Future directions of administrative boundary design in support of Spatial Data Infrastructures

Serryn Eagleson

PhD Candidate
Centre for Spatial Data Infrastructure and Land Administration
Department of Geomatics, The University of Melbourne, Victoria 3010, Australia

Tel: +61 3 8344 4431; Fax: +61 3 9347 4128
Email: serryn@sunrise.sli.unimelb.edu.au
URL: http://www.sli.unimelb.edu.au/research/SDI_research/

Francisco Escobar

Senior Lecturer
RMIT University, GPO Box 2476V Melbourne, Victoria 3001, Australia
Email: francisco.escobar@rmit.edu.au

Abstract

Spatial Data Infrastructures (SDIs) comprise a set of policies aimed at coordinating the numerous layers of spatial information upon which society functions. To achieve this objective effectively an SDI must encompass policies, standards, and procedures for organisations to cooperatively produce and share geographic data. One of the most fundamental problems restricting the objectives of SDI is the fragmentation of data between different agency boundaries. Essentially this problem stems from the differing criteria and methods adopted by agencies designing individual boundary units. This current lack of coordination and unstructured methodologies for subdividing space has lead to difficulties in integrating, analysing and exchanging information across boundaries and through time.

To further the objectives of SDIs in providing mechanisms for data integration, methods by which agencies may derive administrative boundaries using a common framework, which still meet their own individual requirements are being investigated. Through the development algorithms and standards for the design of administrative boundaries within a spatial hierarchy it is envisaged that SDI will incorporate data integration and cross analysis to its range of existing functions.

1. Introduction

We live in an age of information and geographic information is one of the most critical elements underpinning decision making for a range of disciplines (Rajabifard and Williamson, 2001). Health, wealth and population distributions are all examples of spatial information commonly attached to administrative polygons. In fact there are few areas of the economy and environment, which do not rely either directly or indirectly on the integration of data attached to administrative boundaries for planning, maintaining or rationalising activities (Eagleson et al., 2001a). One of the most fundamental problems restricting the objectives of SDI is the fragmentation of data between uncoordinated agency boundaries.

There are a number of advantages to using administrative boundaries for the collection and collation of data. For example once the administrative boundaries are established the data is easy collected and efficient to store. Even in light of technological advancements other forms of geographic data such as address point and line data are still relatively expensive to produce, difficult to manipulate and require large amounts of memory to store (Rajabifard and Williamson, 2001). Therefore many organisations are using established polygon-based administrative boundaries as a base for the collection and collation of spatial data. The majority of these boundaries are established by agencies and subsequently used by a number of secondary organisations for data collection and collation. Two prominently used administrative boundaries in operation across Victoria, Australia are the Australia Post, Postcodes and Australian Bureau of Statistics (ABS), Census Collection Districts (CCDs).

One of the greatest problems faced by geospatial information users has been the non-coterminous alignment of different administrative boundaries that have accumulated (USGB, 2001). This problem has essentially occurred because in the beginning organisations hand drafted the majority of boundaries on hard copy maps. With advances in technology, these hand-drafted maps have been digitised for incorporation into GIS a technology for which they have not been adequately designed. Administrative boundaries are a product of the era in which they were developed and change is now required to meet the changing needs of geospatial information analysts.

This paper is based around ongoing research into the delineation of administrative boundaries (Eagleson et al., 2001a). The objective of the paper is to highlight future directions of administrative boundary design, delineation and dissemination, which meet the needs of a number of stakeholders within the Australian SDI (ASDI). To achieve this objective, the paper proposes a framework to facilitate the design delineation and dissemination of administrative boundary design in support of SDI.

2. Spatial Data Infrastructure (SDI)

SDI is a means to assemble the best available spatial data to serve a variety of users at a specific political/administrative level. SDI is fundamentally about facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial data community. SDI constitutes dynamic partnerships between inter- and intra-jurisdictional stakeholders. The principal objective for developing SDI for any political/administrative level, is to achieve better outcomes for the level through improved economic, social and environmental decision–making

(Rajabifard et al., 1999). Additionally the role of SDI is to provide an environment in which all stakeholders, both users and producers, of spatial data can cooperate with each other in a cost-efficient and cost-effective way to better achieve organisational goals.

One of the main problems in today's spatial or geographic information management framework is geospatial data conversion and integration. Very often, GIS developers and users need to import geospatial data from different sources. Administrative and political boundaries constitute the basis for a variety of these essential data sources. Therefore the different agency boundaries must be co-ordinated if effective data integration and analysis between organisations and data layers is to eventuate. This paper proposes future directions of administrative boundary design in support of SDI objectives to reduce duplication and facilitate data integration across administrative boundary systems and through time.

2.1. Current administrative boundary problem

Historically, countries have divided social, economic and political responsibilities amongst a variety of organisations. In turn, these organisations have established independent administrative, planning and political boundaries that rarely coincide, (Huxhold, 1991; Robinson and Zubrow, 1997). Due to the structure of boundaries as polygons, problems occur when technology such as GIS is used to integrate and cross analyse data based on these non-coterminous boundary units. Therefore, to empower SDI framework implementation and an optimum level of analysis in the spatial information industry, the core components of SDI in relation to administrative boundaries requires investigation. The following section aims to provide an example of the problem of non-coterminous boundaries within the Australian SDI.

2.2. Administrative Boundaries within the Australian SDI

The Australian SDI (ASDI) comprises an umbrella of policies aimed at solving many of the data compatibility, integration and metadata issues associated with data transfer and integration. The potential of the ASDI would dramatically increase if the problems associated with uncoordinated boundary systems were solved (Escobar et al., 2000). One of the largest problems limiting the implementation of SDI policy to administrative boundaries is the current uncoordinated management of administrative boundaries. Currently within the ASDI agencies define individual boundaries to meet a range of individual needs. Table 1, highlights key administrative boundary systems in operation within the ASDI. It is clear from table 1 that boundaries in Australia are often a function of political arbitration, service delivery routing, topography or aggregation from existing boundaries. In particular CCD and Postcode boundaries form core boundary systems for aggregation in a number of secondary boundary systems. Table 1 also highlights that many boundary systems are the responsibility of individual state government departments and agencies. Consequently methods used in constructing these boundaries vary between each of the state and agency.

Boundary System	State/Federal	General method of delineation
Cadastre .	State Government	Survey
Address Point	State	PSMA – GNAF
Property	State Government	Survey
Postcodes	Australia Post	Service Delivery

Electoral	AEC	Political Arbitration
ASGC	ABS	Service Delivery/Aggregation
Suburb	State Government	Political Arbitration
Locality	State Government	Political Arbitration
Fire Districts	State Fire Authorities	ASGC Aggregation
Police Districts	State Police Authorities	ASGC Aggregation
Health Districts	State/Federal Government	Postcode Aggregation
Education	State Government	Postcode Aggregation
Catchment	State Government	Topographic Boundaries
Parish		Distance and Population

Table 1, Commonly used administrative boundaries, coverage and delineation techniques.

(Escobar et al., 2000)

The current ad hoc approach to administrative design is currently resulting in the fragmentation of data between different administrative boundary units and layers. Therefore it is proposed for the future a coordinated approach to administrative boundary design must take place. The following section outlines the future directions of administrative boundaries within the ASDI.

3. Future Directions of Administrative Boundaries within the ASDI

The geospatial industry has experienced a phase of transition from a data poor society, especially spatial data, to one now comparatively data rich. However the means of organising, managing and actually using data to which there is now access have not kept pace (Openshaw, 1998; UCGIS, 2000). In order to meet the future needs of geographical information analysts institutional initiatives must be developed to address the different aspects of administrative boundary integration, sharing and management within an SDI (Feeney and Williamson, 2000). The following section aims to address each component of ASDI (policy, technical standards, access networks, data and people) highlighting current research developments aimed at technically providing a solution to problems conditioned by current data models (UCGIS, 2000).

3.1. Access

Improved technology and greater penetration of GIS into government, business and society has in turn produced a driving need for access to reliable and accurate geographic information (Nairn and Holland, 2001). However due to economics, culture and laws governing the extent of disclosure of spatial information it is often impossible for an geographic information analysts to gain access to the data they require (Framework, 2001).

Administrative boundaries fulfill a niche market within the geospatial market, they are relatively inexpensive to produce, meet privacy standards and yet provide GIS analysts with an array of information. Postcodes are a prime example of administrative boundaries within the SDI "...with postcodes you can locate people and see the hows, where's and whys of markets, customers and prospects, competitors, prices, suppliers, routes and profits. Postcodes neatly define convenient demographic zones and are familiar to everyone." (AUSLIG, 2000). As the potential of data analysis based on administrative boundaries is realised, policy related with data

access issues such as pricing, copyright and licensing along with technical data standards need to be firmly established.

3.2. People

The interaction between the spatial data users, data suppliers and any value-adding agents in between, drive the development of any SDI (Rajabifard et al., 2001). Considering the important and dynamic interaction between people and data. To develop effective SDIs we must consider the changing nature of communities (people) and their needs, which in return require different sets and standards of administrative boundary data.

In general users of administrative boundary data are far more experienced and aware than previously and have increasingly demanding and more diverse expectations (Openshaw et al., 1998). As a result there is an increasing need to deliver administrative boundaries which meet the needs of users. One problem creating confusion amongst geographical information analysts is the attempt of some organisations to aggregate their data to boundaries that are representatives of existing publicly recognisable units. One prime example is the derived postcode. This boundary set has been formulated by the Australian Bureau of Statistics (ABS) for the representation of postcode data. Derived postcodes constitute an aggregation of smaller ABS units, namely Census Collector Districts. However, in some regions the derived postcode fails to resemble postcode boundaries as illustrated in Figure 1.
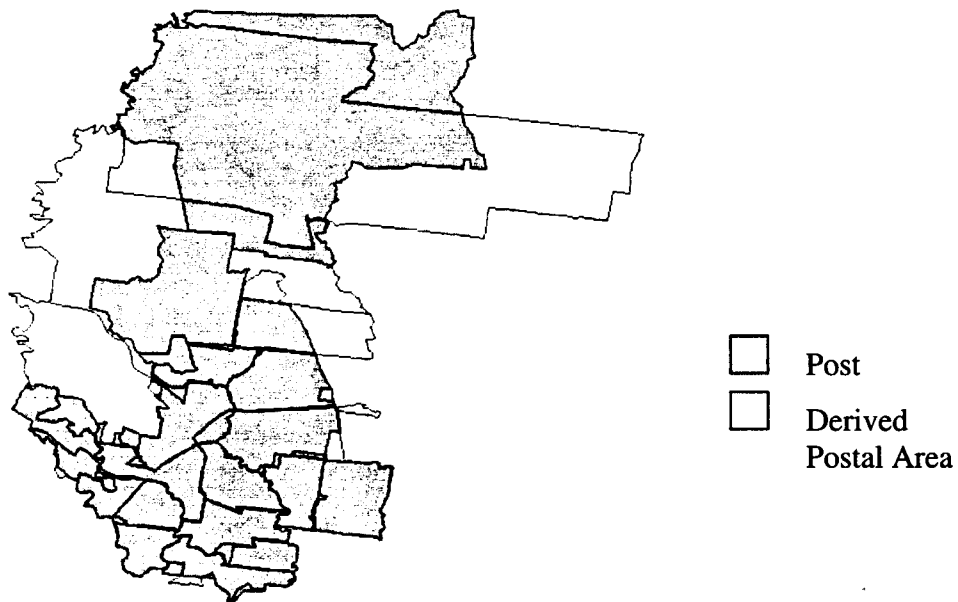

☐ Post

☐ Derived Postal Area

Figure 1. Illustration of the difference between derived postcode and actual postcode boundaries in the North West Melbourne health division.

As a result, derived postcodes and postcode boundaries are far from coincident and decisions based on the derived postcode will not necessarily reflect those based on the actual postcode units. Just as users of data should be aware of the origins of data, users should also be aware of

the ways data can be misrepresented through the use of derived boundaries. If users remain uninformed about the origin of the data boundaries they are using, the decisions made will not be well supported. The usage of these derived boundaries can lead to confusion between agencies using the data when differences between derived postcodes and postcodes are not clearly identified by the user.

3.3. Technical Standards

Technical standards are essential for efficient sharing of products and to provide information about geospatial data. Technical standards are designed to simplify access and data quality and integration. Currently the ASDI policy outlines that "standards are required in reference systems, data models, data dictionaries, data quality, data transfer and metadata" (AUSLIG, 2001). Even though the design of administrative boundaries should fall under the heading of "data quality" there are very few technical standards governing the design and delineation of administrative boundaries. This section aims to summarise current research being undertaken by the authors into the formation of framework standards applicable for the design and delineation of administrative boundaries. It is intended that through the application of these standards the objectives of SDI, to enhance data integration, will be facilitated.

3.4. Hierarchical Spatial Reasoning applied to administrative boundaries

It is proposed that through the reorganisation of administrative agency boundaries, within a common hierarchical spatial framework, will provide the framework to revolutionise data integration and analysis methods. Figure 2 illustrates the proposed solution. Through the application of HSR theory the spatial boundaries of different agencies are organised in a coordinated hierarchical system [Car, 1997 #17]. Data exchange and aggregation is possible within, and amongst individual agencies providing aggregated data at all levels. Currently, hierarchical principles are used in an array of different disciplines to break complex problems into sub problems that can be solved in an effective manner (Timpf and Frank, 1997). Although spatial hierarchies are designed using the same principles – to break complex tasks into sub tasks or areas – relationships between levels within the hierarchies are complex (Eagleson et al., 2000; Eagleson et al., 2001b).

Figure 2 Abstract illustration of the ideal spatial hierarchy. Each agency is able to utilise the common base layer for the construction of individual layers within the hierarchy.

In the past much research has focussed on the properties of two-dimensional hierarchical structures to model networks, such as road and drainage systems. This research however, aims to utilize the three properties (Whole-Part property, Janus Effect and Near Decomposability) inherent to hierarchies utilise them for boundary design. These properties provide an insight into the way that each layer within a hierarchy interacts with each other and also with the whole system.
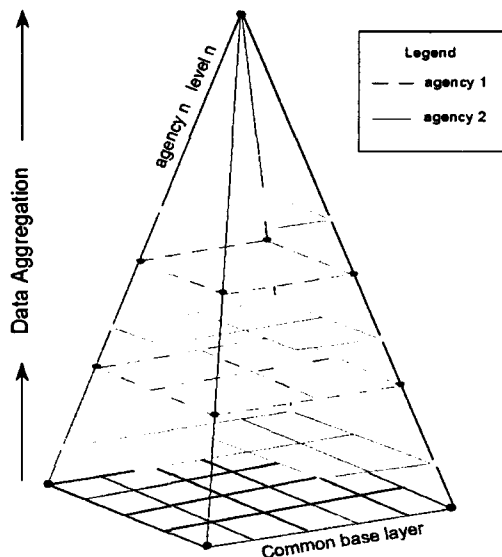
Using hierarchy for the development of a framework it will be possible for agencies to integrate data horizontally between organisations as well as vertically between different administrative boundary layers.

3.5. Administrative Boundary Structure

Structurally within a GIS administrative boundaries are considered as objects in a layer such that each layer contains the same type of boundary interacting in the same way among themselves (Car, 1998). The layers differ only in the degree of detail. However to establish each layer in a hierarchy a set of rules are required. These rules must consider the applications both functional for the agencies and the display and analysis of a wide number of social and economic attributes without displaying bias.

In order to effectively integrate HSR theory and GIS technology for the design of administrative boundaries, a model incorporating the requirements of agencies at each layer of the hierarchy must be established. Arguably one of the most complex problem to overcome in this research is the lack of clear guidelines and constraints governing the design and shape of administrative boundaries. Therefore it is imperative that common criteria can be established for the design of coordinated administrative boundaries.

3.6. Summary of Administrative Boundary Prototype.

Previous research has been undertaken by the authors into the delineation of administrative boundaries within metropolitan regions (Eagleson et al., 2000). This research involved the formalisation of the business rules established by two administrative agencies, namely Australia Post and the ABS, within a prototype for the automated delineation of administrative boundaries. The prototype operates in a coordinated and consistent manner incorporating data stored at the lowest level of the hierarchy such as address points through to state and national administrative boundaries.

In establishing this prototype for the hierarchical allocation of administrative boundaries, it became evident that there are several advantages to automating the process of boundary design. For example automated boundary design allows boundaries to be created quickly, the process is repeatable and flexible. The flexibility of the system enables additional parameters such as size, density of households, centres of community interest and shape to be incorporated into the boundary design process. The ability of the system to incorporate additional parameters will enable it to meet the requirements of users in different agencies and/or different regions with different needs. Being repeatable means that agencies will be able to adopt similar methods for the design of administrative boundaries, thus limiting subjectivity. Additionally, this method will aid in the comparison of datasets over time as each set can be broken down to the base layer and in turn reaggregated to meet the needs a range of geospatial analysis applications.

For further information about the algorithm and to download sample scripts and data used within the project please refer to the project website (http://www.sli.unimelb.edu.au/AUSLIG/).

3.7. Policy

It has been established that exchanging, sharing and integrating spatial data based on administrative boundaries from various sources has become increasingly important. However very little research into the policy governing the design and delineation of administrative boundaries exists. The aim of previous research into the design of administrative boundaries has been predominately focussed on technical aspects of boundary design. Through this research it has also been proven that technically it is possible to develop a hierarchy of boundary units based on the criteria of two agencies. It is therefore important to develop policy that will further support these technological advancements. In turn facilitating the sharing and exchange of information between the public and the private sectors.

Although it must also be recognised that developing a policy alone can not ensure the free flow of information from one organisation to another unless institutional issues are addressed (NSIF, 2001). In order to begin addressing these issues there is a need to better understand the complex nature of SDIs to facilitate implementation of new methods for designing administrative boundary into the future. Additionally it is proposed that incentives for agencies to participate in the hierarchical design framework need to be established. These incentives may include the accreditation of agencies establishing boundaries within the hierarchy standard and/or benchmarking administrative boundary hierarchies to assess the comparative effectiveness of the system.

3.8. Summary

Table 2 aims to summarise the components of SDI and the mechanisms required to guide enhance adequate design, delineation and dissemination of administrative boundaries and polygon based data.

Current SDI Components	Role of an SDI	Recommendations
Access Networks	Provide users with mechanisms to access administrative boundary data	- Improve data availability and ongoing assessment of requirements - Provide a range of data products at different file sizes to facilitate a range of user needs.
People	To develop partnerships between administrative boundary users and the agencies establishing administrative boundaries.	- Education and Promotions - Ongoing assessment of Requirements
Technical Standards	Provide standards for the design delineation and dissemination of administrative boundaries.	- Establish criteria for boundary delineation - Establish methods for automated boundary delineation - Derive metadata standards specific to

		administrative boundaries.
		• Ongoing assessment of requirements
		• Improve mechanism for changing and recording boundaries and notification of changes made.
Data	Provide standards for data attached to administrative boundaries. Reduce cost	• Complete and uptodate data beneficial for a range of applications. • Reduced duplication of datasets
Policy	Policy is required which facilitates the coordinated design, delineation and dissemination of administrative boundaries along with data attributed with administrative boundaries.	• Ongoing assessment of requirements • Design policies • Delineation technology and methods • Access and dissemination methods established. • Incentives to participate (Accreditation, Benchmarking and Standards)

Table 2, Current SDI components and mechanisms required to further complement the use of administrative boundaries within the SDI.

4. Future Developments impacting on the role of administrative boundaries within an SDI

Technology is impacting the way agencies do business. For example the internet has been suggested as a future tool to conduct censuses (Mobbs, 1998). If this form of collection is realised then the boundary delineation criteria set for establishing boundaries to represent this data will no-longer need to consider the distance and time taken by census collectors. Therefore the method established for boundary design will need to be flexible and dynamic taking into account the technology related changes of the future.

It may also be possible for the application of the prototype to be expanded to a wide array of commercial applications. For example, it is recommended that businesses requiring boundaries employ techniques such as the one outlined in this paper to become part of the spatial hierarchy. This would facilitate businesses, requiring boundaries for the analysis of market trends and the functional product distribution, to set the criteria for their boundaries inline with agency boundaries efficiently. As part of the spatial hierarchy this would allow businesses to cross analyse data with other agencies, such as the ABS, further enhancing their marketing and distribution techniques.

5. Conclusion

As SDI develops around the world as a mechanism facilitating the transfer and access of geographic data to a wide array of data users administrative boundaries the structuring of administrative boundaries will become increasingly important. This paper has focussed on the

role of administrative boundaries within the SDI and the development of an organisaitonal framework for development of administrative boundaries, which support the objectives of SDI.

The construction of a GIS prototype for the automatic allocation of administration boundaries offers a solution to the problem of boundary delineation and provides the means for accurate data exchange between agencies. It facilitates a quick, objective and improved method to administrative boundary subdivision.

In conclusion, this research aims to complement effective data management strategies so that the full potential of spatial data can be truly realised.

6. Acknowledgments

7. References

AUSLIG (2001). " Australian Spatial Data Infrastructure", *AUSLIG*. <http://www.auslig.gov.au/asdi/> (17/10/2001, 2001).

Car, A. (1998). "Hierarchical Spatial Reasoning: a GeoComputation Method". *3rd International Conference on GeoComputation*, University of Bristol, United Kingdom.

Eagleson, S., F. Escobar and I. Williamson (2000). "Hierarchical Spatial Reasoning applied to the automated Design of Administrative Boundaries Using GIS". *URISA 2000*, Orlando Florida, 18 - 23 August (CD-ROM)., URISA.

Eagleson, S., F. Escobar and I. P. Williamson (2001a). "Developing a theoretical framework for the delineation of administrative boundaries within a rural context". *To be presented at AURISA 2001*, Melbourne, Australia.

Eagleson, S., F. Escobar and I. P. Williamson (2001b). "Hierarchical Spatial Reasoning theory and GIS technology applied to the automated delineation of administrative boundaries." *CEUS* (Forthcoming - Special Edition September 2002).

Escobar, F., Williamson, I. P. and S. Eagleson (2000). *Developing a Hierarchical Reasoning Based Model for the Australian Spatial Data Infrastructure (ASDI)*.

Presented to AUSLIG. 1, AUSLIG.

Feeney, M. and I. P. Williamson (2000). "Researching Frameworks for Evolving Spatial Data Infrastructures". *SIRC 2000 The 12th Annual Colloquium of the Spatial Information Research Centre,* Dunedin, New Zealand.

Huxhold, W. (1991). *An Introduction to Urban Geographic Information Systems,* Oxford University Press.

Mobbs, J. (1998). "Australia comes to its census". *FIG 7,* Melbourne Australia.

Nairn, A. and P. Holland (2001). "The NGDI of Australia - Achievements and Challenges from a Federal Perspectives", <http://www.gisdevelopment.net/application/gii/global/giigp0003.htm> (19/10/2001, 2001).

NSIF (2001). "Geospatial Synergy", *National Spatial Information Framework,* <http://www.nsif.org.za/standards/background.html> (19/10/2001, 2001).

Openshaw, S. (1998). "Toward a more computationally minded scientific human geography." *Environment and Planning A* 30: 317-332.

Openshaw, S., S. Alvanides and S Whalley (1998). "Some further experiments with designing output areas for the 2001 UK census School of Geography, University of Leeds,", . <http://www.geog.soton.ac.uk/research/oa2001/resources.htm> (12/11/2000, 2000).

Rajabifard, A., T. O. Chan and I. P. Williamson (1999). "The Nature of Regional

Spatial Data Infrastructures. Presented at the Conference,". *AURISA `99,* Blue Mountains, Australia.

Rajabifard, A. and Williamson, I. P. (2001), 'Regional Administrative Boundaries Pilot Project', Report Presented at 7th Meeting of the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP), 23-27 April 2001,Tsukuba, Japan.

Robinson and Zubrow (1997). "Restoring continuity: exploration of techniques for reconstructing the spatial distribution underlying polygonized data." *International Journal of Geographical Information Science* 11(7): 633-648.

Timpf, S. and A. U. Frank (1997). Using hierarchical spatial data structures for hierarchical spatial reasoning. In *Lecture Notes in Computer Science,* S. Hirtle and F. A.U. Berlin - Heidelberg, Springer-Verlag. **1329:** 69-83.

Tomlin (1992). *Geographic Information Systems and Cartographic Modeling* Englewood Cliffs, Prentice Hall

UCGIS (2000). "Spatial Analysis in a GIS environment.", *University Consortium of Geographic Information Systems USA.* <http://www.ucgis.org/research_white/anal.html> (10/10/2001, 2001).

USGB (2001). "Ask Giraffe", *United Kingdom Standard Geographic Base.* <http://dataintegrator.askgiraffe.org.uk/> (5/3/2000, 2000).

Author Biography

Serryn Eagleson B Geom(Hons)/BArts(Melb).
Serryn completed a combined degree in Geomatics and Arts with a major in geography. Currently Serryn is undertaking PhD research at the University of Melbourne, Australia specialising in the areas of GIS, Hierarchical Spatial Reasoning and administrative boundary design. Serryn was recently awarded the Horwood Critique Student Prize at the URISA 2000 conference Orlando, Florida.

Dr Francisco Escobar
Francisco Escobar was born in San Sebastian Spain. He completed a bachelor degree in Geography at the University of Alcala de Henares, Spain. He obtained a master degree in Urban and Regional Planning at the University of Bordeaux III, France. He completed a PhD in GIS in July 1996 at the University of Alcala de Henares. He is currently a Senior Lecturer in the Department of Geospatial Science at the RMIT University. He teaches GIS related subjects in undergraduate and postgraduate programs. His research interests are on GIS applications in public health, data integration, cognitive space and GIS and temporal GIS. He collaborates with the University Louis Pasteur, France, the University of Alcala de Henares, Spain and the North American Society of Primary Care Research.