Mobile Information Services: Enriching Information Architecture with Urban Design

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ABSTRACT

Ubiquitous wireless communications, information mobility and location-based information services have created a new layer of urban experience, an information layer. The information services that deliver this layer to the urban actor (particularly pedestrians) will soon be ubiquitous and using those services a normal and integral part of the urban experience; more than an optional and utilitarian adjunct to it. The urban setting for these services prompts the question as to whether urban designers should be playing a role in their design and development; a role that seems conspicuously absent from current services.

This thesis explores mechanisms which might facilitate a greater role for urban design by seeking ways in which the information *architecture* that underpins these information *services* might better reflect the qualities and complexities of urban space that urban designers recognise and value. The work of a range of prominent urban design thinkers is reviewed for ideas, constructs and elements that can be incorporated into an enriched information architecture which could in turn deliver information services that do justice to the depth and complexity of the urban environment. Technologies and standards associated with the 'semantic web' are identified as those which might best accommodate an appropriate information architecture; in particular, the ability to reflect the network characteristics of urban space viewed as a multi-dimensional graph of interconnected nodes. This view of urban space is contrasted with the relatively flattened view offered by global geo-spatial capability.

An information model is built (only one of many possibilities) and validated using a limited test area in central Sydney. Practical and institutional issues which may impinge on the realisation and deployment of such a model in a real world setting are briefly considered in an appendix.

DECLARATION

This thesis is my own work and, to the best of my knowledge and belief, it contains no material published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgement has been made in the text.

Stewart Wallace 27/03/2009

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I would also like to recognise the supportive and stimulating environment at the City of Sydney Council where I first gained an appreciation of the interplay between information and urban space. Thanks also to the City's mapping unit for the extract from the 3D city model which was used for the underlying imagery in figures 1-1, 1-3, 1-11, 1-12, 1-15, 2-3, 2-12, 6-4 and 7-18.

Finally, I would like to thank Emma Grahame for her generous and professional assistance with editing.

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Chapter 1 Introduction

1.1 Background

1.1.1 The layers of a city

Beneath the immediate physical and visible presence of the urban landscape lie hidden layers of meaning and patterns to which we respond subconsciously and emotionally.

Some layers are temporal; the appearance of weathered stone and ancient architectural styles tell of an historical past, of events and owners and occupiers long gone. Leaves on the ground and clear light through the branches of street trees are a reminder of a more recent season when the mood was different. A building site presages changes to come. Exposed rock may serve as a reminder of the deep geological time that preceded any human presence.

Some layers are morphological; the shape and arrangement of urban places can provoke deep-seated emotional responses. They can create feelings of enclosure either reassuring or disturbing. A path can simply be a route from one place to another or it might incorporate a strong sense of departure and arrival and reveal a succession of goals and surprises which give the experience shape and purpose and turn a utilitarian act of movement into a journey. The interconnectedness of places can concretely affect who is present, how often and to what purpose (Hillier 1996).

Some layers are thematic; a city's architectural, political, religious or military stories present widely different views of the urban landscape and highlight different places and different times.

In these ways, cities are not unlike human brains. In each brain, the evolution of the human species is still immanent, the various reptilian and mammalian stages still present in different physiological structures and in the pre-wired patterns laid down during embryonic development. The structure and morphology of cities and the presence of layers beyond the visible surface are of more than passing interest; they map very directly into the structures of the human minds that perceive and use them (Smith 1977 Ch 8).

Many aspects of human culture and experience exhibit this layering; it is possible to appreciate a sophisticated piece of music without being aware of the subtle manipulation of keys that the composer has used to turn a progression of individually attractive sounds into a journey with a beginning, middle and end. Cities are not simply "agglomerations of necessity" (Smith P 1977 p16) created to facilitate function; they *affect* and they are experienced independently of their function and, as the semioticians would put it, they have a language and

engage in a discourse with those inhabiting them. The hidden layers contribute to that effect as surely as the underlying and dimly perceived changes of key in a piece of music.

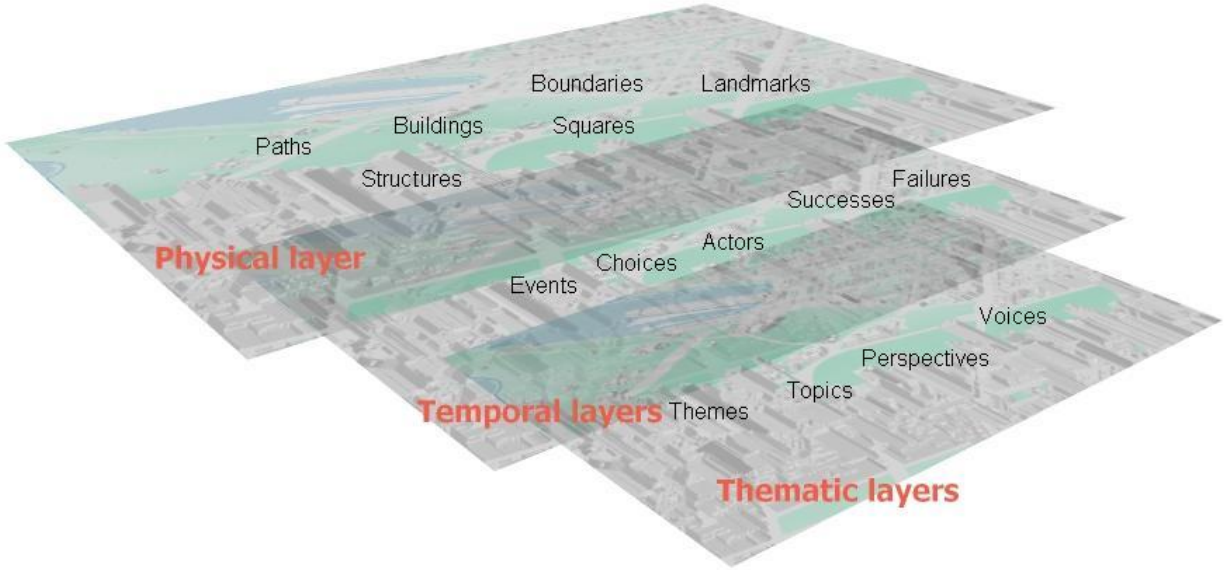


Figure 1-1 – Layers of the city. City images courtesy of the City of Sydney Council.

Much has been written of another layer added to the city in the last decade or so; an 'information layer'. The recognition of a connection between cities and information is not new; cities and information have always had a symbiotic relationship. Cities have been described as places of intensified information aggregation (Anthony Townsend referenced in Thackara 2005 p69). Transaction and movement within cities is often undertaken for the purpose of information retrieval and/or exchange. The very process of moving through urban space involves significant information exchange with the surrounding environment, ranging from a simple awareness of visible signs to far more subtle psychological effects related to morphology and texture (Smith P 1977 Ch 10; Salingaros 1999b). There is a large body of literature on urban semiotics.

However, the information layer (or "urban information overlays" as Bill Mitchell refers to them, Mitchell 2003b p120) has taken on increased significance with the advent of ubiquitous wireless data, information mobility and location-based services (Mitchell 1995; Mitchell 1999; Horan 2000; Townsend 2000; Townsend 2001a; Townsend 2001b; Mitchell 2003a; Mitchell 2003b). Mitchell has described this as the coming together of "atoms and bits" or "bits com[ing] home" (Mitchell 2003b p128) and returning to a more intimate relationship with the physical environment they describe after an extended period of isolation in cyberspace (Mitchell 2003b p3). Digital information and the physical world are no longer separate realms; information can have place and shape, and information services can now reflect the fact that *where* we are is a significant determinant of *what* information we seek or require.

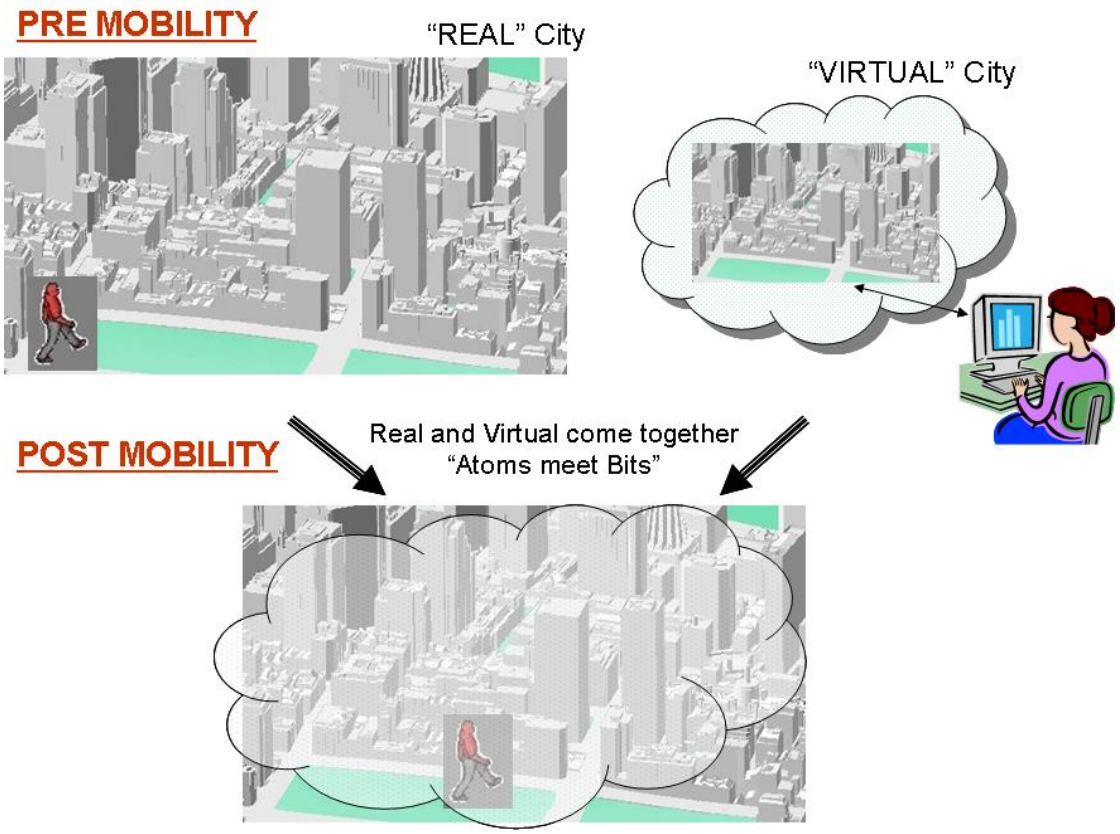


Figure 1-2 – "Atoms meet bits"

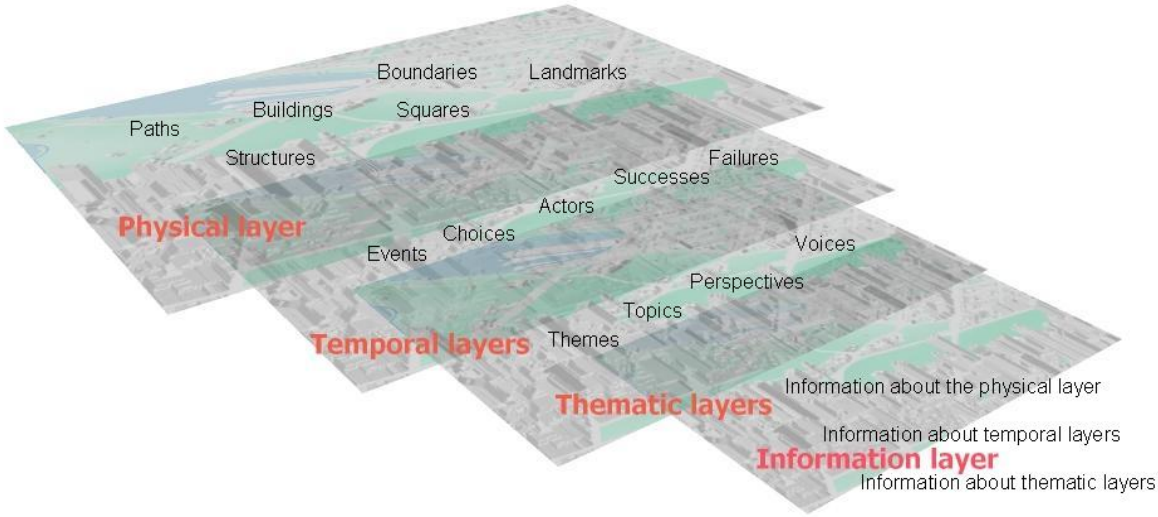


Figure 1-3 – The additional information layer of the city

The key information technologies that have contributed to the development of the information layer are the internet and geo-spatial data. The latter, once the realm of specialists in Geographical Information Systems (GIS), now deliver spatial representations of the entire planet to everyone through platforms like *GoogleMaps*™ and *GoogleEarth*™ and *VirtualEarth*™. Information can now be 'placed' with relative ease and there is an ever-increasing expectation that it will be placed (or 'geo-referenced' or 'geo-coded').

Tapping into this information layer are an ever-expanding array of urban information services which are, or soon will be, available instantly and ubiquitously from a handheld device to anyone operating within or moving about the urban environment. The devices through which the services are accessed (handheld or otherwise) are not necessarily the critical factor in these developments. As information access points proliferate, the limitations of the small, hand-held, screen will become less important. E-paper (which can be folded up like a newspaper) may enable larger mobile information windows; parts of the physical infrastructure, such as a section of a wall or window, may be capable of 'activation' as an information portal. Of more enduring concern is the information content that these services deliver; how it is created, who owns it, how it is maintained, where it derives its authority from, how it is structured and categorised.

As these services become ubiquitous and affordable, information will cease to be simply an adjunct to or an artefact of urban environments and will instead be an integral part of it: something to be experienced and used as much as the physical infrastructure and something to which design principles can be applied creatively, poorly or not at all.

These developments are at their most potent where the urban experience is most intense, which is also where the influence of urban designers is greatest. They are also of most significance in the spaces *between* built objects where a greater range of choices is available to the urban actor. By contrast, once *inside* a building, existing directory services are likely to take over with specific information about the organisations in the building and the products and services they offer. An interesting reference is Nolli's map of Rome (see section 7.3) which identifies public space both between the buildings and within them.

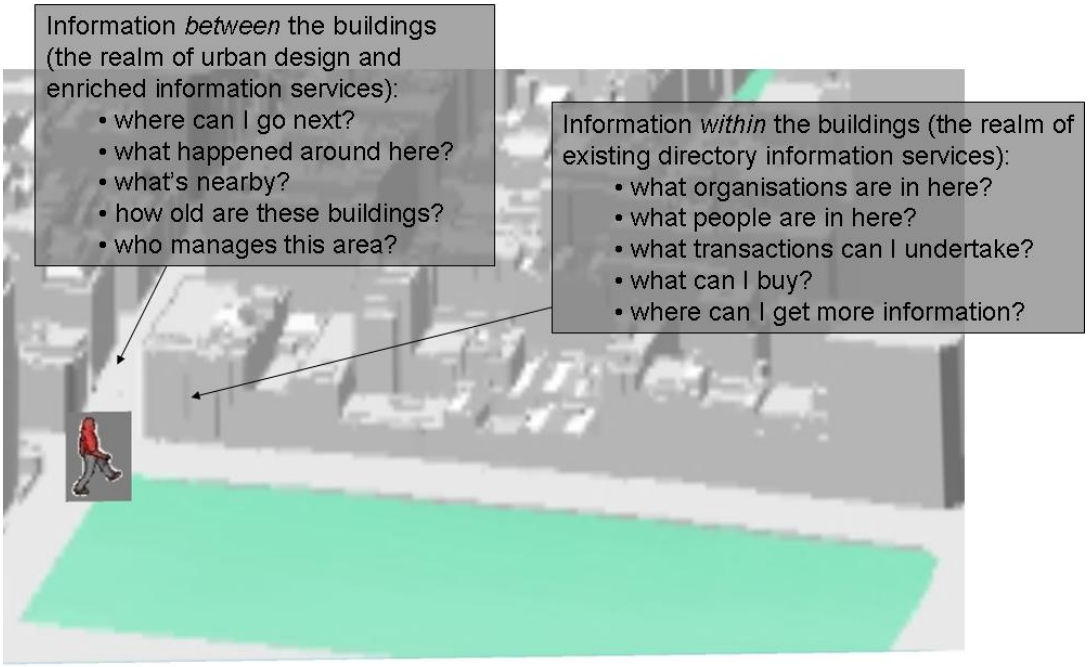


Figure 1-4 – Information between buildings and inside buildings

The space between built objects is the domain of urban design and this prompts some questions:

- to what extent should urban designers be involved in the design and delivery of these urban information services?
- are urban information services of sufficient importance to warrant the attention of urban designers?
- are urban information services amenable to the design concerns of urbanists?

These questions have been raised before, almost as soon as it was realised that the long-speculated possibilities of ubiquitous mobile information were becoming reality. In 2001, Anthony Townsend asked "Do designers of mobile computers and applications read the work of thoughtful practitioners like [Kevin] Lynch?" (Townsend 2001b p3). His answer at the time was a qualified "no". The initial impetus for this thesis arose from a desire to explore ways to facilitate a closer connection between urban design and urban information services and to find mechanisms that might assist urban design to find a 'voice' in the development of these information services.

Three further questions are now explored to lay out some more of the necessary background.

1.1.2 What is the information in the 'urban information layer'?

If the information layer is accessed by connecting, from anywhere, to the internet, the information this access makes available can be virtually anything. This is a source of great utility and forms part of the revolutionary, and laudable, democratisation of knowledge instigated by the advent of the internet. Similarly, global geo-spatial data provides a detailed map of the world to anyone, anywhere, at any time.

However, other commentators have seen that this bonanza of information has not come without its costs, particularly with regard to its relationship with the urban environment (Brown & Duguid 2000 Ch 1 'Limits to Information' is just one example). The view of the world made available by the internet and geo-spatial information is essentially a bird's eye view; the information user is able to survey a vast expanse of information or geo-spatial data and search for or zoom-in to a precise snippet of information or a precise point on a map. That searching may not result in the desired information immediately, of course, but the internet encourages repeated broad searches rather than attempts to drill in more forensically (although developments in the semantic web, or 'Web 3.0', to be discussed extensively in 2.3.1, are offering alternative approaches).

This results in a general flattening out of information that robs it of depth and additional layers of meaning and interpretation. Many will argue that the removal of the 'gatekeepers' of

interpretation, whose role in many cases was largely one of categorisation, has been a good thing (figures 1-5/6) but, as the basis for an urban information layer, it sits awkwardly with the intrinsic nature of *depth* that cities embody.

Similarly, although the plan view of the city, highlighting solids and voids, or figure and ground, has been with us at least since Giambattista Nolli's 1748 map of Rome (reproduced in Gosling & Maitland 2003 p42), the normal human physical view of urban space has remained the same; a view which takes place through the eyes (and other senses) positioned 1.5 to 2 metres off the ground.

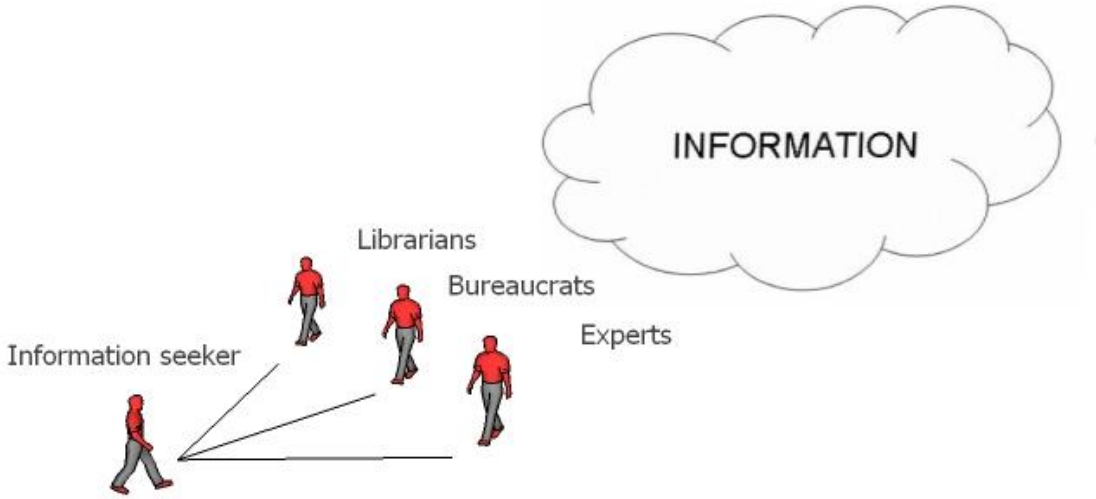


Figure 1-5 – Until recently, access to information was mediated by various expert 'gatekeepers'

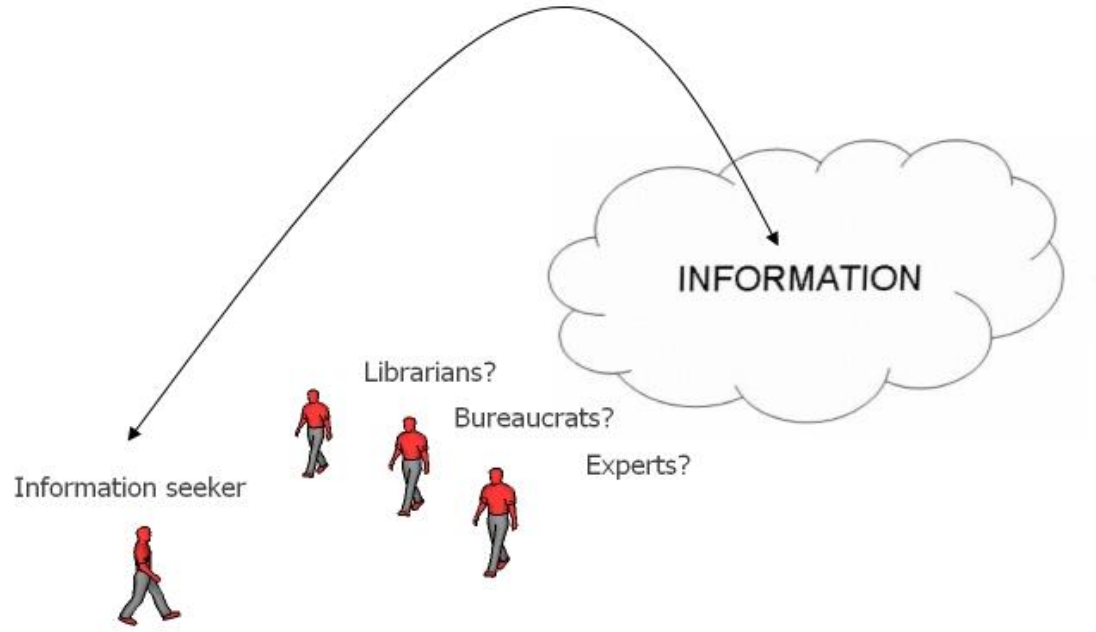


Figure 1-6 – The internet, search engines, tagging and mass content-creation have all resulted in the 'gatekeepers' being increasingly bypassed

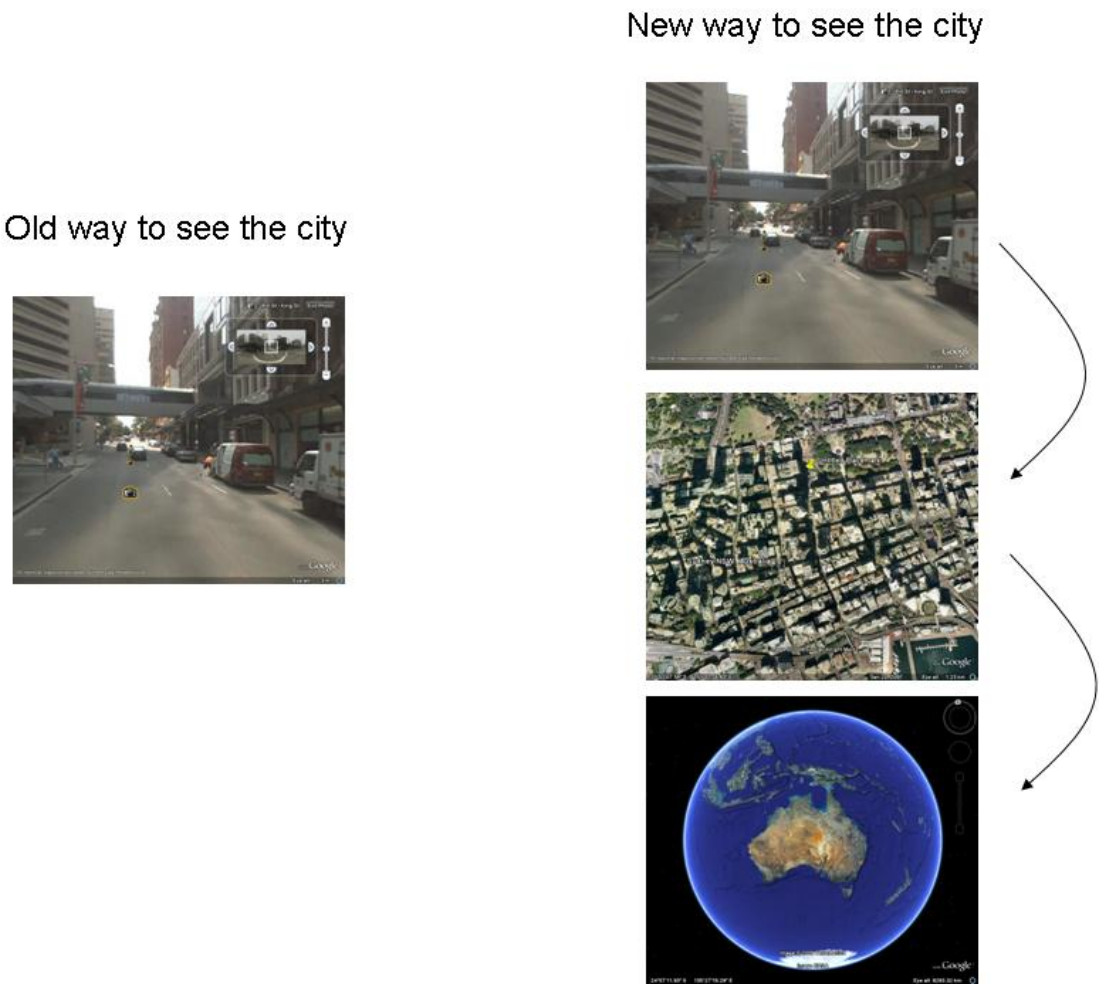


Figure 1-7 – Old and new ways to see the city

Urban designer Gordon Cullen will be discussed more extensively in 2.2, but two of his key concepts illustrate this point. At the very front of his book *Townscape*, Cullen analyses the actual physical experience of urban space from the viewpoint of a human actor moving through it using the concept of 'serial vision': that is, a series of views as they reveal themselves to someone moving through urban space (Cullen 1961 p17). While he illustrates his notion with both street-level pictures and a plan view of the various points in the series, the latter is used as an explanatory device, less as an input into the design process.

In discussing 'Place', Cullen also stresses the importance of 'here and there'; there can be no awareness of a 'here' without some apprehension of a relatively localised 'there' (Cullen 1961 p12). Contrast this with the situation in which we can access global-scale information about 'there' through instant access to a map of and information about the whole of the rest of the world; the 'there' is lost when 'there' becomes 'everything and anywhere else'. The point is illustrated in figures 1-9/10 - in a fairly extreme form perhaps - but the constant sight of people walking the streets with their attention firmly fixed on their mobile devices suggests that the version of 'there' shown in figure 1-10 increasingly reflects actual experience.

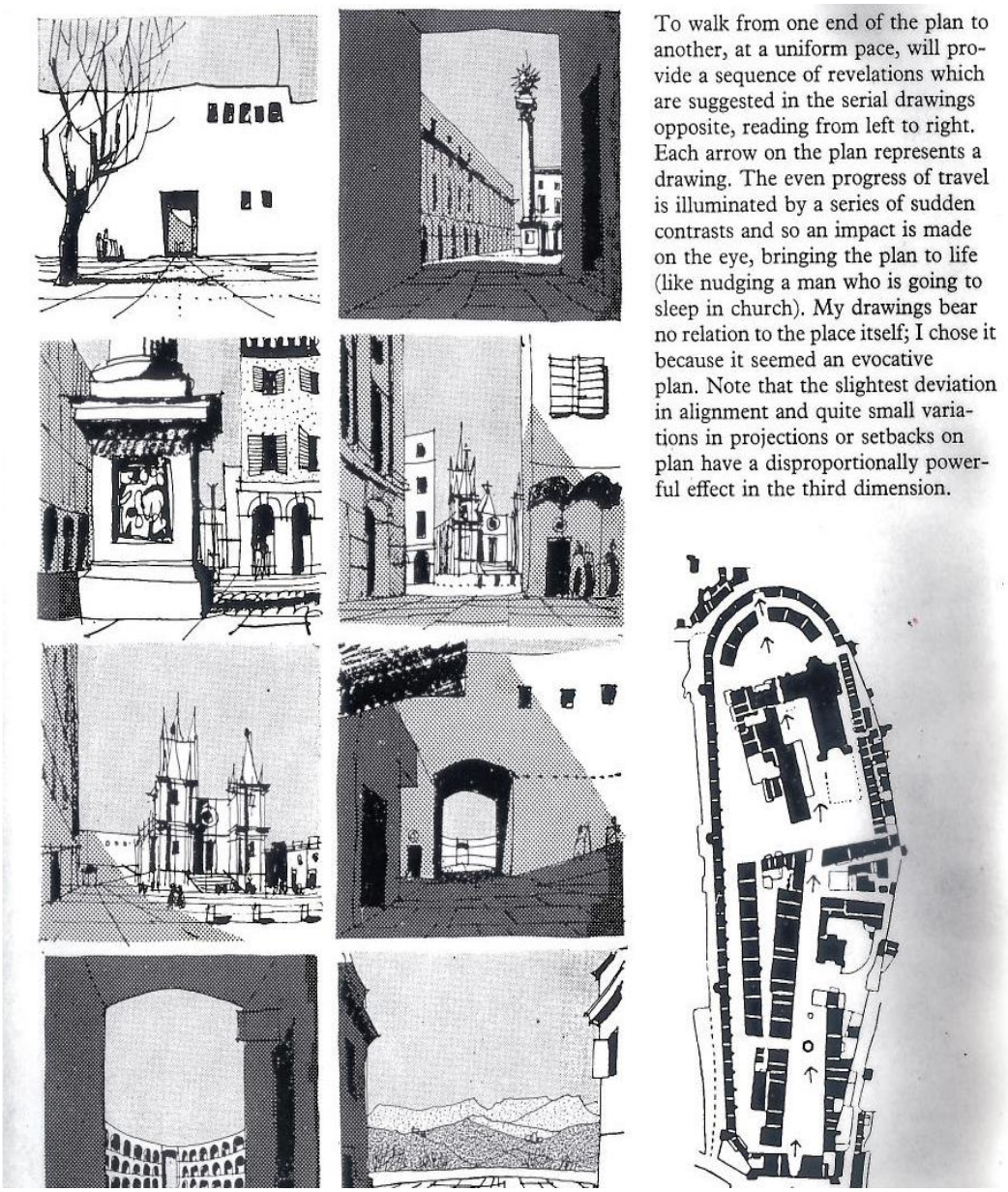


Figure 1-8 – Cullen's 'Serial Vision' (Cullen 1961 p17)

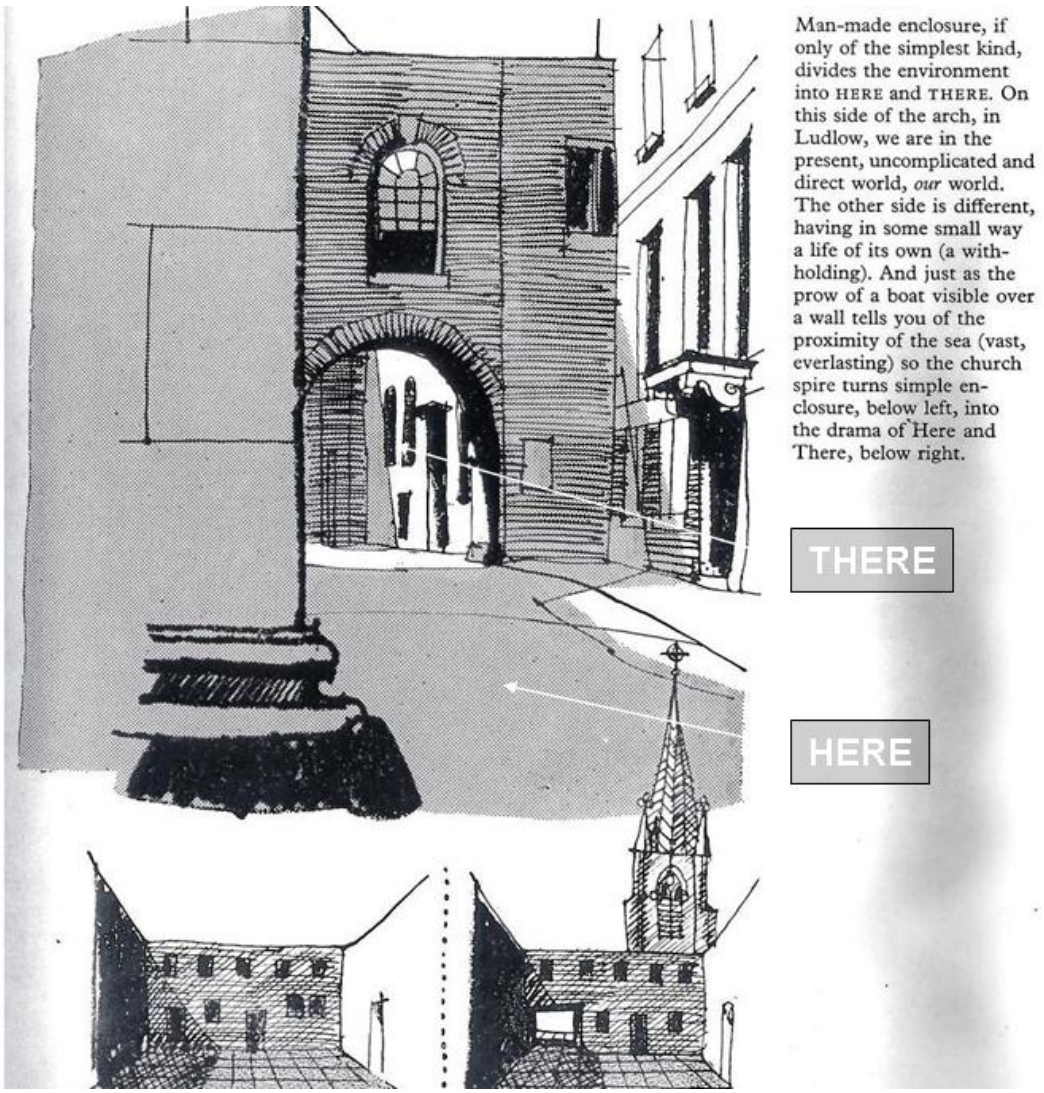


Figure 1-9 – Cullen 'Here and There' – what we can see physically (Cullen 1961 p183)

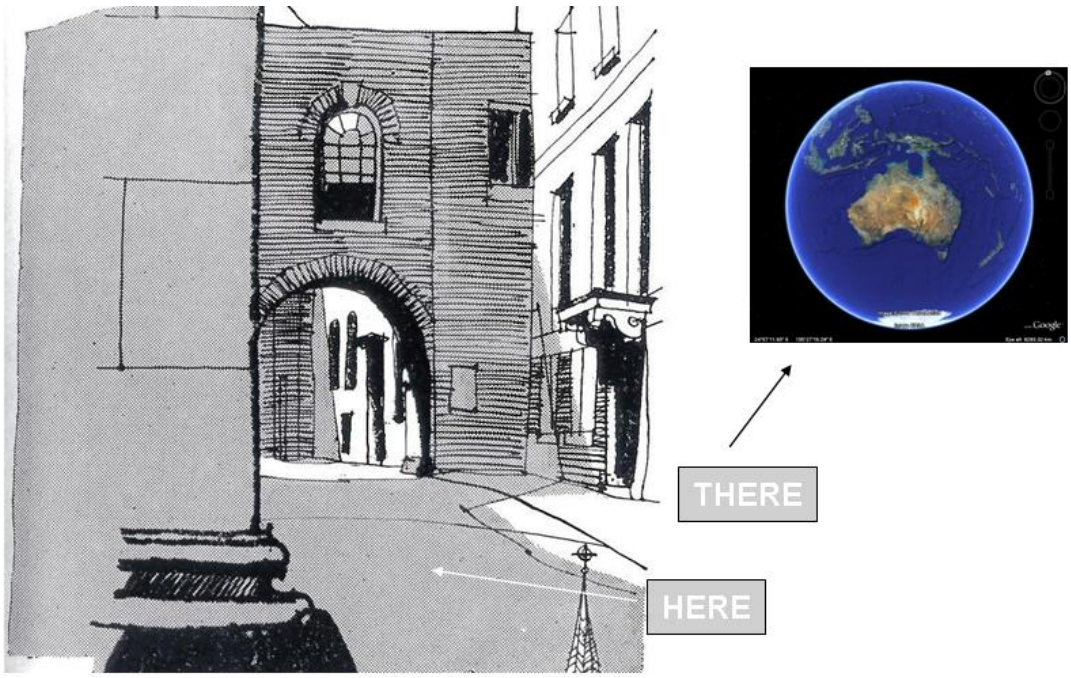


Figure 1-10 – 'Here and There' now – what we can see digitally

Serial vision also incorporates intrinsically a temporal dimension that ubiquitous information denies. When all of 'there' is immediately accessible, events and experience take on a quality of simultaneity; the digital revolution of recent decades is often described in terms of the compression of both space and time. Critiques of the contemporary digital world stress the need to slow everything down again, whether through 'slow food' or experience enriched by an emphasis more generally on "the close, complex and slow…" (Thackara 2005 p215 – discussed further in 2.2).

Particularly when used in conjunction with essentially utilitarian directory services (discussed in the next section), this immediate access to the 'there' tends to speed up our experience of urban space; it enables us to find the shop more *quickly*, reach the entertainment more *quickly*, catch the transport to somewhere else more *quickly*. In exploring alternative information architectures for the urban information layer, one of the goals may be to find both information structures and content that encourage the urban actor to interact and move through urban space more *slowly* and reflectively rather than more quickly and efficiently.

This brief discussion of Cullen introduces a process of investigation which is used repeatedly in this thesis, which is to seek out and analyse significant urban thinkers and to examine which of their ideas might inform the design of an urban information layer with greater richness and depth.

1.1.3 What is an urban information *service*?

Mobile-accessible urban information services are proliferating rapidly. Navigation and directory services such as *GoogleMaps* (http://maps.google.com/) and, in Australia, *Whereis*, are examples (http://www.whereis.com/). Increasingly, these are accompanied by directories of entertainment, food and other services. Before visiting a city, one can now 'download' it from a service like *Vindigo*™ (http://www.vindigo.com/).

These services are impressive and of great utility; they offer the equivalent of having at hand, at all times, a detailed map and a business directory (they are sometimes referred to as 'yellow maps', i.e., a combination of yellow pages and a map). However, as these services become ubiquitous and deliver richer content, they will become a normal and integral part of urban experience, not just an optional utility. What will be explored in this work is the possibility of taking these sort of services further (or creating new ones) so that they better reflect some of the depth and richness of urban environments and in so doing even become sources of "firmness, commodity and delight" (Vitruvius, The Ten Books on Architecture) in their own right.

The essentially functional and utilitarian nature of existing services is reflected in the categories of information that they offer. The *Vindigo City Guide* offers directory services for Food, Shops, Bars, Music, Movies, Services (laundry, garage etc), Museums and Bathrooms. *Whereis* offers searches for Train stations, Parks, Restaurants and Hotels. The default 'Places of Interest' from *GoogleMaps* features Dining, Places of worship, Bars, Banks, Cemeteries, Coffee shops, Fire department, Gas stations, Grocery stores, Hospitals, Lodging, Major retail, Movie rental, Pharmacies, Schools and Shopping malls. Most of the services in these lists are delivered inside buildings and the purpose of the information service is to move you more quickly *through* the urban environment to the appropriate building and then get you *off* the street and *into* the building to access the service.

Is it fair to imply that such services fail to be sources of "firmness, commodity and delight"? It has already been asserted that the very power of contemporary information access, which facilitates the direct retrieval of almost any discrete item of information from a global store, tends to flatten out our view on the world and rob it of the *depth* which is intrinsic to the urban environment in which the information is often accessed and used. The examples of services described above do not alter that assertion in that they provide relatively flat directory structures to facilitate the most rapid retrieval of an available service. This emphasis on simply finding and navigating to a service like a restaurant or a laundry means that the paths that are offered are only operating on one level of the city, that of narrowly utilitarian navigation. The presence of other layers as described in 1.1.1 raises the possibility of more complex paths through the city that explore these other layers:

Figure 1-11 – A simple path through physical urban space

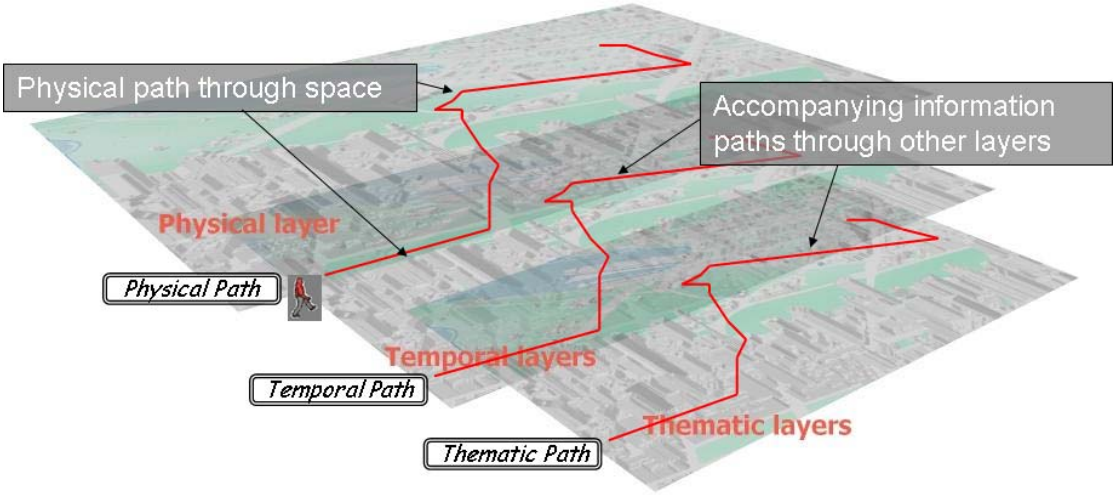


Figure 1-12 – More complex paths through physical and temporal space

An enriched urban information service would facilitate these other paths as well.

An urban designer might actually argue that what is offered by the navigation component of these existing services are not 'paths' at all but simply 'routes'. *Paths* have no independent standing in these services but are constructed through the connection of nodes (primarily intersections) that define the shortest *route* between two selected points (sometimes with variations for pedestrian or vehicular travel and avoiding tolls). Paths for urban designers, on the other hand, are complex and subtle phenomena and critical components of any urban environment.

This is best illustrated with an example. Here is a route through part of Sydney generated by an existing information service:

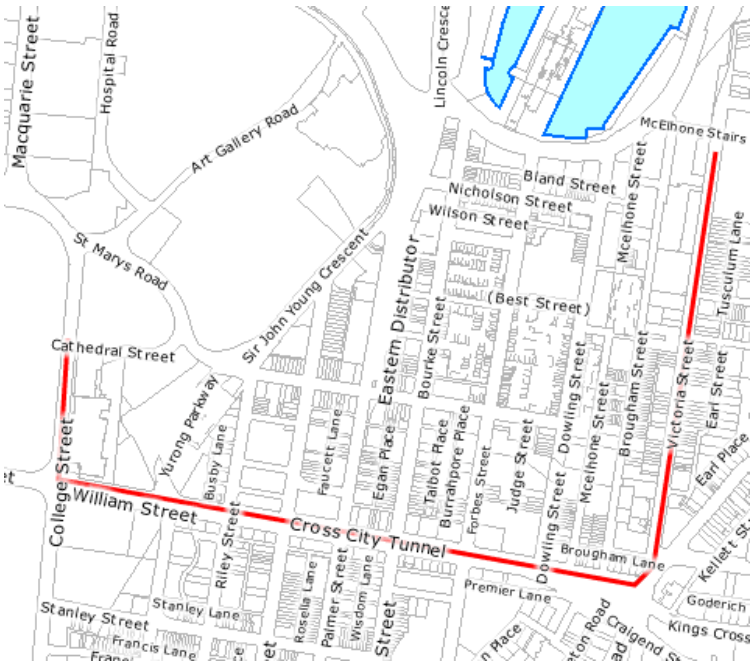


Figure 1-13 – Path through inner Sydney as offered by existing information service (adapted from Whereis™ navigation service)

This has utility as far as it goes but what would an urban designer make of that path? What qualities would they reference in seeking to define the best path rather than just the shortest route? Qualities such as:

- Visibility and continuity
- Gradient (topography, use intensity, age)
- Purpose – a beginning and an end (goal)
- Some variety of experience along the way
- Intermediate nodes – for orientation and a sense of progress

Applying these qualities to the urban area in question may result in quite a different path; the alternative shown in figure 1-14 certainly incorporates more of those qualities than the original suggestion and is in fact about 100 metres shorter! (The existing service showed little imagination in using anything other than existing main roads.)

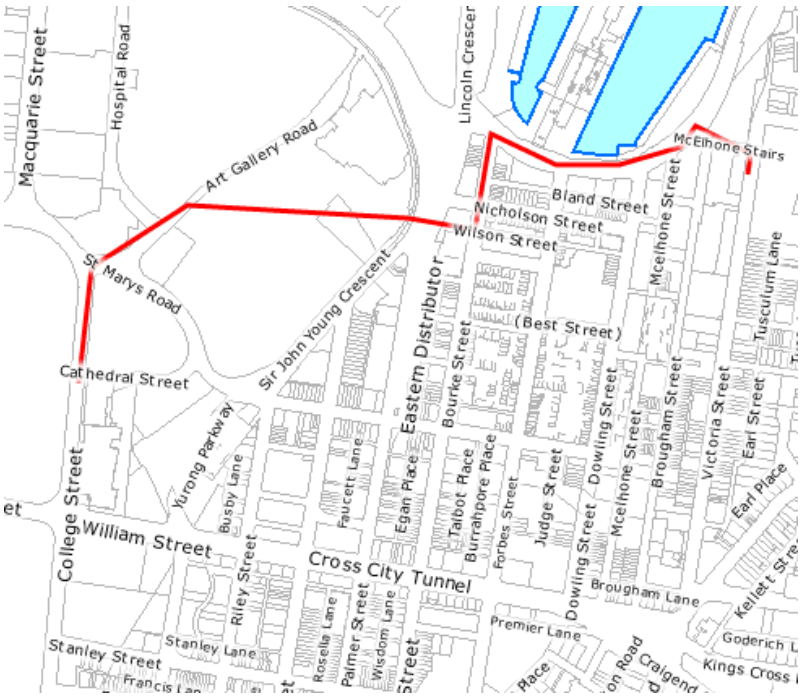


Figure 1-14 – Alternative path through inner Sydney

An urban designer could readily identify this path by examining the area in question with a critical and experienced eye.

1.1.4 What is Information Architecture (IA)?

The title of this thesis gives primacy to the term Information Architecture (IA). IA can be and is used in many different ways but its purpose here is quite clear. It is used to distinguish the persistent information that many different information *services* might draw on and, in particular, how that information is organised and structured and what information management mechanisms are used to store and deliver it.

The term IA can be used a little more broadly to cover a range of basic information services that might be combined into a richer urban information service. Mostly, however, in this thesis the focus is on the IA that underpins that service in which the concerns of urban design are encoded and delivered.

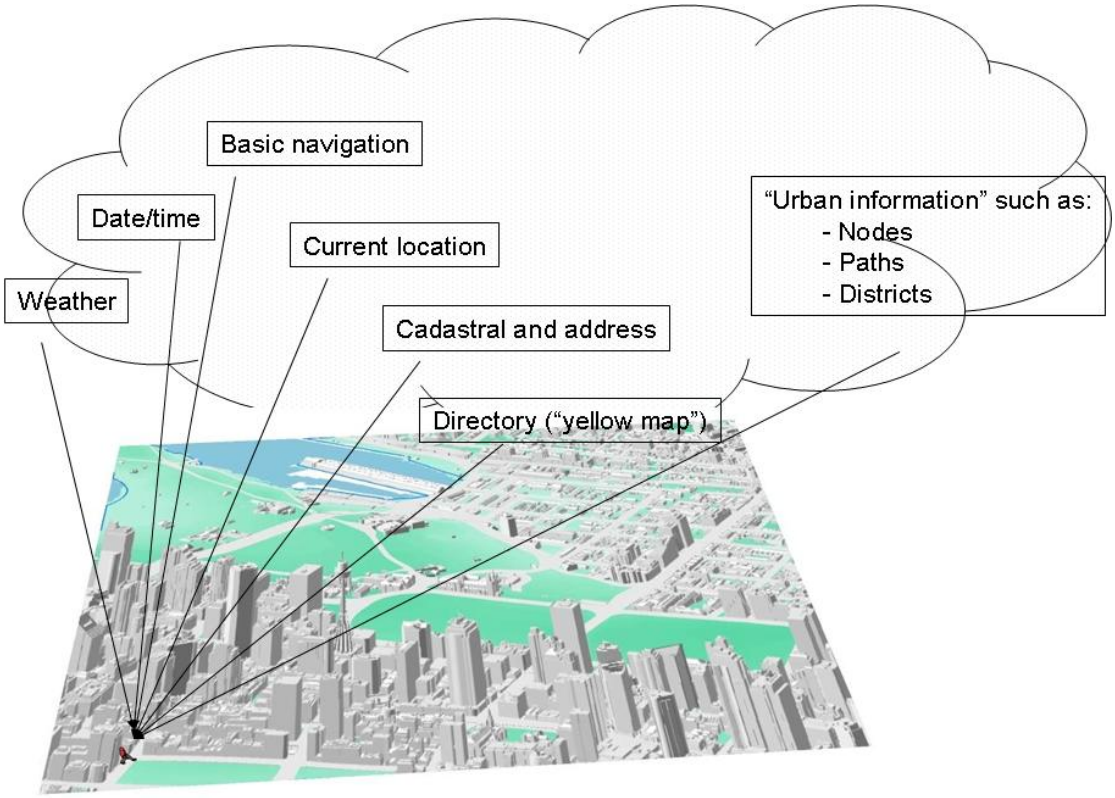


Figure 1-15 – Information services including the 'urban information service'

It should be emphasised that this work does not consider in any detail the visual design of the actual interfaces through which these services might be delivered. It is almost impossible to keep up with developments in this area and there are many people and organisations involved in this sort of design work. Once the information is encoded and stored, interface designers and the human-computer-interaction disciplines will continue to develop a range of imaginative and functional options for presenting the information to the end-user.

In 2.3.1, an area of research and a set of standards will be described that is known collectively as the 'semantic web'. This has emerged from the next wave of development of the world wide web, starting with Tim Berners-Lee's call for the creation of just such a platform almost a decade ago (Berners-Lee 1998). The semantic web incorporates many aspects which lend themselves to encoding and expressing urban design concerns, ranging from simple mechanisms to link objects into rich networks of interconnectivity to more complex encodings of domains of knowledge known as 'ontologies'.

1.1.5 Are enhanced urban information services necessary?

Some assumptions underpin the assertion that this exercise is worthwhile.

These services are of most value in a pedestrian setting and it is assumed that there will continue to be many pedestrians interacting with urban space who may benefit from them. After some decades in the 20th century of ever-increasing vehicular domination, there is now a consistent trend to try to recover urban space for pedestrian use. Examples include Jan Gehl's work in Copenhagen and Melbourne.

It is assumed that urban information services will become increasingly ubiquitous and a normal adjunct to urban experience. Countries such as Japan and Korea offer examples where mobile information services (operating within the 'i-mode' model in Japan) have reached near-saturation levels (Mizuko et al 2005). Many developing countries are using wireless communication to 'leapfrog' into ubiquitous digital communication while avoiding the heavy costs of wired infrastructure.

The increasing capability of these services is beyond doubt and technical issues with wireless spectrum bandwidth do not seem to stop the spread of ever more widely available access to greater volumes of data at lower cost.

Whether there is a place for enhanced services that better reflect the qualities of the urban environment they operate in, is less predictable. The argument made here is that the information layer of cities is becoming as intrinsic to the urban fabric as the physical objects and should therefore be as amenable to being *designed* as is the physical environment.

In part, this thesis presents a plea and an encouragement for urban design to have a voice in the development of these services; it also identifies and explores mechanisms for an IA which might better support the development of this voice.

1.1.6 Key research questions

The key questions to be explored are:

- what ideas and patterns can be taken from urban design literature to form the basis for an IA that could underpin richer urban information services?
- how can those ideas and patterns be encoded into an IA and what might the key elements be?
- what are the best information platforms and standards to use for this purpose?

The scale at which the concerns of this thesis operate is necessarily fairly intimate and corresponds with a *pedestrian* urban experience. Urban design writers largely deal with the

fine-grained and subtle effects of urban form and function as they are directly perceived by an actor in the physical environment; less so by an actor cocooned in a vehicle. The actor's movements, perception and choices discussed in this work are very largely those of someone moving on foot.

1.2 Chapter overview

Literature from various disciplines relevant to this study is reviewed in chapter 2 and grouped broadly into:

- Digital urbanism
- Urban design
- Information science

The first two explore widely and are more descriptive, essentially harvesting ideas from a range of urban thinkers. The final group is far more technical and surveys the range of mechanisms and standards (mostly from the semantic web) that might be employed in pursuing the goals of the thesis.

Working from the literature, chapter 3 identifies a set of requirements that an enhanced IA needs to meet. These requirements operate at a number of levels; some are quite specific, e.g., concerned with the qualities of paths; some are more abstract, e.g., capturing the fractal nature of urban experience or making temporal dimensions more accessible. Some broad alternative approaches to designing the interaction of physical and information layers are also proposed.

Chapter 4 describes a 'toolkit' of techniques and standards identified in the information science group of the literature review. They are not discussed in great detail; their application to the development of the model in chapters 6 and 7 is more important.

Chapter 5 develops a number of important building blocks that will be used in the IA.

In chapter 6, an IA is actually built working from the requirements outlined in chapter 3 and using elements from the toolkit described in chapter 4 and the building blocks from chapter 5. This represents only one of many possible ways to meet the requirements but it will illustrate many of the key points which any solution should address.

In chapter 7, the IA is applied to a small area of central Sydney as a reality check on the adequacy, utility and practicality of the IA and the information it contains.

Chapter 8 discusses and analyses the model and presents some findings and conclusions. In brief, these conclusions are that:

- There is an opportunity for urban information services, particularly those location-based services delivered to mobile devices, to deliver a richer additional layer to urban experience; one that more closely mirrors the qualities of the urban environment in which it operates.
- Semantic web constructs and standards represent a viable platform with which to build an IA that could support such enhanced services.
- Urban Designers are well placed to provide the additional information constructs which this IA requires.

Appendix A briefly considers some of the other factors that would come into play if such an IA were to be successfully implemented and widely deployed.

Appendix B contains some code samples.

Chapter 2 Literature review

No literature was found which specifically deals with the approach put forward in this thesis. Part of the original impetus for this research was a growing awareness of a lack of cross-reference between literature dealing with recent digital developments (Mitchell, McCullough and Thackara among others) and that which has emerged directly from the urban design discipline (Lynch, Jacobs, Cullen, Alexander, Trancik etc.). There is little connection even between the writers on digital developments and other urban writers who place a heavy emphasis on information in their urban analysis (though not necessarily *digital* information) including Arida, Salingaros, Hillier and Batty & Longley.

The review is grouped into the following broad headings:

- *Digital urbanism* – these are writers whose work combines many insights into information, information services, mobility and design in a largely urban setting. They often talk broadly of 'place' but, given their interest in information, that place is often a city where information density is greatest. Half a dozen names stand out and in many ways they were the key inspirations for the work – Bill Mitchell, Malcolm McCullough, John Thackara, Anthony Townsend and Stephen Graham & Simon Marvin.
- *Urban design* – this is an extensive literature and no attempt has been made at a comprehensive survey. Instead, some prominent and widely quoted examples were chosen – Kevin Lynch, Gordon Cullen, Christopher Alexander, Jane Jacobs. As much of this work dates from the 60s, some more recent writers were added, David Shane, Roger Trancik and Peter Smith along with some who have a more analytic and information-based interest in the urban environment, Nikos Salingaros, Ayssar Arida, Bill Hillier, Michael Batty & Paul Longley. Some writers also offer particular perspectives on *time* including Yi Fu Tuan and Stewart Brand.
- *Information science* – this is less a review than a summary of some key developments.

It is worth clarifying what is sought from these different disciplines:

- From *Digital urbanism* – the big picture on the developments that make the topic of the thesis of interest and broad design considerations for the development of mobile information services.
- From *Urban design* – the most crucial group: ideas, theories and design patterns related to the quality of urban space and how and where urban design can influence it. Closest attention is paid to ideas that can potentially be encoded into an IA. It is primarily from this group that *requirements* for the IA are derived.

- From *Information science* – a toolkit of standards and mechanisms that might be deployed in designing and building the urban IA.

Some other disciplines were reviewed but not pursued in detail and remained in the background of the subsequent research effort. These included:

- *Urban history* – includes seminal works by Lewis Mumford (Mumford 1961) and Peter Hall (Hall 1998). The very long-term view in these works provided a valuable deeper context for the work of other writers but did not offer as many practical ideas for application in the IA.
- *Human–computer interaction* (HCI) – is a large and varied area of research with a significant history and body of theory attached to it. There are many projects and papers in this area of relevance to the use and utility of urban space, particularly with regard to navigation. There is a fairly overwhelming emphasis on the mechanism of information delivery as opposed to the content, however, and many exercises appear to focus on replicating functions at which humans are naturally skilled (visual interpretation etc.). HCI has also grown from a technological base although there is a branch of HCI increasingly concerning itself with steering the discipline towards a more 'human-centred' design strategy, an example being work by Antti Oulasvirta on "humanistic research strategies" (Oulasvirta 2004). Thackara (see 2.1) also remind us that, in the headlong rush of technological change, it is easy to reach a point where "It's no longer clear to which question all this stuff … is an answer" (Thackara 2005 p2). HCI was not investigated closely primarily because of its focus on the front-end interface of information services rather than the persistent back-end information architecture which those services draw on.
- *Emergent behaviour* – emergent behaviour and chaos theory have been explosive areas of research in the past three decades (Johnson 2002). They have started to appear in *urban* behaviour studies recently, primarily in connection with the concept of 'swarming', i.e., sudden large aggregations of people dynamically organised through mobile phone communication and the 'virus'-like spread of content among the wirelessly connected (Rheingold 2002). The IA mechanisms discussed later may well generate information entities capable of viral behaviour and their use may, therefore, have unexpected emergent properties, but these are almost impossible to predict. There is also potential for a study of the use of urban space as a *complex system* that exhibits emergent behaviour which may change with the introduction of mobile accessible information, but that is for another research effort.
- *Wayfinding and navigation* – this is another area with a long history and substantial literature. Research into appropriate signage and navigation aids contributes much to the picture of information in urban space although generally within a fairly narrow

area of interest (navigation) or with a fairly narrow operational focus (transport interchanges, shopping malls etc.).

These various literatures might be presented in a diagram such as 2-1. The width of the lines indicates the strength of the connections:

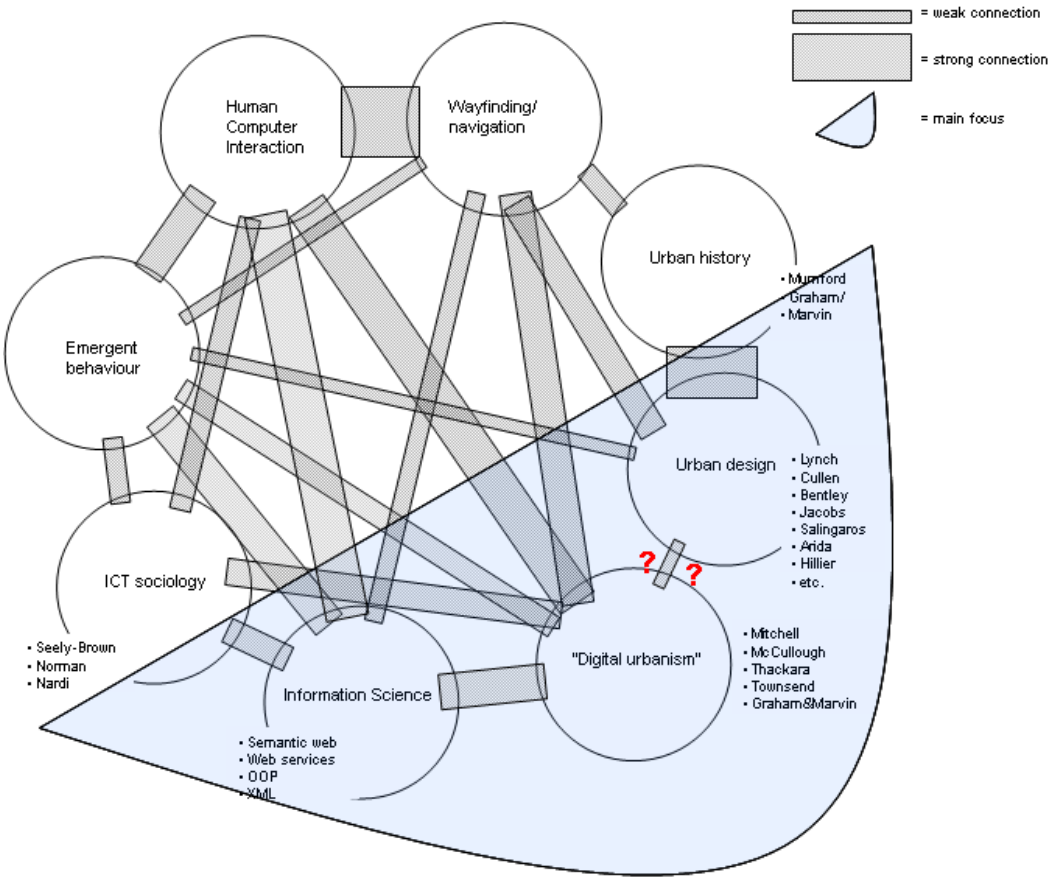


Figure 2-1 – Literature review

2.1 Digital urbanism

'Digital urbanism' is my term; it is not a recognised discipline with a discrete literature but there are several writers who, in recent times, have considered the significance for the urban environment of developments in ICT (Information and Communications Technology).

Bill Mitchell

Bill Mitchell's three books, *City of Bits* (Mitchell 1995), *eTopia* (Mitchell 1999) and *Me++* (Mitchell 2003) are widely quoted texts with regard to cities and ICT. Mitchell's intention, and the manner of his exposition, is essentially speculative and descriptive rather than analytical. His books have alerted various disciplines, and the public at large, to the implications of new ICT for many aspects of life. Mitchell at times deals directly with the "urban information overlays" (as he terms them) that are of interest to this research. He provides a general update on the state of technology at the time of writing (there being, for

instance, much more emphasis on mobile computing in his more recent books) and then describes a wide range of possible applications and highlights potential problem areas like security and equity.

One of the key points he makes in *Me++* is that information mobility and geo-referenced information are bringing back together information (bits) and the physical world (atoms) after they developed in parallel for a number of decades. He also makes a case for an ethical dimension to digital interconnectivity where "the ancient principle of reciprocity" (Mitchell 2003b p211) is applied on new, expanded scales. Ethics is not a core concern of this thesis but, as will seen later, there are opportunities for urban information services to either connect or isolate parts of the urban fabric.

While not putting the question as bluntly as Townsend, Mitchell clearly hints that urban design could play a greater role in these developments – "It is, I suggest, a moment to reinvent urban design and development and to rethink the role of architecture." (Mitchell 1999 p8). Mitchell also draws revealing parallels with orators of the past (Cicero, Quntillian) who used architectural metaphors as tools for mnemotechnics (the art of memory); memorising concepts by mapping them onto the rooms of remembered buildings. In comparing this with the contemporary city, Mitchell provides one of the best summations of the new relationship between information and the city:

> *In today's emerging electronic mnemotechnics, information is stored in digital devices rather than heads, it is associated with physical places through geocoding, it may be retrieved by actually moving from place to place, and it may be presented in multimedia format on devices such as see-through video displays and audio earpieces. In this fashion, a whole city becomes a vast, collectively constructed memory palace that divulges its contents to inhabitants as they circulate through it. (Mitchell 2003b p128)*

Malcolm McCullough

Malcolm McCullough's work, *Digital Ground* (McCullough 2004), is analytical and certainly more polemical in advocating a certain approach to the methods employed and goals pursued in the design of new information services. With regard to methods, McCullough argues for placing the development of information services within the paradigm of interaction design (McCullough 2004 Ch 7) and avoiding a purely technological approach that ignores the input and aspirations of the human users of technology and information. Later on, he goes much further to argue that the goals for this design should be positioned within a project to re-align social values away from runaway consumption. He asks "Can place-centered design demonstrate how value transcends price?" (McCullough 2004 p194) and answers in a hopeful

affirmative. McCullough also notes how information mobility and embedded systems are making it increasingly difficult to separate traditional physical architecture from the interactivity that ubiquitous information affords. This means that information architecture for urban information should be designed with interactivity as well as retrieval in mind.

McCullough provides a list of some of the differences which arise when computing and data are 'Universal' as opposed to 'Situated'; these are a useful additional commentary on the flattening created by universal information access and ubiquitous geospatial data (McCullough 2004 p68):

Universal	***Situated***
Anytime-anyplace	Responsive place
Mostly portable	Mostly embedded
Ad hoc aggregation	Accumulated aggregation
Context is location	Context is activity
Instead of architecture	Inside of architecture
Fast and far	Slow and closer
Uniform	Adapted

Some of the items in this list resonate with earlier comments about flattened data structures facilitating speed and distance rather than slowness and closeness. Interestingly, McCullough points out that portability is not always the key concept and that more situated processing may in fact be locally embedded rather than ubiquitously accessible.

In discussing a list of key components of pervasive and embedded computing, McCullough notes that "Knowledge representation remains perhaps the fundamental challenge … the discourse has shifted from artificial intelligence to ontology …" (McCullough 2004 p91). Although he doesn't go on to discuss the semantic web specifically, the reference to "ontology" suggests an awareness of its possibilities.

John Thackara

John Thackara (Thackara 2005) ranges across a very broad range of design concerns, making him a less obvious member of the 'digital urbanism' group. However, he is clearly aware of the potential power of new information services and does focus on them at various points. Much of his writing on design is concerned with achieving greater depth and finer granularity in design rather than following a top-down paradigm which threatens local identity and differentiation. He is looking for richness of experience in "The close, complex and slow…" (Thackara 2005 p215) and emphasises the importance of context and situation which encompasses the use and purpose of space as well as its physical characteristics. He also identifies the problem that, notwithstanding an ever-increasing technological capability, "…we are increasingly at a loss to understand what to make and why." (Thackara 2005 p189).

This is an important plea, echoed by others, to avoid a purely technology-driven approach to the development of new services (Crawford 2003 Introduction; Norman 1998 Ch 2).

Anthony Townsend

Anthony Townsend posed the key question, quoted earlier, as part of a series of articles written while at the Taub Urban Research Institute that examined a variety of aspects of the relationship between cities and ICT (Townsend 2000a, 2000b, 2001a, 2001b, 2001c). He identified earlier than most the potential importance of mobile devices rather than just the internet. The passage in which the key question mentioned above appears warrants longer quotation:

> *You wouldn't let a software engineer design your house would you? On the other hand, most architects avoid rewriting CAD software for every design project by buying off-the-shelf software. It seems to me that there has been little dialogue between what I'll call the professions of location — geography, urban planning, and architecture — and the wireless development community. While no doubt a number of Geographic Information Systems professionals are playing key roles in the location-based sector, there has not been a systematic engagement of the base of knowledge these disciplines have built up over the years about how people relate to the places where they live, work, and play. Do designers of mobile computers and applications read the work of thoughtful practitioners like Lynch? I sincerely doubt it. And it shows in the poor quality, even naiveté of services and ideas that are being developed. And it's hindering adoption of wireless Internet. (Townsend 2001b p3)*

This thesis identifies urban designers as potential contributors in this area; an approach which still sits comfortably with Townsend's identification of professionals in "geography, urban planning, and architecture" given that urban design is often positioned between urban planning and architecture. Perhaps time has not borne out Townsend's concern that this paucity of design has "hinder[ed] adoption of wireless Internet" but an email exchange with this author confirmed that he believes that paucity was still an issue up until recently. Townsend has in fact concluded that it is easier to make the information professionals aware of urban design issues than make urban designers aware of the importance of information! He believes there has been some progress in the last couple of years, nevertheless.

Stephen Graham and Simon Marvin

Stephen Graham and Simon Marvin produced one of the earliest substantial works on cities and ICT, *Telecommunications and the City* in 1996. In 2001, S*plintering Urbanism* (Graham & Marvin 2001) was published, presenting their central thesis that the paradigm of public technological infrastructure which dominated the early part of the 20th century has broken

down near the end of the century and has started to be replaced by 'splintered' urbanism and infrastructure. Their focus is largely on the physical technical infrastructure that supports ICT networks and as such is several levels lower down the technology 'stack' (see Appendix A) than the layers that are the focus here.

Nevertheless, 'information infrastructure' (the data) is a concept rapidly gaining a level of recognition equal to that of physical telecommunications infrastructure (the wires). As ubiquitous wireless communications are alleviating many of the early concerns about potential inequities associated with the uneven rollout of wired infrastructure, attention is turning to the consistency and reliability of higher layers of information such as basic geospatial data and, above that, cadastral and other property-related data, i.e., the 'information infrastructure' that underpins applications and services to the end-user. Enhanced urban information services will depend on information infrastructure like this and there is already substantial 'splintering' of underlying information as telcos and other organisations scramble to assemble their own directories of information and services.

These concerns are more relevant to the deployment and maintenance of an IA than its design (which is the main concern here) but they are considered further in Appendix A.

2.2 Urban design

As already indicated, a comprehensive review of urban design literature is not germane to the purpose of this thesis. What is presented in this section is the result of 'harvesting' the works of a range of prominent urban design writers for models, rules-of-thumb, ideas, concepts and typologies that are candidates for encoding into an IA intended to be the basis for richer urban information services.

Some ideas are abstract and encoding them presents a formidable challenge, for example …

- Alexander – "Every increment of construction must be made in such a way as to heal (make whole) the city" (Alexander 1987 p22)

… whereas others are quite specific and encoding them seems more feasible, for example:

- Alexander – "[intermediate] goals [in a path] should never be more than a few hundred feet apart" (Alexander et al 1977 p588)

Simple or complex, the literature is rich in possibilities.

Kevin Lynch

Kevin Lynch's seminal work, *The Image of the City*, identified key urban elements which have been part of the vocabulary of urban design ever since (Lynch 1960 Ch III):

- Paths
- Nodes
- Edges
- Districts
- Landmarks

Lynch expanded on the characteristics and qualities of these elements and their combination. Some of these qualities are summarised below; some are descriptive and definitional, some are more normative qualities that might enhance a given element rather than just define it.

- Paths:
  - have visibility and continuity – the availability of clues, visual or otherwise, as to where the path is going and to what it leads. An absence of significant interruptions
  - have gradient (topography, use intensity, age) – some sense of progression and change – uphill or downhill, a movement from residential to commercial, from the old to the new
  - have purpose – a beginning and an end – a discernible reason for commencing on the path and an identifiable end which represents the culmination of a journey with some purpose
  - exhibit some variety of experience along the way rather than an urban monoculture of all residential, all built or all gentrified etc.
  - include nodes – for orientation and a sense of progress – intersections as a starting point but ideally something with which to identify waypoints
  - are scaled – have a sense of the relationship of the path to features on a bigger or smaller scale – some indication of how this path interacts with others paths or with other urban elements
- Edges:
  - represent a boundary between two 'areas'
  - are visually prominent
  - are continuous in form
  - are often impenetrable, not necessarily simply physically, perhaps visually or psychologically
  - are reinforced if they are also a path
  - may have directional qualities – they are experienced differently depending on the direction from which they are approached
- Districts:
  - are areas an observer can mentally go inside
  - have thematic continuities which may be brought about by a wide range of physical characteristics such as texture, space, form, detail, symbol, building type, use, activity, inhabitants, degree of maintenance, topography, façades, noise, ease of orientation and rhythm
  - are less defined by edges than might be expected
  - are often defined by a strong core with a thematic gradient that dwindles away

- Nodes:
  - their size depends on the scale being considered
  - transport junctions are critical nodes
  - are partly defined by a functional focus
  - are junctions or concentrations
  - their physical form is not always essential in their definition
  - successful nodes are unique is some way and intensify some surrounding characteristic
- Landmarks:
  - have some unique singularity
  - their top is more significant than the base
  - are recognisable at many levels
  - are reinforced by sound and smell
  - can reinforce each other and link together through anticipation.

Lynch also recognised the significance of non-physical attributes. "Meanings and associations, whether social, historical, functional, economic, or individual, constitute an entire realm lying beyond the physical qualities we deal with here" (Lynch 1960 p108). Even just the names of elements, he asserts, are "important in crystallizing identity".

The outcomes of Lynch's investigations in *The Image of the City* were static maps and although participants were asked to describe journeys and their experiences along the way, the end results were plan view maps of their mental images.

Gordon Cullen

Gordon Cullen operates at an intimate and experiential level and emphasises the street-level experience of urban space, in particular, the 'serial vision' with which the surrounding environment is revealed to the pedestrian as a "series of … revelations" (Cullen 1961 p11). For Cullen, this notion splits the experience of urban space into two fundamental constructs, the 'existing view' and the 'emerging view' (Cullen 1961 p11). This is an important notion because the digital representation of urban space is often assumed to be an all-seeing map but this need not be the case. Rather, location-based information services may present the user with an information journey which takes as its starting point their current location. This provides an initial information window closely connected to the physical information that they are simultaneously receiving through their senses. As that window then moves with the user, digital information may also be presented as a "series of revelations".

'Serial vision' is one of three broad concepts which Cullen employs, the others being Place and Content.

'Place' he analyses in terms of every person's awareness of "the position of [their] body in its environment" (Cullen 1961 p12). From this position (which is our 'here') he identifies the necessity for a 'there' and the importance of the interplay between those two concepts; "… we discover that no sooner do we postulate a HERE than automatically we must create a THERE, for you cannot have one without the other" (Cullen 1961 p12). If geo-referenced information enables us to place information and context around our 'here', what best constitutes, in terms of information, our 'there' becomes an interesting question. It has already been suggested that the 'there' should be something other than 'everything' or 'anywhere'.

'Content' for Cullen is "the fabric of towns: colour, texture, scale, style, character, personality and uniqueness" (Cullen 1961 p13). His greatest concern is for creating (or better, allowing) "character and individuality" and "nuances of scale and style" within "…a commonly accepted framework" (Cullen 1961 p14).

Cullen summarises his three main concepts through juxtaposed pairs (Cullen 1961 p14):

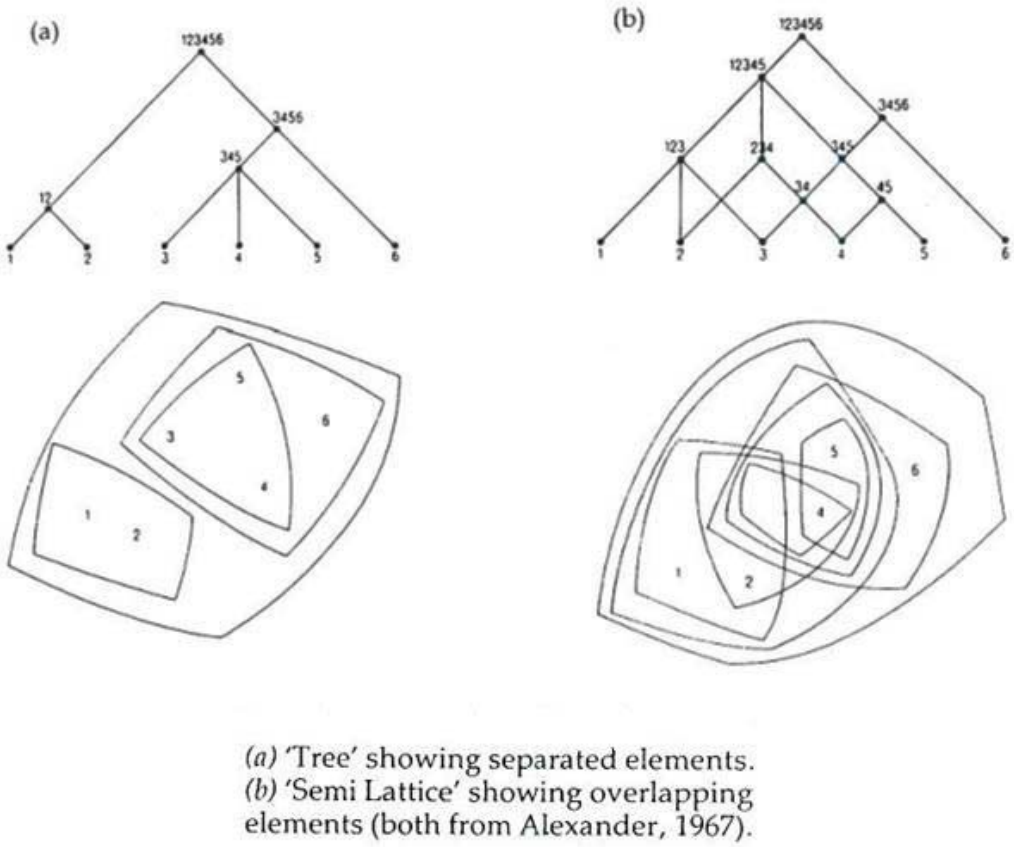
Serial Vision	↔	Existing and Emerging
Place	↔	Here and There
Content	↔	This and That

Christopher Alexander

In *A New Theory of Urban Design*, Christopher Alexander describes an organic process of urban growth in which each expansion gives rise to interlocking and hierarchical nodes or centres, with other sociological and morphological concerns coming into play with each expansion (Alexander 1987 Ch 2, The Overriding rule). Alexander doesn't use the term 'fractal', but there are clear parallels with fractal patterns in the self-similarity, at different scales, of each increment of growth. According to Alexander, new centres emanating from an existing centre should be larger, smaller and similar in size to the existing centre or node.

Alexander's other contribution of interest here is his assertion that "a city is not a tree but a semi-lattice" (Alexander 1965) and that hierarchical models cannot capture the complexity and myriad feedback effects at work in a complex urban fabric. A semi-lattice is a form of a network comprising nodes connected by arcs. Paths are linear networks of nodes connected by arcs.

Network and graph theory is discussed further in 2.3.2 and they will play a crucial role in the development of an IA.



(a) 'Tree' showing separated elements.
(b) 'Semi Lattice' showing overlapping elements (both from Alexander, 1967).

Figure 2-2 – Alexander's network types (Alexander 1965 reproduced in Broadbent 1990, p144)

Jane Jacobs

Long before digital information became a focus of interest and analysis, theorists and advocates of urban design were describing models and options for urban design with significant information content.

Jacobs recognised cities as systems of *organized complexity* in which low-level behaviours (like street interaction) give rise to higher-level benefits. *Emergent* behaviour (as it would now be termed) is commonplace now in the theory of complex and chaotic systems but it was a more original insight in 1961 (Jacobs 1961 p54 – Jacobs does not use the term 'emergent' herself but others have characterised her work in these terms, see Johnson 2002 p94). The key point that Jacobs identified was that on-street interaction and visibility are not undertaken with the express *purpose* of providing greater security and social vibrancy; those are qualities which *emerge* from millions of daily interactions. As she puts it, those thousands of individual street transactions "… unite in their joint effect upon the sidewalk…". The emergent properties of millions of *electronic* interactions are still a separate area of investigation and debate.

Roger Trancik

Roger Trancik identifies three broad strands of urban theory based around figure-ground, linkage and place respectively (Trancik 1986 Ch 4). These broad concepts are further stimuli to the IA and some consideration will be given in chapter 7 as to what might be the 'figure' and what the 'ground' in the urban information layer. This leads also to the concept of 'positive space': space that is not simply that which is left over once buildings and other objects are in place. A 'positive information space' may represent a deliberate aggregation rather than simply a collection that happens to be geo-referenced to a given spot.

The themes of linkage and place recur frequently: 'path and district' in Lynch, 'serial vision and place' in Cullen, 'armature and enclave' in Shane (see below), 'space and articulation' in Smith (see below). This prompts consideration of an interplay between sequentially delivered information that matches a person's necessarily linear progress through a city and that which corresponds with a point of pause; information about a *place* rather than information that follows a *path*. Other qualities might accompany the two states:

Path/linkage/linear/armature ↔ sequence, flow, time-passing, breadth
Place/enclave/district/area ↔ settlement, stasis, time-stopped, depth

These will be explored further in the modeling in chapters 6 and 7.

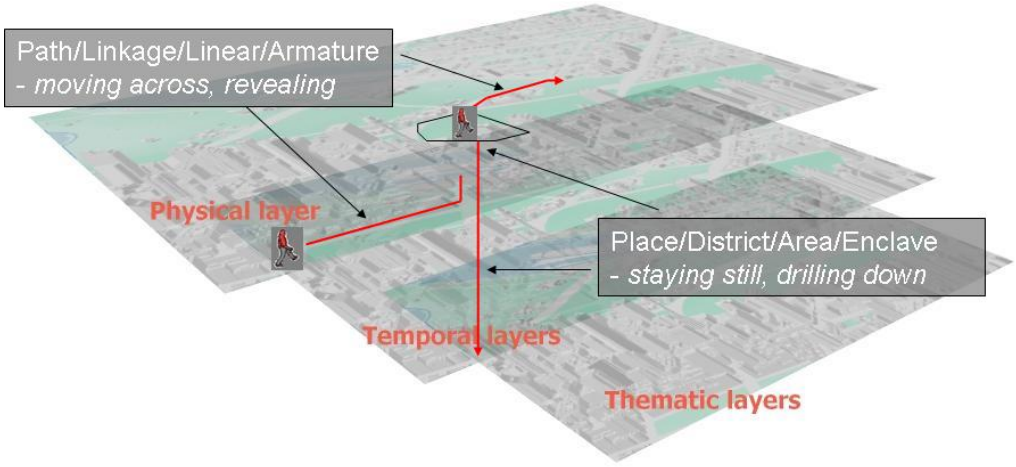


Figure 2-3 – Armatures and enclaves (by different names)

David Shane

David Shane, under the title *Recombinant Urbanism*, identifies three fundamental elements, enclave, armature and heterotopia (Shane 2005, Ch 3). Some of the ideas prompted by the first two have been mentioned immediately above. The third is an interesting concept from the point of view of information because almost any place, including one that might be physically simple, can be a complex and confusing information heterotopia if enough information about it is aggregated and delivered. This prompts consideration of choices either

made or offered as to how much information can be accessed from a given point and what criteria other than simple spatial proximity might be applied.

Shane also looks at a number of models in which city elements are identified and assembled as a series of '…ages': Decoupage, Collage, Bricolage, Photomontage, Montage, Assemblage and Rhizomic Assemblage (Shane 2005 p140). These various models highlight the fact that part of the complexity of cities arises from the interaction of elements in ways that are not always predictable.

The granularity of Shane's elements affects how much can be achieved with their combination. To take a simple example, a single element of 'street' cannot easily be recombined into alternative paths; on the other hand, 'street-segments' connecting 'nodes' can be recombined much more easily. In urban design terms, the key element is neither the street nor the street segment but the *path*, a more complex, higher-level, concept. Enhanced urban information services (and the IA which underpins them) will need to deal with these higher-level elements, as they are still the most prominent artefacts encountered in the urban environment.

Peter Smith

Peter Smith takes a more psychological approach and emphasises the importance of allowing people to interpret and interact with their urban environment at different levels simultaneously. Broadly, these levels reflect our need for "… novelty and surprise on the one hand and security and stability on the other …". Psychologically, Smith identifies four ways we can perceive: (Smith P 1977 p86)

- Serial, cognitive, logical, verbalistic
- Holistic, patterned, intuitive
- Imposing on data symbolic coloration
- Limbic-intensive

The first two roughly coincide with activities directed by the left and right hemispheres of the brain respectively. The third explores our ability to perceive underlying symbolic patterns, such as centre-and-periphery, and the ambivalent nature of basic urban ingredients like water (alternately nurturing and threatening). The fourth is a more visceral mode of perception, a subconscious response to colour, texture and decoration.

A rich urban information service might offer something for all these modes of perceiving. Smith also emphasises the dangers of both monotony and overload in sensory stimulation, a point echoed by Ayssar Arida (see below). Smith also analyses and, to some extent makes a

case for, articulated urban spaces which exhibit close, extended or attenuated coupling and thereby offer varied experiences of "the here and the beyond" (Smith P 1977 p163).

Consideration is now given to some writers whose work includes an examination of the nature and importance of information in urban space – they do not, however, focus on digital information and they tend to write more directly from an urban design viewpoint than the 'digital urbanists'.

Nikos Salingaros

Nikos Salingaros (Salingaros 1998, 1999a, 1999b, 2000a, 2000b, 2003) has developed a number of proposals and observations on morphology and urban perception that heavily emphasise the information content of urban space. His focus is generally on the direct, visual, information affordance of built structures and physical form. His analyses go further, however, to suggest how this information content enhances urban experience and, in particular, how it can bind together urban spaces.

Salingaros has developed a theory of 'information fields' in urban space (Salingaros 1999). In this case, he is looking at the characteristics of physical structures that give the richest and most accessible information to those experiencing them. These include (Salingaros 1999 Part A):

- Complexity in surfaces – colonnades, fluting, variety of light reflection, protruding edges and corners, domes, vaults and arches
- Information focusing spaces – courtyards, amphitheatres
- Accessibility through convex curved surfaces
- Information depth through fractal scaling
- Concavity and enclosure
- Use of materials, textures and pigments to maximise information exchange from all angles

These are physical and spatial attributes that maximise visual information in urban space. Do they have equivalents for information of other sorts, including that delivered electronically? Salingaros's bugbears are modern, smooth surfaces that convey little information (Salingaros 1999, reprinted in Salingaros 2005 pp50–51). An analogy with regard to information might be single dimensional information about a place, for example the availability of only commercial information.

An archetypal example of the sort of effective urban structure Salingaros praises is an amphitheatre (Salingaros 1999, reprinted in Salingaros 2005 p46). Is it possible to imagine

presenting an amphitheatre of information? What are the qualities of an amphitheatre that are valued?

- It focuses the attention of many people.
- It enables shared experience.
- It facilitates awareness of context by enabling a view beyond that which is being focused on, realised through stepped or sloped seating and a resulting view over the top of or around the stage.
- It gives a reassuring, but not claustrophobic, sense of enclosure.
- It enables a pleasing, fractal-like, repetition of design elements (the enlarging scallops of the *palazzo* in Sienna).

What might be an experience of urban information that matched these qualities?

- Access to information relevant to the current location but also access to that which lies just beyond (but not to *everything* that lies beyond).
- A mechanism to share the information quickly.
- An ability to keep drilling down into the information to get to the level of detail desired.
- An ability, if desired, to interact with the information source.
- A sense of enclosure is difficult; perhaps a reassuring sense of orientation provided by knowledge of the broader context of the information.

Salingaros reminds us that there are certain aesthetic qualities that the human brain seems to respond to instinctively, particularly a fractal-like ability to drill down through successive layers, including the appreciation of structures and facades at different scales (Salingaros 1999, reprinted in Salingaros 2005 p56). This is a powerful analogy for the designer of urban information services; a key design issue should be the appropriate layering of information in ways that best facilitate its delivery at a scale that matches the requirements of the information user.

This idea can also be applied to the temporal depth that information can give to urban experience. As has already been mentioned, cities are like human brains with various reptilian and mammalian stages still present. Where they have not been returned to *tabula rasa*, cities mirror this; their history and development still resonating in contemporary structures. (The layout of Sydney's streets, for example, still follows to some extent early colonial and possibly even Indigenous routes.) Where the physical traces have been obliterated, a body of information somewhere still documents what has gone before.

The morphological and other principles Salingaros highlighted in his series of papers between 1998 and 2004 have as their basis mathematical constructs of various levels of rigour. The principles of most interest here might be summarised as follows:

- Nodes are not just physical constructs – they connect human activity.
- Effective networks involve paths that are numerous, irregular, on a variety of scales and incorporate some redundancy.
- Over-clustering of nodes results in sub-optimal path networks.
- Overloading channels through the coalescence of many paths results in blockage.
- Paths should connect complementary nodes.
- Fractal scaling not only describes much of the form and development of cities, it is intrinsic to human appreciation of physical form. For example, traditional forms of fenestration and detailing afford more interest and convey more information at multiple scales (from a metre away to 100 metres) than do smooth modernist surfaces.
- Concavity and enclosure also respond to human needs, particularly around public spaces (colonnades, porticos and amphitheatres are examples).
- Multiple scales are critical to both the functioning and appreciation of urban form and rules can be proposed for the distribution of scales. Salingaros proposes an inverse power law which interestingly matches with recent findings on networks (such as the internet) which also follow power laws (Barabási 2002 pp 150–1). He goes so far as to state that "...the internet follows the same structural laws as the traditional city" (Salingaros 2003).

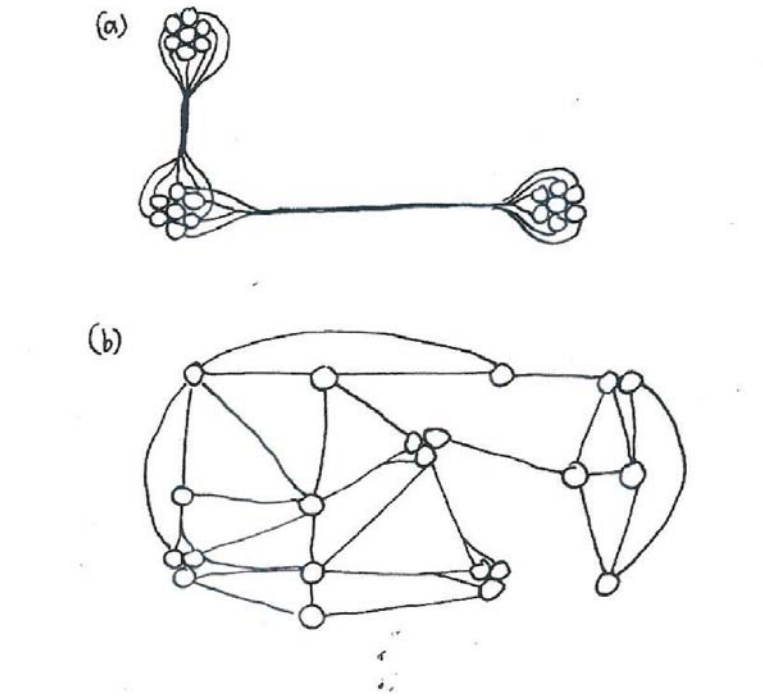


Fig. 2 Over-concentrations of nodes and connections create a singularity.
(a) Nodes are concentrated into three separate clusters, and all connections are forced into two channels. Such connections exceed the carrying capacity of the channels.
(b) The same nodes distributed with connections that work much better.

Figure 2-4 – Over-concentrated nodes and arcs compared with distributed (Salingaros 1998 reproduced in Salingaros 2005 p22)

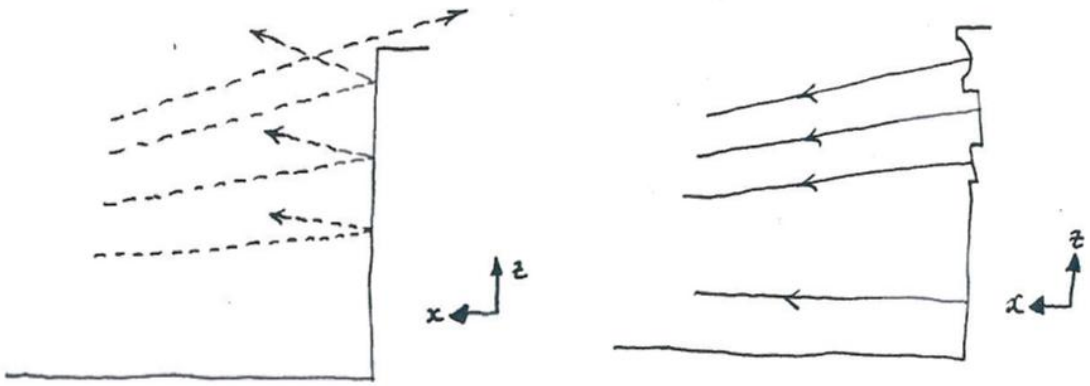


Figure 2-5 – Enhanced information affordance from complex surfaces (right) compared with smooth surfaces (left) (adapted from Salingaros 1999b reproduced in Salingaros 2005 pp50-51)

Salingaros is not particularly concerned to apply these principles to information architecture *per se* but information and information exchange play a significant role in some of them and his work is a rich source of structural ideas that can be applied to urban information as well as the physical urban environment.

Salingaros and Andrew Coward (Coward & Salingaros 2004) take these ideas further, applying concepts from IA directly to larger urban forms, particularly with regard to the role of information exchange between 'modules' at various scales. The boundaries of modules are defined by the presence of more intense information exchange within the module than without (these modules need not necessarily match a physical area). The optimal arrangement is that which minimises the overall load of information transfer by ensuring strong connectivity where it is needed (which leads to an argument against block zoning) (Coward & Salingaros 2004).

Michael Batty and Paul Longley

Salingaros's recognition of the fractal nature of cities is based largely on the work of Batty & Longley, writing 15 years ago. They applied fractal mathematics to describe both the dynamic process and static results of urban growth and assert that cities are *intrinsically* fractal objects (Batty & Longley 1994). The authors speculate on the utility of basing urban growth on certain fractional (fractal) dimensions.

Ayssar Arida

Ayssar Arida takes another iconic branch of 20th-century science as his starting point, quantum theory (he also mentions complexity and chaos theory as influences). He describes the role of 'event horizons' that ripple out from events (which might be nodes or activities). These event horizons are spheres of influence, complexity and meaning. 'Diventity', (as he

coins it, a mixture of identity, diversity and density) occurs where the fields overlap and interfere (Arida 2002 pp210–212).

Arida also discusses information in urban experience and the importance of striving for "optimal density of varied information", enough to create identity and differentiation but not so much as to overwhelm (Arida 2002 p176). Arida refers here to what can be seen and heard rather than digital information; he is measuring 'diventity' using, among other things, information density. This mirrors Peter Smith's concern for finding a balance between sensory deprivation and overload.

Almost unbearable sensorial stimulus in the 'real' part of Beirut. What the photo misses is the disorienting aural noise.

Almost unbearable stillness in a Dutch new town. The only hint to orientation is the sound of children from a nearby playschool.

Figure 2-6 – Information overload and underload (Arida 2002 p163)

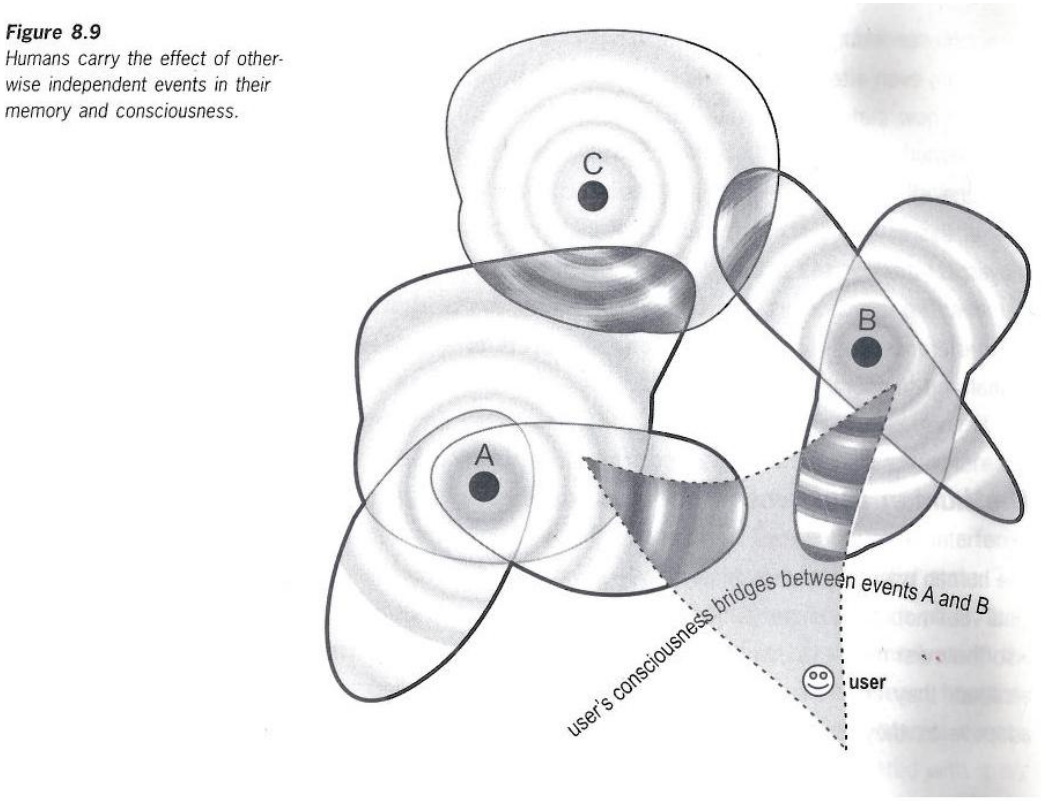


Figure 2-7 – Overlapping nodal 'event horizons' (Arida 2002 p154)

Bill Hillier

Bill Hillier also uses rigorous mathematical modelling but follows a completely different analytical path, focusing on the qualities of visibility and connectedness inherent in different morphologies in a system called Space Syntax™ (Hillier 1996). The conclusions are certainly normative in their analysis of 'dis-connected' spaces and their effects on, for example, social isolation and dysfunction (Hillier 1996 Ch 5).

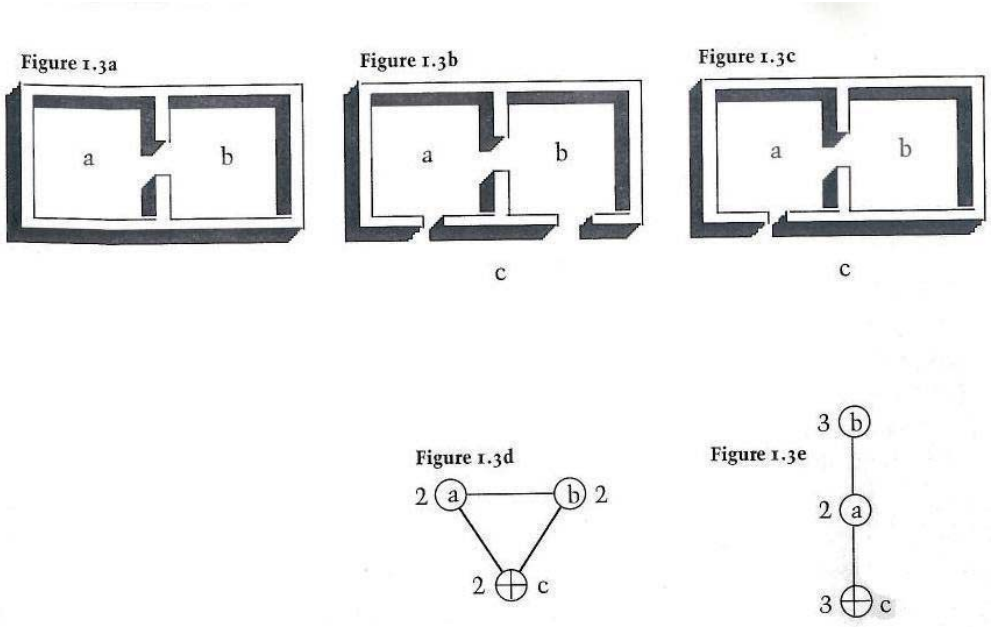


Figure 2-8 – Connectivity diagrams (Hillier 1996 p34)

These last few 'information-aware' urban thinkers all highlight the importance of information in the functioning and experience of a city. Generally, they have been concerned to apply their findings to the enhancement of the physical environment; in this thesis, their ideas will be applied to enhancing the architecture of the information layer itself.

The final two writers provide insights into another dimension of urban experience – time.

Yi Fu Tuan

Yi Fu Tuan emphasises the relationship between space and time and the way in which distance implies time in a way that mere length does not. The contraction of space and time is one of the clichés of the digital age. Does it mean anything now to assume that I can't interact with a place which is 'over there' because it will take me 15 minutes to get there when much of 'over there' might be available to me instantly on a handheld information device? Some options for capturing 'over there' in an IA will be considered in chapters 6 and 7.

Tuan also states "Space is historical if it has direction or a privileged perspective" (Tuan 1977 p122); from this standpoint, maps are too uniform and neutral to be truly historical (though that neutrality can be challenged) in contrast to a landscape painting which has a perspective and a point of view and in which choices have been made. Tuan's analysis suggests that, for a location to be given more than a facile sense of historical time, something more than a simple collection of temporally encoded snippets of information might be needed.

Stewart Brand

Stewart Brand (Brand 1994) describes the different speeds at which time moves and information changes, depending on the 'layer' at which one is operating. He defines a structure, or 'stack', of layers. At the bottom is the 'site', where information changes only very slowly; at the highest level is the 'stuff' that is highly personalised and changes constantly:

Layer	***Time-scale of change***
	Fast
'Stuff'	1 day – 1 month
Space plan	3–30 years
Services	7–15 years
Skin	20 years
Structure	30–300 years
Site	Eternal
	Slow

Figure 2-9 – Adapted from Stewart Brand – Pace layering in buildings (Brand 1994 p13)

Brand expanded this notion to cover broader aspects of society:

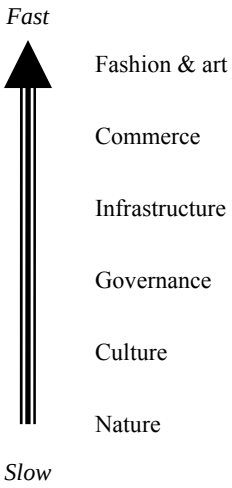


Figure 2-10 – Adapted from Stewart Brand – Pace layering in society (Brand 1999 p37)

Peter Morville has noted the implications of this for the pace of *information* change at the various levels (Morville 2005 p141). This idea of pace-layering can be applied more broadly to a wide range of information that might be delivered about a place as listed in the following table:

Information	*Timescale (information likely to change in….)*
Natural topology – what is the shape of the land beneath my feet?	1000s of years (unless large-scale human intervention)
Environmental – climate, soils and rocks, hydrological characteristics	1000s of years
Who owns the land?	Years, decades
Who occupies the land?	Years, decades
Who has jurisdiction over the land?	Decades, centuries
What are the boundaries of various jurisdictions?	Decades
For what purposes can the land be used?	Years
Who owns the built structures?	Years
Who built them?	Years
How are they built, what of?	Life of the buildings
For what purposes can the built structures be used?	Years
What are the built structures being used for now?	Decades, years, months
Who occupies the built structures now?	Decades, years, months
What are the methods of accessing and leaving this area?	Years
What services are available from the people and organisation occupying the built structures now?	Years
What transactions can I undertake with the people and organisations in the buildings?	Weeks, days, years
What are the current micro-climatic conditions at this point	Hours
When can I move on or away next and how (public transport etc.)?	Hours, minutes

Virtually all of this information is now available electronically and it is, or will soon be, accessible from any point at any time. Over time, the majority of it will be geo-coded as well, meaning that it can be automatically filtered on the basis of where it is accessed from.

2.3 Information science

There has been an explosion of activity in recent years around the definition and management of information. Some of this has come out of Artificial Intelligence (AI) disciplines. Some has been concerned with the next wave of development of the world wide web (starting with Tim Berners-Lee's call for the creation of a 'semantic web' (Berners-Lee 1998). Some has come from more prosaic efforts by organisations to improve their systems and processes for managing information, records, documents, content and knowledge. These efforts go under many names and 'Information science' is just a convenient collective term here.

In this section, some key recent developments are summarised, primarily for the purpose of assembling a 'toolkit' with which to respond to the requirements for an enhanced urban IA. Those requirements are outlined in the next chapter.

2.3.1 Web 1.0, Web 2.0, Web 3.0

Webs 1.0, 2.0 and 3.0 have become useful (though not uncontested) shorthand for different phases of the internet's development since the appearance of the world wide web ('www', 'the Web') and browsers in the early 1990s.

Web 1.0:

Web 1.0 was the original web of static data and manually encoded hyperlinks in html, later expanding to incorporate database-driven websites. The model was essentially broadcast-based with little interactivity.

Web 2.0:

Web 2.0 is a loosely defined collection of technologies and design principles that facilitates and advocates much greater interactivity and end-user input. One method of enabling this interaction is through 'tagging' whereby end-users are enabled and encouraged to label content with their own 'tags'. With sufficient usage, broadly accepted categorisation emerges in the form of a 'Folksonomy', a taxonomy generated by mass usage. *Flickr*^{TM}, *del.icio.us*^{TM} and *YouTube*^{TM} are three prominent websites which exploit the use of tagging. The quality of the resulting categorisation comes not from the deliberations of experts but from widespread adoption and self-correction; importantly, these are *emergent* qualities that depend on mass use.

Web 3.0:

The term Web 3.0 is largely (not entirely) synonymous with the 'semantic web' although it has not caught on as a label to the extent of 'Web 2.0'. The structures and technologies it identifies are intended to enable more 'meaning' to be built into information on the internet (rather than leaving all the intelligence to be supplied by a human mind examining and interpreting static data). Key technologies underlying this include XML (Extensible Markup Language), RDF (Resource Description Framework) and OWL (Web Ontology Language). There are others, but these are the best known.

These technologies are intended to describe and store information and in that sense they resemble databases but there are some fundamental differences. The semantic web has been designed from the start with the internet in mind. It is intended, therefore, to cater for the fact that, on the internet, anyone can say anything and anything can be labelled in any way; it is not a controlled environment.

The core semantic web standard, RDF, incorporates naming conventions based on fully qualified URIs (Uniform Resource Identifiers) that ensure that resources can be uniquely identified and effectively shared and connected (whether they are wholly electronic or labels for physical resources). Connection is the key purpose of RDF and the semantic web generally. RDF's basic information structure is called a 'triple' and comprises only three elements (as the name implies): a Subject, a Predicate (also referred to as a Property) and an Object. Triples are used to assign properties to objects of interest; the following ones identify elements and relationships that might model a Path:

Subject	***Predicate/Property***	***Object***
Node1	HasType	Intersection
Node2	HasType	Intersection
Node3	HasType	Intersection
Street_segment1	hasBeginNode	Node1
Street_segment1	HasEndNode	Node2
Street_segment2	hasBeginNode	Node2
Street_segment2	hasEndNode	Node3
Path	hasSegment	Street_segment1
Path	hasSegment	Street_segment2
Street_segment1	hasGradient	1:10
Street_segment2	hasGradient	1:12
Path1	hasAverageGradient	1:11

From these simple tri-part structures, more complex webs of information can be built. It is readily apparent that large data sets will require many 'triples' and sets of over a billion are already common. RDF also facilitates the sharing and combining of different knowledge domains.

The models which can be developed to describe how these triple structures might be organised and inter-related are known as ‘ontologies’ (not used in the original philosophical sense but as a label for models that describe a domain of knowledge). Ontologies can be designed in such a way that they are amenable to processing by a particular sort of logic known as ‘description logic’ and this opens the possibility of a certain amount of intelligence being built in to the information contained in the ontology. A very simple ontology already widely in use is Friend-of-a-Friend (FOAF) for describing people and relationships (http://xmlns.com/foaf/spec/).

The development of the ‘semantic web’ has not been without controversy and critics, and some have seen it as an attempt to reimpose top-down systems of categorisation and information management; perhaps even representing an attempt by the ‘information gatekeepers’ to fight back after being sidelined by global search engines, ubiquitous information access and Web 2.0. Peter Morville in his book *Ambient Findability* makes a case for treating Web 2.0 and Web 3.0 as complementary rather than exclusive approaches. He argues that the best technologies incorporate both ‘top-down’ and ‘bottom-up’ approaches and both are of value (Morville 2005 pp123–4).

Interestingly, as an illustration, Morville summarises the information requirements of a reasonably iconic urban activity, ‘A Walk in the Park’ (Morville 2005 pp153–4). He identifies these requirements as:

- faceted classification (more than a hierarchical taxonomy based on parent/child relationships)
- polyhierarchy (multiple parents)
- “pluralistic aboutness” (rich linking between concepts)
- temporal pace layering (as described in 2.2 with reference to Stewart Brand and referenced in Morville 2005 p141)

Semantic web technologies aim to meet many of these requirements:

- ontologies (rather than traditional classification hierarchies or taxonomies) provide faceted classification and polyhierarchy. In their fullest realisation, ontologies can enable the application of description logics and reasoning to complex knowledge domains
- RDF is primarily a framework and syntax for flexibly defining relationships between resources or concepts. A given thing or concept can of course be connected to many others and categorised in many ways which facilitates Morville’s “pluralistic aboutness”.
- The use of RDF also results in information being structured as a directed graph which can be navigated by hopping from node to node. This has obvious analogies to movement through urban space
- Sophisticated base ontologies of time have been developed and these facilitate the pace layering identified by Brand and encouraged by Morville.

This is not the place for a detailed technical exposition of these technologies, and there are many texts on OWL and RDF (Allemang & Hendler 2008 and Powers 2003 are just two this author consulted). Morville's book is an excellent and succinct introduction to some of the accompanying issues and debates.

It is a key assertion of this thesis that the semantic web technologies represent a rich and suitable framework for the encoding of urban design concepts.

2.3.2 Graph Theory and Social Network Analysis (SNA)

In the popular imagination, it all started with Kevin Bacon and a game to find out which actor shares movie credits with the most other actors. This led to the notion of 'six degrees of separation' and widespread interest in the characteristics of networks, particularly networks like the internet and those formed through social connections.

Formal graph theory preceded this popular awareness by some decades and it gave rise to results and techniques that impinge directly on the concerns of this thesis. Barabási gives a useful summary (Barabási 2002). The fundamental notion is that some systems are organised and can be navigated as a 'directed graph', i.e., a collection of nodes joined by arcs.

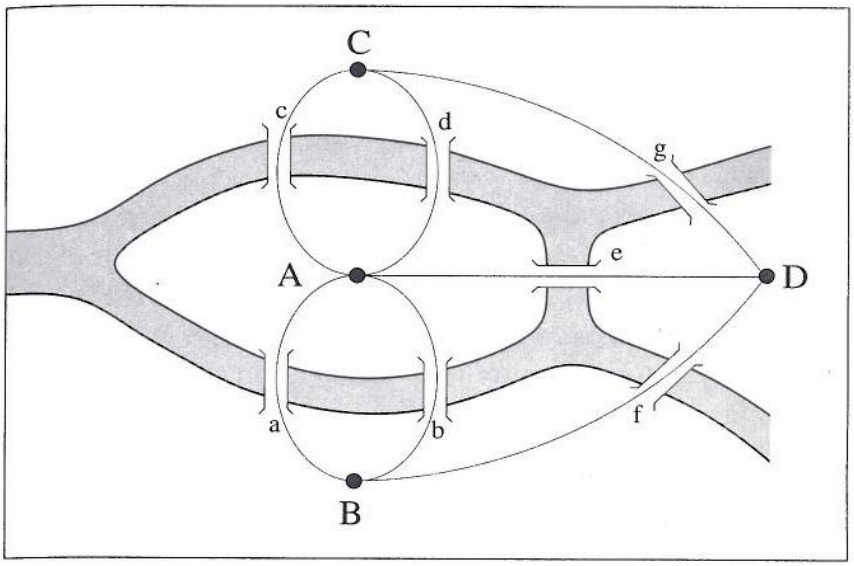


Figure 2.1 Königsberg Bridges. *The layout of Königsberg before 1875, with Kneiphof island (A) and the land area D caught between the two branches of the Pregel River. Solving the Königsberg problem meant finding a route around the city that would require a person to cross each bridge only once. In 1736, Leonhard Euler gave birth to graph theory by replacing each of the four land areas with nodes (A to D) and each bridge with a link (a to g), obtaining a graph with four nodes and seven links. He then proved that on the Königsberg graph, a route crossing each link only once does not exist.*

Figure 2-11 – Graph theory originating in an 18th century urban design problem (Barabási 2002 p11)

These graphs are highly analogous to the structures used in the semantic web *and* to the physical urban environment, particularly when it is described in terms of nodes and segments.

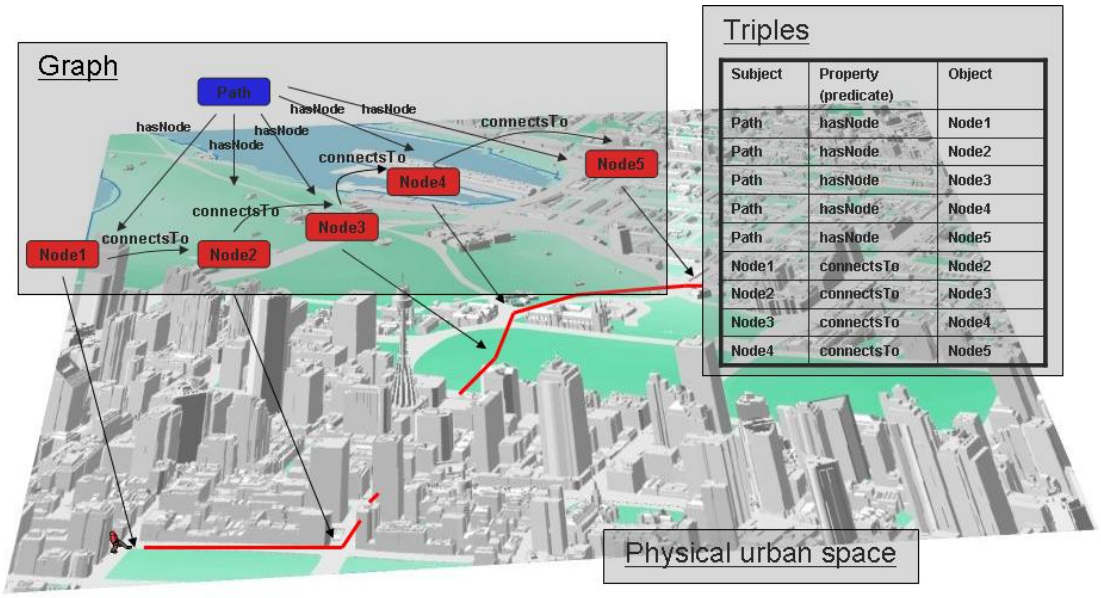


Figure 2-12 – Physical urban space mapped onto a graph mapped onto triples

This close mapping between urban space, graphs and RDF triples, as shown in figure 2-12, is the major reason for focusing on semantic web technologies.

A complete branch of analysis known as Social Network Analysis (SNA) accompanies the description of directed graphs. As the name implies, its initial focus was on networks of human-to-human relationships but its techniques can be used on any body of data that is graph-like. The sorts of analyses it supports include:

- Shortest path analysis – what is the shortest path from A to B based on the number of links between nodes on the path, i.e., the 'degrees of separation'?
- Ego-groups – which nodes (commonly meaning 'which people') are the most connected?
- Cliques – where are the 'cliques', i.e., groups of nodes which are strongly interconnected?
- Graph density – how closely connected is the graph as a whole?
- Robustness – how many links must be broken before the graph as a whole splits in two?

And there are many others. These are immensely powerful functions for modelling and analysing urban space. There has, in fact, already been a substantial intellectual effort which mirrors the techniques of graph theory although it wasn't expressed in exactly those terms when it was first put forward. Bill Hillier's Space Syntax analyses spaces as nodes which are

connected through physical access and visibility. The Space Syntax charts follow closely some of the constructs from social network analysis:

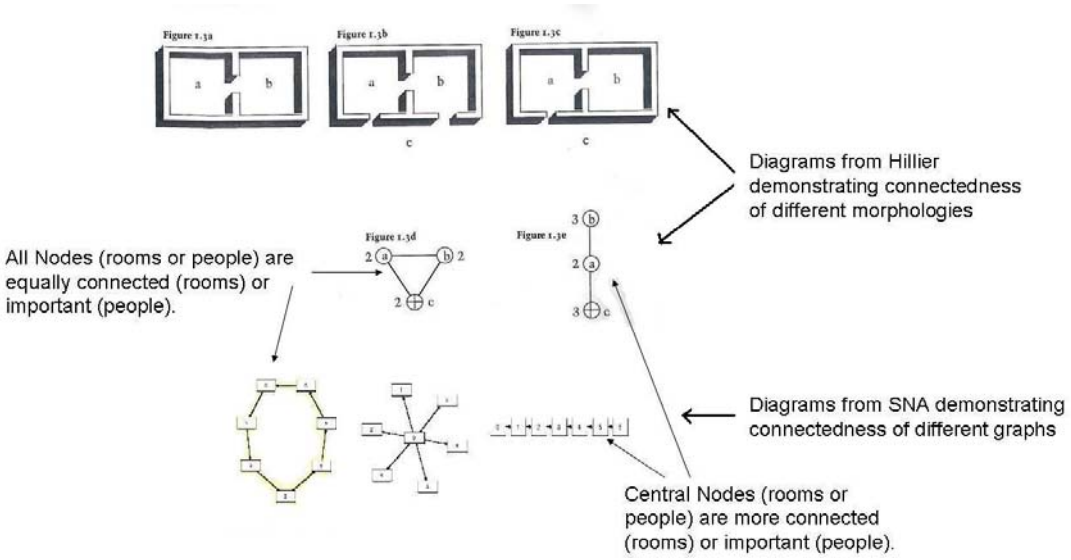


Figure 2-13 – Space Syntax analysis and Social Network analysis (adapted from Hillier 1996 p34)

2.3.3 Object Orientation (OO)

Initially a programming model (and an alternative to procedural programming), object orientation focuses on carefully defining the persistent 'objects' in a system and giving them clean interfaces so they can interact reliably with applications that use them and with other objects (Booch 1994 is a standard text on OO). Objects are normally organised into classes that share certain characteristics. Where objects are arranged systematically in hierarchies they can also take advantage of *inheritance* where sub-classes of objects inherit characteristics from higher level classes. For example a class of 'Building' might inherit characteristics from the broader class of 'Structure'.

Objects only interact through carefully designed interfaces, known as *methods*, which determine exactly what can and can't be changed within objects and what processes the objects can both deliver and participate in.

Part of the task for the designer of an IA is to identify the appropriately persistent 'objects'. In the urban environment, some readily suggest themselves, e.g., buildings and places (though even these concepts have many complexities); some, like paths, districts or networks are more subtle and the boundaries around these require careful analysis.

2.3.4 Geographic Information Systems (GIS)

GIS and spatial information generally have become very widespread in organisations dealing with spatial data in the last 20 years and have spread to mass usage (at least in simplified form) through *GoogleMaps* and similar platforms.

The basic capabilities of GIS are well known and include:

- Spatial search
- Measures of adjacency and overlap
- Distance and area
- Proximity of objects

Apart from defining the underlying grids and creating basic layers of topographical and cadastral data, GISs offer excellent platforms for placing and relating a wide variety of objects, many of which are urban. Increasingly, information on these objects will be drawn from ontologies and Frederico Fonseca and colleagues (Fonseca et al 2002) describe ideas for 'ontology driven GISs' which implement a model where spatially defined objects can inherit different 'roles' from different ontologies. For example, a lake may have a role of 'habitat' within a biological ontology but a role of 'recreation area' within an ontology of community facilities.

2.3.5 Services-Oriented Architecture (SOA)

This is a broad approach to systems design which developed over the last decade and quite closely mirrors the use of methods within object orientation. Rather than developing monolithic or tightly interdependent systems, development based on SOA focuses on building more loosely integrated systems which provide services to each other or to end-users. These services are commonly called and responded to via 'messages'. Often, though not always, these messages will be delivered back and forth via XML-based web services which are simply pieces of structured text (human-readable for easier management) which may contain requests for information and subsequently the response to that request. This is similar to the way objects communicate through methods. This paradigm has developed in conjunction with the internet where the possibility has arisen of delivering application functions across the web that could previously only be accessed within a closed system. For example, a system that supports the sale of merchandise, e.g. books, may expose services which allow another system or end-user to:

- check the availability of a given book (based on its ISBN perhaps)
- request the price
- order a copy

These services may be used remotely across the web without anyone actually having to directly access, i.e. 'log in', to whatever system is managing the transactions and information.

SOA also encompasses the notion of 'loose coupling', a term which encapsulates the importance of *not* creating a huge, integrated, edifice in which no component can be changed without risking the stability of the whole system. Components are instead designed as relatively independent services. This shift is reflected in broader design advocacy. One of McCullough's principles is 'from design as project to design as service' and, in an environmental context, Amory Lovins calls for a move away from 'goods and purchases' to 'service and flow' (Lovins et al 1999).

2.4 Literature discussion

In section 2.1, certain expectations were outlined as to what the four broad areas of literature could deliver. These are now assessed in more detail.

In general, the literature review did not uncover any work attempting to make a direct connection between urban design and information architecture for urban information services; the connection that is the prime concern of this thesis. Specific literature of this kind was sought initially from journals and conference proceedings, as there are no books or monographs specifically on the subject. When it wasn't found, the search reverted to broader-based sources for ideas on urban design and IA.

2.4.1 From *Digital urbanism*:

… the big picture on the developments that make the topic of the thesis of interest, and broad design considerations for the development of mobile information services.

The literature of 'Digital Urbanism' indirectly makes a strong connection between developments in information delivery, particularly mobile delivery, and the urban environment simply by setting much of its discussion within cities, starting with the 'City of Bits'. None of these writers goes on to analyse the possibilities of an underlying IA but that is not necessarily surprising as it represents an area outside their normal domain.

What is more surprising is that, despite the urban setting of much of the discussion, there is relatively little reference to the literature of urban design, apart from Townsend who raised the initial question over this apparent gap. What is found otherwise is only a some passing references to Lynch or Jacobs. A possible source for this disconnect is suggested by this quote from McCullough:

> *The pioneering work of the urbanist Kevin Lynch is known to many technology designers forty years later. Following Lynch, academic enthusiasm over mental maps of built environments perhaps reached a peak in the early 1970s. Then as psychologists found limits to geometric coherence, and architects found some of their essential understandings unquantifiable, research interests moved on. (McCullough 2004 p33)*

McCullough goes on to note that 'intent' and 'context' then began to assert their importance (McCullough 2004 p33) but this may have been a case of the baby being thrown out with the bath water; the 'mental maps' of Lynch weren't just cognitive constructs, they were representations of real, physical, urban artefacts that people navigate and use and that urban designers design and build. It seems unfortunate that they should have failed to find a place on the palette of the designers of urban *information* services.

There are certainly some broad design principles that emerge from writers like McCullough and Thackara; they assert that new mobile information services:

- should be 'situated' in time and space – not just anywhere and anytime
- should be embedded in physical infrastructure
- should be designed with interactivity in mind
- should facilitate the "close, complex and slow" (Thackara's description but broadly shared by McCullough)
- may need to cater for the fact (if not necessarily being able to counter it) that infrastructure, including the higher levels of information infrastructure, is tending towards increasing fragmentation rather than uniformity

2.4.2 From *Urban design:*

… the most crucial group, ideas and theories regarding the quality of urban space and how and where urban design can influence it. These ideas are harvested, in particular, for those aspects that can potentially be encoded into information structures. It is primarily from this group that requirements for the IA are derived.

The urban design writers in 2.2 are only a small subset of those that might have been referenced. As stated, the main purpose was to harvest a representative sample for ideas for encoding into an IA; there will always be other writers with other ideas. Also, is *not* the purpose here to critique these writers and their ideas regarding, for example, what constitutes a good Path; these ideas are taken largely at face value. Again, the main interest is in the potential encoding into an IA.

That said, there were some clear and revealing differences such as the contrast between the relatively 'static' analysis of writers such as Lynch, Shane and Arida with the more 'experiential' approach of others like Cullen. Those labels are probably unfair to both sets of writers but certainly Cullen (and perhaps Peter Smith) takes a great interest in *movement* (primarily pedestrian) in urban space. There are writers too who give great attention to the network characteristics of urban space such as Alexander and Salingaros. This gives rise to two modes of interaction with urban mobile information; that when we are stationary and that when we are on the move, the latter representing an opportunity to pause, reflect and dig deeper rather than survey, anticipate and look beyond.

From the urban design literature also comes, as anticipated, the identification of a wide range of specific elements like paths, nodes, districts and networks, and ideas and prescriptions for their effective design.

More broadly, writers like Alexander, Salingaros, Smith and Batty & Longley recognise deep-seated patterns of recognition that humans respond to:

- fractal layering of perception
- networks of complementary nodes
- the ability to perceive and interact at multiple levels simultaneously
- the ability to perceive underlying structures and symbols, possibly employing more ancient structures within the brain
- the importance of both diversity and connection in creating meaning
- the ability of space itself to create connection or isolation (Space Syntax).

Time:

Time is lamented by some as a 'lost dimension' (Virilio 1984) and from writers like Tuan, Brand and Thackara, we learn that time is not simply a neutral and uniform background dimension. We also learn from Brand that at different layers time moves at different speeds and our experience shouldn't be dominated solely by the fastest changing conditions in the highest layers of transaction and decoration.

The modelling and representation of time is a significant challenge in IA. Some mechanisms for capturing this time dependency will be discussed in chapters 6 and 7. The most important point to be taken from these writers is their plea that time be recognised as a valid dimension and that systems and information should at least be temporally aware and acknowledge that the structures and activities and networks of urban space all exist in time, are subject to change and have a history.

An urban IA should have the ability to reflect the dynamic and temporal as well as the static and spatial.

2.4.3 From *Information science:*

… comes a toolkit of standards and mechanisms that might be deployed in designing and building the urban IA.

A rich range of platforms and techniques has emerged from this review, particularly clustered around the semantic web. These will not be discussed further here but will be utilised in chapters 6 and 7.

Chapter 3 Requirements for a richer IA

Before considering how the material from urban design and 'digital urbanism' might be translated into a set of requirements for an enhanced IA, it is important to pause and consider just what the purpose and goals of that enhanced IA might be. There are different ways in which the information layer can interact with the physical city: four broad types of interaction are identified and considered below.

Efficiency:

The information layer may enable the more *efficient* use of the physical layer through enhanced navigation and information about the facilities, organisations and services that are contained within the urban area of interest. This is essentially what the 'yellow maps' services offer.

Appreciation:

The information layer may enable a deeper *appreciation* of the hidden layers of a city; these are mostly temporal: the history, stories, unseen alternatives and failed plans that lie beneath the visible structures. As suggested, part of this may be achieved through the provision of information that has the effect of slowing people's movement in urban space rather than speeding it up.

The information layer can add to the identity of a place in this way but it may also draw attention to diversity that is not immediately obvious; in combination, this may enhance the 'diventity' (Arida's term).

Connection:

The information layer may facilitate the achievement of normative urban design goals, in particular, the greater *connection* of parts of the urban fabric that are physically disconnected. It does this by making disconnected – 'invisible' – parts of the fabric 'visible'. This sort of digital visibility may even prove to be capable of ameliorating physical disconnectedness.

Integration:

Efficiency, Appreciation and Connection are all attractive adjuncts to the urban environment but it has already been asserted that the information layer has become a layer of similar status and importance to the other layers of the city and should do more, therefore, than merely describe those other layers. In other words, the information layer should offer an engaging and rewarding experience in its own right. This does not mean it is to be experienced independently of the physical city (though it could be) but that it is structured in a way that continually enhances and complements the physical experience.

One approach to achieving this is to design the information layer in such a way that it *shares the most rewarding qualities* of the urban environment it accompanies. I have labelled this approach *integration,* which does not entirely capture the idea, but will serve as a label. It is because urban designers are deeply concerned with identifying those qualities that their ideas are used so extensively in attempting to achieve this 'integration' in what follows.

Appreciation, because it is intended to tap into other hidden layers, also features prominently in what follows. *Connection* is treated more as a potential outcome of the other two. *Efficiency* features less as it is already, and increasingly, catered for by existing services.

The urban IA is intended to facilitate an *integrative* approach that results in the information layer sharing certain qualities with the physical urban environment as well as encouraging the greater *appreciation* of its hidden layers. What are the requirements that emerge from this discussion? They include:

- Cities are *networks of nodes* that may be *connected* or *articulated* with varying degrees of strength.
- Cities are *complex* and they reflect some of the characteristics of *complex systems*. They are a *multi-layered polyhierarchy* and cannot be described with a simple hierarchy or taxonomy.
- Cities exhibit *fractal qualities* at almost every level, from the large-scale growth patterns at a scale of many kilometres to the appreciation of textured surfaces at a scale of metres.
- Cities are made up of a very wide array of *elements* which should be recognised and manipulated at a fine degree of *granularity*.
- Cities achieve connection and meaning through the relationship of *diverse and complementary* elements, not through uniformity.
- Cities have larger-scale *underlying structures* (such as patterns of centre and periphery) which may be perceived and appreciated subconsciously.
- Cities are experienced *sequentially in time* and the view they offer as they are traversed changes continually.
- Cities are *temporal environments.* Such temporality might operate at five levels:
    - *Experiential* time – reflecting changes as the city is experienced, e.g., as it is traversed on foot
    - *Daily* time – reflecting the different roles that static elements take on at different times – particularly night vs day
    - *Seasonal* time – reflecting annual changes that also influence the roles elements fulfil (a deciduous street tree offers shade in the summer but not in the winter)
    - *Historical* time – reflecting what has gone before with regard to the human habitation of a place
    - *Deep* time – reflecting the long biological and geological history of a place before people ever reached it.

Taken together, all these add up to an ambitious set of requirements for an IA but there is an impressive toolkit assembled to try to accommodate them.

Some more technical requirements arise from the review of the information science literature:

- A services-oriented approach
- Loose coupling and robust information asset management
- An IA that can be easily shared and extended
- At a more practical level, it must be possible to query the IA effectively and flexibly deliver the information it contains.

Chapter 4 The IA 'toolkit'

It was mentioned in section 2.5.3 that the review of developments in information science provides a toolkit of platforms and techniques to deploy in meeting the requirements outlined in chapter 3. What is in that toolkit?

Services:

Information services supply data on request in standardised formats across the internet. A set of information services to support an urban IA is outlined in the next section.

Objects and classes:

Objects are coherent packages of information about both real-world physical objects and more abstract concepts. Objects are organised in hierarchies of c*lasses*. Classes may inherit the properties of parent classes.

The semantic web adopts many of the characteristics of objects but with some significant differences. In particular, properties (relationships) in the semantic web are first-class elements of equal status to objects and their classes. In fact, objects are defined not by their membership of a class but by the properties that are applied to them (i.e., the relationships in which they participate).

Objects for use in an urban IA need to be sufficiently granular but also persistent and robust. For example, a 'street segment' object is useful in defining paths but a small section of street kerbing would be too small to be useful (although it might be useful in the context of an asset management system). A set of objects for use in this urban IA will be described in chapter 5.

Graphs and social network analysis functions:

As noted earlier, semantic web standards lend themselves ideally to the definition and manipulation of directed graphs of the sort that are amenable to social network analysis (SNA). Superimposing onto the existing street network graphs that encapsulate urban design qualities is one technique employed in chapter 6. Social network analysis functions have already been mentioned including shortest path analysis, identification of ego-groups and cliques and the measurement of graph density and robustness.

Spatial querying:

Arising from the work in GIS, a sophisticated range of spatial queries is now available. Several functions have already been mentioned including spatial search and measures of adjacency, overlap, distance, area and proximity.

Temporal querying:

Various temporal querying functions are also available including points in time, time intervals and measures of before, after, overlap and simultaneity

Ontologies:

Ontologies are models of domains of knowledge that can be translated into semantic web structures (sets of 'triples' specifically). Ontologies can encode hierarchical classes of object-like elements as well as hierarchies of the properties of those objects.

Usefully, ontologies can also encapsulate rules about classes and their relationships. In semantic modelling, *properties* define the relationships between elements as well as the characteristics of elements. Rules are expressed in terms of properties and are formally called *restrictions*. An example might be a class of *street-segment* objects that have a property *has-traverse-time* so we might have:

street-segment-1	has-traverse-time	5 (minutes)
street-segment-2	has-traverse-time	15
street-segment-3	has-traverse-time	9

A restriction called 'shortSegments' might then be defined on the property has-traverse-time which encapsulates the rule 'has-traverse-time < 10'. This effectively creates a new *set* of objects containing all those street-segments with a traverse time of less than 10 minutes. That set can then be queried directly.

There are a number of high-level ontologies that encode standard forms of spatial and temporal objects and other generic objects and their properties. These can be inherited and used by lower-level ontologies describing more specific domains of knowledge such as an urban environment.

Semantic web triple-stores and Sparql:

Ontologies are models of domains whereas the actual content, i.e., the individual items that describe real-world things, are kept in *triple-stores*. These triple-stores can be queried using a language known as Sparql (http://www.w3.org/TR/rdf-sparql-query/) which has now been accepted as a standard by the world wide web consortium (the W3C). The advantage of Sparql (and query languages targeted at the semantic web generally) is that it implements very naturally sequences of *nested* queries. For example:

- Find my nearest Node (more on Nodes in the following chapters)
- Find all the Nodes close to my nearest Node
    - Of those – find those which are accessible on foot
        - Of those – find those which don't have any steps
            - Of those – find those which are safe
                - Of those – find those which are lit
                    - Etc.

This sort of nested query is possible, but not nearly as easy, in other environments (like SQL queries directed at a relational database). It is, however, the natural and normal way to 'dig into' a triple-store using a language like Sparql.

4.1 A note on the status of semantic web tools and applications

Although some of the basic semantic web standards like RDF have been in existence for more than a decade, broad adoption has been slow and the whole endeavour possibly distracted by some of the more esoteric possibilities offered by ontologies and associated description-logic techniques.

As a result, full semantic web applications are still rare and the maturity of some of the tools less than might be expected. Nevertheless, there has been a surge of commercial activity in the last 2–3 years which may indicate that a tipping point of acceptance and implementation is approaching. For example, a semantic web version of *Wikipedia* called *dbpedia* is now under development.

Some of the techniques and functions described in this chapter are not yet commonly available in off-the-shelf software but there are enough signs that they soon will be to justify their use in the modelling below. For example, social network analysis functions and a full set of spatial and temporal query functions are not yet available in the standard semantic web query language, Sparql. However, they *are* available in lower-level programming environments.

For this exercise, an ontology modelling tool known as *Topbraid Composer*™ (http://www.topquadrant.com/topbraid/composer/index.html) was used along with an associated interactive programming environment (running Lisp and Prolog) called *Allegro CL*™ accessing a triple-store called *AllegroGraph*™. These products come from Franz Inc (http://www.franz.com/), a company that develops semantic web software. Contact with the developers of these tools has confirmed that many of the shortfalls in functionality discussed here are being addressed in future releases; they are also all under active discussion at the W3C for incorporation into languages like Sparql.

It was never part of the purpose of this thesis to develop a full application or undertake a large amount of new code development, so the models described below take some of the required functionality as given in the knowledge that it is likely to be actually available within the next year or two as part of the standard suite of semantic web tools.

Chapter 5 Building blocks

Using some elements of the tool kit, some basic building blocks of the IA will now be identified. These include:

- services
- classes of objects
- basic spatio-temporal elements
- scales

5.1 Services

The IA of interest here needs to be positioned within a broader range of information services that it will both call on and contribute to. Once defined, these services will be treated as 'black boxes' for the remainder of the analysis and it will be assumed they are available to provide the required information as and when necessary. Treating the other services in this ways keeps the focus on the particular service (and the IA that underlies it) that attempts to encode and deliver those urban qualities described in the requirements in chapter 3: this will be referred to as the 'urban information service'.

The full set of services might include the following (there could be others):

- Current location service – simply gives the user's current coordinates. There are various techniques used for this including GPS and triangulation using mobile phone towers or wifi outlets. These have varying levels of reliability but, for current purposes, it is assumed that an immediate and a reasonably accurate position can be obtained.
- Date/time service – a service to deliver the current date and time.
- Visibility service – a service that indicates whether a given date/time in a given location is in daylight, dusk or dark.
- Weather service – a service that gives current weather information like temperature, humidity and wind and that indicates what season a given date/time and place is in.
- Cadastral and address service – providing information on addresses and properties.
- Basic navigation service – providing a basic, shortest-path, service based on the existing road grid.
- Directory service – the 'yellow map' providing information on services, organisations and events.
- Urban information service – the main one of interest here – that provides an overlay of information which enables deeper and richer urban qualities to be part of this suite of urban information services.

All these services, except the last, are already available although not necessarily backed by semantic web-based structures.

5.2 Object classes

Also required is a collection of appropriate objects of adequate richness and granularity organised into classes. The various services outlined in 5.1 will already be supported by appropriate objects, for example information about land parcels, organisations and the street network, but the focus here is the objects that will support the urban information service.

There are in fact relatively few of these basic elements and much will be achieved simply with nodes connected by arcs (which represent the segments between nodes).

NB: from here on, elements that become part of the modelling below will be capitalised (e.g., Node, Path).

5.2.1 Nodes:

In many ways, Nodes are the fundamental objects in the model; Segments and Paths are defined by connecting Nodes; even Districts, at certain scales, may be described as a Node or a collection of Nodes.

Nodes will initially be modelled as points (x,y, optionally z for altitude). A Node can, of course, be something other than a point-like urban element. Depending on scale, a Node might be anything from a square or intersection to an entire city at a larger scale. Larger Nodes will still be modelled as points but the point carefully placed where it is acting as a surrogate for a larger element which might, at a smaller scale, be modelled as an area.

Nodes can be of a wide range of types. As Lynch points out, a Node may be formed simply by the coincidence of transport routes. Alternatively, it may be more 'themed'; a concentration of commercial or cultural activity or even of architectural style or land-use (Lynch 1960 pp72–5). In many cases, therefore, Nodes cannot simply identify themselves through physical characteristics the way, for example, street segments or intersections can; they will need to be identified and labelled by an external agent, perhaps by an urban designer.

Nodes of some types will have a certain sphere of influence; something akin to Arida's 'event horizon'. This will apply primarily to themed Nodes which reflect some area of potential interest to the urban actor; an area of commercial, cultural or architectural interest, for example. This 'sphere of influence' might be expressed as a radial distance around the Node. Its presence might, however, also be signalled by clustering Nodes with shared characteristics and this is the approach taken below.

Nodes may have temporal attributes. Commercial or cultural Nodes may be 'active' only during business hours; a Node of purely architectural interest may be of interest both in the day and at night if adequately lit (and may be of even more aesthetic interest in the dark).

Nodes may have other attributes, such as whether they are accessible by foot, car, public transport or all or some of these.

We now gather these attributes into the specification of a Node object:

- Type
- Location (x,y,z)
- Active hours
- More subjective qualities, such as the presence of a view

An initial list of Types might include:

- Intersection
- Transport hub
- etc

Or they might be more generically defined as (which is the approach taken below):

- Major Nodes
- Minor Nodes
- Intersections (for navigation only)

Thematic labels might include (and need not be restricted to one per Node):

- Commercial
- Cultural
- Architectural

5.2.2 Segments (Arcs):

Segments are linear sections, normally of streets, but also other routes. Segments are 'atomic' elements which are not broken down any further for the purposes of this modelling. Segments have various properties:

- a starting point (Node) and an end point (Node)
- the presence or absence of steps and other accessibility impediments
- time-dependent qualities that might include lighting, safety (associated with lighting) and shade
- gradient
- size – this might be length given the largely linear nature of segments or there might be a value for the *speed* of a Segment as a measure of the time taken to traverse it.

Segments join Nodes and can, therefore, be modelled not as a class of objects but as Arcs between Node objects; this is explained further in the next chapter.

5.2.3 Buildings and Structures

There are urban elements that do not directly relate to urban design concepts like Path and District but which will be used in conjunction with them. These include:

- Buildings
- Parks and open spaces
- Structures like bridges
- Street trees

Attributes for these might include:

- Buildings will have:
    - Location
    - Optionally a Name
    - Type (residential, commercial, public, mixed)
- Addresses will have:
    - Location (normally obtained from an address service like *Whereis*)
- Streets will have:
    - Name
    - Streets will be linked sets of segments
- Parks and open spaces will have:
    - Location
    - Type
    - Name
- Structures like bridges will have:
    - Location
    - Name
    - Type (mode)
- Street trees will have:
    - Location
    - Evergreen or deciduous

Urban environments are complex, full of millions of elements of different types and this collection of elements could be added to almost endlessly.

5.2.4 Actors

Actors, for the purpose of this analysis, are people and groups such as organisations. People have preferences and intentions to which the urban information service needs to respond. Organisations commonly offer products and services, they occupy buildings and those buildings have addresses with geolocations (this is the model used by most 'yellow map' services).

People:

Encoding individual preferences is the subject of a great deal of work within the disciplines of HCI and 'interactive environments' and this aspect will be kept reasonably simple here. To illustrate the point, however, a simple ontology for personal preferences can be posited:

- Person
    - Preferred activities
        - Shopping
            - Clothes
            - Books
        - Eating
            - Italian
        - Cultural
            - Opera
            - Architecture
    - Characteristics
        - Mobility
            - No steps
            - Daylight only
            - Safety needs (hi, med, lo)

These preferences can be mapped to appropriate services and to appropriate qualities in the physical urban infrastructure, particularly where they relate to Paths.

Organisations:

Organisations are the other main actors in the city. They normally occupy buildings and frequently are the end-goal of urban movement. A small hierarchy of organisational types will be used in the model:

- Organisation
    - Retail
        - Clothes
        - Books
        - Etc
    - Food
        - Restaurant
    - Entertainment
        - Opera
    - Public
    - Etc.

In general, these hierarchies are kept relatively flat; the flexibility of the class structure means that deep and inflexible hierarchies are not required.

5.2.5 A note on temporally dependent objects

Objects organised into classes, like those listed above, correspond fairly intuitively with their physical counterparts. They also exist relatively independently of people's interaction with them.

Some objects are more complex, however: they are made up of more basic elements (like Nodes and Segments) and their definition often reflects a temporal dependency and requires some sort of interaction with a person. They are also more likely to be dynamically generated and be retrieved in conjunction with some sort of temporal query. Some examples follow:

Basic (physical) element	***Complex element***	***Interactivity***	***Temporal dependency***
Series of segments =	Path	When used by a person	Possibly only in daylight
Topographic high-point + large body of water =	View	When viewed by a person	Possibly only in daylight
Street tree =	Shade	When used by a person for relief from heat	Only in daylight and possibly only in summer
Prominent building, tower or natural feature =	Landmark	When used by a person as an aid to navigation	Possibly only in daylight
District =	Commercial	People transacting	Business hours
District =	Cultural	People engaging in cultural activities	Open hours unless 24-hour (e.g., outdoor sculpture – although then possibly daylight only)

This is another potentially endless list and those described above are only some that have a connection with the concerns of urban design.

5.2.6 Paths

Paths are made up of Segments which connect Nodes. Those Nodes may simply be Intersections which help construct the physical route or they may be more significant Nodes which give intermediate points of pause and interest and identify milestones, including the final destination. In this way they turn a route into a true Path. Paths which connect Nodes of this sort are more likely to instil a sense of leading from *somewhere* to *somewhere* or from *here* to *there;* a quality highly valued by Alexander, Cullen and others.

A Path might therefore have the following attributes. Many of these will be aggregated attributes based on the Segments that comprise the Path:

- Has a beginning Node and end Node
- Aggregate gradient – or a simple measure of the different altitudes of the beginning and end Nodes
- Aggregate or average speed or time to traverse
- Mode – indicating the suitability of the Path for pedestrian, bikes, cars etc.

Paths must, of course, be capable of being dynamically generated because Actors may want to go anywhere at any time.

5.2.7 Districts

Districts share with Nodes a mixture of physical and thematic characteristics; Lynch describes them as exhibiting "thematic continuities" (Lynch 1960 p67). Lynch also recognises fuzziness in the boundaries of Districts and the transition from one District to another is rarely abrupt (Lynch 1960 p69). Lynch also suggests some Districts are "introverted", some "extroverted" (Lynch 1960 p71). This may be a subjective perception but it may also be matched by a more quantitative measure such as the 'connectedness' analysed in Space Syntax.

Connectedness in fact offers an alternative modelling approach in which Districts are defined as a dense clustering of connected Nodes. For example, a commercial District may be defined by the clustering of retails outlets, a cultural District by the close proximity of cultural venues, a 'vibrant' District by the clustering of all the above with extended access hours.

Districts may, therefore, be given boundaries but they may also be inferred from the presence and density of connected Nodes with allowance for appropriate temporal attributes that encode those times when these districts fulfil these thematic roles (perhaps only at night for a cultural District).

5.2.8 Landmarks

Landmarks are difficult physical elements to match with a useful digital equivalent because they tend to rely on their very physicality and visibility to fulfil their role as a Landmark. One way they might provide added utility to an urban information service is if the end-user can, whenever they require it, be given an indication of the direction and distance of certain defined Landmarks (perhaps those they have themselves chosen).

Frequently, some other urban element (a building, tower, church or natural feature) will have the attribute of being a Landmark. Properties of Landmarks may include:

- Location
- Operative scale
- Visibility
- Temporal attributes – at what time is this a landmark (daylight only etc)?

5.3 Space and time

5.3.1 Low-level objects

Low-level spatial and temporal objects and functions include:

- Spatial
    - Point
    - Line
    - Area/Polygon
- Temporal
    - Point-in-time
    - Time interval

5.3.2 Events

Events are the fundamental element of historical time. They are a key access point into temporal layers. Events have been modelled in many contexts and commonly comprise:

- Start date/time
- Stop date/time
- Place
- Type
- Connection to other Events or objects
- Various associated Themes or ‘topics’

5.4 Scale

It has already been suggested that many aspects of this IA will be scale-dependent. For example, the whole of a CBD might be considered a Node when the scale is the entire city but, at a smaller scale, reflecting pedestrian experience, a small town square might be a Node, one that would not even appear at the larger scale.

It will introduce unmanageable complexities if we attempt to allow for an open-ended continuum of scales within the model. As noted in 1.1.6, the concerns of this thesis are positioned at a relatively intimate scale corresponding with a pedestrian experience. Two reference scales have been defined that correspond with two types of Node, Major and Minor (Intersections are added only to construct actual physical Paths as will be explained further in 6.1.2):

- Major Nodes – are significant precincts of at least a square kilometre that might define a District: for example, a CBD or 'downtown' area or a significant hub outside the city centre. Nevertheless, an area still navigable on foot in most circumstances.
- Minor Nodes – are Nodes close enough to be within about three minutes' walking time and therefore, at all times, reasonably 'within reach' – a maximum of about 250 metres apart.

The purpose and properties of these three types of Nodes are explained in more detail in the next chapter.

Chapter 6 Building the IA

The task ahead might be summarised as follows:

Use these items from the IA 'toolkit'	►	▪ Web services ▪ Objects and Classes ▪ Graphs and SNA functions ▪ Spatial querying ▪ Temporal querying ▪ Ontologies ▪ Triple-stores and Sparql
To create these building blocks	►	▪ Information services ▪ Objects classes (Nodes, Segments/arcs, Buildings and Structures, Actors, Paths, Districts, Events) ▪ Space and Time constructs ▪ Scales
To use in an IA that meets these requirements	►	▪ Network of Nodes ▪ Multi-layered polyhierarchy ▪ Fractal qualities ▪ Diverse and complementary elements ▪ Temporal awareness

One of the aims of this modelling is to get beyond what might be termed the 'tyranny of the geospatial': that flattening out of all the spatial features that comes with ubiquitous geospatial capability.

Any design process involves the privileging of some aspects of the object of design over others. An urban designer will identify and privilege some Nodes over others in assessing or creating a piece of urban space. That privileging will come about as a result of the assessment of qualities other than simple spatial proximity; utility, aesthetic reward, legibility, the complex of factors that contributes to 'affordance'.

To achieve this, the modelling here will deliberately *not* commence from a geospatial standpoint. This means that it will not commence with a digitally encoded map and consider "what spatial queries can be applied here to determine where I am and what is nearby?" Instead, it will commence with a set of Nodes and consider how they are related. For Cullen, urban design is the "*art of relationship*" (Cullen 1961 p10 his emphasis); the relationship of one building to another, of one urban space to the next, of one view in a sequence with what precedes and follows, of the existing and the emerging, of the here and the there. It is surely significant that, in the whole of *Townscape*, there is scarcely a single measurement or ratio or quantitative analysis of distance; these are simply not the most important aspects.

Geospatial capability will still play a role in this model but often it will only be called upon briefly at the start to provide an initial position, and then only for the purpose of identifying the nearest Node.

As indicated at the end of the last chapter, Nodes will be either Major, Minor or Intersections. These will be discussed initially in relation to their role in navigation.

6.1 Nodes for navigation

6.1.1 Minor Nodes

The most important are the Minor Nodes. They perform two functions:

- They provide a network of deliberately placed Nodes chosen for qualities of significance, interest, connectedness or other factors identified by an urban designer. They are used as the basis for generating Paths that, by virtue of the fact that they pass through these Nodes, will have more of the qualities urban designers value including the presence of successive destinations, a sense of progression and opportunities for pause. They will have more of these qualities than Paths generated simply by joining intersections. Minor Nodes may be positioned to *avoid* offering Paths through inaccessible or unsafe areas.
- Secondly, through their strategic positioning in the urban fabric, these Nodes can have other elements attached to them such as squares or other urban features, buildings, organisations or events. The whole structure can then be interrogated to reveal different 'slices' of the city depending on preferences and intentions.

As they are being used as an alternative to simple shortest paths (routes), Minor Nodes have to be close enough to cater for most movement requirements and therefore should generally be no more than about 250 metres, or three minutes' walk, from each other. Where the urban fabric is denser and the experience of it more intense, they may be closer together; where the fabric is either sparser or more uniform and less intense (e.g., a dormitory suburb rather than a CBD), they may be further apart.

They may also be absent if a given area has effectively no Nodes with attractions in their own right or that might usefully participate in defining a Path. This does not render that area invisible, it just means that, if there is a genuinely intended destination in that area, the standard geospatial navigation service can be employed rather than the 'urban information service' with its overlay of privileged Nodes and Paths.

Other urban objects (like the Buildings and Structures) can be related to Minor Nodes. This means they can be more intelligently attached than by mere geospatial proximity; it is a familiar urban phenomenon that an object that appears to be in close proximity from the map may be practically inaccessible compared with other objects at greater distance but better connected.

Note that, from here on, Nodes and other objects will be indicated on *maps* (background maps from *GoogleMaps* as utilised in *Topbraid Composer*) with a placemarker symbol …

… but on the *graphs* (which accompany many of the maps in this chapter and chapter 7) with a different symbol …

Note also that these graphics were generated by the semantic web modelling tools (primarily *Topbraid Composer*) and are not necessarily as clear or flexible as might be desirable for the diagrams below but altering their appearance was not practical.

Figure 6-1 – Minor Nodes (red)

6.1.2 Intersections

Once a Path, connecting several Minor Nodes, is identified, normal shortest-path routes between the Nodes are still required to actually offer effective navigation given that a straight line between Minor Nodes may be nonsensical as a physical route to follow (such as between MinorNode_21 and MinorNode_3 in Figure 6-1) . To achieve this, the Intersections of streets and other Segments are still needed.

In the modelling that follows, the Intersection Nodes are identified and used as required, but this sort of navigation might well be called as necessary from an existing navigation service like *Whereis* or *GoogleMaps* or more sophisticated systems like *Navman*™.

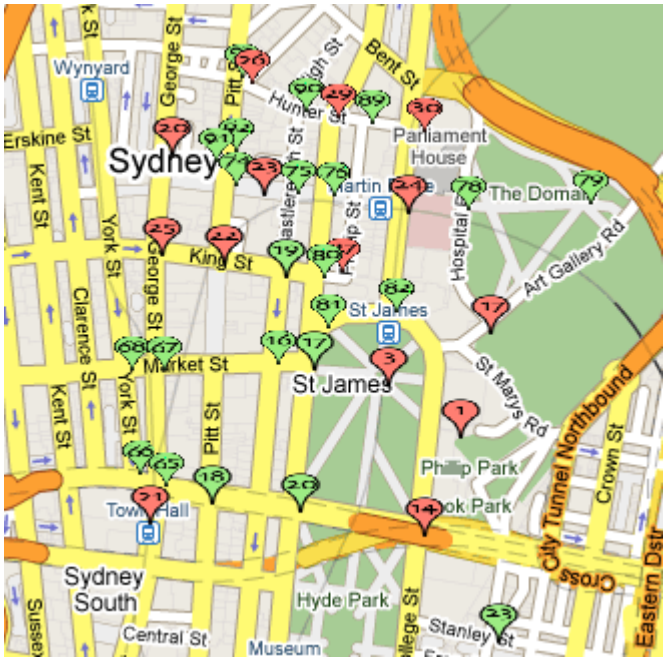


Figure 6-2 – Minor Nodes and Intersections (green)

6.1.3 Major Nodes

Minor Nodes operate at a relatively intimate scale but, even as pedestrians, we are often assessing whether to move between Nodes at a larger scale; from the CBD to 'Downtown' or from one District (however defined) to the next.

Major Nodes also identify central points of thematically defined Districts, like cultural precincts or CBDs, that might fulfil the object of a sentence like "I'm going to …the city centre or Chinatown etc". *Minor* Nodes are more likely to be encountered on the way to somewhere (while nevertheless providing intermediate points of interest or pause); *Major* Nodes are more likely to *be* the somewhere.

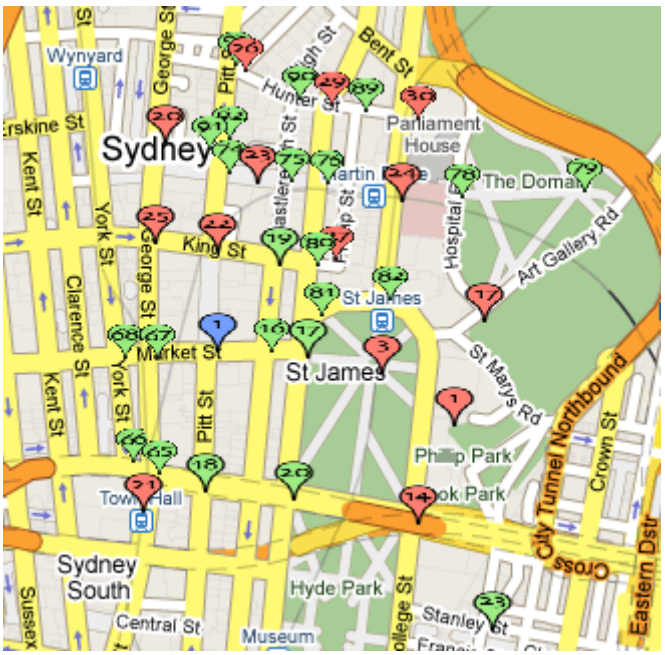


Figure 6-3 – Minor Nodes, Intersections and a Major Node (blue)

6.1.4 Node hierarchy

For the purposes of generating useful Paths, Nodes need to offer comprehensive coverage. It would be untidy to overload a given point with a Minor Node for some purposes and an Intersection for purely navigation purposes. Therefore, Nodes of any type can participate in the delivery of an actual Path by all acting as the endpoints of Segments. To facilitate this, the Nodes are kept in a basic class hierarchy as follows:

- Node
  - Intersection
  - MajorNode
  - MinorNode

This enables Major or Minor Nodes or Intersections to be queried discretely or, as required, all Nodes together can be queried through their common collective class ‘Node’.

6.2 Segments/Arcs

Segments will be modelled as the Arcs between Nodes; in semantic web terms, this effectively means that the segments are Properties of Nodes. The terminology can be confusing at this point: Segments, Arcs and Properties are effectively referring to the same thing as far as the model is concerned, as shown in Figure 6-4.

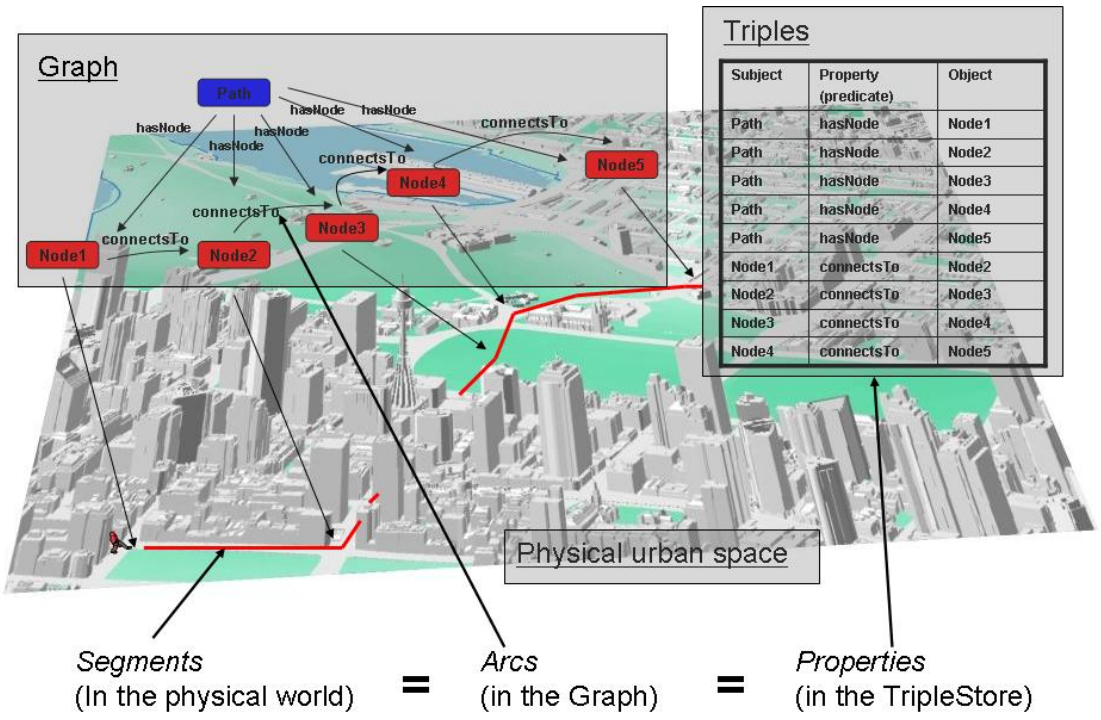


Figure 6-4 – Segments, Arcs and Properties

Why model Segments as Arcs (Properties) of Nodes? Why not model them as a class of objects in their own right? The advantage comes in the application of social network analysis (SNA) functions such as shortest-path algorithms. For example, if we are seeking only those Paths between two points that have certain qualities, such as 'safe at night' or 'no stairs', then we want the model to deliver Paths made up of Segments that have those qualities. Shortest-path functions operate by searching through specified Arcs that connect Nodes. If we define a Segment by creating an Arc of the type 'hasSafeConnection' and tell the model to generate a Path using only those Arcs, then we will be delivered a Path that contains Nodes connected only by safe Segments. If such a Path cannot be found, then the model will indicate that none is available.

There are only certain, generally more utilitarian, qualities that can be modelled this way because the result needs to be contiguous and the appropriate Arcs set up for every available Segment. For example, if we tried to model 'hasView' in this way in order to deliver Paths that include a view, then we might create Segments between some Nodes using the Property 'hasView' and tell the model to look along these Arcs when determining the path. The difficulty arises because it is likely that the majority of Segments will not have views and it is therefore difficult to construct viable Paths. The qualities modelled as Arcs need to be qualities that apply to most Segments because their absence 'breaks' the network.

Qualities which are not naturally contiguous are better modelled as properties of Nodes; this way, the appropriate Nodes can be selected and the Paths connecting them generated. There will be examples of this approach below.

The other semantic-web construct used here is that of *symmetric* Properties. If a Property is symmetric, then A -> B implies B -> A. A good example is spouse; if PersonA hasSpouse PersonB, then it can be inferred that PersonB hasSpouse PersonA. By contrast, hasHusband is not a symmetric Property. The Properties used to connect Nodes are all symmetric because they may be traversed in either direction.

Note that when it is stated here that something can be *inferred* in a semantic-web model, this means quite specifically that an *inference engine* can be run over the model and the extra data created. Therefore, when NodeA is connected to NodeB with the symmetric Property hasSafeConnection, there is no need to separately connect NodeB to NodeA in the same way.; the inference engine will do so automatically because of the symmetric nature of the Property.

6.2.1 Segment hierarchy

One of the fundamental advantages of the semantic web is that Properties (those constructs which define the connections between things) are first-class objects in their own right. This means it is possible to have hierarchies of Properties as well as hierarchies of objects classes. This has great advantages and so a hierarchy of inter-Nodal connections is defined:

hasConnTo
- ➥ hasSafeConnTo
  - ➥has24SafeConnTo
- ➥hasFlatConnTo
- ➥hasManagedConnTo
  - ➥hasFlatConnTo
  - ➥hasSafeConnTo
    - ➥ has24SafeConnTo

How is this hierarchy used? The key is in using the different levels for different requirements and in applying only some types of Properties to some types of objects. A combination of these approaches is used to actually model three qualities here even though only two are obvious in the hierarchy:

- ‘Flatness’ (absence of steps or other impediments to easy pedestrian access)
- Safety

The third quality emerges from the fact that the Properties which appear under hasManagedConnTo are used only to connect Minor Nodes (and the Intersections between them). The Minor Nodes themselves already capture certain qualities in generating Paths. The relevant Property class is named hasManagedConnTo in order to indicate that Nodes connected by this Property are ‘managed’ in the sense of being deliberately selected and placed, i.e., the Minor Nodes.

So the first decision to be made in using the model is, do I want, as an end-user, (or as an information service utilised by an end-user) to make use of the network of Minor Nodes? If

so, I should seek Paths along those Nodes connected by the Properties collected under hasManagedConnTo. Having made this decision, I can then opt for Flat Paths and/or Safe Paths and, indeed, Paths that are safe at night (through has24SafeConnTo, probably reflecting the availability of adequate lighting). If I am *not* in fact interested in using the 'managed' urban information service and am happy to simply be shown the shortest Path through any Node, the application should use the simple hasConnTo Property which will be used in the model to connect 'unmanaged' Segments between Nodes which lie outside the network of 'managed' Nodes defined by the Minor Nodes.

The point of having these arranged in a hierarchy is that any given Segment between two Nodes need only be assigned to the appropriate lowest level type, as illustrated here:

hasConnTo	→ is simply physically connected
↪ hasSafeConnTo	→ is physically connected and safe
↪has24SafeConnTo	→ is physically connected and safe day and night
↪hasFlatConnTo	→ is physically connected and flat
↪hasManagedConnTo	→ is 'managed', i.e. connects MinorNodes
↪hasFlatConnTo	→ is managed and flat
↪hasSafeConnTo	→ is managed and flat and safe
↪ has24SafeConnTo	→ is managed and flat and safe day and night

An example will clarify. Here are some Nodes connected by different Properties in this hierarchy. Minor Nodes are in red, Intersections in green, Major Nodes in Blue. For this example, a simple graph presentation is used rather than placing the Nodes on an actual map.

We want to get from MajorNode1 to MajorNode2:

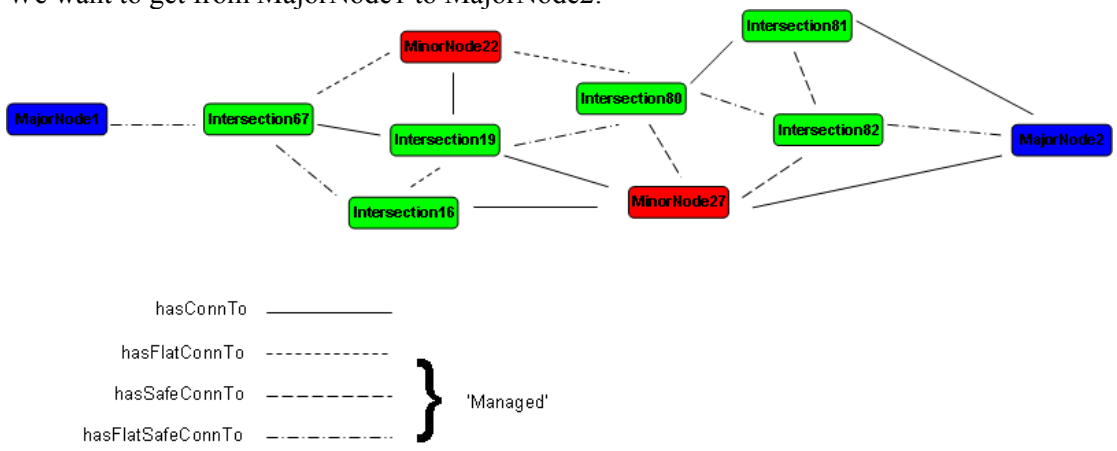


Figure 6-5 – Nodes and connections

If we don't care what sort of Path we want to be offered, the application finds the shortest path using all available connections up to and including simple hasConnTo connections:

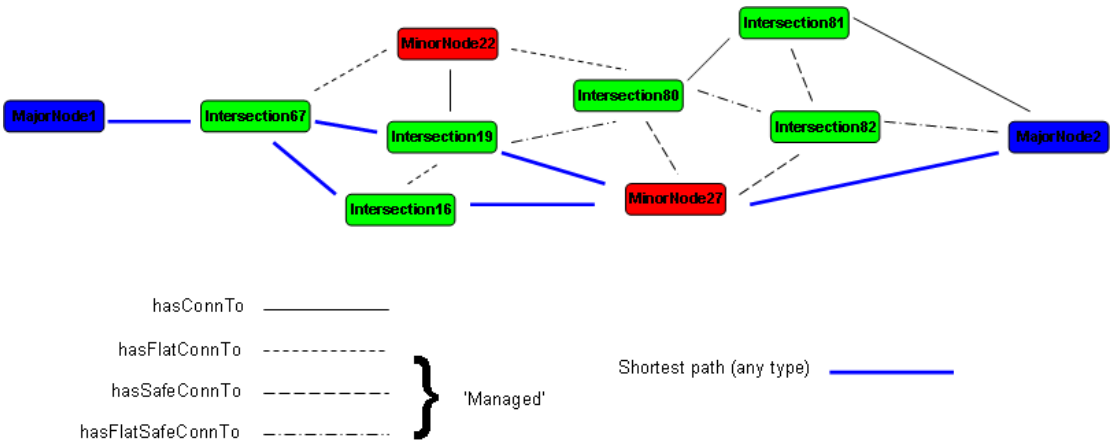


Figure 6-6 – Shortest Paths (2) from MinorNode1 to MinorNode2 through any connection

If we prefer to be offered a 'managedPath', which takes advantages of the thoughtful identification of the Minor Nodes, the application finds the shortest path using all available 'Managed' connections:

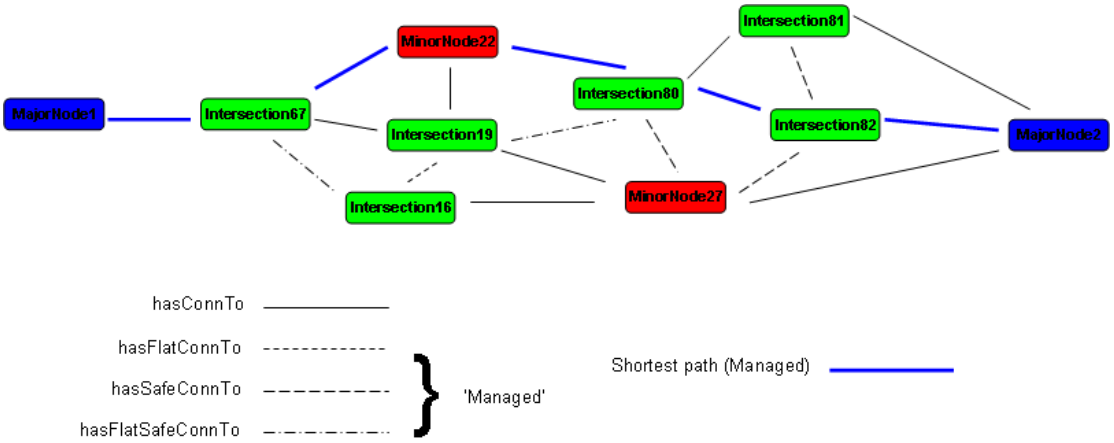


Figure 6-7 – Shortest Path from MinorNode1 to MinorNode2 through 'Managed' connections

If we prefer Paths that are managed *and* flat, the application finds the shortest path using all available connections up to and including hasFlatConnTo connections:

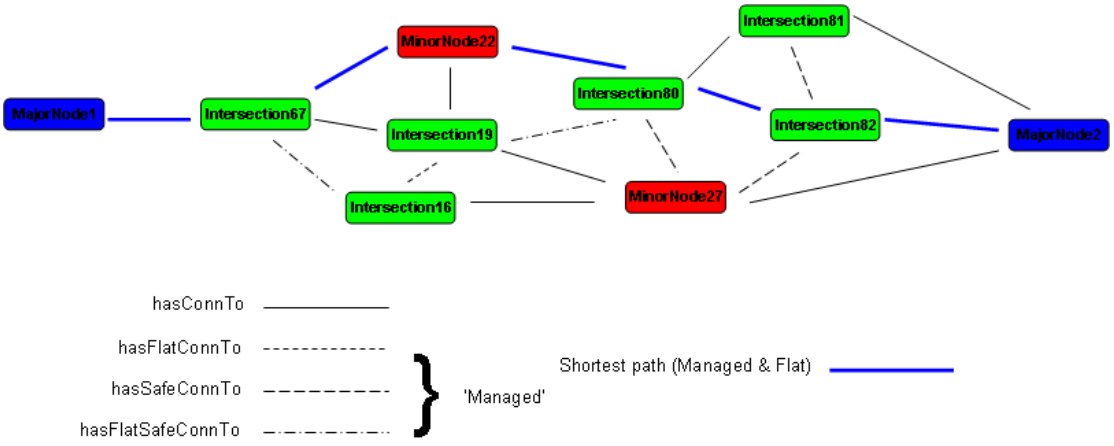


Figure 6-8 – Shortest Path from MinorNode1 to MinorNode2 through Managed and Flat connections

If we prefer Paths that are managed *and* flat *and* safe, the application tries to find the shortest path using all available connections that are both hasFlatConnTo *and* hasSafeConnTo; in this case, such a Path is not available:

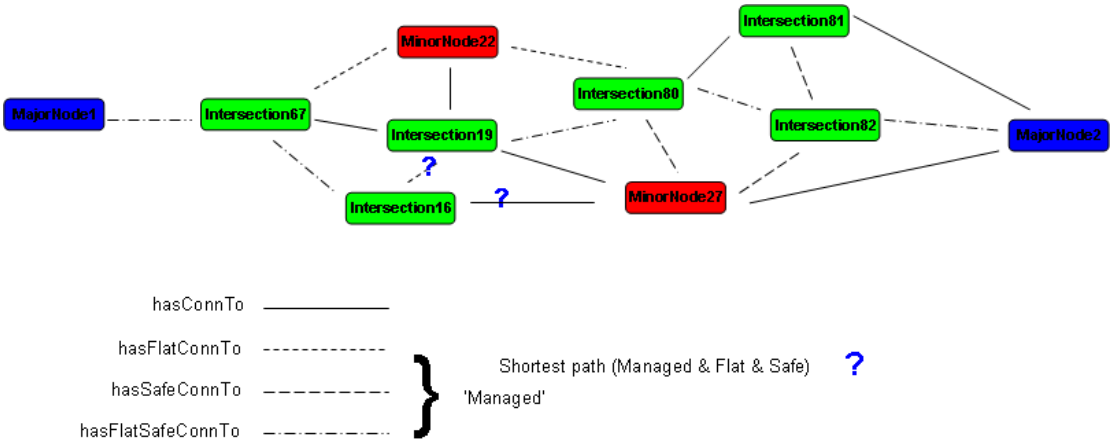


Figure 6-9 – Shortest Path through Managed, Flat and Safe connections

Effectively, the graph is 'broken' by the absence of a Flat and Safe connection leading from Intersection16.

6.2.2 Paths through multiple selected Nodes

The examples in 6.2.1 just connect two Nodes. Frequently, several Nodes will have been selected; perhaps they are Nodes to which are attached other objects of interest (see 6.3). In order to generate a Path through all the Nodes, a slightly more complex function is required which starts with the nearest Node to the starting point, generates a Path to it and then finds each successive nearest Node and builds up a Path through all the Nodes. An example of a Path-generating function like this, written in Common Lisp, can be found in Code Sample 1 in Appendix B. This example also illustrates how the graph-like structure of the data makes iterative functions like this relatively easy to construct and utilise.

NB: These snippets of code have not been extensively developed or fine-tuned (and it should be remembered that this was never intended to be a coding exercise). They were developed only to the extent required to check the validity of some of the modelling concepts.

6.2.3 A note on weighted-shortest-path algorithms

One way around the limitations of what can and can't be modelled effectively as Properties/Arcs is the use of weighted-shortest-path functions. *Simple* shortest-path functions treat all the Arcs with equal value and the shortest path is that with the least number of Arcs (effectively all the Arcs have an equal weight of 1.0). A *weighted* function of this sort will take into account differing weights on the Arcs and adjust the final calculation accordingly.

In fact, current navigation services like *GoogleMaps* and *Whereis* operate like this now; in their case, the *weight* represents the physical distance of the Arc (which matches a physical Segment).

For a path-finding service that takes into account qualities other than just distance, the ideal function would be one which takes various weights into account in identifying the best Paths to deliver. Some of those weights would be binary: for example, a Segment either has steps or it doesn't, so it would have a weight of either 1 or 0 for the Property 'hasSteps'. On the other hand, a Property like 'isSafe' may be weighted on a scale of 1 to 5.

Unfortunately, for this purposes of this modelling, no generally available weighted-shortest-path function for use in a semantic-web environment could be found. However, given the suitability of the semantic web for SNA analysis, there is good reason to expect that such functions will be available in the near future (emails with Topbraid developers, Oct 2008).

6.3 Nodes as aggregators of other object classes

The second main purpose for Nodes is to act as aggregation points for other classes of objects. Those objects might be any from those listed in 5.2: Organisations, Buildings, Structures, Parks and Open Spaces etc.

For this modelling, these objects will be attached to Minor Nodes or directly to Major Nodes where that Major Node is doubling in the role of Minor Node (to avoid having unnecessary overlapping Nodes).

There are alternatives to this approach which have not been followed for the reason outlined below:

- *Just use geo-spatial.* Rather than find those objects attached to the currently nearest Node, why not simply do a geo-spatial search for all the objects of interest within a certain radius? As already stated, one of the intentions in this modelling is to explore how much can be delivered while staying within the network of Nodes and Arcs which the semantic-web structures facilitate. One of the advantages this gives is that, having identified the Nodes of interest, it is quite easy (as described in 6.2.2) to then seamlessly construct an appropriate Path.
- *Attach the objects to any Node, not just the Minor and Major Nodes*. The purpose of attaching as much as possible to the Minor/MajorNode network is to tap into the design intelligence applied to the placement of these Nodes (mainly the Minor Nodes). Intersections are created purely for the purpose of creating contiguous Paths.

Minor Nodes can also be given other qualities which can be used to limit initial selections and which would be too onerous to have to apply to all Nodes including Intersections. For example, if the end-user wanted to be directed to 'Nodes with a cultural theme' which also had bookshops attached, that is a straightforward query in Sparql to find the Nodes so themed with bookshops attached. It gets more complex if those bookshops are attached to a scattering of Intersections, all of which would have to be culturally 'themed' if the query were still to be effective.

6.3.1 Aggregating objects and Districts

The Property used to attach objects to Nodes will be 'nearestNode'. Furthermore, Minor Nodes will be clustered around Major Nodes using the Property 'nearestMajorNode'.

This facilitates the sort of fractal-like recursive querying that we are trying to achieve. For example (and there will be further examples in chapter 7), several Minor Nodes may have bookshops attached to them:

Bookshop_1	nearestNode	MinorNode_1
Bookshop_2	nearestNode	MinorNode_1
Bookshop_3	nearestNode	MinorNode_1
Bookshop_4	nearestNode	MinorNode_4

… and those Minor Nodes may be attached to a Major Node:

MinorNode_1	nearestMajorNode	MajorNode_1
MinorNode_4	nearestMajorNode	MajorNode_1

…a relatively simple Sparql query (see Code sample 2) can then retrieve any Bookshops attached to Minor Nodes which are attached to MajorNode_1 along with (expressed as 'UNION' in the query) any Bookshops that are directly attached to MajorNode_1 (where MajorNode_1 is acting as a stand-in for a Minor Node).

This makes it very easy to conduct successive searches like:

- find all the bookshops just nearby (attached to the nearest Minor Node)

  … and then expand that search to:
- find all the bookshops a little further away (attached to Nodes attached to the nearest Minor Node)

  … and then expand that search to:
- find all the bookshops attached to the Major Node to which the nearest Minor Node is attached.

The last search might be expressed as 'search for all the bookshops in this *District*' if, as suggested, we take our definition of District to be a collection of Minor Nodes clustered

around a Major Node; a definition which sits comfortably with those definitions from the urban design literature that emphasise *connection* over *proximity*.

6.3.2 Serial information

There is a further advantage to this approach in that it facilitates the delivery of 'serial information' in a way which has some parallel with Cullen's 'serial vision', i.e., successive revelations of new material as one moves through urban space.

Having defined a Path through a series of Nodes, there is then the opportunity to retrieve and reveal what is attached to each Node as the path is traversed; this will enhance the role of those Nodes as intermediate goals which help give the Path shape and interest. (Remember that the use of the Minor Nodes in the first place to guide the choice of Path has already helped to ensure that it is a Path along which more and interesting revelation is likely.)

What exactly is revealed at each point will be a combination of all the attached objects (which could be many) filtered according to some choice made by the end-user.

A choice could also be made as to how far out to look at each point. If geo-spatial techniques were being used, this might involve searching 50 metres around or to either side of the current position. Alternatively, where, as here, a network of Nodes is being used, this might involve searching for what is attached to the nearest Minor Node or searching out another 'step' for what is attached to any Minor Node attached to the current Minor Node.

This involves connecting the Minor Nodes in some way and this is done with another Property, 'nextNode', which is used to connect adjacent Minor Nodes (and Major Nodes where they are standing in for Minor Nodes). The nextNode Property is also useful if we want to navigate among Minor Nodes irrespective of the details of physical navigation (as supplied by the Intersections).

6.4 Time

Five types of time were identified earlier as requirements for modelling:

- *Experiential* time
- *Daily* time
- *Seasonal* time
- *Historical* time
- *Deep* time

6.4.1 Experiential time

This was discussed largely in the context of Cullen's serial vision and the temporal element it introduces to the experience of urban space. The corresponding part of this model is its ability to successively reveal information as a Path is traversed through the use of connected Nodes.

6.4.2 Daily time

This has been modelled to some extent by modelling Segments as Properties using some temporally informative Properties like 'has24SafeConnTo'. Nodes and the objects connected to them are amenable to further temporal qualification.

Although sophisticated temporal calculation is becoming available for Sparql and other semantic web tools, this aspect has been kept quite simple in the current model. So, for organisations, it is generally sufficient to define a small set of weekday and weekend opening hours to cater for most cases (in Australia at any rate). These might be:

Whether an organisation is:

- 7 day
- 6 day (Monday to Friday plus Saturday) or
- 5 day (Monday to Friday only).

Opening and closing hours on those days can be separately defined. Organisations are given a Property hasOpDays (has operating days) which can be set to OpFiveDays, OpSixDays or OpSevenDays (these three being instances of a class OpDays). Another small class hierarchy is also defined:

OrgOpDays (organisational operating days)
- ⮑OrgFiveDays
- ⮑OrgSixDays
- ⮑OrgSevenDays

… these classes are in fact *inferred* classes and are defined as follows:

OpSevenDays = Organisations with hasOpDays set to OpSevenDays
OpSixDays = Organisations with hasOpDays set to OpSevenDays *or* OpSixDays
OpFiveDays = Organisations with hasOpDays set to OpSevenDays *or* OpSixDays *or* OpFiveDays

The advantage of creating inferred classes like this is that they can be queried directly. For example, having determined that the current day is a Saturday, we can directly seek Organisations that are of type OrgSixDays, i.e., they are open on the current day, a Saturday. The use of the inferred classes means that, if it is a weekday and we search for OrgFiveDays Organisations, we will automatically pickup the SixDay and SevenDays Organisations as well, as would be appropriate.

Having determined what Organisations are operating on the current day, we can query their opening hours to ensure they are actually open for business. For this purpose, Organisations have the following Properties:

- hasOpeningWk
- hasClosingWk
- hasOpeningSat
- hasClosingSat
- hasOpeningSun
- hasClosingSun

... all with an appropriate value based on a 24hr clock.

Code sample 3 in Appendix B shows a Sparql query which searches for Organisations of type Bookshop which are attached to MajorNode_1 (as in Code Sample 2) but which are also open on a Saturday and open now (11:00am).

There are many other and more sophisticated ways to model this and more complex calendars can be devised but this suffices to demonstrate that *Daily* time can be captured in the model.

6.4.3 Seasonal time

The changing mood of an urban environment brought on by changes in season is such a physical experience that any attempt to mirror it digitally may seem misguided.

One possibility, nevertheless, is with regard to tree cover. We can create a class hierarchy of trees:

Trees
- ➥Deciduous
- ➥Evergreen

These Trees can be attached to Nodes with nearestNode:

DeciduousTree_1	nearestNode	MinorNode_1
DeciduousTree_2	nearestNode	MinorNode_1
DeciduousTree_3	nearestNode	MinorNode_3
DeciduousTree_4	nearestNode	MinorNode_3
EvergreenTree_1	nearestNode	MinorNode_3
EvergreenTree_2	nearestNode	MinorNode_3
EvergreenTree_3	nearestNode	MinorNode_3

An inferred class of Nodes called AllYrShadyNode can then be created which is defined as a Node which will have shade all year around because it has at least some values of EvergreenTree attached to it through the nearestNode Property (in actual fact the *inverse* of

nearestNode – which is defined as isNearestNodeOf – will be used because we want to start with the Nodes and find those to which Trees are attached).

Having determined the current season (from an appropriate web service), we can then filter our selection of Nodes so that if it is winter and we still want shade, Nodes can be chosen from the class AllYrShadyNode.

A natural corollary of this would be a class of ShadyNode which is defined as Nodes which have *any* Trees attached, thereby linking it with the collective class Tree rather than Deciduous or Evergreen. In summer it would be appropriate to choose from the ShadyNode class.

On the other hand, in this case, it might also be best to ignore the information service and just enjoy the shade wherever you find it!

6.4.4 Historical time

Having dealt with the main types of cyclical time, we now explore what sort of information structures might support reaching back into historical time at any given point and thereby enriching our *appreciation* of where we are.

This is a different exercise from those undertaken so far; more static, less morphological, less amenable to the input of urban design and more dependent on the long-term maintenance of information by a wider variety of actors. Nevertheless, advantage can again be taken of the power inherent in using information structures modelled as a connected graph.

There are two main techniques used here:

- *attaching resources* – the first is a simple mechanism to attach temporally encoded digital resources of historical interest (multimedia, text etc.) to defined objects (Buildings, Places, Organisations etc.). This reflects many activities already underway such as the addition of geo-referenced images to *GoogleMaps* and, similarly, placing links to *Wikipedia* entries on *GoogleMaps*. Given these developments are already well underway, this option is dealt with only briefly.
- *Events* – the second approach is to define an information structure for Event. There have been many initiatives exploring event-like structures (one example is the *Historical Event Markup Language,* heml.mta.ca/*).* A relatively simple structure is used here because the main purpose is to link it into the existing network by attaching the Events to Nodes and attaching the Events to each other and to Actors who participated in them. Once Events are connected to they can be navigated in a similar manner to the Nodes and Structures on the 'surface'.

6.4.4.1 Attaching resources

A Property of hasResource is created which can provide a URL for any number of digital resources (preferably temporally encoded) that will enhance the information available for the object they are attached to. For example:

Building_1_Hilton_Hotel hasResource http://nla.gov.au/nla.pic an21295591-45 (Image of Hilton Hotel)

Building_1_Hilton_Hotel hasResource http://en.wikipedia.org/wiki/Sydney_Hilton_bombing (*Wikipedia* entry)

There are of course many copyright and access issues associated with the deployment of digital resources like this but they are not the main concern here.

6.4.4.2 Events

Anything that is in the past is an Event. This point might be debated philosophically but, for the purposes of this modelling, Events provide a flexible mechanism for recording past information.

The structure is very simple. Events have Properties of hasStart and hasFinish (both Date/Time) and a geographic location. Like everything else, Events can be attached to Minor Nodes.

Events can be of an essentially infinite variety of types and only some limited hierarchies are offered here. So Buildings and other Structures may have Events such as:

- Construction
- Opening
- Modification
- Demolition

Events may be themed in any number of ways:

- Political
- Cultural
- Economic

Events may be of identifiable types:

- Demonstration
- Sporting
- Anniversary
- Crime

This is an area where ‘Folksonomies’ can come into their own. Once the Event itself is identified and placed in time and space, people can apply their own thematic categorisations to it. However, not everyone wants to go to that trouble, and many are happy to be guided by another’s educated attempt at categorisation.

The most attractive aspect of this structure for the purposes of this model is that it offers a seamless mechanism for ‘digging down’ into other temporal layers as illustrated in Diagram 1-12. It is even possible to take a ‘temporal Path’ through linked Events between Nodes on the surface.

6.4.5 Deep time

Beyond historical time, there are no Events or familiar objects with which to anchor detailed information. For the purposes of presenting information on deep time, geo-referenced digital resources (similar to those described in 6.4.4.1) can be made available to show, for example, earlier sea levels and shorelines and changing geological structure over deep time. Commonly, these will be presented in the form of GIS-generated layers of spatial information.

6.5 Bringing it all together

The various elements of the model have been discussed separately but much of the richness they might offer becomes more apparent when several are used in conjunction. These possibilities are best explored in the context of some test data involving a real area. This will happen in the next chapter and below are three scenarios that will be used that combine several parts of the model.

Most scenarios begin by calling on putative web services to supply parameters that are the used in further information retrieval:

1. Get current position
2. Find the nearest Minor Node, referred to below as the currentNode
3. Get current day and time
4. Get user preferences for navigation (safety and accessibility)

A variety of different options are then explored through the three scenarios:

Scenario 1:

Step 1. Find any Organisations themed 'cultural' (bookshops, commercial galleries etc.) nearby (i.e., attached to the currentNode).

Step 2. Find any Organisations a little further away (i.e., attached to Nodes attached to the currentNode).

Step 3. If too little is found, search the District (i.e., everything attached to Nodes attached to the nearest Major Node).

Step 4. Check which are open at the current day and time.

Step 5. Find a Path to the Nodes these Organisations are attached to which does not involve going up or down any stairs and use the 'managed' network of Minor Nodes.

Step 6. As the Path is traversed, let the user know about cultural institutions (public galleries, libraries and museums but not shops) nearby or a little further away (as defined in step 2).

Step 7. If a diversion is taken to one of these cultural institutions along the way, reset the Path to the remaining 'cultural' Organisations.

Scenario 2:

Step 1. Find a Path from the current District (i.e., the Major Node to which the currentNode is attached) to the next District (Major Node) which is safe to traverse.

Step 2. Find a 'temporal Path', if there is one, through Events which link the current District to the next District.

Step 3. As the Path is traversed, step through the Events which link the two Districts together and offer any available information concerning those Events.

Scenario 3:

Step 1. From the current position, assess the density of information of different types connected with the immediate area.

Step 2. Access different information 'views' of the surrounding area, highlighting different themes or types of objects.

Step 3. For a given type of object, perhaps buildings of a certain architectural style, retrieve more information about those objects.

Step 4. Find out if those objects are connected to each other in any way.

Step 5. For a given individual object (again, perhaps, a building), explore the boundary between the public information about and around the object and the more private information about what is within it.

Chapter 7 Testing the IA

In this chapter, the model that has been built in the previous chapters is tested on a limited set of real data. A fully fledged case study would involve collating a greater amount of information for a larger area and would include the development of an application for testing on actual end-users. Here, a relatively small amount of information has been created by hand, just sufficient to validate some of the proposed information structures. The sample data is all real, in that it corresponds to actual places, organisations, people and events, but it represents only a tiny sample of the information that might be aggregated for an area as dense and complex as a busy CBD.

The area chosen is in and just to the east of the CBD of Sydney, Australia. There are two clear Major Nodes in this area, the CBD itself and the 'red light' hub around Kings Cross to the east of the city. While the two Nodes are only about 1.5 kilometres apart, they are severely disconnected by the intervening area around Woolloomooloo. This is an area preserved from major redevelopment in the 1970s but subsequently criss-crossed by major transport infrastructure such as a railway, freeways and a cross-city tunnel. These intrusions have exacerbated existing physical features, resulting in an almost impenetrable barrier between two areas that, in other circumstances, might complement each other in an extended 'central city' experience. While an analysis of the urban design characteristics and issues of this particular area is not the purpose here, it is interesting as a test area because of the problems of permeability and navigability it throws up and for the presence of a low-income residential enclave in between two busy and crowded commercial and cultural districts.

Into this area have been placed a range of Nodes and other objects. They are all given a geo-reference (point) and they are indicated with placemarkers as follows:

Major Nodes	
Minor Nodes	
Intersections	
Buildings	
Events	
Organisations – Retail – Bookshops	
Organisations – Food – Restaurants	
Organisations – Public	

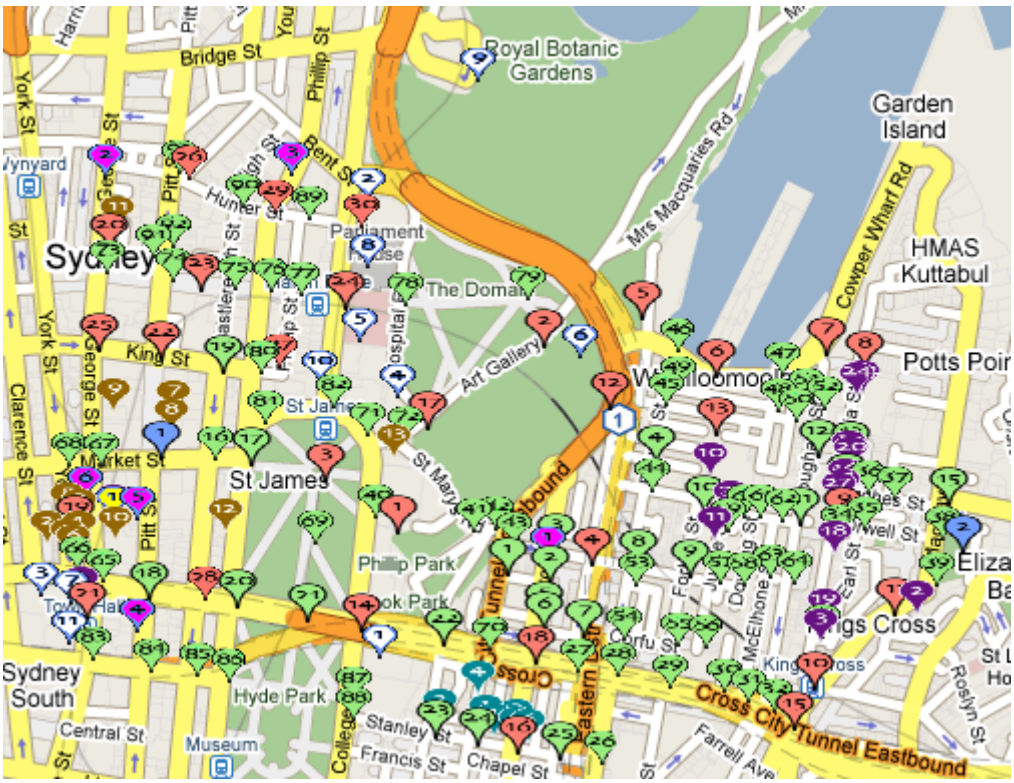


Figure 7-1 – All objects in the test area

The Major Nodes have been placed near the 'heart' of the two main areas; in the CBD at the busiest end of the Pitt St mall (Australia's highest value retail strip), and in Kings Cross, at the El Alamein Fountain (a particularly well-known landmark in a small park in the centre of 'The Cross').

The Minor Nodes have been placed as described earlier, i.e., at places that are, in fact, Nodes in an urban design sense such as:

- places where Paths converge like MinorNode_3
- places where there are points of interest or pause like a café – particularly in an area where other such features are absent – MinorNode_4 is an example of this
- places which may not have such focus but which help to achieve a reasonably even spread of Nodes not much more than 250m apart, e.g., MinorNode_1 and MinorNode_2. However, there are areas where this is not sustainable due to the absence of any viable real Nodes and this reflects the disconnected nature of the central area between the two Major Nodes

The nextNode network between the Minor Nodes (and Major Nodes standing in for Minor Nodes) is shown in Figure 7-2. As will often be the case from here on, this is shown as a graph retrieved directly from the model: in this case it is placed alongside the physical network (shown on a map) to illustrate the connection between the two.

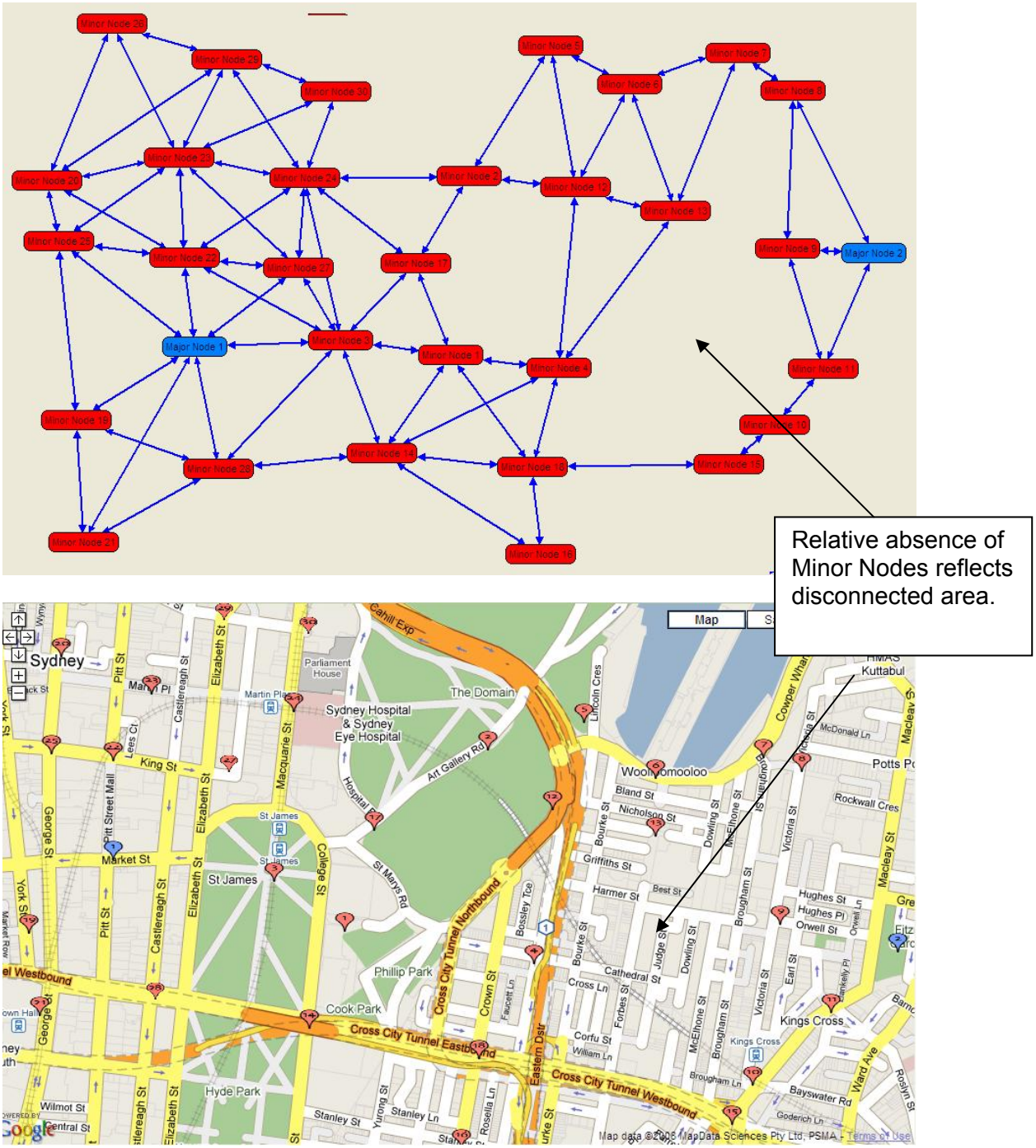


Figure 7-2 – Network of Minor (and Major) Nodes in the test area

To this can be added the Intersections:

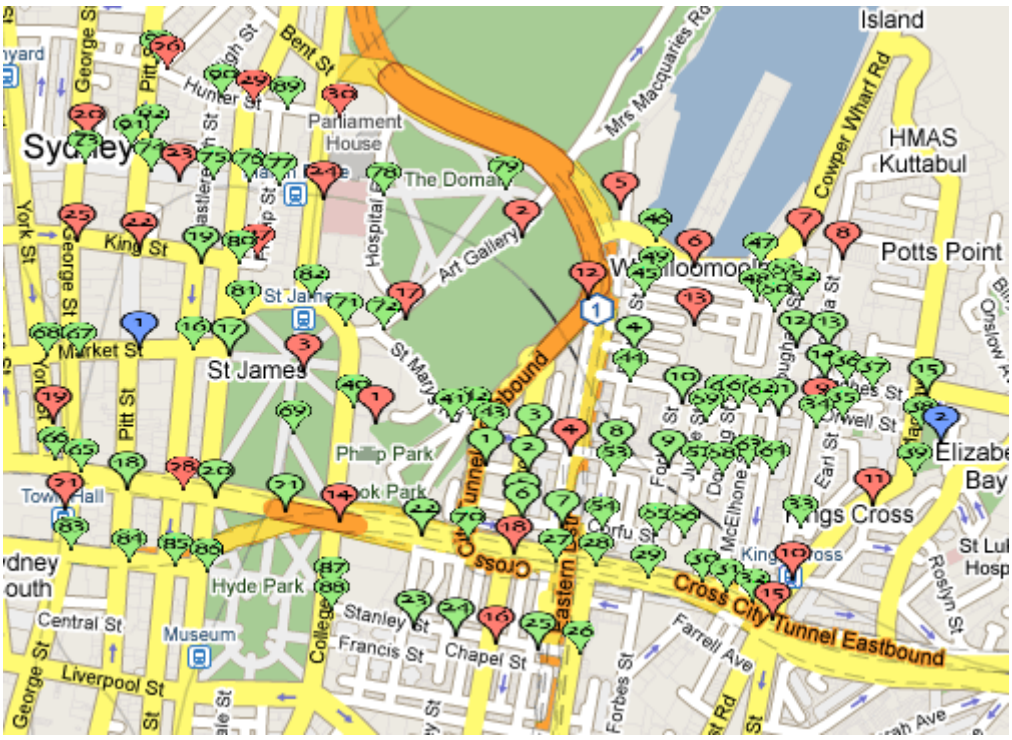


Figure 7-3 – Intersections in the test area

The green Intersections join the Segments that join the Minor and Major Nodes. The Segments themselves do not actually show because they are modelled as Properties (Arcs) of the Node objects (e.g., where MinorNode_3 hasConnTo Intersection_17, the property 'hasConnTo' is effectively the Segment between the two Nodes).

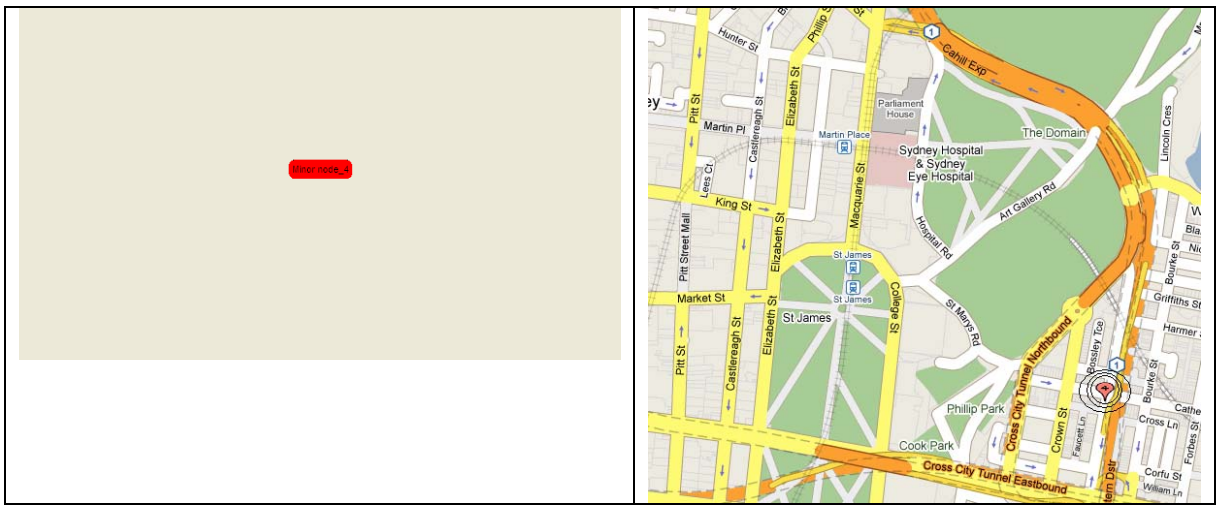
The other objects, the Buildings, Restaurants, Bookshops and Events, are all real objects in the physical space although details such as opening times are not necessarily accurate. They only represent, of course, a fraction of the total range of objects that might be included.

7.1 Scenario 1

We now work our way through Scenario 1. Firstly, the generic settings are established:

1.	Get current position	-	x -33.87298106083651 y 151.21742963790893
2.	Find nearest MinorNode (currentNode)	-	MinorNode_4
3.	Get current day and time	-	Saturday, 11:00 am
4.	Get user preferences for navigation	-	Preference for flat

The Scenario is built up mostly through a series of Sparql queries starting with the Current Node shown in Figure 7-4:



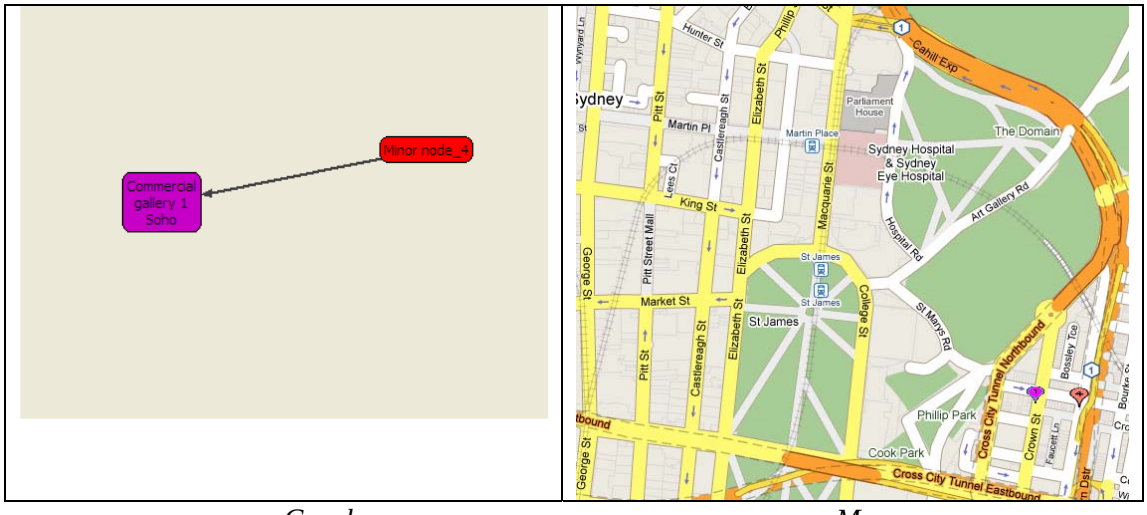
Graph *Map*

Figure 7-4 – The currentNode

The various Sparql queries are shown to give a feel for the queries that are used; however, the illustrations give the clearest guide as to what the IA is delivering. In particular, the patterns of the graphs (on the left) and the way they mirror the physically placed objects in the maps (on the right) should be noted as the scenarios are developed.

Step 1: Find any Organisations themed 'cultural' (bookshops, commercial galleries etc.) nearby (i.e., attached to the currentNode)

```
SELECT ?Cult_orgs ?Nearest_node
WHERE { ?Cult_orgs rdf:type mp1:Orgs_Cultural.
?Cult_orgs mp1:nearestNode ?Nearest_node.
?Cult_orgs mp1:nearestNode mp1:MinorNode_4. }
```

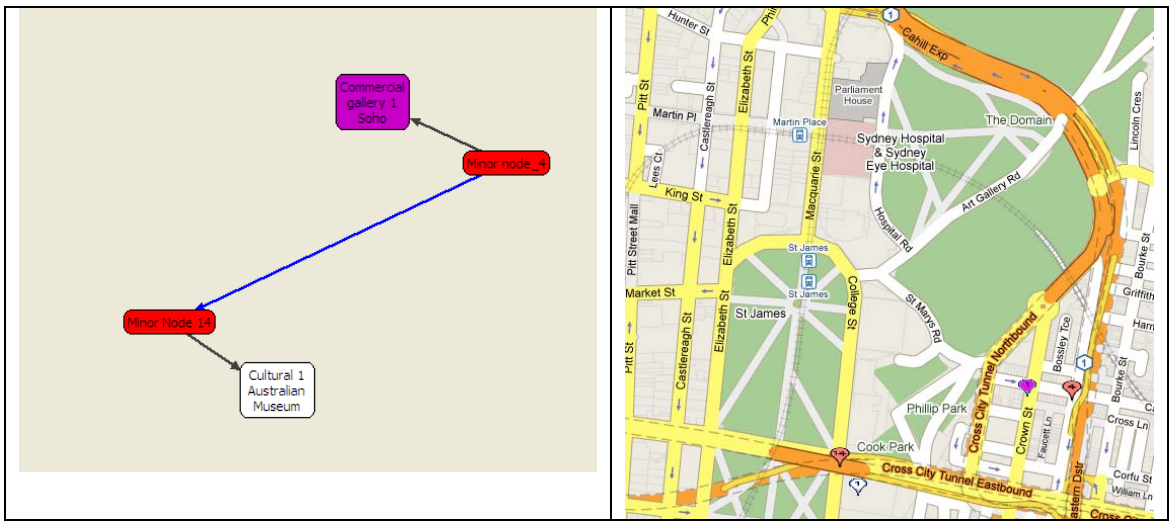


Graph *Map*

Figure 7-5 – Scenario 1, step 1

Step 2: … or a little further away (i.e., attached to Nodes attached to the currentNode, i.e. MinorNode_4)

```
SELECT ?Cult_orgs ?Nearest_nodes
WHERE { { ?Cult_orgs rdf:type mp1:Orgs_Cultural.
?Cult_orgs mp1:nearestNode mp1:MinorNode_4.
?Nearest_nodes mp1:isNearestNodeOf ?Cult_orgs }
UNION
{?Cult_orgs rdf:type mp1:Orgs_Cultural.
mp1:MinorNode_4 mp1:nextNode ?Nearest_nodes.
?Nearest_nodes mp1:isNearestNodeOf ?Cult_orgs. } }
```



Graph *Map*

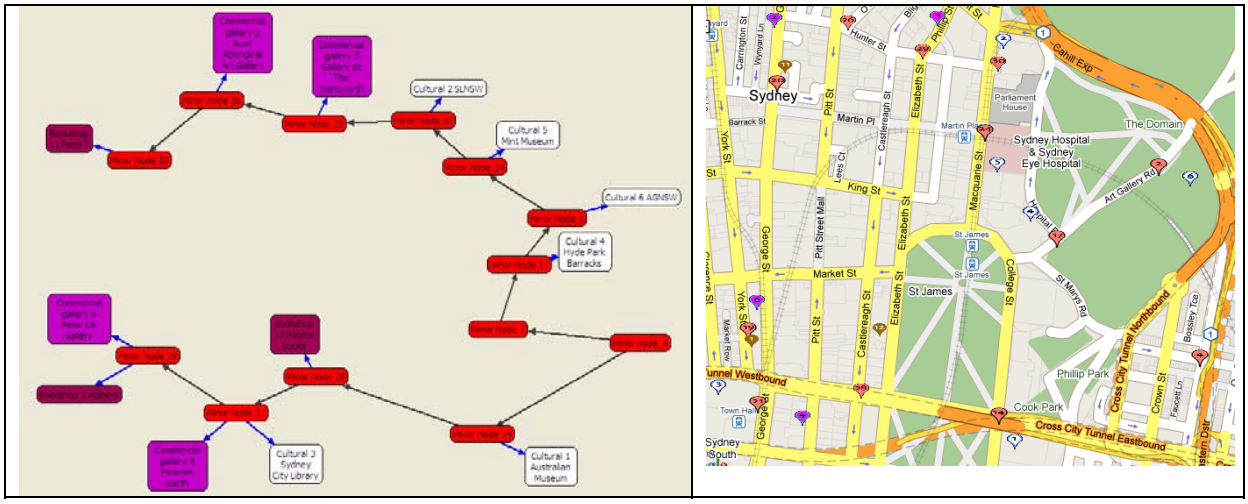
Figure 7-6 – Scenario 1, step 2

This has found one more organisation attached to MinorNode_14 but it's still not a lot, so we expand the search …

Step 3: If too little is found, search the District (i.e., everything attached to Nodes attached to the nearest Major Node, which is that centred on MajorNode_1 to which MinorNode_4 and MinorNode_14 are attached)

```
SELECT DISTINCT ?Nodes ?Cult_orgs
WHERE {
mp1:MinorNode_4 mp1:nextNode ?nn.
?nn mp1:nearestMajorNode ?mn.
?mn mp1:isNearestMajorNodeOf ?n.
?Cult_orgs rdf:type mp1:Orgs_Cultural.
?Cult_orgs mp1:nearestNode ?Nodes }
```

This query is structured a little differently, first finding what Major Node (if any) we are near and then searching for all the Cultural organisations attached.



Graph *Map*

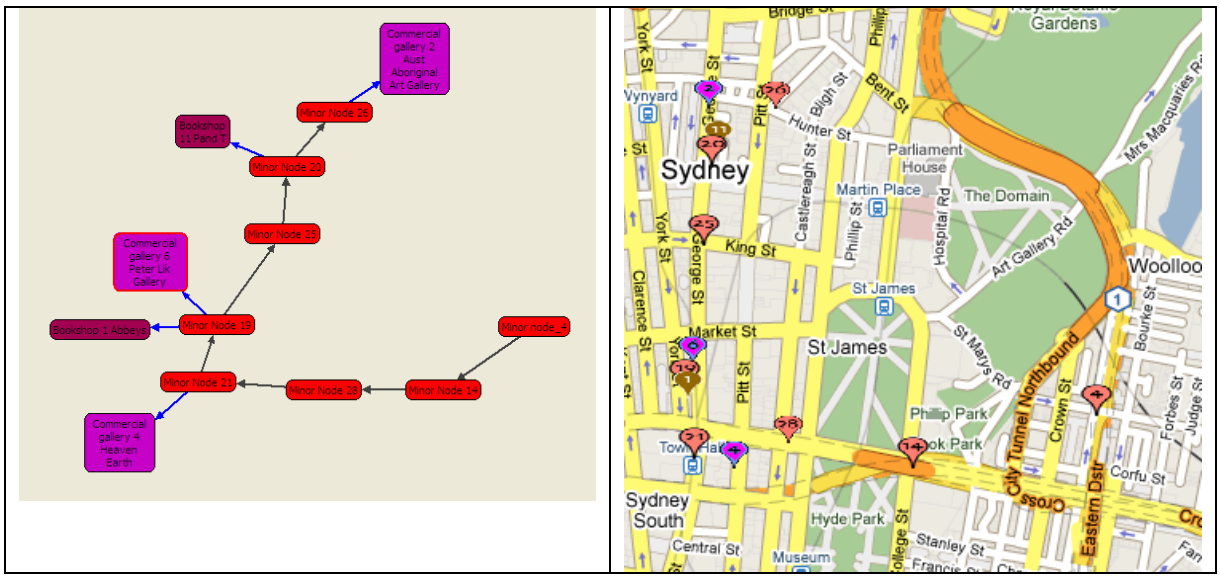
Figure 7-7 – Scenario 1, step 3

Step 4: Check which are open at the current day and time

We need to factor in that it is a Saturday and, therefore, we are looking for 'SixDay' organisations and we are also looking for Retail outlets (albeit 'Cultural' ones).

```
SELECT DISTINCT ?Nodes ?Cult_orgs
WHERE {
mp1:MinorNode_4 mp1:nextNode ?nn.
?nn mp1:nearestMajorNode ?mn.
?mn mp1:isNearestMajorNodeOf ?Nodes.
?Cult_orgs rdf:type mp1:Orgs_Cultural.
?Cult_orgs mp1:nearestNode ?Nodes.
?Cult_orgs rdf:type mp1:OrgSixDays.
?Cult_orgs rdf:type ?t.
?t rdfs:subClassOf mp1:Retail }
```

This reduces the number considerably:

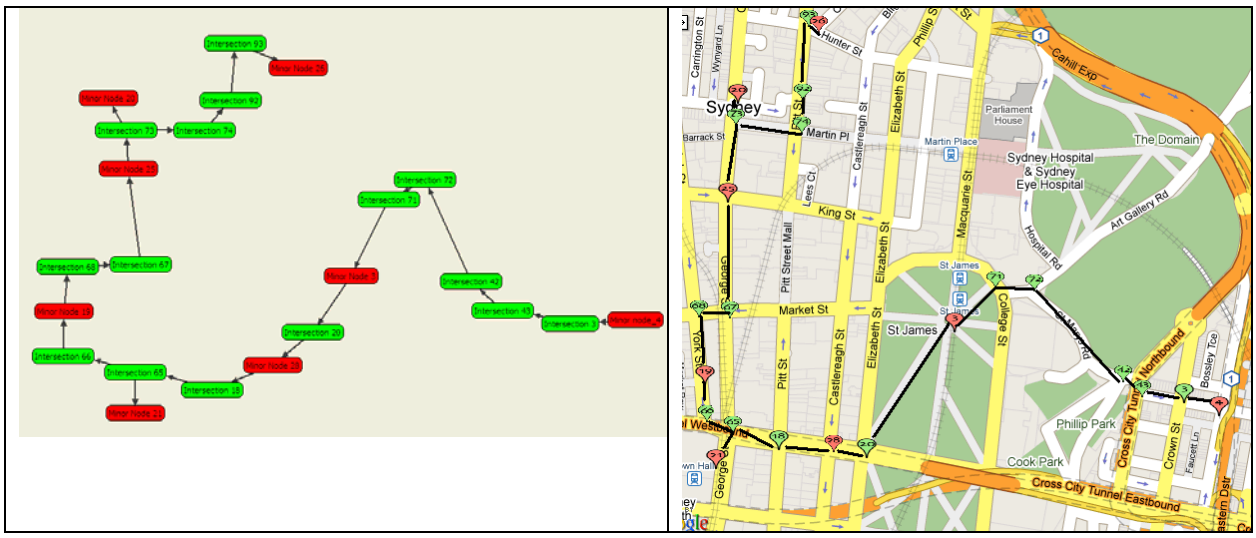


Graph *Map*

Figure 7-8 – Scenario 1, step 4

Step 5: Find a Path to the Nodes these shops are attached to which does not involve going up or down any stairs by using the 'managed' network of MinorNodes

We have established that the Minor Nodes that the organisations of interest are connected to are 19, 20, 21 and 26 to which we add our current Node, 4. A flat Path is now generated using the function described in Code Sample 1 in Appendix B:



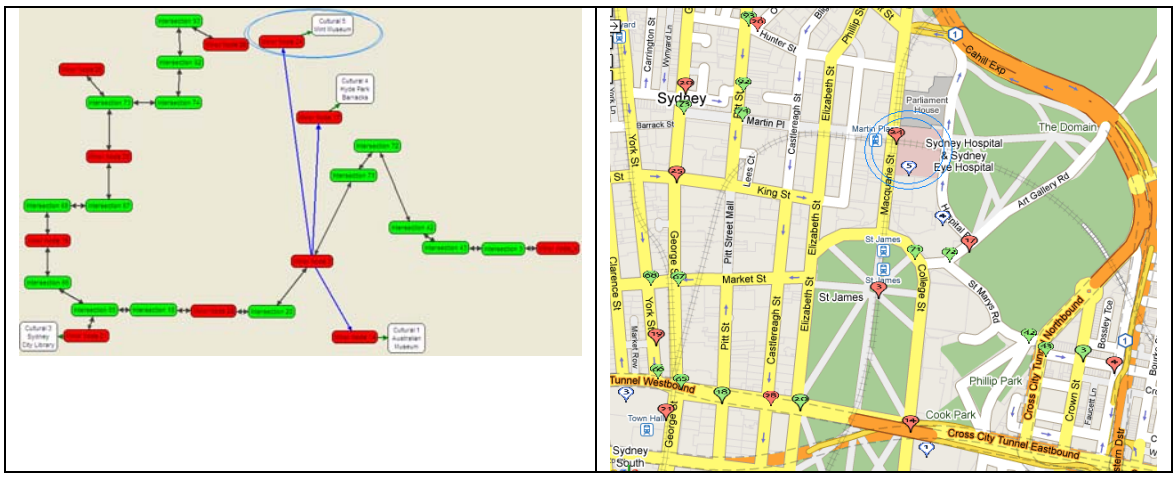
Graph *Map*

Figure 7-9 – Scenario 1, step 5

Step 6: As the Path is traversed, let the user know about cultural institutions (public galleries, libraries and museums but not shops) nearby or a little further away (as defined in step 2)

The Minor Nodes participating in the generated Path are 4, 3, 28, 21, 19, 25, 26. The next step is made a little easier if a temporary Class is created called 'CurrentPath' which contains all the Minor Nodes which are participating in the current Path. A query can then be run to obtain the required set of public cultural institutions attached to Nodes along the path or attached to Nodes attached to those Nodes:

```
SELECT DISTINCT ?Orgs ?NearestNode WHERE { {
?nd rdf:type :CurrentPath.
?nd :isNearestNodeOf ?Orgs.
?Orgs :nearestNode ?NearestNode.
?Orgs rdf:type ?t.
?t rdfs:subClassOf ?s.
?t rdfs:subClassOf :Public.
?Orgs rdf:type ?t.
?Orgs rdf:type :Orgs_Cultural}
UNION
{?nd rdf:type :CurrentPath.
?n :nextNode ?nd.
?n :isNearestNodeOf ?Orgs.
?Orgs :nearestNode ?NearestNode.
?Orgs rdf:type ?t.
?t rdfs:subClassOf ?s.
?t rdfs:subClassOf :Public.
?Orgs rdf:type ?t.
?Orgs rdf:type :Orgs_Cultural} }
```

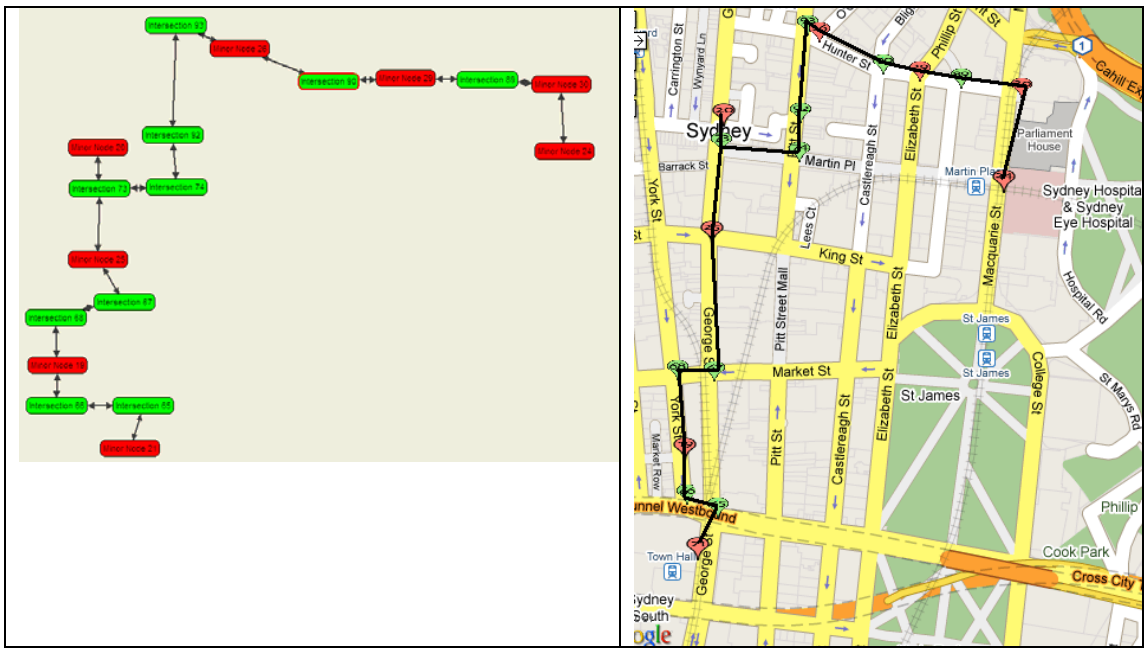


Graph *Map*

Figure 7-10 – Scenario 1, step 6

Step 7: If a diversion is taken to one of these cultural institutions along the way, reset my Path to the remaining 'cultural' shops.

We will assume the end-user diverts to MinorNode_24 to look at the Mint Museum (circled above). To reset the path, MinorNode_24 becomes the currentNode and the remaining Nodes are 19, 20, 21 and 26 (from the original query for the appropriate organisations attached to MajorNode_1, i.e, the nearest 'District'). A regenerated Path connecting MinorNode_24 and the other 4 Nodes look like this and is quite different from the original:



Graph *Map*

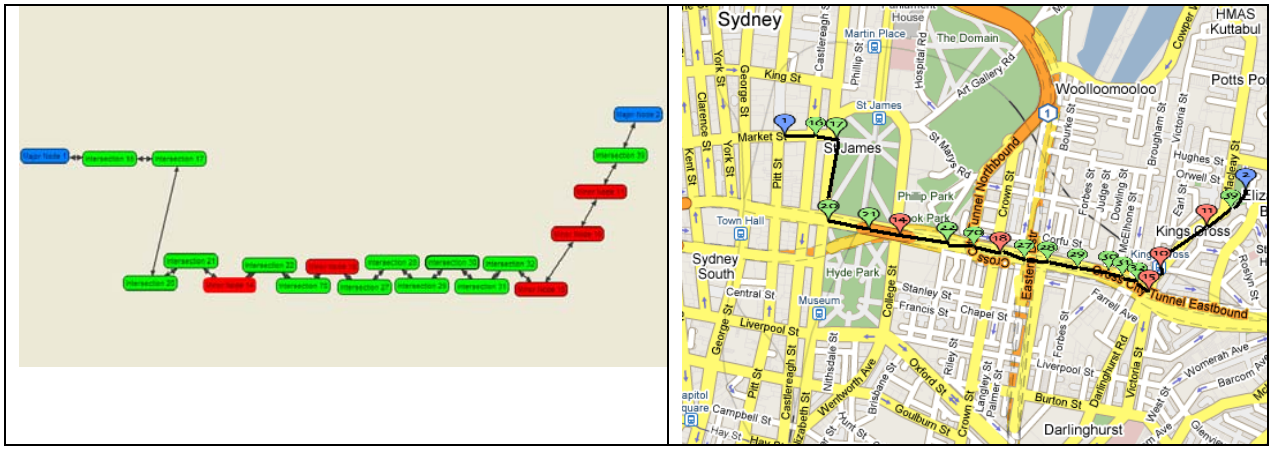
Figure 7-11 – Scenario 1, step 7

7.2 Scenario 2

Our start and end points are the Major Nodes that define the two Districts, MajorNode_1 and MajorNode_2.

Step 1: Find a Path from the current District (i.e., the Major Node to which the currentNode is attached) to the next District (Major Node) that is safe to traverse at night.

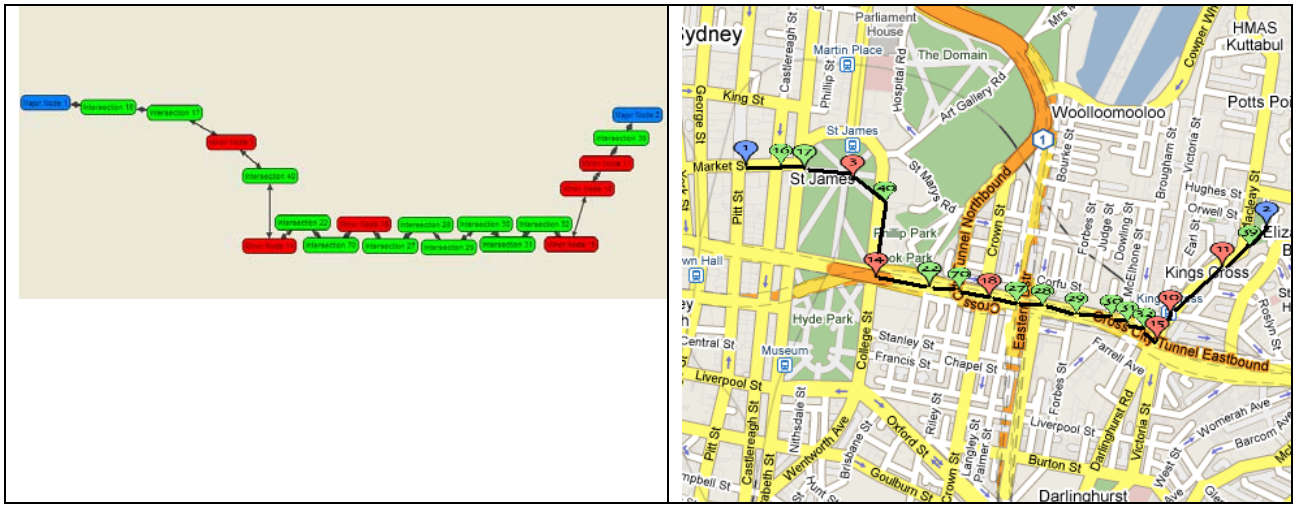
The proposed Path is generated in the same manner as in Scenario 1. A Path which is safe to walk at night is generated by following the has24SafeConnTo links. Not surprisingly, it offers a Path following busy, well-lit streets:



Graph *Map*

Figure 7-12 – Scenario 2, step 1(a)

This is a rather bland experience and relaxing the requirements to just safe rather than night-safe may offer some alternative:



Graph *Map*

Figure 7-13 – Scenario 2, step 1(b)

This is not much different but it has at least offered a detour through the park to give some momentary relief from the traffic.

However, we are after more from this Path than simple navigation; we are looking for an accompanying journey in time. To undertake this, we must look for Events associated with the Path we intend to take.

Step 2: Find a 'temporal Path', if there is one, through Events which link the current District to the next District

To narrow the scope of the search, we firstly create a bounding box around our starting point and destination. This is on the assumption we are happy with some variation in the route taken but we don't want our historical interests to take us widely astray from a sensible Path between MajorNode_1 and MajorNode_2:

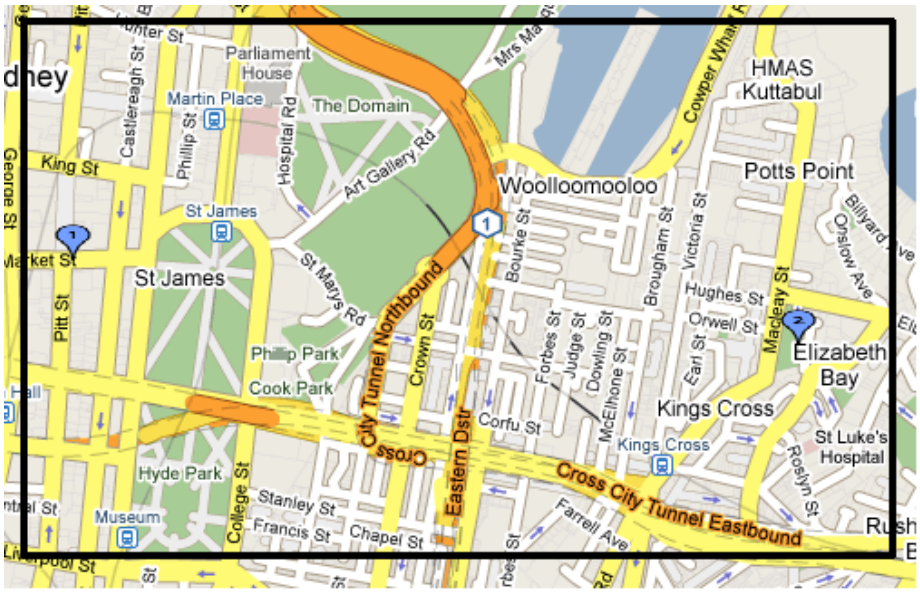


Figure 7-14 – Bounding box between current Node and destination

We now retrieve the Minor Nodes (and the two Major Nodes) within that bounding box and this *does* require a spatial query. These are the Nodes that will have Events attached to them and will be the subject of the next query:

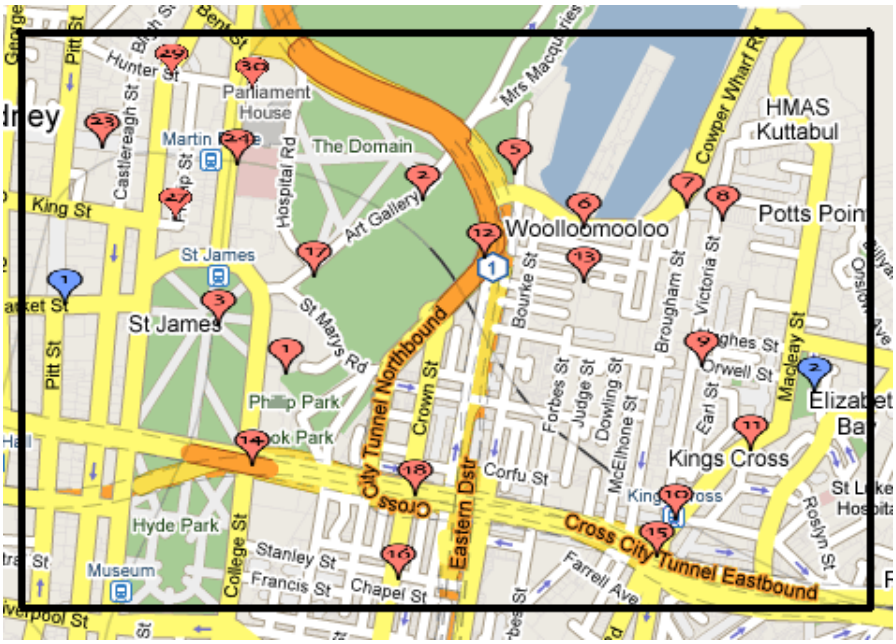


Figure 7-15 – Minor and Major Nodes within the bounding box

For convenience, these Nodes are put into a temporary subclass called CurrentBB.

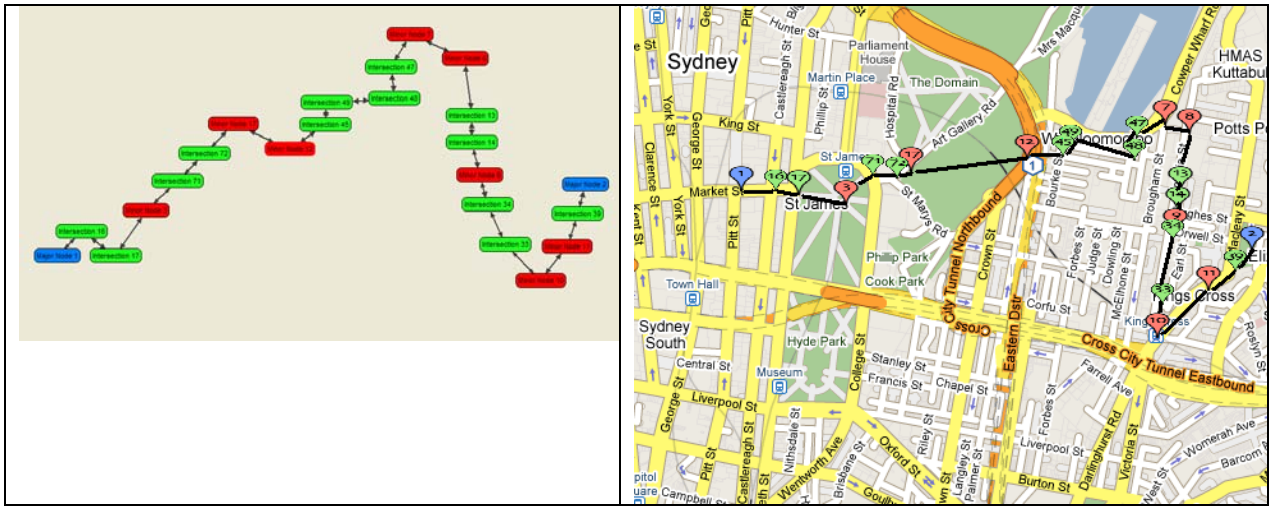
We now look for Events attached to these Nodes and also which Node those Events are attached to:

```
SELECT ?event ?node
WHERE { ?event rdf:type :Event.
?node rdf:type :CurrentBB.
?event :nearestNodeEvent ?node. }
```

For this example, this has retrieved:

Event	*Nearest Node*
Event_1_Hilton_Hotel_bombing	MajorNode_1
Event_2_Juanita_Nielsen_disappears	MinorNode_11
Event_3_Victoria_street_evictions	MinorNode_9

In the same manner as was done with the 'cultural tour' in Scenario 1, these Nodes are interpolated into our intended Path so that we now seek a Path incorporating MajorNode_1, MinorNode_11, MinorNode_9 and MajorNode_2. We are presented with a very different alternative:



Graph *Map*

Figure 7-16 – Scenario 2, step 2

This journey through historical Events may in fact be part of a richer ontology of historical information. For the purposes of this example, a slightly fanciful set of additional relationships (albeit based on real events) was created, involving the somewhat notorious set of characters involved with these Events. All the historical relationships (Properties) used were grouped under a single property called hasLink. This enables Paths to be generated along hasLink incorporating all the modelled historical relations:

hasLink
- ➥nearestNodeEvent (inverse: isNearestNodeOfEvent)
- ➥associatedWith (symmetric)
- ➥interrogated (inverse: interrogatedBy)
- ➥involves (inverse: involvedWith)
- ➥opposed (inverse: opposedBy)
- ➥relatedEvent (symmetric)

The new Property, 'nearestNodeEvent', is used in preference to reusing nearestNode to relate Events to Nodes so that it can be grouped under hasLink and the connections between Events and Nodes traversed more easily.

In this case, the actors and relationships were as follows:

Event_1_Hilton_Hotel_Bombing	involves	Tim Anderson*
Tim Anderson	interrogatedBy	Roger Rogerson
Roger Rogerson	associatedWith	Freddy Krahe
Freddy Krahe	hasLink	Victoria Street evictions
Victoria Street evictions	relatedEvent	Juanita Nielsen disappears

** note: Anderson was eventually cleared of any involvement*

We can now combine our search for a safe Path between MajorNode_1 and MajorNode_2 with a search through the hasLink connections, which gives us a historical journey to match our physical journey. A shortest path function run along hasLink between MajorNode_1 and MajorNode_2 returns the following:

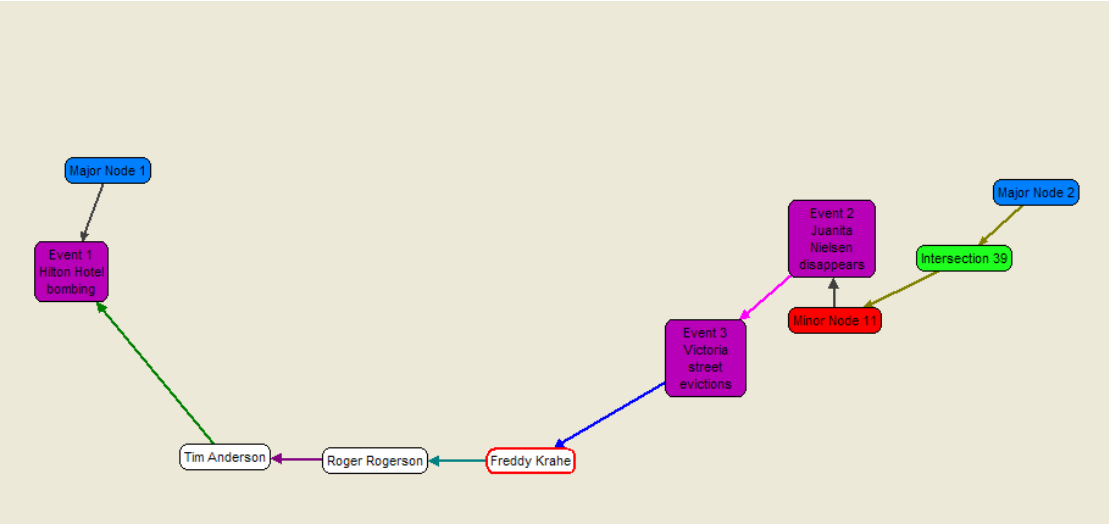


Figure 7-17 – Physical and temporal (Event) connections between current Node and destination

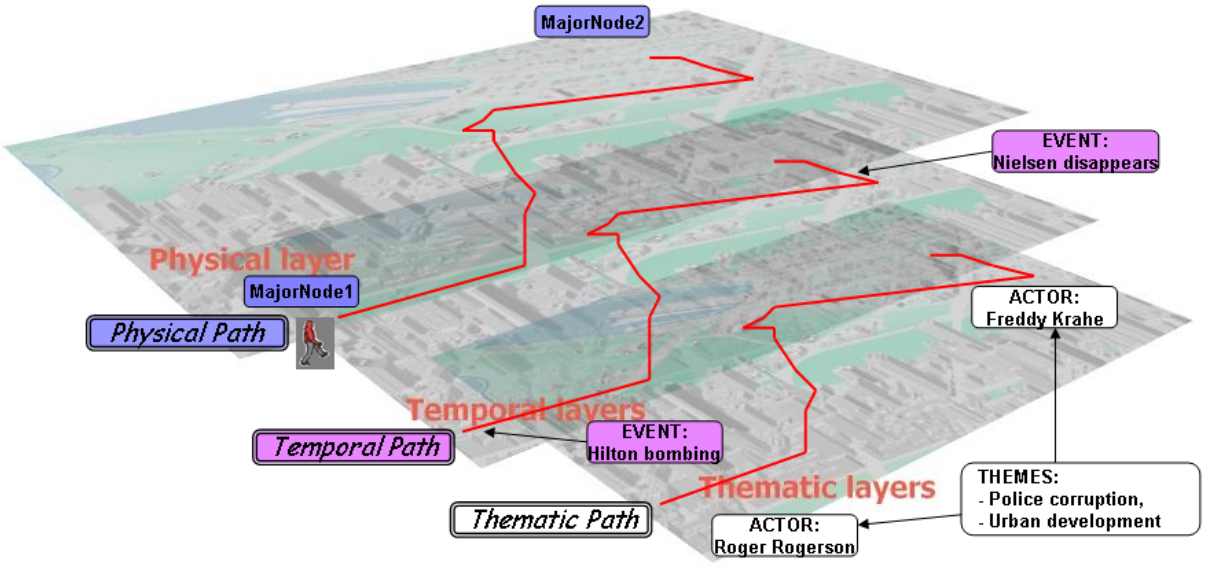


Figure 7-18 – Physical, Temporal and Thematic Paths

Here there has been some success in combining physical and temporal navigation to achieve something like the multi-layered path described in 1.1.3:

Step 3: As the Path is traversed, step through the Events which link the two Districts together and offer any available multimedia concerning those Events.

Events and personalities encountered along the temporal journey can easily have multimedia and other resources attached to them to enhance the experience further. These may be attached as Resources and retrieved with simple Sparql queries along the way. For example, for the Event Hilton Hotel Bombing, the query …

```
SELECT ?urls WHERE
{ :Event_1_Hilton_Hotel_bombing :hasResource ?resources.
?resources :hasURL ?urls}
```

… returns two URLs attached to Resources attached to that Event:

- http://nla.gov.au/nla.pic-an21295591-45
- http://en.wikipedia.org/wiki/Sydney_Hilton_bombing

Again, it is the task of interface designers to consider how these resources might be presented to the end-user; the task of the IA is facilitate access and retrieval.

7.3 Scenario 3

The first two scenarios have focused on Paths and movement. However, a case was also made in section 1.1.2 for using information to facilitate moments of pause and reflection. Scenario 3 is more applicable to an enclave, morphologically representing a point of stasis and an opportunity to dig deeper rather than search wider.

Following Peter Smith's analysis, it is also an opportunity to simultaneously go deeper into the surrounding environment and into our own psyches, exploring the deeper patterns in the urban structure that mirror older limbic structures in our brains and are responded to by them.

Step 1: From the current position, assess the density of information of different types connected with the immediate area.

We will take the current position to be adjacent to MinorNode_21. There are various SNA functions which can assess the overall 'connectedness' of the Current Node. A 'nodal-degree' function searching along the nearestNode and nearestNodeEvent Arcs will return a value of 5 for MinorNode_21 indicating that there are 5 elements attached to the current Node along these Arcs. A 'nodal-neighbors' function will return the actual Nodes themselves, shown graphically in Figure 7-19:

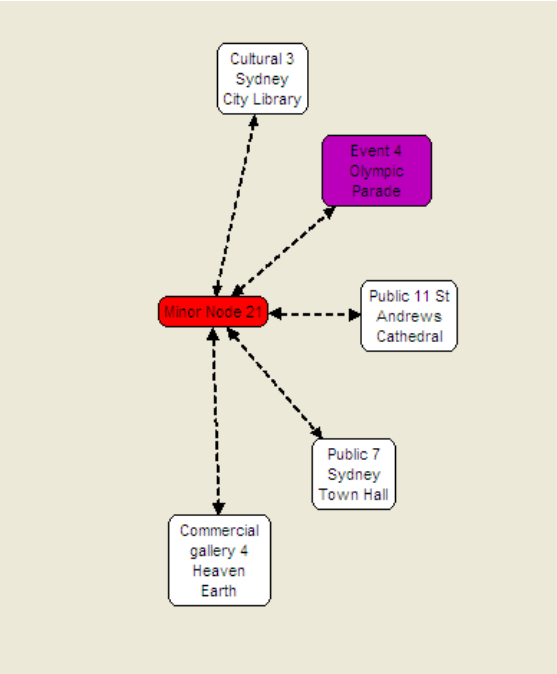


Figure 7-19 – Scenario 3, step 1

An 'actor-degree-centrality' function will give a measure of how central the current node is within the current 'group' (which may be the group of Nodes within a spatial bounding box as utilised in Scenario 2).

These can all give an indication of the richness of local information interconnectivity.

Step 2: Access different information 'views' of the surrounding area highlighting different themes or types of objects.

This can be achieved in a similar manner to Scenario 1. In this case, the set of Themes has been expanded slightly to include the following:

Theme
    ➥Architectural
        ➥Colonial

… and the 'Colonial' Theme has been added to a number of Buildings to enable a search in the current District for buildings which are examples of Colonial Architecture. To facilitate the query, these are gathered into an inferred set called Buildings_Colonial (defined using the restriction of hasTheme = Colonial).

```
SELECT DISTINCT ?Build_col
WHERE {
:MinorNode_21 :nextNode ?nn.
?nn :nearestMajorNode ?mn.
?mn :isNearestMajorNodeOf ?n.
?Build_col rdf:type :Buildings_Colonial.
?Build_col :nearestNode ?n }
```

This returns 6 buildings (strictly speaking these are Organisations but in this case they are sufficiently synonymous with the buildings within which they operate):

- Public_11_St_Andrews_Cathedral
- Public_9_Conservatorium
- Cultural_5_Mint_Museum
- Public_10_St_James_Church
- Public_8_NSW_Parliament
- Cultural_4_Hyde_Park_Barracks

Step 3: For a given type of object, perhaps buildings of certain architectural styles, retrieve further information about those objects.

This can be facilitated by the fact that the model is set up in such a way that Resources can be attached to any Class or Subclass. For example, Resources are attached to the Subclass Colonial and retrieved:

```
SELECT DISTINCT ?resource ?url
WHERE {:Colonial :hasResource ?resource.
?resource :hasURL ?url}
```

This returns a Resource which points at a website concerned with images of colonial architecture in Sydney:

http://www.sydneyarchitecture.com/STYLES/STY-C01.htm

Step 4: Find out if those objects are connected to each other in any way.

Here we might explore some more links between objects of interest. An additional Link subtype has been added:

```
hasLink
    ➥designed (inverse: designedBy)
```

… and two of the Colonial buildings listed above linked with the famous convict architect Francis Greenway using this Property. This enables a query for any Links between the objects of interest:

```
SELECT DISTINCT ?all_links ?these_links ?link_type
WHERE {?buildings rdf:type :Buildings_Colonial.
?buildings :hasLink ?all_links.
?all_links :hasLink ?these_links.
?all_links ?link_type ?these_links
FILTER (?link_type != :hasLink) }
```

This returns results highlighting the fact that Francis Greenway designed two of the buildings (Francis Greenway himself could, of course, be the starting point for a new exploration):

all_links	*link_type*	*these_links*
Francis_Greenway	designed	Cultural_4_Hyde_Park_Barracks
Francis_Greenway	designed	Public_9_Conservatorium

Step 5: For a given individual object (again, perhaps a building) explore the boundary between the public information about and around the object and the more private information about what is within it.

One interesting aspect of Nolli's map of Rome is that it shows in white not only the spaces between the buildings but also the public spaces within buildings, particularly churches (Dehaene & De Cauter 2008 pp5–6). This creates a seamless fabric of public and semi-public urban space.

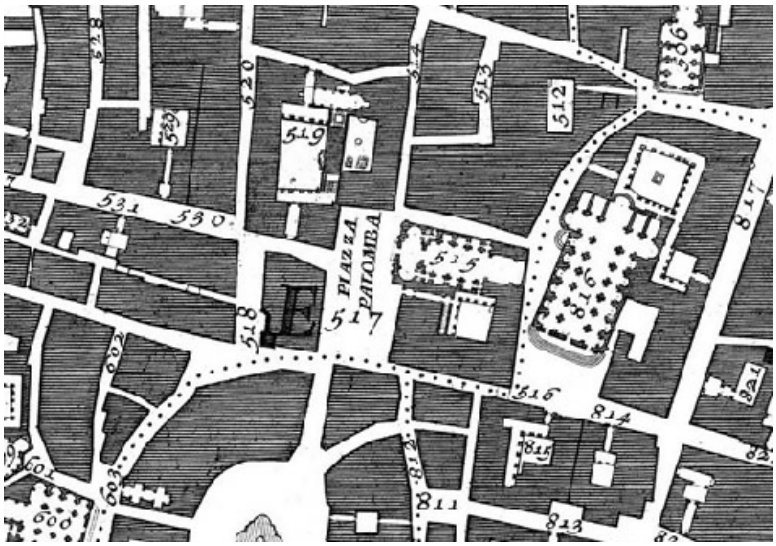
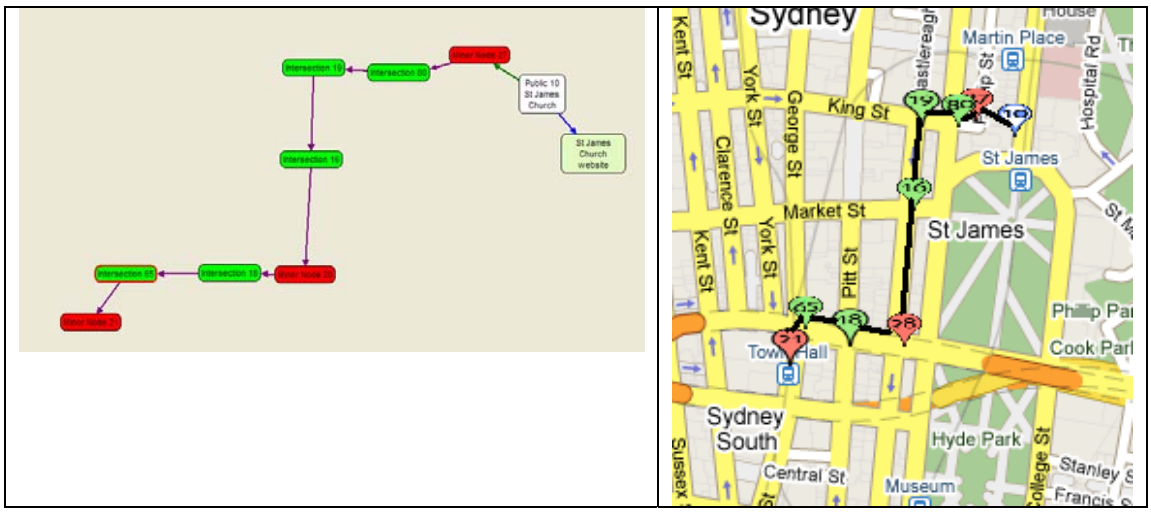


Figure 7-20 –Nolli's map of Rome (extract reproduced in Gosling & Maitland 2003 p42)

Information about organisations that occupy buildings is now widely available on the internet which raises the interesting possibility of constructing information Paths which lead the end-user not only to the entrance of a building but inside it, corresponding with Nolli's extended network of public space. This may be characterised as a design decision as to what is 'figure' (information made positively available) versus 'ground' (the background mass of information surrounding the 'figure' information) in the information layer. Connecting together more and more information through semantic structures may be a way to gradually make available more 'figure' information in a controlled manner.

For example, if we plot a Path from the current Node all the way to the Organisation 'St James Church', we get the following:



Graph *Map*

Figure 7-21 – Scenario 3, step 5

This has effectively led us along a single Path both *to* the building and *into* the building and then to a Resource that tells us about what is inside. If that Resource were itself delivered using a semantic-web-based IA, the Path could extend further into the Organisation and beyond (no doubt with some caveats regarding information security and access).

7.4 Taking the model further

In responding to the three scenarios above, an IA that achieves a high level of *integration* with the urban environment within which it is delivered has been the goal (as described in chapter 3). Nevertheless, there has still been a significantly functional slant to the examples; finding Paths, retrieving information, seeking out objects of different types. Is it possible to achieve a deeper level of integration between the IA and some of the less obvious and more mysterious influences of urban morphology?

The notion of the *centre* is one of the most widely referenced in the urban design literature. Alexander talks of urban growth through organically aggregating a 'field of centers' (Alexander 1987 p23) and Smith identifies it as the most powerful symbolic influence on our subconscious, limbic perception of the city, reaching back to mandala forms and dominant as a city model from Sumerian times to the early modern period (Smith P 1977 p57).

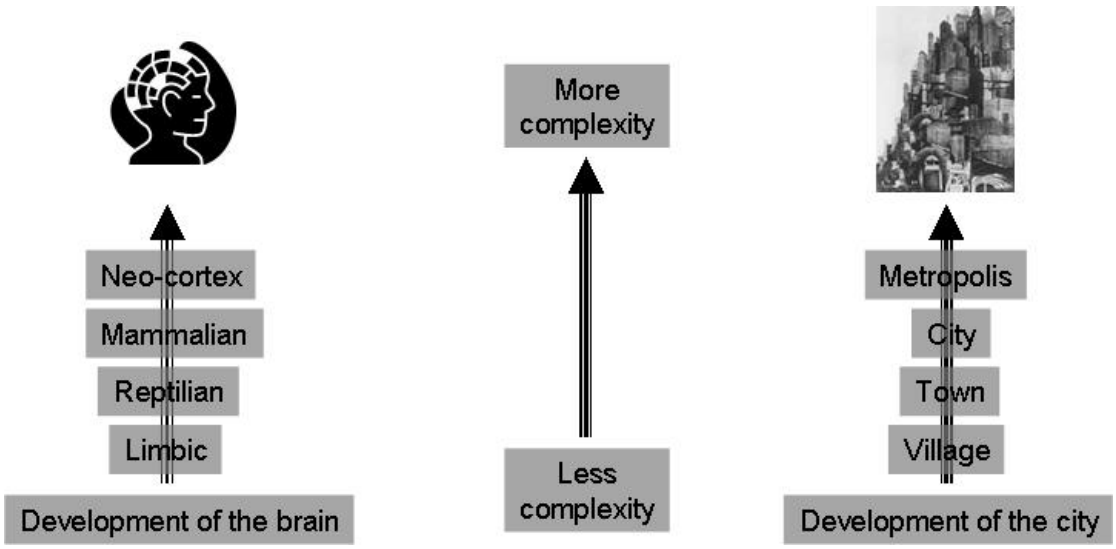


Figure 7-22 – Development of brain and city

These centres have both spatial and political or spiritual aspects; the cathedral sits spatially at a centre of the city and also represents the point closest to God; the town hall on the main square is a seat of political power.

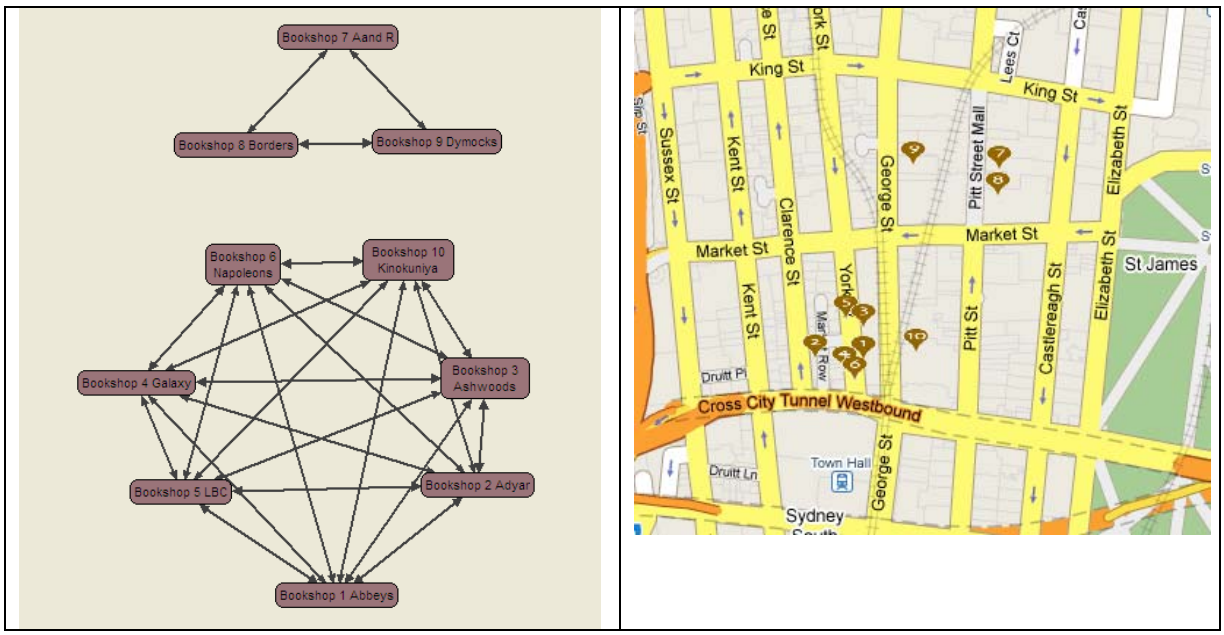
On the face of it, such centres are inimical to the modern information landscape which encourages such a democratic spread of material and opinions. Nevertheless, some of the ideas already explored have been an attempt to reintroduce some structure into that flat landscape (even at the risk of some hierarchy!).

Information 'centres' in the IA presented here are better modelled as dense clusters of information rather than single points or Nodes. A suitable mechanism from SNA for this is the 'clique', which is a group of Nodes where every Node is connected to every other.

In the example, two clusters of Bookshops have been modelled as cliques and these can be retrieved with a Sparql query:

```
SELECT DISTINCT ?Cluster WHERE {
?a rdf:type mp1:Bookshop.
?a mp1:hasCliqueMember ?Cluster }
```

Visually presented, the cliques are obvious:



Graph *Map*

Figure 7-23 – Cliques of bookshops

Cliques of clustered Events might be defined in a similar manner. Much of Woolloomooloo (the area between the CBD and Kings Cross) is as it is today as a result of union-imposed 'Green Bans' in the 1970s. A clique of tightly clustered Events associated with the campaign could lead one to a different sort of 'centre', in this case, a centre of radical urbanism in central Sydney.

Information 'centres' don't have to mirror spatial relations (like clusters of bookshops or Events in close proximity) but, where they do, they represent another example of the way semantic-web-based information structures can deliver a more *integrated* experience between the physical and information layers of the city.

To take an Event-based example, the 'Green Bans' of the 1970s in Sydney might be modelled as a clique of Events representing the major bans (which took place in The Rocks, Woolloomooloo and Victoria St, Kings Cross), and each of these might be associated with lower level Events plotting the detailed story of each of the bans. Furthermore, the bans may be given some common thematic attribute, such as 'Urban_Activism'. This enables queries such as *Find Events associated with Urban Activism in the current District* (which in this case are those attached to a Node which is attached to MajorNode_2):

```
SELECT ?Events
WHERE { ?Events rdf:type :Event.
?Events :hasTheme :Urban_Activism.
?nn :isNearestNodeOfEvent ?Events.
?nn :nearestMajorNode :MajorNode_2.}
```

This returns:

- Event_32_Victoria_St_Green_Bans

Then find out if that Event is a member of any cliques (this is a Lisp SNA function rather than a Sparql query):

```
(cliques !mp1:Event_32_Victoria_St_Green_Bans EventLink :minimum-size 3 :maximum-size 16)
```

This reveals that this Event is both associated with other Green Bans …

- Event_30_The_Rocks_Green_Bans
- Event_32_Victoria_St_Green_Bans
- Event_31_Woolloomooloo_Green_Bans

... and associated with lower level Events which were part of the unfolding story of the Victoria Street Green Bans:

- Event_32_Victoria_St_Green_Bans
- Event_17_First_evictions_030473
- Event_26_Squatters_move_in_July_1973
- Event_29_Bans_lifted
- Event_18_Bans_declared_-_Apr_1973
- Event_16_Initial_property_buy-up_Mar_70-June_71
- Event_2_Juanita_Nielsen_disappears
- Event_24_BLF_storms_Fowlers_flat_and_retakes_it_030573
- Event_23_National_Trust_lists_Victoria_St_020573
- Event_21_Joe_Meissner_runs_evictions
- Event_22_Mick_Fowler_tries_to_reclaim_flat_300473
- Event_19_Victoria_St_Action_Group_formed_080473
- Event_25_Woolley_plan_released_and_endorsed_by_National_Trust_040673
- Event_28_Oct_1974_Federal_BLF_intervention
- Event_20_Arthur_King_abducted_140473
- Event_27_Squatters_removed_030174

The other two Green Bans also have associated lower-level Events:

- Event_30_The_Rocks_Green_Bans
- Event_7_Peoples_Plan_commissioned_301072
- Event_9_Ban_lifted_1975
- Event_6_First_evictions_140172
- Event_5_Residents_Action_Group_founded_Oct_1971
- Event_8_Peoples_Plan_presented_Apr_1973

- Event_31_Woolloomooloo_Green_Bans
- Event_13_Plan_revised_again_Apr_1974
- Event_14_Bans_lifted_Jan_1975
- Event_11_Bans_placed_140273
- Event_10_Residents_Action_Group_founded_Oct_1972
- Event_15_Agreement_signed_270675
- Event_12_New_plan_anounced_210273

This enables both a broad view of the location (and times) of the main bans and enables drilling down into the details of each ban.

The connections show clearly again on a graphical presentation of the information:

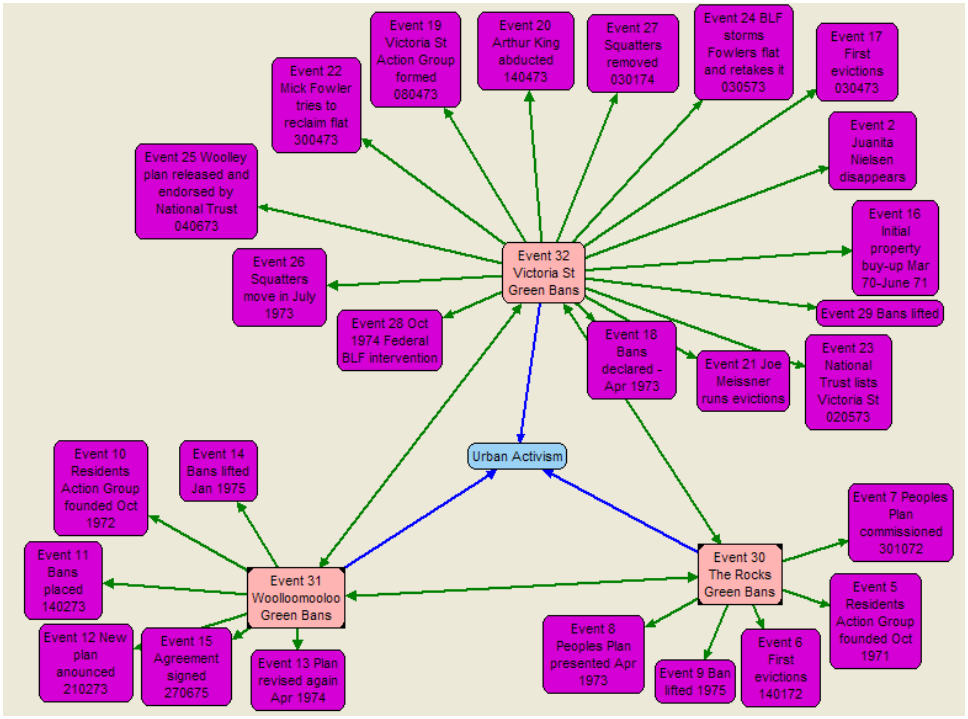


Figure 7-24 – Graph of Green Ban Events

Not all of these lower-level Events can be positioned spatially, of course, so the spatial representation of the Events looks a little less crowded.

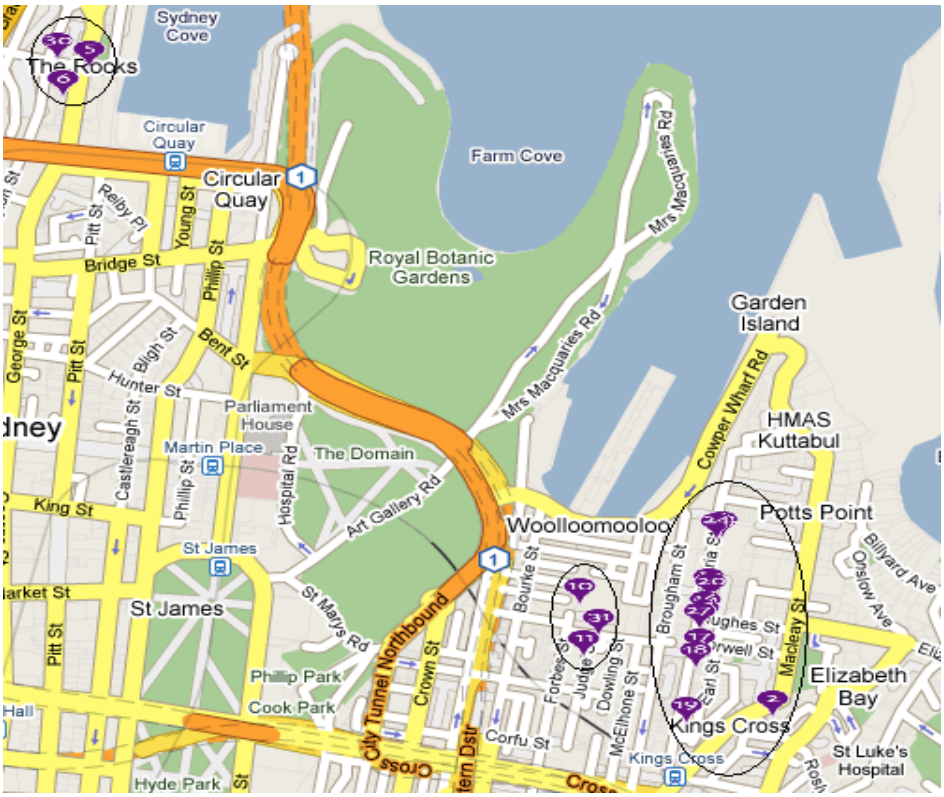


Figure 7-25 – Map of Green Ban Events

Either presentation, however, gives a vivid indication of the hot spots of activism during a crucial time in the history of Sydney's urban development. Once retrieved, these Events could be integrated with spatial information and form the basis for generated Paths in the same way as demonstrated in Scenario 2.

Chapter 8 Review and Conclusions

There are both normative and technical aspects to this research.

Normatively, it is a plea for urban design to find a voice in the design and delivery of urban information services as they become an integral and ubiquitous part of urban experience. These services should be as amenable to the influence of urban design as the buildings and streets.

Technically, the case is made that the information underpinning the services is more important in the long run than the front-end interface. A search was undertaken, therefore, to find the basis for an Information Architecture (IA) that better reflects the most interesting qualities of the urban environment referenced in the work of significant urban design thinkers. Such an IA could provide an appropriate framework within which urban design qualities are reflected and could involve urban designers.

In *Chapter 1* the possibilities for a richer IA underpinning urban information services was freely explored, focusing on the work of Gordon Cullen as one example. The *need* for enhanced services was also considered and problems with the *flatness* and *lack of depth* that comes with ubiquitous geo-spatial information identified and explored. This introduced a particular slant to the subsequent approach which focused on mechanisms that enable some aspects of the urban environment to be privileged over others, which is part of the task of urban design.

The literature review undertaken in *Chapter 2* surveyed initially relevant writings in 'digital urbanism'. Some of these came close to addressing the concerns of the thesis and certainly provided motivation and background to the research. However, it was noted how little they referenced urban design writers and bridging this gap provided further motivation.

In reviewing the literature of urban design itself, a comprehensive survey was not attempted but a number of prominent thinkers sampled and their work examined for useful and inspirational ideas and constructs.

Recent developments in information science were also included but this was not so much a review of the literature as a technical description of some areas of interest, in particular, the 'semantic web' and associated technologies.

Working from the literature review, *Chapter 3* identified a set of requirements which an enhanced IA should address including the ability to:

- represent and explore more than just the surface layer of the city – more than just the here and now
- iteratively dig into information at different scales in a fractal-like manner
- store and present information in a way that reflects the interconnected, graph-like nature of the urban environment.

At this point, it was proposed explicitly that semantic web technologies were well suited to meeting these requirements.

Chapters 4–7 then gradually built up the elements of such an IA and then tested it on a limited set of data.

Chapter 4 described in more detail the available items in the information 'toolkit' of the semantic web technologies:

- Information services
- Objects and their Classes
- Graphs and Social Network Analysis (SNA) functions
- Spatial querying
- Temporal querying
- Ontologies
- Semantic web triple-stores and the Sparql query language

In *Chapter 5*, building blocks to be used in constructing the IA were introduced:

- Utility information services – current location service, date/time service, visibility service, weather service, cadastral and address service, basic navigation service, directory service – all of which could be utilised by the service of interest, the *urban information service*
- Main objects and classes – Nodes, Segments, Buildings and Structures, People and Organisations, Paths, Districts
- Basic Space and Time elements and Events
- Three types of Nodes – Major, Minor and Intersections.

In *Chapter 6*, the IA was constructed to a level of detail that could actually be applied. The ideas and constructs presented are only one of many ways in which the requirements could be addressed within a semantic web framework.

In *Chapter 7*, the IA was applied to a small area of central Sydney and a sample of data from that area. The intention was to ensure that the ideas and constructs put forward in Chapter 6 could be practically delivered. The scenarios were not complex and the code and Sparql queries not particularly sophisticated (certainly not to the eye of a professional ontologist or programmer) but they demonstrated that practical results could be obtained from information appropriately structured.

Did the proposed IA pass the test? Did it meet the requirements identified in *Chapter 3* and summarised above?

The ability to represent and explore more than just the surface layer of the city – more than just the here and now:

The mechanisms are certainly available to intertwine explorations through different ontologies by combining paths through both spatial and temporal information. The demands on the structuring and consistency of the information would be significant to support this on a wide scale. However, it presents a more hopeful prospect than trying to retrieve information from, for example, a disparate set of unintegrated relational databases.

The ability to iteratively dig into information at different scales in a fractal-like manner:

The RDF-based information structures are certainly amenable to iterative querying which drills into information at different layers and scales. That process is not necessarily fractal in nature unless the information structures being queried are themselves fractal in nature. Only two scales were really explored, the District (represented by a Major Node) and the 'local' (represented by the currentNode and the other Minor Nodes attached to it). It is not hard to imagine this being extended by gathering Districts into larger aggregations and then those into the city as a whole. This would allow for a more extensive range of queries from the city in its entirety right down to the immediate locality and this would certainly give a stronger fractal quality to the process.

The ability to store and present information in a way that reflects the interconnected, graph-like nature of the urban environment:

This requirement the IA supports supremely well by virtue of the fact that it *is* an interconnected graph. Once that urban environment is seen in those terms, the navigation of the RDF-based information offers a perfectly matching analogy to the physical urban fabric.

The availability of an appropriate platform will not of itself result in a greater involvement by urban designers; some of the impediments to and facilitators of implementation are discussed in Appendix A. The work of the Space Syntax group has already shown the way to some extent in demonstrating the power of network models in analysing space (Hillier 1996); it is not such a large step to take this further and use that analysis to deliver information to the end users of urban space as well as to the professionals involved in its design.

The semantic web boasts a very rich set of tools and the modelling undertaken in chapters 6 and 7 is only a modest indication of the possibilities. Nevertheless, some particular constructs and patterns did emerge that have potential for further investigations of this sort, including:

- the use, wherever possible, of the graph of Nodes to retrieve information and offer options in contrast to reliance on repeated geo-spatial querying. At the relatively small pedestrian scale, the physical distance between things matters less than the nature of their interconnection. Geo-spatial information can only measure proximity; semantic-web-based IAs can model connection and provide richer meaning as a result.
- the use of deliberately placed Nodes (the Minor Nodes) to anchor the placement and interconnection of urban objects and the generation of Paths. These Nodes provide an opportunity for urban designers to apply their skills and knowledge in deciding where to place the Nodes, how many to use and what qualities to model in the Arcs that connect them.
- the modelling of Segments between Nodes as Arcs/Properties and the application of social-network-analysis functions to the resulting graphs.
- the use of hierarchies of Properties to deliver different outcomes: for example, in the delivery of different Paths based on user preference for flatness or safety (a technique which a weighted-shortest-path algorithm would give more flexibility to).
- the use of interconnected Nodes rather than a physical boundary to define Districts. Boundaries drawn on a map often simplify whereas networks of connections can be as granular, as fractal and as *meaningful* as necessary.

These provide an initial set of patterns that might be applied in a more extensive modelling project and, subsequently, application development. Development of an end-user application was not undertaken here; it was taken as given that any of the information designed and retrieved above could, with the involvement of an expert interface designer, be effectively presented within an end-user application, whether that be a mobile phone or one of myriad other possibilities that developments in mobile and location-based information devices will bring to light.

The use of more advanced modelling techniques (such as the use of restricted classes and inferencing) only point the way to more sophisticated modelling that might be undertaken by expert practitioners.

The primary purpose of this thesis has not been to undertake either the most comprehensive assessment of urban design literature or the most far-reaching and sophisticated information modelling. Its purpose has been to demonstrate the potential connection between these two disciplines and to bridge the gap between the literature of digital urbanism and the literature of urban design. It has done so by drawing attention to the existence of an information framework that provides a platform on which the concerns of both can come together.

The technical development of detailed models and applications will continue to be the concern primarily of information professionals. However, by adding to the information infrastructure a few key extra components, such as the Minor Nodes and the Arcs that connect them, the influence of urban design could spread significantly into these information services. Increasingly, information applications are being constructed by aggregating information services accessible across the internet; this is the clear trend in information delivery. Urban design has simply to give itself the opportunity to create and contribute to one of those services and then encourage its adoption.

The inherent ability of semantic web models and data to be shared and repurposed also encourages this approach. Once good models are defined and specific data created, it is extremely straightforward to incorporate them into other semantic-web-based models and applications. Already, large data sets, such as the *geonames* (http://www.geonames.org/) database of several million geographic names, are being made available in RDF and re-used in other applications.

The vision of the semantic web is that of a network of knowledge that creates meaning through interconnection. As Gordon Cullen points out, the presence of and connection with *there and then* creates the meaning of *here and now:* in this sense, information architectures based on semantic web structures will enable the development of services that reflect deeply within their structures the hidden meanings of urban environments and our interaction with them.

The 'Urban Information Designer'

The ideas explored in this thesis show that the opportunities for a rewarding involvement by urban designers in the development of urban mobile information services are many and varied and that platforms are available to support an IA which facilitates that involvement.

A new role of *Urban Information Designer* is one that should become more prominent if the development of our urban environments is to keep pace with and benefit from the technological developments that impinge upon it.

Appendix A – Prospects for implementation

The IA described above yields promising results for richer and more imaginative urban information services. But who will create, manage and deliver the extra layers of information?

Urban designers are the people who work closely every day with the concepts modelled in chapters 6 and 7. They could apply their knowledge and experience to the task of identifying the Nodes, Paths and other elements that make up the urban IA and could then contribute to richer urban information services. However, making the case for involvement in these services by public authorities and those organisations in which urban designers most commonly operate is not easy. As Bonnie Nardi points out, all information-based technologies and systems operate within ecologies (Nardi & O'Day 2000) and urban information services will be no exception.

Before considering how urban designers might make a case for their contribution, it is important to understand the nature of the information 'stacks' that underpin mobile and other information services.

Information 'stacks'

An information system is commonly described in terms of a 'stack'. At the bottom of the stack are the wires and processors, the hardware on which the systems run and data is transmitted. At the top is a 'services' layer (including presentation services) where users interact with the data and, hopefully, retrieve needed information, solve problems, access transactions, communicate meaningfully etc. Figure A-1 is an example (there are many versions):

Presentation
Applications
Information Infrastructure
Information Management (database or alternative)
Operating System
Network Protocols
Hardware

Figure A-1 – Technology 'stack'

At each layer, various corporate and cooperative bodies define standards and vendors implement actual solutions based on those standards and/or participate in and/or subvert the standards (the whole model is anything but tidy). In general, the lower down the stack, the fewer players involved and the more standardised the technology: this is with good reason because implementing applications would be unfeasible if there were, for example, too many competing standards at the network layer.

The general trend is to try to define, and gain acceptance for, standards higher up the stack, to enable more consistent and interoperable systems and services. A prime example is geographic information: as spatially-aware systems (online maps and more) have become widely available, there has been increasing pressure to try to deliver a consistent layer of geographical information as the basis for location-based and navigational services. Another information 'stack' illustrates the point. Geographical information commences with the basic 'grid', which represents the shape of the earth, over which are laid layers of topography and land form (see Figure A-2). Above this, human artefacts start to apply in layers of cadastral information, transport and other networks, and built forms:

Occupancy – Services – Transactions
Built structures/Networks
Higher-level morphological characteristics
Cadastre property boundaries and ownership)
Land forms
Topography
Grid

Figure A-2 – Geographic information stack

On top of the spatial layers comes the detailed information on occupants, services and transactions that end-users commonly deal with every day. All the other underlying infrastructure is designed to deliver the top layer of information and situate it in space.

At each layer, different providers (some public, some private, some community-based) create and maintain the information. A key point about these layers is that they are, or should be, interdependent; each provides a service of some sort to the layer above. A layer that is not to some extent reliant on the layer underneath is not really part of the 'stack' (once again, the implemented model is not always tidy).

'Firmness and commodity' are qualities sought from the lower layers of the information stack; we don't seek 'delight' from a networking protocol or a database management system, we seek reliability, availability, performance and, increasingly, invisibility (Norman 1998). Delight will be served by the upper layers of the information stack but information services cannot provide a window into the complexity and fascination of a city unless a sufficiently subtle IA underlies them.

At what point in the stack should an urban IA be positioned? The focus for such an effort is likely to be the middle layers of the stack, above the wires and operating systems and above the underlying geographic grid but below the services and transactions, somewhere between the cadastre and the built form.

Many parts of these 'stacks' of relevance to urban information services already exist. It is not a tidy picture: the layers don't fit neatly one on top of the other and the creation and maintenance of processes and standards applied to the information at each level vary enormously. One possible urban information 'stack' with ten layers (there could be many other versions) is shown in Figure A-3 with a few key points noted about the information at each layer: all the ratings (from Very Low – VL to Very High – VH) are my own assessment. The potential point in the stack where the urban IA might be positioned is also shown:

Layer	***Institutions defining, creating, maintaining***	***Level of information control***	***Level of information fragmentation***	***Rate of information change***	***Importance of information consistency***
Transaction	Service providers	VL	VH	VH	L
Services	Directory services	VL	VH	VH	L
Occupation	Some state and local govt	L	VH	H	L
Urban Information Architecture?					
Built structures	Some state and local govt	L	H	M	L
Networks	State and local govt, utilities and commercial	M	H	L	M
Administrative/Land use/Zoning	State and local govt	H	L	L	VH
Cadastre/ownership	State and local govt	H	L	M	VH
Land form	National and state govt, some commercial	M	H	VL	H
Topography	International/national and govt, some commercial	H	VL	VL	H
Grid	International	VH	VL	VL	VH

Figure A-3 – Urban information 'stack'

Current urban information services are generally a combination of commercially purchased map layers (including addresses) combined with directory databases (often compiled and maintained by the information service provider themselves); they do not plug neatly into this stack.

The different layers require different qualities; dependability and consistency at the lower layers and flexibility and increasing personalisation in the upper layers. Different frameworks and technologies are needed support to these different qualities.

Plugging the urban IA into the 'stack'.

Plugging into the information stack will not be easy or feasible in all cases for the organisations that traditionally employ urban designers (particularly local and city governments). What is feasible will be highly contingent on the legal and commercial characteristics of a given city. Identifying opportunities to influence or contribute to, or even regulate, this sphere will be very different in Singapore than in Sydney. It is necessary to identify the different layers required to support mobile telecommunications and the different players operating at each layer:

Content owners	private and public custodians of information (local governments, utilities, commercial organisations)
Content providers	'portal' providers , *Vindigo*, directory services, vertically integrated telcos
Content infrastructure providers	public and private who create and deliver cadastral and other underlying information and standards which underlie higher-level offerings
Mobile service providers	new players, sometimes associated with a specific technology
Retail network services	smaller telcos and other operators purchasing bandwidth from wholesalers
Wholesale network services	telcos
Network infrastructure	telcos operating under varying levels of state regulation with occasional joint partnerships with public utilities

Figure A-4 – 'Stack' layers underlying existing mobile information services

In Australia, Telstra is an example of an organisation that attempts to provide everything from infrastructure to content. In other countries, public authorities have introduced various models whereby the layers are defined separately and competitive offerings tendered for each layer.

The complexities of how and at what layer to participate or intervene vary so widely that they will not be pursued in detail here but an awareness of this environment will be indispensable to the organisation seeking to deploy an urban information service because it will be jostling for the information space along with all the other players listed in Figure A-4.

Making the case for involvement.

Given the potential difficulties outlined, the case for getting involved needs to be compelling. It was canvassed briefly in Chapter 3 that enhanced urban information services could contribute to normative urban design goals, in particular connectivity. It is not hard to imagine that other goals could be served as well.

Participation by public authorities in this area to date has focused largely on transport-related initiatives intended to make more granular and reliable public transport information available through mobile phones or other devices. This is essentially a goal around *efficiency* and clearly is intended to have a follow-on benefit for other aspects of transport design and therefore of planning and urban design; it is assumed (presumably correctly) that better knowledge of public transport will lead to better use of public transport. Possibly better knowledge of urban space will result in its better use in other ways.

Urban design involves many aspects other than just transport and navigation of course. Below are a series of lists of 'design elements' adapted from Carmona (Carmona et al 2003), the

authors often drawing on lists from other sources. Next to this are intuitive ideas on the possible use of information services to enhance or facilitate these elements:

Design element	**Possible enhancement or influence through information services.**
Morphological:	
⇒ Permeability	Seeing through impermeable urban space through navigational utilities
⇒ Public space network	Awareness of isolated public spaces
⇒ Navigational complexity	Navigational aids through complex or 3D areas. Assistance to visually impaired or at night
⇒ Granularity	Enhanced awareness finer grained spaces beyond the shopping mall
Perceptual:	
⇒ Identity, structure and meaning (after Lynch)	Enhanced 'meaning' through historical or cultural information about a site (more than is available on the graffiti-covered plaque)
⇒ Cognitive, affective, interpretative, evaluative	
⇒ Legibility, imageability, meaning and symbolism	Enhance the street-level view where that is inadequate for legibility
⇒ Attributes of successful places	
▪ Comfort and image	Ability to make more use of physically attractive areas by being able to do more things there electronically
▪ Access and linkage	Again, awareness beyond the normal visual and enhanced navigation
▪ Uses and activity	Attractive places become a base for other activities
▪ Sociability	Safety through enhanced information. Greater ability to share and exchange electronically
Social:	
⇒ Public realm	Enhanced awareness of what is the public realm and where it is and how it got there
⇒ Neighbourhoods (villages)	Precincts are to some extent defined by their information as well as by their boundaries
⇒ Safety and security	Enhanced knowledge of both dangers and refuge
⇒ Accessibility and exclusion	
⇒ Equitable environments	Equity in information access at the place where the information is relevant
Visual:	
⇒ After Smith	
▪ Sense of rhyme and pattern	Information may given pattern to seeming chaos
▪ Appreciation of rhythm	
▪ Recognition of balance	Balance a barrage of commercial information with other information
▪ Sensitivity to harmonic relationship	
⇒ Kinaesthetic experience	Changing the information with the movement
⇒ Positive/negative space	Bringing to the foreground much of what is in the background or invisible
⇒ Facades, after Buchanan	
▪ Sense of place	Places as defined by information about them
▪ Mediate between inside and out	Bring more outside in and vice versa
▪ Windows to suggest and frame internal life	Information gives context
▪ Character and coherence with adjacent buildings	Coherence through information giving legibility and meaning where that is not available visually
▪ Compositions that create rhythm and repose and hold the eye	
▪ Sense of mass and materials	

expressive of the form of construction	
▪ Substantial, tactile and decorative natural materials	
▪ Decoration that distracts, delights and intrigues	Information that distracts, delights and intrigues or draws attention to physical detail
⇒ After the Royal Fine Art Commission (RFAC)	
▪ Order and unity	Information giving order where there is none visually
▪ Expression	Hearing unheard voices through information
▪ Integrity	
▪ Plan and section	Different views of the built environment
▪ Detail	Drilling down into information in or about built structures
▪ Integration	
Functional:	
▪ Comfort	Attractive places become a base for other activities
▪ Relaxation	More mixed use for attractive places through the ability to transact on the move
▪ Passive engagement	
▪ Active engagement	Ability to interact and transact electronically with surrounds
▪ Discovery	Information leading one on to greater discovery and knowledge – taking you to places not otherwise perceived
⇒ Movement	Enhance or change movement through information. Stretch people beyond the normal paths through information as an attractor
⇒ Connectedness/integration	Expand the normal sensory bubble in which we move
⇒ Privacy	Shield one from unwanted aural and visual intrusion through better targeted and more personalised information retrieval
⇒ Mixed use	More mixed use for attractive places through the ability to transact on the move
⇒ Density	Spread out work and leisure activity through being able to do more on the move
⇒ Environment	
Temporal:	
⇒ Continuity	Enhance a sense of continuity through access to historical information
⇒ Robustness	
⇒ Temporal depth	Access to historical information

Figure A-5 – Ideas for enhancing urban design goals with information

Most, but not all, of these ideas are utilitarian and might be categorised under the heading 'efficiency' as described in Chapter 3. Broader public policy goals might also be served by enhanced urban information services; some of these goals may be attractive to public organisations:

- encouraging awareness of the public domain through easier and more transparent access to public information
- enabling and encouraging people to dig beneath the surface of the urban spaces they use every day and know a little more about them
- enable public participation in information-gathering exercises, perhaps related to environmental initiatives

- ensure some public or at least collective presence in the mobile information sphere so that it is not completely dominated by commercial concerns
- facilitating access to a diversity of views
- enhanced urban design *per se* through recognising information as an integral part of that design.

Some of these are nebulous and towards the periphery of what might be on an urban designer's agenda but they can help make a case for some involvement.

Appendix B – Code samples

Code sample 1

Function to build up a composite Path by successively finding the nearest Node in a list of Nodes and generating the shortest Path between each pair (using all available Nodes, not just those passed in the list):

```
(defun getPath (nlist)
 (let ((lnl (- (length nlist) 1)) (p nil) (d nil) (stn nil) (fnn nil) (sp nil) (st nil) (fn nil))
 (dotimes (i lnl d)
 (setq st (nth 0 (first nlist)))
 (setq stn (first nlist))
 (setq fnn (getNearestNode nlist))
 (setq fn (nth 0 (getNearestNode nlist)))
 (setq sp (all-bidirectional-search-paths st fn ConnTo :maximum-depth 50))
 (if (eql i 0) (setq d (append d (first sp))) (setq d (append d (rest (first sp)))))
 (setq nlist (remove stn nlist))
 (setq nlist (remove fnn nlist))
 (setq nlist (cons fnn nlist))
 (setq p d)
 )
 (first (list p))
 ))
```

Function to get the nearest Node to the first Node in a list selected from the other Nodes in the same list – called by getPath above:

```
(defun getNearestNode (node-list)
 (let ((tmpd 0) (ln 1000) (n nil) (cn nil) (nnn nil) (nn nil) (p nil) (sp nil))
 (dolist (i (rest node-list) d)
 (setq cn (nth 0 (nth 0 node-list)))
 (setq nn (nth 0 i))
 (setq nnn i)
 (setq tmpd (bidirectional-distance cn nn ConnTo))
 (if (< tmpd ln) (Progn (setq ln tmpd) (setq d nnn))))
 (first (list d))
))
```

Calling the function:

```
(setf proposedPath (getPath currentPath))
```

Code Sample 2

```
SELECT ?subject
WHERE {{ ?subject rdf:type :Bookshop.
?subject :nearestNode ?nn.
?nn :nearestMajorNode :MajorNode_1. }
UNION
{?subject rdf:type :Bookshop.
?subject :nearestNode :MajorNode_1. }}
```

Code Sample 3

```
SELECT ?subject
WHERE {{ ?subject rdf:type :Bookshop.
?subject :nearestNode ?nn.
?nn :nearestMajorNode :MajorNode_1.
?subject rdf:type :OrgFiveDays.
?subject :hasOpeningSat ?osat.
?subject :hasClosingSat ?csat.
FILTER (?osat <= 11)
FILTER (?csat >= 11)
}
UNION
{?subject rdf:type :Bookshop.
?subject :nearestNode :MajorNode_1.
?subject rdf:type :OrgFiveDays.
?subject :hasOpeningSat ?osat.
?subject :hasClosingSat ?csat.
FILTER (?osat <= 11)
FILTER (?csat >= 11)
 }}
```

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