minimise duplication in the maintenance and data entry process;

- Multipurpose usage in the context of data, currency and accuracy that is suitable to many users;

- Interoperable spatial cadastral data to integrate both aspatial and spatial data sets

Customers of spatial cadastral data

While the strategy of the supply side customers has been elucidated, the expectation is that other customers will have similar requirements. Increased usage and awareness will add to the pressure for a truly multipurpose cadastre, which will subsequently pressure the content and maintenance of the spatial cadastral map. This is evident in NSW where user demands are changing the content of the digital map from its original land parcel specification.

A1.5   Data dimension

The major spatial data update source for the digital cadastral maps for NSW, is the plan of subdivision lodged by the surveyor to the LTO.

The digital cadastral map data content for NSW is listed below. The World Wide Web site specific to NSW (Land Information Centre) provides up-to-date information about the available digital cadastral products and their content.

Spatial data:
- **Parcel boundaries** – The graphical cadastres maintained by NSW means that the parcel boundary is a graphical depiction of the parcel's relative position.

- **Property boundaries** – A specification of the NSW capture program was to ensure that all legal land parcels were depicted in the property based data sourced from the water utilities, resulting in the loss of the property depiction.

- **Occupation boundaries** – In NSW there have been a number of funded programs to capture these occupation boundaries to consolidate and verify the base cadastral map, most notably the capture of crown land boundaries. LIC are continuing to upgrade the deficiencies of their spatial data in this area.

- **Easements or right of ways** – In NSW a limited number of easement types are maintained as a separate layer to the base cadastre.

- **Cadastral administration boundaries** – The nature of the centralised state wide cadastral system means that the cadastral boundaries are only relevant at state boundaries, with no cadastral administration boundaries internal to the state.

- **General administration boundaries** – LIC's cadastral map model holds these boundaries as a separate layer.

- **Roads** – NSW maintains road polygons, it also derives road centrelines from the DCDB in urban and metropolitan areas. These are topologically associated with rural roads maintained as part of the topographic mapping program.

- **Other sub parcel data** – NSW includes spatial data to reflect three dimensional ownership in addition to legal ownership instruments such as strata titles resulting in sub parcel spatial data.

Aspatial data:
- **Parcel identifier** – Since the initial capture phase the NSW DCDB has maintained a unique identifier at polygon level that is for parcels, road segments, etc.

- **Survey identifier** – A *lot on plan* notation identifies individual parcels on subdivision plans as registered at the LTO are held in the NSW DCDB.

- **Street names** – These are an essential part of the lodged survey plan and are transferred to the DCDB.

- **Street address** – In NSW street addresses are not part of the DCDB.

- **Accuracy indication** – NSW does not have accuracy indicators directly associated with the individual data elements. Metadata supplied with the digital spatial data reflects relative accuracy associated with the hardcopy map scale from which the spatial data was originally captured.

Proposed data:

Proposed DCDB data represented by subdivision plans submitted to local government and utilities by the surveyor for planning purposes, but not yet registered by the Land Titles Office are in no way represented in the NSW DCDB. The entire NSW DCDB has always only reflected the legal parcel fabric at a post title registration stage.

Historical data:

NSW has no formal processes for the retention or publishing of historical data related to the DCDB.

A1.6   Function dimension

The spatial cadastral processes for NSW are defined as follows:

Spatial representation of subdivision for planning approval

Planning approval must be sought from the local government authority. This may often only involve a rough sketch of the proposed subdivision to convey development intent and assess compliance with planning regulations.

Creation of the cadastral survey plan for subdivision

The cadastral survey data originating with the surveyor is the basis for the spatial data that will construct the subdivision plan. The survey plan also provides the necessary spatial information to update the digital cadastral map.

Distribution of the proposed plan of subdivision

Upon receipt of plans of subdivision, local councils have a statutory obligation to refer these plans to a number of referral bodies for noting and approval. This generally involves mailing photocopied subdivision plans to the appropriate referral authorities. The surveyors will often submit their plans to some of the referral bodies at the same time, or prior to them being submitted to the councils, with the intent of speeding up the approval process. The water authorities may demand that surveyors digitally lodge large subdivision plans to secure even greater efficiency (PSMA 1996).

In NSW the custodian of the cadastral map are not amongst the institutional entities to which local government must refer subdivision plans. Acquisition of proposed or pre-built subdivision plan information for preliminary update of the DCDB would require that the information be sourced at this planning stage, often months before the subdivision plan is lodged at the LTO.

The custodian of the NSW DCDB has initiated a number of investigations and trials to assess the feasibility of acquiring proposed plans of subdivision from local councils at plan certification stage, i.e. after the local council approval of the subdivision plan.

Approval of subdivision plans

The local council is charged with enforcing local planning and land use regulations; the local council must formally approve the subdivision plan. The council's approval is dependent on the responses from the statutory referral bodies that include

authorities responsible for water, gas, electricity, sewerage telecommunications, etc. The approved plan, bearing the council signature, is termed the certified plan, and is returned to the surveyor for submission to the land registration body.

Lodgement of subdivision for title registration

The hardcopy plan of survey, approved by local council, along with other legally supporting textual and legal documentation, are required to be lodged with the titles office to initiate the land registration process. At lodgement, the plan of survey is registered, becomes a legal document and becomes available for public perusal.

Survey Examination of plan of subdivision

The role of the government in guaranteeing land title means that the LTO for NSW employ surveyors to check the correctness of cadastral surveys. The island nature of cadastral surveys requires that prior to the examination of any new cadastral survey plan all adjoining plans need to be collated. Examination of the spatial cadastral data therefore involves checking that the new survey information is consistent with all registered plans surrounding the new subdivision.

A traditional, full survey examination ensures that:

- land in the plan agrees with stated references to title and locality details, and existing easements are correctly depicted;

- all existing boundaries are correctly defined;

- common boundaries with existing parcels have been adopted;

- the plan is mathematically correct;

- the land in the plan is wholly within and includes the whole of the land denoted by the subdivider's title;

- new easements are correctly defined;

- all survey markings and connection to survey control are correct;

- all statutory requirements have been met.   (LTO 1998)

This examination process is largely conducted by hand on hardcopy plans. The nature of this survey examination has changed over the years resulting from the reduction in the number of examining surveyors being employed, the requirement to fast track land registration, and the impact of technology. There is a growing trend for the plan

examination to concentrate on those spatial aspects that verify the consistency with adjoining land parcels, leaving the internal integrity and correctness of the subdivision plan the responsibility of the individual surveyor.

The NSW LTO has implemented a prototype, computerised process that incorporates and checks the new survey subdivision information with the existing cadastral information. To fully implement this would in fact require both a survey accurate digital, cadastral map and database of all survey measurements (LTO 1998).

Distribution of registered plan of subdivision

The LTO provides a service that allows customers to receive copies of all newly registered plans of subdivision. This is usually in hardcopy format, with scanned images available in NSW. This is a critical source for updates to the DCDB since most changes to the spatial cadastral framework must pass through the LTO.

Councils, utilities and other bodies, with access to the subdivision information at planning stage, will be customers of this LTO service, to note the change of status of the plans of subdivision from proposed to legal. Further, those organisations maintaining their own versions of the DCDB will need to ensure changes to the survey plan during the title registration phase are reflected in their spatial databases.

To ensure the integrity and completeness of the DCDB other data sources such as government gazettes, parish plans, etc are consulted to capture all boundary data.

Maintenance of the DCDB

For NSW this includes both update and upgrade as follows:

- recording all new legal subdivisions;

- sourcing and recording changes administrative boundaries, street names and addresses;

- ensuring map completeness including recognised backlog or holes in the map still incomplete from the capture phase;

- increasing the spatial accuracy of all or any part of the cadastre;

- including more survey control and measurements;

- aligning the spatial cadastre with topographic features;

- Changing the spatial data models to introduce (or delete) entities;

Distribution of spatial cadastral changes

The distribution of updates to the DCDB has always been a major focus of the cadastral map custodians of NSW. Considerable effort has been allocated to meet the diverse range of user mapping technologies, data requirements and geographical extents. The updates to the DCDB are made available in a range of digital formats and supplied to the user as follows:

- Hard copy plots of specified areas;

- Whole file replacement for predefined areas or map sheets or the whole of the state.

- Mirror sites. NSW has implemented the concept of mirror sites for either internal customers or specific customer research projects. In this instance the customer's spatial database is a site external to the custodians, all spatial cadastral updates are applied as an automated process each night, week or at other specified times. This requires customers to have similar or predetermined hardware and software and the maintenance of communication technology.

A1.7 Network dimension

This is a listing of the locations where the spatial cadastral industry operates, and where digital or hardcopy versions of spatial cadastral data reside.

- Field surveyors;

- Survey offices across the state submitting their data to a number of councils and utilities;

- Local government. In NSW there are 177 local government bodies with approximately 40 in metropolitan Sydney;

- Utilities In NSW there are currently six power utilities and two large water authorities. For the remainder of NSW the councils are generally responsible for water, sewerage and drainage with three county councils (groups of councils) formed for this purpose;

- The centralised LTO located in the state capital of Sydney;

- The Cadastral map custodian. This is the LIC, centred in the rural town of Bathurst, with two regional offices in metropolitan Sydney and eight rural office locations.

A1.8   Schedule dimension

These are events, which do not necessarily change the spatial data, but events that signify the progression of the spatial cadastral data through the cadastral system.

- Prepare development application with preliminary spatial data;

- Lodge development application with local government;

- Local Government planning approval granted;

- Surveyor conducts detailed survey and prepares plan of subdivision;

- Surveyor lodges survey plan with local Government. In NSW the surveyor may lodge survey plan for preliminary survey approval with the LTO to fast track subsequent land registration process.

- Survey plans referred to specified authorities;

- Approval gained from referral bodies, utilities, water authorities etc;

- Approval of subdivision plan by local councils (Plan Certification);

- NSW provides preliminary titles office approval of survey plans.

- Lodgement of cadastral survey information to the LTO;

- Survey plan approval and title registration;

- Registered plan distributed by LTO to customers, including state custodians of DCDB;

- Update DCDBs;

- Distribution of updated state DCDB to users on request or predetermined intervals.

The list above is roughly in chronological order and reflects the end on end nature of the progression of spatial data from the surveyor to the custodian of the cadastral map in NSW.

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