

*A Method for the Visualisation of Historical
Multivariate Spatial Data*

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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List of Acronyms

CAARP	Cinema and Audiences Research Project
DEM	Digital elevation model
ECAI	Electronic Cultural Atlas Initiative
EDA	Exploratory data analysis
GBHGIS	Great Britain Historical Geographic Information System
GIS	Geographic information system(s)
HRS	Hierarchical regional space
IM	Infant mortality
IT	Information Technology
TIN	Triangulated irregular network

Abstract

The use of spatial technologies and geographical concepts for historical investigation is an area of increasing academic interest. This interest has led to the emergence of the field of Historical Geographic Information Systems (Historical GIS), in which history and geography are inextricably linked in both technology and scholarship. Utilising historical sources requires greater emphasis to be placed on the temporal aspects of the data and often involves the tracking of historical events over time. This temporal focus has challenged the suitability of current visual representations utilised in Historical GIS. This is because the majority of projects rely on conventional geographic visualisation representation designed primarily for emphasising the geographic, not temporal, aspects of the data.

This thesis establishes a visualisation method for investigating and analysing the temporal and geographical nature of historical events. In particular, it will focus on addressing the importance of visualising multiple variables and depicting change of these variables over time, with the aid of a Historical GIS and data graphics, for understanding the patterns and relationships between them. The visualisation method enables these temporal and geographic aspects of historical spatial data, along with multivariate capabilities, to be incorporated effectively by extending the spatial dimension of time-series graphs, meaningful classification, and by utilising the capacity to show change and variability in linear spatial objects.

This thesis demonstrates the benefits gained from visualising historical, geographic, temporal, and multivariate data concurrently through a Case Study on the history of Melbourne's cinema venues between 1946 and 1986. The history of cinema operation involves information on 289 cinema venues across a period of great cultural and technological change. Application of the visualisation method was used to address a number of Geographic Questions relating to specifics of cinema venue change by representing chosen venue locations and operation variables (such as seating capacity and ownership) over a specified temporal period. This has enabled data that is usually reserved for written communication to be visually analysed, interpreted, and displayed in a way not previously explored. It has been found that by creating visual access to multivariate and temporal spatial information it is possible to produce new insights into the geographic and temporal patterns and relationships present in historical data.

1 Introduction

1.1 Introduction

This research project will develop a method for visualising historically changing, multivariate, spatial information for both visual display and analysis. The visualisation of multiple variables together with spatial and temporal data is important for interpreting and analysing historical geographic patterns that change over time. It not only creates visual access to information typically reserved for written communication, but also reveals aspects of the data and therefore aspects of history that have previously gone unnoticed.

Historical data is inherently temporal; whether it depicts a snapshot of historical time, or the temporal change of historical events over time. When coupled with a spatial component, this data often requires the interpretation of changing historical spatial information. One way to depict this change is through visualisation. This study adopts the definition of visualisation put forward by Andrienko and Andrienko (2006, p. 166) defining it as “making data and the corresponding phenomena perceptible to the mind or imagination of the explorer”. What is notable about this definition is the absence of the word visual in visualisation. This research

has adopted this definition because whilst the method creates visual access to data, the main focus is on successful communication, or making phenomena perceptible to the mind. Visualisations have been largely associated with graphical representations, even though the definition does not specify so. The reason for this is that graphical representations can very effectively make data perceptible to the mind. Visualisations therefore reveal patterns within the data and have the ability to stress the spatial aspects of historically significant information. What this project aims to achieve is to communicate and analyse historical spatial data through the development of a visualisation that integrates historical events and spatial and temporal concepts in a holistic multivariate display.

The first two sections of this chapter will provide a background to the study; outline the reasons for conducting the research; and the main research objectives. In particular, the background will define the fields in which the research is placed and the areas that will be enhanced by the study, the Case Study of Melbourne's cinema venues that the visualisation will be applied to, and an account of the literature that has addressed similar issues. The main aims and objectives of the research will be stated along with the rationale for the study. This will discuss both the reasons and needs of the research within the field of history and historical geographic information systems (Historical GIS) and the significance and original contribution to the Case Study field of cinema. The remainder of the chapter will include a brief outline of the study and thesis organised into chapter sections.

1.2 Research Objective

The main aim of the research is to develop a method for analysing and representing historically changing, multivariate, spatial information by creating visual access to information typically reserved for written communication. In addition, there are a number of Research Questions that will be answered in addressing this aim. These are:

- 1) How can historically changing, multivariate, spatial data be analysed and communicated visually?
- 2) How can temporal change of static entities be represented using spatial technology?
- 3) What are the issues related to working with historical data?

In addition, there are two Research Questions that specifically address the Case Study and the success of applying the visualisation to the cinema data. These are:

- 4) What are the important spatial and temporal aspects, and associated attributes related to cinema venue operation?
- 5) Can a visual mode of communication enhance the understanding of the history of Melbourne's cinema venues?

Each of these Research Questions will be addressed through the development of the research and will aid in analysing the success of the method and resulting visualisation.

1.3 Background and Rationale

History and geography are inextricably linked, for understanding place requires a historical perspective, whilst understanding periods of time requires a geographical perspective. Despite this link, the two disciplines have many fundamental differences which make incorporating both historical and geographical aspects within the one study challenging. One important difference is communication. On the one hand, a historian's main mode of communication is through the written word and on the other; a geographer is more comfortable with visual images (Baker 2003; Bodenhamer 2008; Knowles 2008a). Historians do make use of visual

images such as fine art, photography, and historical maps, but do not generally regard images as sources of evidence (Doel and Henson 2006; Knowles 2008a). Generally, historians struggle with visual communication, with creating visual images that convey a historical interpretation (Bodenhamer 2008). However, with the increase in mapping and spatial technology being applied to historical data (known as the *spatial turn*), the ability to be able to communicate historical data visually becomes increasingly important. This research will address the need for a greater appreciation of visual communication and expand on the use of visualisations that not only support claims but are used as evidence and in analysis within historical scholarship. This will be achieved by creating a visualisation that supports aspects of historical and spatial data including change over time, thereby allowing historians to make geography an integral part of their study by embracing the benefits inherent in visual communication.

The use of spatial technologies and concepts for historical investigation, such as geographic information systems (GIS) and cartographic techniques, has provided new insights into the relationships between geography and history, and enabled new patterns and trends both temporally and spatially to be analysed for historical spatial data. Visualisations utilising historical spatial data can help bridge the gap between geography and history, especially in terms of successful communication. The majority of visualisations using historical spatial data are produced through the use of a Historical GIS. To the historian, a GIS can be considered as a database that can handle geographic location data and also qualitative and quantitative information of historical events or entities (Knowles 2000); a tool that can provide geographic context, new methods of historical investigation, and new insights and conclusions to research.

Mapping and visualisations are a natural consequence of Historical GIS, as they dominate both analysis and the display of results and findings. A review of the visualisation techniques used in Historical GIS reveals a number of approaches, the main types being: differentiating and ordered visual variables (Cunfer 2008; Donahue 2008; Fyfe and Holdsworth 2009; Piatti et al. 2008; Ray 2002a; Schlichting et al. 2006; Sheehan-Dean 2002; Wenzlhuemer 2009); isarithmic mapping (Carter 2008; DeBats 2008; DeBats and Lethbridge 2005; Elliott and Talbert 2002; Gong and Tiller 2009; Gragson and Bolstad 2007; Knowles 2008b), choropleth mapping (Beveridge 2002; Cunfer 2002; Dorling et al. 2000; Gregory 2008; Healey and Delve 2007; Lancaster and Bodenhamer 2002; Pearson and Collier 2002); charts and graphs (Beveridge 2002; Gregory 2000, 2009; Norman et al. 2008; Skinner et al. 2000); and three-

dimensional representations (Elliott and Talbert 2002; Harris 2002; Piatti et al. 2008; Rumsey and Williams 2002; Shimizu and Fuse 2006; Talbert and Elliott 2008). Whilst all of these techniques have a historical and geographical focus, they vary in their inclusion or exclusion of representing change over time, and also in the number of variables that are included. The vast majority of techniques are used to represent one or two variables in the data. The temporal component is present in all cases, and many depict change over time. However, there has been little research into representing multiple variables, especially involving change over time. The significance of the visualisation method developed in this research lies in the ability to visualise multivariate spatial data which incorporates change over time through extending the spatial dimension of time-series graphs to enhance the explanatory power of graphic displays (Tufte 2001), and by developing a multivariate temporal visualisation through a cartographic technique rather than technology.

Contributions will also be made to fields concerned with visual communication and analysis including *Information Visualisation*, *Geovisualisation*, and *Exploratory Data Analysis*. Each of these fields have a strong emphasis on technology providing multivariate and temporal capabilities within a visualisation, such as multiple and linked displays and querying (for examples see: Andrienko and Andrienko 2007; Chen et al. 2008; Guo et al. 2005; Jern and Franzen 2006; Ray 2002a; Schroeder 2010). Yet there are also techniques present that handle such data without computer interactive displays, such as Minard's classic seminal of Napoleon plight (Tufte 2001) (to be discussed in section 2.4.4). There is a current need to address the challenges associated with visualising multiple variables concurrently, as there is greater complexity in the visualisation techniques adopted as well as increased difficulty in effectively displaying and understanding the datasets (Klippel et al. 2009). Visualising large numbers of data sets and variables is often an integral part in understanding patterns and relationships between them (Guo et al. 2005). This research will be a significant and original contribution to the limited range of techniques available for understanding patterns and relationships within multivariate, historical, spatial data in a holistic display.

The research method and final visualisation will be developed through a Case Study of the history of cinema venues in Melbourne, Australia between 1946 and 1986. Cinema venue data can be seen as spatial, multivariate, and temporal, for whilst the location of venues are geographically static, they have associated variables that change over time such as seating capacity and ownership. For cinema historians, applying spatial methods and representations to cinema venue data (a movement also dubbed the *spatial turn*) enables a spatial history to be

constructed and analysed. However, it has not been until recently (mainly over the last decade) that the significance, history and practice of cinema itself, removed from film content, has been examined (Maltby 2007). It has been argued that in order to recognise the cultural significance or impact of cinema, it is essential to examine the cinema's role as a site of social and economic activity (Bowles and Maltby 2008; Maltby 2007). Through this change in emphasis and the move towards alternative methods of communication and interpretation, the spatial significance of cinema venues is a rising influence in cinema studies. As a result, the spatial and visual focus of this research will expand the use of visualisations in cinema studies that emphasise the spatial significance of cinema venues, by making an original contribution to the *spatial turn* in cinema studies. In addition, it will provide a method for understanding and interpreting new patterns and relationships of cinema characteristics to realise the cultural significance and impact of cinema.

There has been very little Australian research into distribution and exhibition practises, especially during the post-war period (Verhoeven 2006), despite it being a time of much cultural change. In relation to the geographical distribution and significance of Melbourne's cinema venues, this project is the first of its kind to analyse and represent all operating venues within Melbourne during the time period. This will significantly add to the construction of a more complete history of Melbourne's cinema venues and stand as an example to enable cinema historians to consider new sources of information for understanding audience and business behaviour in the cinema industry. The geographic and temporal scope for this research refers to those venues that are classified as either *city* or *suburban* theatres in the Cinema and Audiences Research Project (CAARP) database within the entire extent of greater Melbourne. This has created a geographical extent that is largely within 50km of Melbourne's city centre; however, given the irregular proportions of greater Melbourne, there are also a number of venues that lie outside this distance. These are also included. The temporal extent refers to the period between 1946 and 1986. It is not within the scope of this research to investigate the applicability to other histories or other locations; however it is quite likely that, with modification, the visualisation method would be transferable.

Just as there is a lack of visualisations for spatial historical data, there is an equal lack of visualisations that are appropriate for multiple variable, temporal, and spatial dimensions within spatial cinema data. The majority of visualisations currently used for spatial cinema data do not consider change over time. Instead, they are used to locate geographic features or provide a spatial context to cinema research. Visualisations in cinema studies are mainly

concerned with the areas of mapping the geographies of film production and consumption (Caquard 2009b; Naud 2010; The University Library 2008), and in the analysis of geographical patterns of cinema operation and influence (Caquard 2009b; Hallam and Roberts 2009; Klenotic 2007; Verhoeven et al. 2010; Verhoeven et al. 2009). A significant outcome of this research is the development of a visualisation method for historical investigation of cinema data; one that can incorporate the multivariate and temporally changing elements found in many cinema data sources.

1.4 Overview of the Research

The research method has been organised into a number of chapters that address the aim and Research Questions outlined in section 1.3. The chapters are designed to present the research in stages of development – each of which is discussed in the following sections.

Chapter 2

Visualisations of historical spatial data have been used in historical investigation for communicating findings and for spatial and temporal analysis of the data. The coming together of history, geographical concepts, and mapping invites a number of issues to be discussed, including the relationships between geography and history and the role of spatial data, geographic information systems (GIS), and visualisation in historical research. Chapter 2 will provide a discussion of these topics, and definitions of *visualisation* and *Historical GIS* will be addressed. A review of visualisation techniques adopted by academics using historical and spatial data will be undertaken and discussed in relation to the complexity of the data that is represented. This will determine the ways in which space, change, and variables are handled within current visualisation techniques. Discussions will significantly contribute to addressing Research Questions 1, 2, and 3 (outlined on page 3), which relate to understanding how historically changing, multivariate, spatial data can be analysed and communicated visually; how can the temporal change of static entities be represented; and understanding the issues involved with working with historical data.

Chapter 3

Chapter 3 provides a background to the Case Study; the history of cinema venues between 1946 and 1986 in Melbourne, Australia. The discipline of Cinema Studies has begun to

embrace spatial concepts and technologies and the success of mapping and visualisations are an important component of enhancing the role that geography and spatial concepts can play in this discipline. This *spatial turn* will be discussed in Chapter 3, including its theoretical origins in the discipline. The differences between the terms *cinema* and *film* will be addressed and the Case Study specifics of the City of Melbourne and Melbourne's cinema industry will be outlined. As presented in Chapter 2, this section will also review the visualisation techniques adopted by academics, but will focus on the visualisations utilising cinema and spatial data in particular. This section will contribute to addressing Research Question 4, relating to understanding the important aspects of cinema venue operation.

Chapter 4

The development of the method has been designed for historical spatial data, and as a result, the nature of this data, the data sources, and data analysis all play a major role in the visualisation concept. Three *Geographical Questions* were created from the cinema data, all of which address different aspects of cinema venue history, and were used as a basis for the development of the visualisation. The three questions are:

- 1) The longevity of Melbourne cinemas operating in 1946 – why did some cinemas survive the 40 year span to 1986 and others closed?
- 2) The openings and closures of cinema venues between 1950 and 1970, a particular period of cinema decline – what were the characteristic and geographical aspects of cinemas operating during this period?
- 3) The operation of large cinema companies with multiple venues (cinema chains) within Melbourne's cinema industry – how successful were large cinema companies between 1946 and 1986 and what were the characteristic, spatial and temporal differences between the different companies?

These three Geographical Questions will be outlined in Chapter 4 along with the specifics of data collection, sources, data handling, and analysis. The formation and data specifics of the Geographical Questions will greatly contribute to Research Questions 3 and 4, in identifying the important aspects for cinema venue operation and the issues in working with historical spatial data.

Chapter 5

Chapter 5 will form the development of the visualisation method and technique from concept to technical refinement and will address the first two Research Questions of how to visually communicate historically changing, multivariate, spatial data and the temporal change of static entities. The visualisation approach is based on extending the spatial presence in time-series graphs, multivariate visual analysis, and emphasising the historian's importance of time. Taking the data and analytical requirements of the three Geographical Questions, the chapter develops the visualisation concepts through meaningful spatial classification, the non-aggregation of geographic entities, and change detection. Aggregation has been avoided because of the highly variable data and the implications of depicting individual venues as an area of aggregated values. This has meant that the visualisation has been able to represent each venue as a separate geographic entity, complete with associated variables and temporal variations. Outputs of the visualisation approach will be a graphic visualisation with the capabilities of communicating and visually analysing historical multivariate point data in a holistic view.

Chapter 6

The success of the visualisation is assessed through applying the technique to the three Geographical Questions identified in the Case Study. The visualisations are created using the cinema venue data relevant to each question (spatial, temporal, and associated variables) which is handled within a GIS. The resultant visualisations depict each individual cinema, tracking changes over time of the chosen attributes, with the aim of investigating the particular Geographical Question. Chapter 6 outlines the Case Study application and verifies the success of the visualisation through the ability to analyse and identify patterns and relationships held within the data. This chapter will address Research Questions 4 and 5, by identifying the important aspects of cinema venue operation and whether a visual mode of communication can enhance the history of Melbourne's cinema venues.

Chapter 7

The final chapter will discuss the effectiveness of the visualisation to display and analyse multivariate, temporal, spatial data. Whilst this will be assessed in relation to the ability to investigate the history of cinema venues, this section will also discuss the potential of the visualisation approach in other areas of historical inquiry and more disparate areas of application. This section will outline the limitations with both the Case Study data and the

visualisation method and address the success of the study to answer the Research Questions put forward in the study objectives in Chapter 1. In conclusion, the chapter will outline areas for further research that this study creates.

1.5 Conclusions

This chapter has identified that the aim of the research is to develop a method for visualising historically changing, multivariate, spatial information for both visual display and analysis. This aim will be addressed with the support of additional Research Questions that deal with specific issues within the research area and Case Study. A brief background and rationale for the study was discussed, and will be addressed further in future chapters. The research method and organisation of the thesis was outlined in the overview of the research by order of chapter. The development of the visualisation method is a result of the literature review and concepts discussed in chapters 2, 3, and 5. It will also be seen that it is a result of the need for an alternate approach to visualising historical data and particularly the unique characteristics of spatial historical data. The visualisation itself (discussed in chapter 5) will be applied to the Case Study of Melbourne's cinema venues and evaluated in the subsequent chapters.

The next chapter will discuss a number of issues relating to the role of spatial data, GIS, and visualisation within history and establish definitions within these areas. Chapter 2 will provide a review of the visualisation techniques adopted for historical spatial data.

2 *Visualisations for Historical Spatial Data*

2.1 *Introduction*

Visualisations of historical spatial data have relied primarily on conventional cartographic techniques. However, in order to effectively communicate and analyse data that is both historical and geographic, it is important to understand the differences and relationships between the two disciplines. This chapter will discuss these important aspects of historical spatial data, including the role of visualisation in historical research and the emerging field of Historical GIS. A review of the visualisation techniques of historical spatial data will be discussed, identifying five main cartographic techniques currently utilised in geohistorical projects. In addition, these techniques will be assessed in relation to the complexity of the data that is represented. This will be outlined in the final section of the chapter and organised by the way in which the temporal and variable aspects are handled within each technique.

2.2 *Historical Spatial Information*

This section will discuss those aspects of geographical and historical research that are particularly relevant to visualising historical spatial data. This will be addressed by looking at the disciplines of history and geography through their similarities and differences and need for greater integration; the unique nature of historical spatial information including data sources, communication, and treatment of time; the role that Geographic Information Systems (GIS) have played in historical scholarship and managing historical spatial information; and the importance and use of visual communication.

2.2.1 *History and Geography*

Every object or phenomena has its own geography, its own history, as well as its own structural forms and associated functions. Despite their coexistence, geography and history can be treated quite separately as disciplines. Geography with a focus primarily on places whilst history is focused on periods (Baker 2003). Yet, as Baker goes on to stress:

“Geography and history are different ways of looking at the world but they are so closely related that neither one can afford to ignore or even neglect the other” (2003, p. 3).

Incorporating both geography and history within the one study, whether it is through written communication or visualisation, should therefore be encouraged. Addressing both aspects can only enhance historical and geographical understanding. It is this mutual importance for both geography to history and history to geography that has brought about the interdisciplinary studies that combine the study of history and geography. Figure 2.1 depicts the relationship between geography, history, and their subject matter forming the separate fields of historical geography and geographical history (Baker 2003).

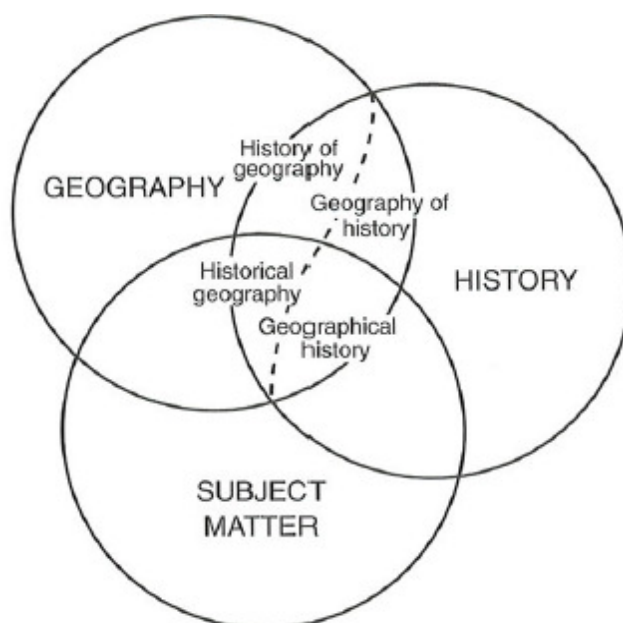


Figure 2.1: The relationship between history and geography (Baker 2003, p. 3)

The difference between the two can best be viewed by different perspectives – historical geography is concerned with the historical dimension in geography, and geographical history with the geographical dimension in history (Baker 2003). Both have been given many different definitions. E. W. Gilbert defined the function of historical geography as reconstructing the regional geography of the past (1932), whilst Darby identified historical geography as an approach in which geographical problems and methods are addressed with historical data (1979). Darby also identifies the field of geographical history defining it as the “investigation of the influence of geographical conditions upon the course of history” (1979, p. 69). Further research areas that address geography and history include time geography, geographies of temporality, spatial histories, and locational histories. The common thread amongst these fields is the relationship between geography and history; whether it is the focus of space and time, or periods and places.

Despite the strong relationship between history and geography, there are notable differences that make combining the two often difficult. As Baker states:

“Geography and history are perspectives; they are different ways of looking at the world. Geography and history do not have different subject matters, so that any distinction between them cannot be made on those grounds” (2003, p. 36).

This view is also depicted in Figure 2.1. History and geography can examine the same subject matter, but they do so through different perspectives. For example, the subject of railways in Australia can be examined geographically through their distribution and spatial patterns, and also historically through their development, social influence etc. So if there is not a difference between subject matter, what are the differences? Knowles (2008a) identifies a number of disparities. Historians and geographers seek causal explanations by establishing the temporal sequence of events, or spatial proximity and distance of conditions respectively. Differences also include the ways in which they publish their research and in the technical training they receive. One of the most profound differences is in communication. Historians communicate through the written word, whilst geographers are more comfortable with visual forms of communication such as maps. Difficulties arise therefore when historians attempt to incorporate the geographer's mode of communication. To quote Bodenhamer:

“Our (historians) difficulty comes when we seek to communicate visually. We construct textual images that we embed in our story, but we struggle to create visual images that convey our interpretation” (2008, p. 225).

As a result, visualisations that are a product of historical and geographic enquiry can (especially from a historical point of view) still rely heavily on the written word to explain what is found in the visualisation itself. This also points out an important difference concerning the creation of visualisations; the data used. Geographic and historical data often come from vastly different sources, and the ways in which these data are handled is also contrasting. Combining the two creates data that is both historically and geographically focused. The resultant geographic/spatial historical data therefore inherits the richness and also the pitfalls of the combined data sources.

2.2.2 The Nature of Historical Spatial Information

Data that is both historical and spatial is as varying as the subject matter they discuss. A review of projects conducted as part of this research (discussed in sections 2.3 and 2.4) that make use of both historical and spatial data (often referred to as geohistorical projects) reveals that the majority do not simply want to show or describe historical locations; instead they have a strong thematic focus. Topics range from segregation (Schlichting et al. 2006),

battlefield stories (Knowles 2008b; Lowe 2002), and social and demographic studies (Gregory et al. 2001; Orford et al. 2002), to literature locations (Piatti et al. 2008), archaeology (Harris 2002), and the Salem witch trials (Ray 2002a). Addressing such topics from both a historical and geographic perspective can allow analysis and understanding of relationships that might not otherwise have been considered if studied separately (Siebert 2000). However, to be able to integrate the two disparate information types we need to understand and overcome their differences. Since data used for geohistorical projects vary considerably, differences in data characteristics need to be discussed.

Historical data is usually sourced and interpreted from verbal texts (Knowles 2008a) and is often rich in the details of historic events. The format of much historical information used as evidence is text and is communicated in the same way. Historians also make use of visual images such as fine art, photography, and historical maps, but historians do not generally regard images as sources of evidence (Doel and Henson 2006; Knowles 2008a). Historical data is often incomplete, imprecise, and unreliable. To a historian, not only the data but also the past is incomplete and irretrievable (Bodenhamer 2008). Historian Geoff Cunfer accepts and agrees that historians are comfortable with this type of incomplete and imprecise information, as traditional written history (as he describes) is:

“built upon the scraps of information left behind – what happened to get written down, what happened to be preserved, what the researcher happened to find” (2008, pp. 113-114).

For textual data and communication, such incomplete and imprecise data is accepted and managed well. Yet, much of the data used by historians can be viewed as *geographically enabled* data, although the spatial component is often not used (Bailey and Schick 2009). As a result, the spatial data embedded in historical data also inherits the incompleteness and inaccuracies associated with the historical sources.

Possibly the most significant distinction to be made for historical data is the presence of time. For many, historical data implies information about a past time. Often this can be reflected in the data as a date to place it in a historical context. Much historical research addresses change over time or the telling of history through a sequence of events. This requires records of change – whether it is non-spatial such as the reign of kings and queens, or spatial such as the changing geographical distribution of coal mines.

The importance of time and space can be seen as an instigator of integrating historical and geographical data for research. Massey (1999) argues that there is a need for incorporating both space and time into analyses. Time is important because it tells a story of how a place develops, and space is important because without it only one story can be told. Therefore it can be assumed that whatever story is told it will inevitably happen in another place (Massey 1999). Knowles (2000) offers a number of reasons as to why space should be an important part of historical analysis, including the need for accurate spatial boundaries for historical statistics, a greater understanding of the spatial aspects of human history, and that particular dimensions of historical reality and change can be revealed only through mapping data. Baker (2003) argues that historical research and geographical research should be able to explore change over both space and time. As discussed further in section 2.4.2, historical spatial data do not always have the capacity to show such changes.

Geographic data (usually depicted in the form of geographic coordinates) does not need a temporal component to exist. However, with the addition of time it is possible to place geographic features and characteristics in a temporal context or to show change in their location or associated variables over time. The primary focus of geographic data is spatial location and is found primarily in tables and maps. Geographers are not as comfortable with incomplete and inaccurate data as are historians. The sources of geographic information are usually more reliable and accurate in their recordings, such as GPS data, remotely sensed data, aerial photography, and census records.

Combining geographic and historical research to either *geographically enable* historical data or to integrate different geographic and historical data produces what is known as historical spatial data. Historical spatial data can be found in maps, photographs, census, and voting records (Siebert 2000) and inherits a period or instance of historical time. It is also inevitable that the uncertainties bound up in historical data are carried over to the associated geographic component of the historical spatial data.

Historical spatial information also shares many of the same characteristics with spatial temporal information. Spatial temporal information includes data that has both a spatial and a temporal component but does not typically come from historical sources or used for historical investigation. Instead, contemporary sources are usually utilised. Spatio-temporal data typically includes data that depicts change to the spatial location of geographic entities over

time. The handling and visualisation of such data is a challenging area of research in current geographic analysis (Andrienko and Andrienko 2006; Hornsby and Egenhofer 2000; Lohfink et al. 2007). Historical spatial information does not infer changes to historical geographic entities over time; more often than not it is concerned with changes in attribute values over time. Another important difference to make between historical and temporal spatial information is access to data sources. The kind of information that is missing from the historical world is almost routinely created for the contemporary world (DeBats 2008), and this in turn creates a great restriction for collecting and utilising historical spatial information.

Applying historical spatial data to historical research can be done in a number of ways, through visualisation; with the aid of Geographic Information Systems (GIS); and in spatial analysis. As mentioned in Chapter 1, the recent *spatial turn* in historical scholarship can be attributed largely to the emergence of GIS technology in the field. So in order to apply this temporally significant and often incomplete data to the precise and exacting technology of GIS, it is important to understand the abilities and issues associated with the rise of GIS in historical scholarship.

2.2.3 Historical Geographic Information Systems

The ability to ask geographical questions, to gain new insights from historical investigation, and to present these insights and findings in a way that stresses the geographical context of the research, are the aspects that drive the field of Historical Geographic Information Systems (Historical GIS). The area of historical scholarship has applied GIS to the study of history in order to explore geographical aspects of their research, and in so doing have shaped the field of Historical GIS. This interest in the spatial aspects of history has been dubbed the *spatial turn*, and is becoming increasingly present in current historical and geohistorical research. The emergence of Geographic Information Systems (GIS) in the early 1980s opened up the fields of spatial statistics and geographical analyses to those who wanted to explore the geographical aspects of their research. GIS also made the process of geographical analysis and mapping much more productive, pushed the digitisation of spatial data, and as GIS developed it made GIS software easier to use. Those to benefit from the development of GIS are varied, the fields include: geography, environmental science, land-use management, and the humanities to name a few. In order to understand the impact GIS has had on historical scholarship it is important to understand the study of GIS. Due to its wide application,

defining GIS is not a straightforward task. Instead, definitions reflect the variety of applications and differ depending on how and why GIS is used. An early and frequently quoted definition is taken from Burrough (1986, p. 6), describing GIS as “a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes”. It can also be widely defined as “a system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which are spatially referenced to the Earth” (*Handling Geographic Information: Report of the Committee of Enquiry* 1987, p. 132). These two definitions focus mainly on the functionality of GIS, but besides this, their common link is the reference to spatial or geographical data; data that has a location on the earth’s surface. When this spatial or geographic data is given a historical context and is used together with GIS for historical research, we refer to what has become known as Historical GIS.

A review of the literature concerning Historical GIS describe the field loosely as the use of GIS in historical research or scholarship (Gregory and Ell 2007; Gregory and Healey 2007). According to Gregory (2007), researchers using GIS often refer to it as *following a GIS approach*, which does not highlight the unique nature of the field. From the mid-1980s, aspects of GIS software have been used in the study of history, but it was not until the early 2000s that the field began to receive greater attention with a special edition devoted to Historical GIS of the *Social Science History* journal (Knowles 2000), and later a book on collected studies of the use of GIS in history *Past Time, Past Place* (Knowles 2002b). Because of the focus on the application of GIS to history in its infancy, the first attempt to define the field did not appear until 2008 in a book titled *Placing History* (2008c) which focused on a number of studies of GIS and history, but also provided readers with an introductory chapter on the status of the field (Knowles 2008a), a discussion of the implications for the discipline (Bodenhamer 2008), and a review of the potential for temporal GIS (Goodchild 2008). It is in this introductory chapter that Knowles defines the discipline by detailing the characteristics of Historical GIS:

1. Geographical questions drive a significant part of the historical inquiry.
2. Geographical information provides a good share of the historical evidence.
3. The bulk of evidence, or the evidence that provides the study’s key analytical framework, is structured and analysed within one or more databases that record both location and time.

4. Historical arguments are presented in maps as well as in text, graphs, tables, and pictorial images; maps serve in particular to show patterns of change over time (2008a, p. 7).

This definition emphasises the unique nature of Historical GIS. GIS is given a historical context not only in its application but in its scholarly practice, and supports the claim that it is more than just a collection of methods; it is now being recognised as a subfield within historical studies (Knowles 2008a). GIS has the capacity to extend analysis to questions, scales, and evidence that are currently considered in historical scholarship – it makes space an explicit part of analysis (Knowles 2000). Historical GIS in particular has the potential to reveal spatial patterns of people and events, to provide visual and analytical tools for historical inquiry, and to challenge long-standing understanding and interpretation (Knowles 2002a).

The importance of visualising data in Historical GIS is apparent if the definition above is investigated; Knowles (2008a) lists it as one of the four characteristics of the discipline, emphasising that historical arguments be presented in a way that shows patterns of change over time. It is therefore essential to prioritise the use of visualisation for historical spatial data in order to successfully communicate the significance of the integrated data and the conclusions that can be drawn from close inspection.

2.2.4 Visualisation

In order to review the visualisation techniques adopted for historical spatial data and their role in historical research, it is essential to be able to address the meaning of visualisation. The term *visualisation* has been used extensively, in many different contexts, and the definition and meaning has been varied amongst different fields. As discussed briefly in Chapter 1, the definition adopted for this research refers to “making data and the corresponding phenomena perceptible to the mind or imagination of the explorer” (Andrienko and Andrienko 2006, p. 166). Adopted from the work of Andrienko and Andrienko (2006), this definition has been founded on the concept of the term to *visualise* and focuses on graphic communication. Visualisations have been largely associated with graphical representations, even though the definition does not specify so. The reason being is that graphical representations can very effectively make data *perceptible to the mind*. An example of their effectiveness over tables or

text can be seen in the graphic by William Playfair (see Fig 2.2). Here he has plotted three parallel time-series graphs depicting price of wheat, wages, and the reigns of British kings and queens. Trends and patterns can easily be interpreted from the graphic, making it clear that the price of wheat in proportion to mechanical labour was best in 1810-1815 (Tufte 2001). Interpreting the same information in the form of tables and text would be extremely time consuming and complex. In terms of assessing which one is more perceptible to the mind, the time-series graph is a clear winner. Therefore, the assumption that most researchers make that visualisations refer to graphic representations is not false or misleading, for they are the primary way of making data perceptible to the mind.

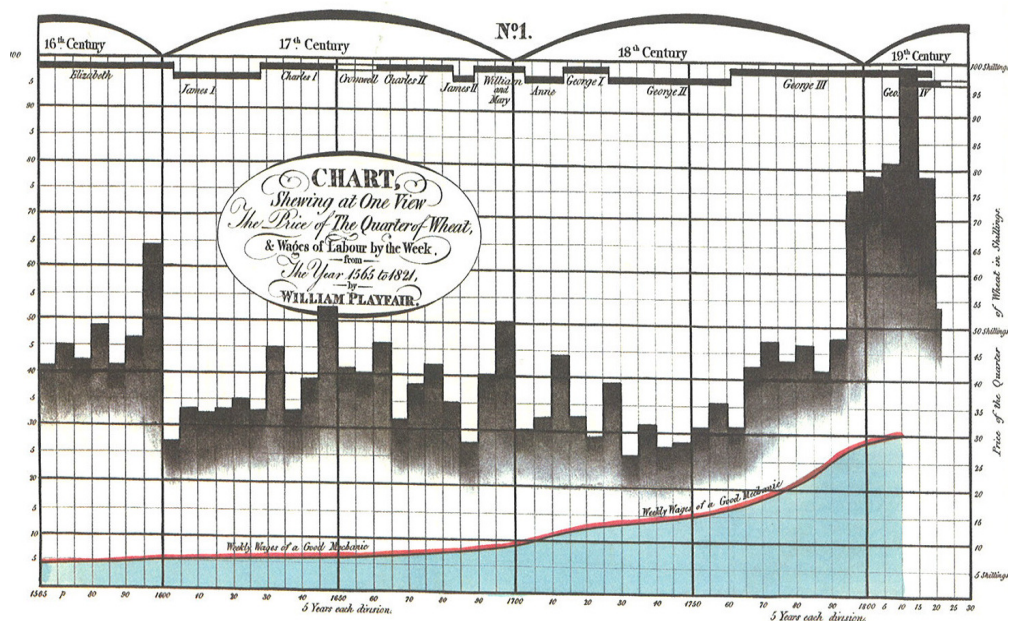


Figure 2.2: Parallel time-series graphs (Tufte 2001, p. 34)

Graphic representations come in many forms: graphs, charts, diagrams, plots, and maps. In what he terms graphical excellence, Tufte (2001) stresses the importance of graphic design to efficiently communicate complex quantitative ideas in the form of data graphics. Data graphics make use of points, lines, coordinate systems, numbers, symbols, words, shading, and colour to visually display measured quantities (Tufte 2001). The work of graphic experts such as J. H. Lambert, William Playfair, and Jacques Bertin have paved the way for modern visualisations. Their principles and techniques are still applied widely to the benefit of graphical representation for related fields. Related fields, such as information visualisation, scientific visualisation, and Exploratory Data Analysis (EDA) also refer to visualisation largely as graphic representations (Andrienko and Andrienko 2006; Chen 2006; Dykes et al. 2005; Slocum et al. 2009). Visualisations that are applied specifically to geographic data can be placed under the umbrella of geographic visualisation or geovisualisation, where the use of

graphical representations are particularly prevalent due to mapping conventions. However, it has been argued that geographic visualisation involves a highly interactive graphic display (MacEachren 1994, p. 6). Visualisations have been extended beyond graphic representations, using advanced computer software and systems to create these highly interactive displays of thousands of records that include the capacity for querying, exploratory data analysis, and linked displays. This more contemporary view of the term visualisation has also been expressed as any recently developed, novel method for displaying data (Slocum et al. 2009).

In the context of this research, visualisation is not limited to only graphic representations or graphic representations in an interactive graphic display. What is distinguished which is not made clear in the definition adopted for the research, but hopefully in discussion, is that the focus of this research is graphic representations as opposed to other means of making data *perceptible to the mind*, such as tables or text. Amongst the graphic representations are those that utilise interactive computer displays through to representations that are created and utilised in the most simplest of means.

As discussed previously in section 2.2.1, the classic mode of communication for geographic data is visual, often in the form of maps. But why such an emphasis on the visual? Andrienko and Andrienko (2006) relate the importance of perception to visualisation to ideas from cognitive psychology, that perception provides material for thinking and thinking involves perception, that is, they are inseparable. Perception not only provides but organises material into concepts and thereby enables, as Arnheim states, “the grasping of relevant generic features of the object” (1997, p. 153). Andrienko and Andrienko bring these ideas of cognitive psychology back to techniques in graphical representation, stating that;

“Thinking operates with mental images, which are of the same nature as or at least equivalent to images formed by means of vision. Therefore, it is quite natural and appropriate that data visualisation is meant first of all for human eyes, by providing graphical, cartographical, or pictorial representation of data” (2006, pp. 168-169).

Visualisations are important to a number of fields because they reveal patterns and trends within the data (Tuft 2001). This is true too for the field of Historical GIS, or those that make use of historical spatial data. For the discipline of history, which relies on literary accounts almost solely, visual and often quantitative visual information need to be effective and

persuasive in presenting results, supporting evidence, and geographical context even more so than those disciplines that have more of a visual mode of communication. It needs to be twice as convincing and twice as effective.

Due to the emphasis on the applications of Historical GIS, the development of effective visualisations has rarely gone beyond the conventional methods of visualisation used in GIS and cartography. Scholars have adopted these methods because more often than not, the data suits these types of representation. The use of GIS software for visualisation can also limit the ways in which the data is presented. Techniques available in GIS software are effective for visualising spatial data, but when we are looking to visualise spatial and attribute patterns which change over time, the largely static nature of GIS falters in its effectiveness. However, since the introduction of GIS to historical investigation, the use of visualisations has increased extensively.

2.3 *Visualisation Techniques*

The use of visualisation techniques for historical spatial information is an area of increasing academic interest, especially since spatial technologies such as GIS have been embraced by historians and cultural geographers (Knowles 2000, 2008a). This of course does not mean that historical spatial information was not visualised prior to the introduction of GIS. High quality atlases of historical information were being produced many years before GIS (for examples see: Barraclough 1978; Fox and Deighton 1957; Oddvar 1975, to name a few) and there are a number of outstanding examples of visual representations used to communicate the spatial history of events, such as Minard's graphic of Napoleons march of 1812-1813 (to be discussed in section 2.4.4). The majority of visualisations prior to the recent spur of research make use of conventional cartographic techniques (for examples see: Brunger 1982; Dennis 1989; Dooppers 1986; Fruin 1978; Wareing 1981, to name a few). However, it should be noted that it was not until the more recent *spatial turn* and the increased use of GIS in historical studies that there has been such a presence of spatial representations for communicating, supporting, and analysing historical thought.

The conventional techniques that dominated earlier studies have gone on to become the dominant techniques used in more recent research. A map is one of the most popular forms of communication for geohistorical projects and others that use spatial information for historical

investigation (Gregory and Ell 2007; Knowles 2008a). Yet despite their extensive use, the decision to use a particular visualisation technique is rarely discussed, and apart from notable examples such as Gregory and Knowles (Gregory and Ell 2007; Knowles 2002b, 2008c), the topic of different visualisation techniques for historical spatial data has not been thoroughly investigated. In their chapter concerning the use of GIS to visualise historical data, Gregory and Ell (2007) provide us with a background to mapping principles within a GIS with a particular emphasis on the choropleth mapping technique popular to many historians. Other visualisations mentioned include cartograms, the use of animations, and the creation of virtual landscapes (Gregory and Ell 2007). Whilst these visualisations are used for historical data, a review of visualisation techniques for geohistorical projects reveals a number of techniques that Gregory and Ell do not highlight, but are more widespread and used more extensively than some of those described.

Through a review of the visualisations used, a number of techniques in visualising the diverse range of historical arguments have been identified, forming a typology of five approaches to the visualisation of historical spatial data: Choropleth Mapping; Isarithmic Mapping; Differentiating and Ordering Visual Variables; Graphic Depictions; and Three-dimensional Representations. Their focus is largely on thematic visualisation used to display the geographical pattern of a theme or subject as opposed to general-reference maps that focus on location (Slocum et al. 2009). The reason for this is that the research usually investigates a theme/subject about a particular place and the visualisations support this investigation.

The review focuses primarily on the literature that has been generated since the spatialisation in historical scholarship, for this is where the majority of work has been performed and reflects those visualisations that were developed prior. Each of the techniques offers something different, whether through the type of data that can be handled, the capacity for depicting change over time, the level of data aggregation, or the ability to visually analyse the information presented.

2.3.1 Choropleth Mapping

Due to the availability of historical administrative area thematic data, such as census data, choropleth mapping was one of the first techniques to be embraced by historians and continues to be one of the most widespread approaches to visualisation for historical spatial

data. Choropleth mapping is arguably the most popular visualisation technique that is used in thematic mapping (Slocum et al. 2009), where a variable forming a statistical surface is represented by the values associated to areal boundaries. A statistical surface exists for “any distribution that is mathematically continuous over an area” (Robinson et al. 1995, p. 494), such as rainfall or elevation. But particularly relevant to thematic mapping and historical studies, a statistical surface can include demographic and social statistics that can be computed over the entire geographical extent of the study. This can be represented in many ways; however choropleth mapping makes use of area symbols to represent the values marked by areal boundaries such as administrative boundaries. For example, the figure below (Figure 2.3) shows a choropleth map using *Decennial Supplements* published by the General Register Office data of the relative rates of infant mortality in the 1870s for each district (Gregory 2008). The locations of infant mortality are only known at district level and are therefore represented at this aggregated level. In addition, records are collected every ten years and can therefore only be displayed once each decade. This type of data aggregation (which is particularly prominent in census data where individual recordings of a question at individual housing locations are aggregated to a value representative over county level boundaries) is necessary for the technique of choropleth mapping, and can be seen as a positive and also a pitfall of the technique (as will be discussed toward the end of this section).

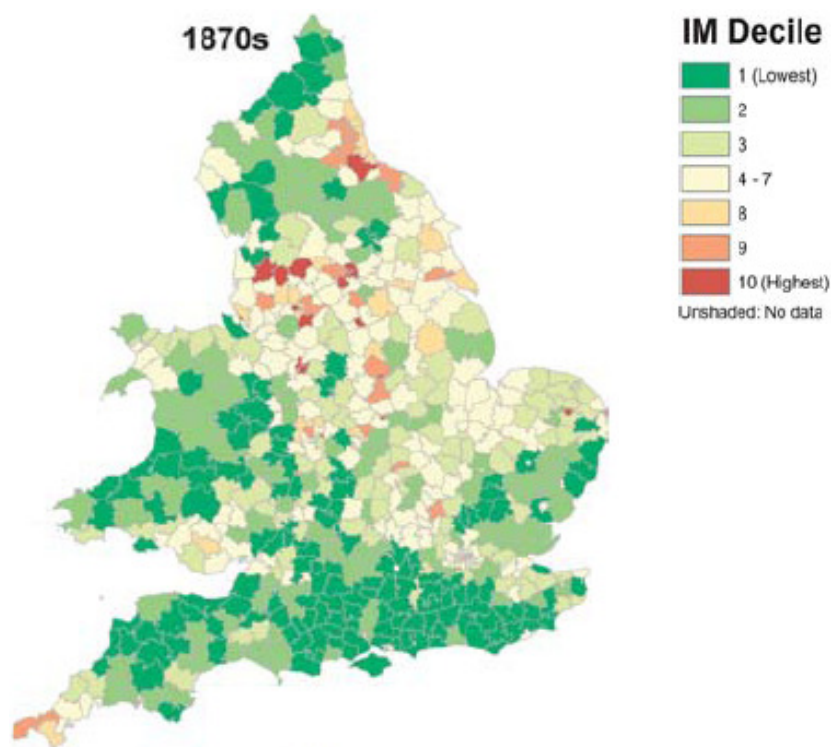


Figure 2.3: Choropleth map of relative rates of infant mortality (Gregory 2008)

Choropleth mapping has been used extensively to support historical arguments, provide spatial context for statistical data, form a major part of the analysis process for many GIS databases, and to present research findings and results. A large majority of the earliest examples of Historical GIS have adopted the technique of choropleth mapping, and is therefore an approach that is quite well developed for integration into historical studies. Five out of the twelve case studies described in *Past Time, Past Place* (2002b), the first book to focus on case studies for Historical GIS projects, adopted the technique as the basis for their analyses or to support an argument (Beveridge 2002; Cunfer 2002; Gregory and Southall 2002; Lancaster and Bodenhamer 2002; Pearson and Collier 2002).

This initial interest was due to the relative ease of obtaining, understanding, integrating, and producing visualisations and statistics of Census data. The range of Historical GIS projects addressing historical issues using Census data is extensive, addressing areas of social-demographics (Beveridge 2002; Gregory 2009; Gregory and Ell 2005; Healey and Delve 2007; Norman et al. 2008), the geographical expanse of the agricultural revolution (Pearson and Collier 2002), health indicators and the spread of diseases (Dorling et al. 2000; Ell and Gregory 2005; Orford et al. 2002; Tuckel et al. 2006), through to use in archaeological investigations into slavery (Armstrong et al. 2009), and investigating the political impact of churches and religion on voting practises (Stepan-Norris and Southworth 2007). In an early study involving Historical GIS, Andrew Beveridge (2002) uses Census data for choropleth mapping to look at a period in American history (1900-2000) that has undergone many broad changes in the geography of immigrant and native-born demographics. The choropleth visualisations are a result of the analyses of Census data producing a number of maps based on Census Tracts showing population density, change in population density, minority population percentages, and immigrant population percentages. These maps are used as supportive evidence to the history of segregation change in areas of Metropolitan New York, where census data is analysed to reveal patterns of demographic changes over time and to act as a starting point for textual explanation and further research in order to explain such patterns.

When choropleth maps are created for different dates, it is possible to track changes over time for a variable through a number of approaches. A *snapshot* treatment of time is used extensively in representing change for choropleth maps (see Armstrong et al. 2009; Cunfer 2002, 2008; Fitch and Ruggles 2003; Gregory and Ell 2005; Gregory and Southall 2002; Lancaster and Bodenhamer 2002; Owens 2007 for examples) and involves creating two or

more choropleth maps of different moments in time producing a sequence of images that can track the change of the variable over the geographic area and temporal period. Another approach to time treatment is to represent the rate of change between two dates as a variable for spatial data, resulting in a single choropleth map that depicts change of a variable (Ell and Gregory 2005; Gregory et al. 2001; Gregory and Ell 2005; Orford et al. 2002). For example, Gregory and Ell (2005) use Census data to show the change in population in Britain from 1841 to 1851 and 1851 to 1861 by using the rate of change as a percentage of the total population of the boundaries as the new theme being depicted (Figure 2.4). In this case the authors are showing the geographical distribution of the decline in population during and after the Great Irish Famine. The treatment of time for choropleth mapping and other techniques will be discussed more thoroughly in section 2.4.2.



Figure 2.4: Decline in population as rate of change (Gregory and Ell 2005)

Despite the popularity and success of choropleth mapping in historical scholarship, there are a number of issues inherent with the technique. Choropleth mapping requires aggregation; both of the thematic data and also the locational data. Aggregation is the process of simplifying information; taking exact measures of both location and attribute and grouping them together into common geographical areas and common attribute classes. It does not allow for differences in the thematic data within the areal boundary, instead it gives one value for the entire areal unit, and also does not allow for the uneven geographical distribution within the

areal unit itself. Gregory and Ell (2005) provide a telling example of the problems associated with aggregation by comparing infant mortality at local government district level to a further aggregated County level (Figure 2.5). Whilst the mean death rate is not noticeably different between figures 2.5(a) and 2.5(b) (57.3 and 59.0 respectively), aggregating the 1827 areal units to 63 counties lead to massive differences in individual areal unit rates. These include a lowest rate of zero to a maximum of 400 at the finer scale, to a very subtle difference of 38.1 for the lowest and 92.5 for a maximum rate at County level. The detailed level of attribute data is lost at the expense of aggregation. Also, by gaining the ability to analyse and visualise intercensal statistics, we compromise not only the detail of attribute data but of fine scale spatial distribution and geographical patterns.

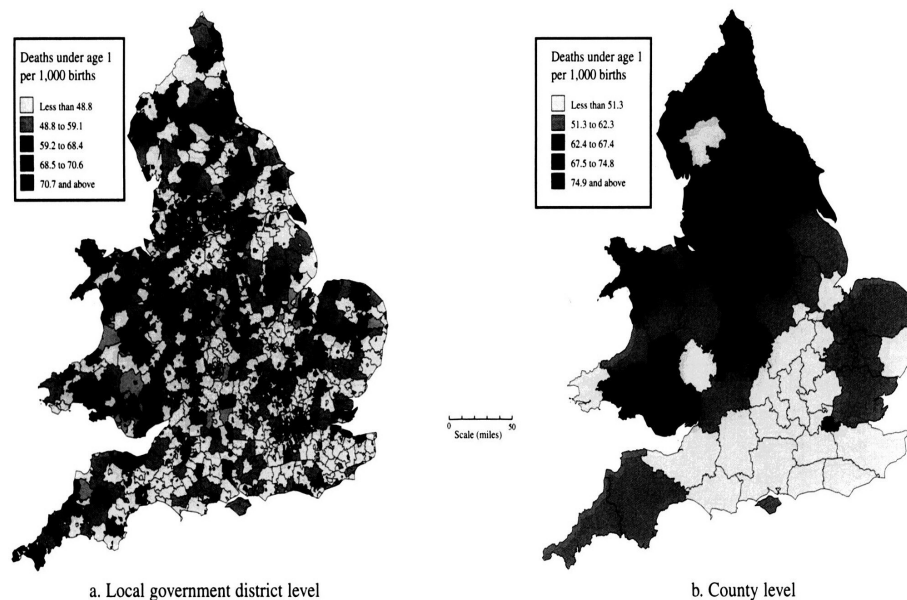


Figure 2.5: Comparison of choropleth aggregation levels (Gregory and Ell 2005)

Ian Gregory has been a pioneer in Historical GIS and in particular in the use of choropleth mapping of historical census data, but he was also one of the first to write about the limits of such a technique and the problems associated with the changes to administrative boundaries over time (Gregory 2000; Gregory and Ell 2005, 2006, 2007).

A review of the Historical GIS projects using census data for choropleth mapping supports the claim that:

“the problem of intercensal boundary changes has meant that analyses using census data have usually either focused on the spatial detail of a single snapshot or have had to massively aggregate data to relatively stable units such as American states or British counties to look at long-term change” (Gregory and Ell 2005, p. 151).

There are a number of ways to avoid resorting to such high levels of aggregation for investigating change over time that move beyond the single snapshot approach. Surface models have been developed to address the problem of boundary change (Gregory 2002), and so too has the application of modifiable areal units (Gregory 2002), but the use of areal interpolation techniques is the most commonly adopted and developed in Historical GIS projects. Areal interpolation is the process of transferring data “from one set (source units) to a second set (target units) of overlapping, non-hierarchical, areal units” (Langford et al. 1991, p. 56). Therefore, by using the capabilities of GIS, a range of areal interpolation techniques can be used to take a set of administrative boundaries from a number of differing census dates and combine them to form an estimated single set of standardized target units (Langford et al. 1991). In a paper by Gregory (2002), a number of areal interpolation techniques are compared using historical census data and errors are analysed. He concludes by stating that “the effectiveness of the technique depends on the variable to be interpolated and the choice of target geography” (2002, p. 293). Uncertainty is always going to be introduced when original data is manipulated into a form that can be used in relation to other information, but one can minimise the amount of uncertainty by choosing the best technique for the individual study.

Another issue with choropleth visualisations in communicating attribute information is that administrative units vary in size and are usually a reflection of the population, so that rural areas tend to be large and the more densely populated areas small. As a result, the visual impact of the map is dominated by large rural areas, whilst small urban areas of large populations attract little attention and are sometimes difficult to see. Such dominance can greatly distort the way in which we interpret geographical and attribute patterns and distributions (Gregory and Ell 2007). Cartograms, where the size of an area (administrative unit) is proportional to its population or another variable, can be used to counteract this side effect of choropleth maps and is used in a number of geohistorical projects (Dorling 1995; Gregory 2000; Gregory et al. 2001; Gregory and Southall 2002). Figure 2.6 (Gregory 2000) below shows an example of a traditional choropleth map and its cartogram counterpart using

circle size to represent proportional population of registration districts of England and Wales in 1880.

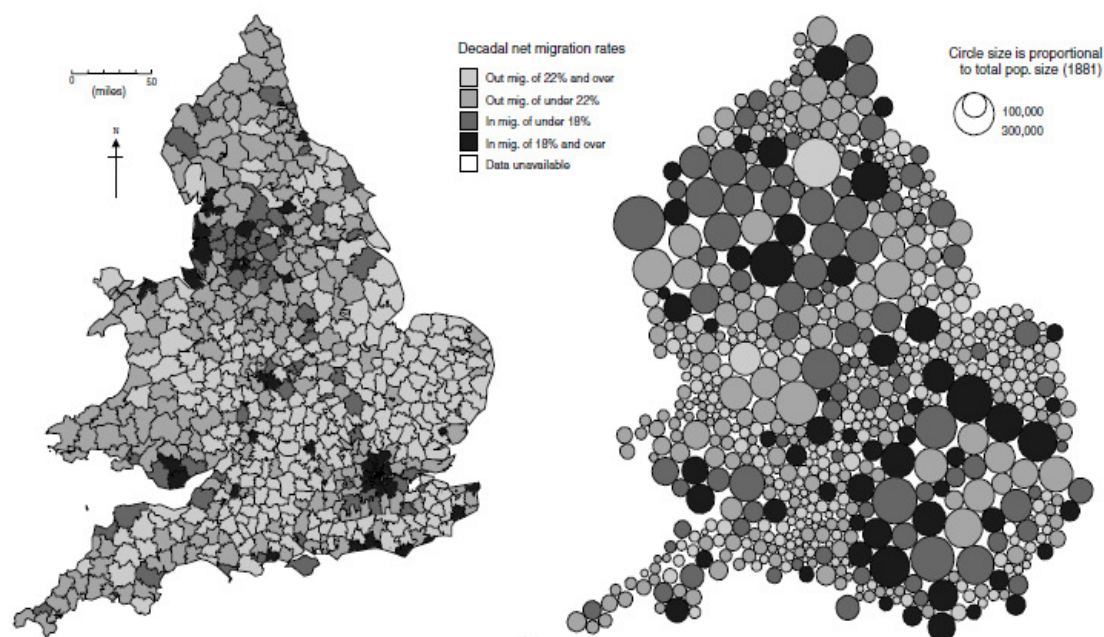


Figure 2.6: Choropleth and Cartogram comparison (Gregory 2000)

If investigating demographic related variables, this technique is very useful for it emphasises those areas where population density is high but areal size is small. For example, the small geographic area of London in the previous figure is not distinguishable using choropleth mapping, but is emphasised in the cartogram representation enough to distinguish the distribution and differences in migration rates in an area where migration is significantly important. Yet, this advantage comes at a price; spatial accuracy. Spatial integrity is maintained as much as possible by making the overall shape of the area resemble reality as closely as possible, and by arranging the individual circles approximately in their correct place with the same neighbouring areas. However, this inevitably results in a decrease in spatial accuracy and can distort the areal unit locations and the overall map enough to make it difficult for the reader to interpret.

2.3.2 *Isarithmic Mapping*

Isarithmic maps are one of the oldest and, after the choropleth map, probably the most widely used thematic mapping technique (Slocum et al. 2009). Its use for historical investigation is also wide, and is applied extensively to the representation of densities and distributions of historical demographic statistics. The technique of isarithmic mapping, as with choropleth

mapping, has been designed to depict a statistical surface, one that is continuous and can be given a value over the entire extent such as elevation, rainfall, or percentages. But instead of representing such values over a surface of strict areal boundaries, it creates a surface of isolines that represent values of the thematic data through interpolation. This is best explained through the process of producing elevation contours on a topographic map, the most recognisable form of isarithmic mapping. Contour lines represent the elevation of a landscape through connecting points of equal elevation, in a process known as interpolation, to form an imaginary line of specific height. This imaginary line known as an *isoline* or *isarithm* is therefore the result of showing elevation mapped as a *z* coordinate with respect to the horizontal location (*x* and *y* coordinates). A map is created when these lines are combined to show elevation levels at certain intervals, resulting in a quantitative and analytical elevation surface (Robinson et al. 1995).

Although representing the geographical landscape is important to geohistorical studies and is used in Historical GIS (Elliott and Talbert 2002; Knowles 2008b), the use of isarithmic maps in this field is dominated by the visualisation of thematic data, and is achieved simply by substituting the elevation *z* value with another attribute with location such as population or demographic percentages. For example, Gragson and Bolstad (2007) make use of isarithmic mapping to form probability density functions for comparing town placement and population, see Figure 2.7. They conclude, through the use of the visualisation, that there is strong clustering of town placement and a positive correlation between placement and population locations. These conclusions are heavily supported by other visualisations of data, tables, graphs, and also a lot of statistical explanation as text.

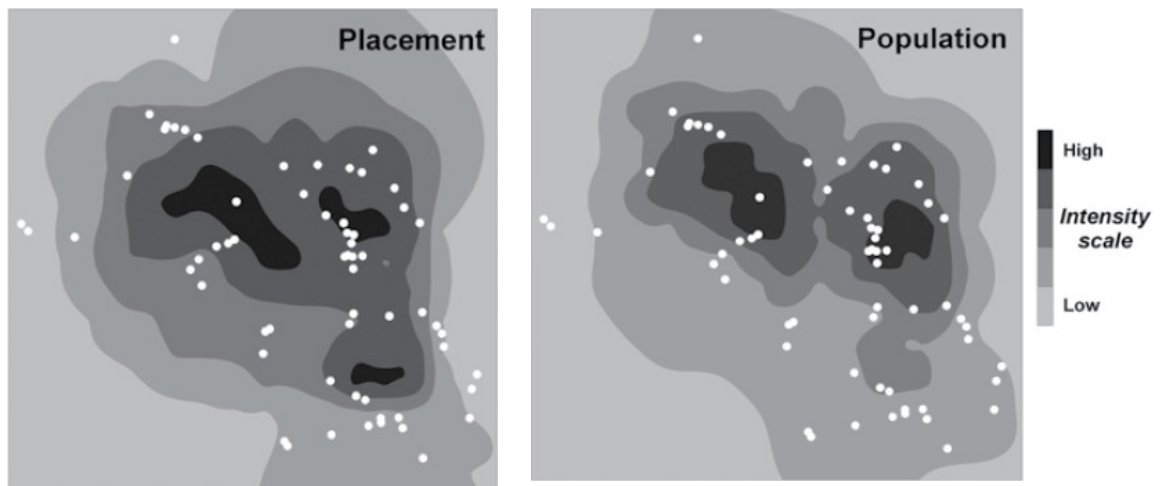


Figure 2.7a: Isarithmic map of town placement density (Gragson and Bolstad 2007)

Figure 2.7b: Isarithmic map of town population density (Gragson and Bolstad 2007)

As a result, the isarithmic map only forms part of the overall picture and relies on multiple images to compare variables. Despite this, it is very effective in showing densities; creating images of generalised patterns which can be used to derive insightful conclusions.

Isarithmic density visualisations are effective for many types of data and for varying themes. Population and demographic statistics density mapping has been applied extensively in a project that looks at Census and tax records for comparing different urban locations in terms of demographic distribution, densities, and relationships (DeBats 2008; DeBats and Lethbridge 2005). The visualisations have been used both to support claims and to also provide a visual and statistical method for analysis and discussion. Figure 2.8 shows how the author has used the isarithmic maps to compare the densities and distribution of German and Irish populations by separate image comparison (DeBats and Lethbridge 2005). Areas of similar research have utilised isarithmic mapping to investigate the relationships between two variables or between locations and densities (DeBats 2009; Dobbs 2009; Gong and Tiller 2009), and the comparisons of different areas or attributes (Carter 2008; Gragson and Bolstad 2007).

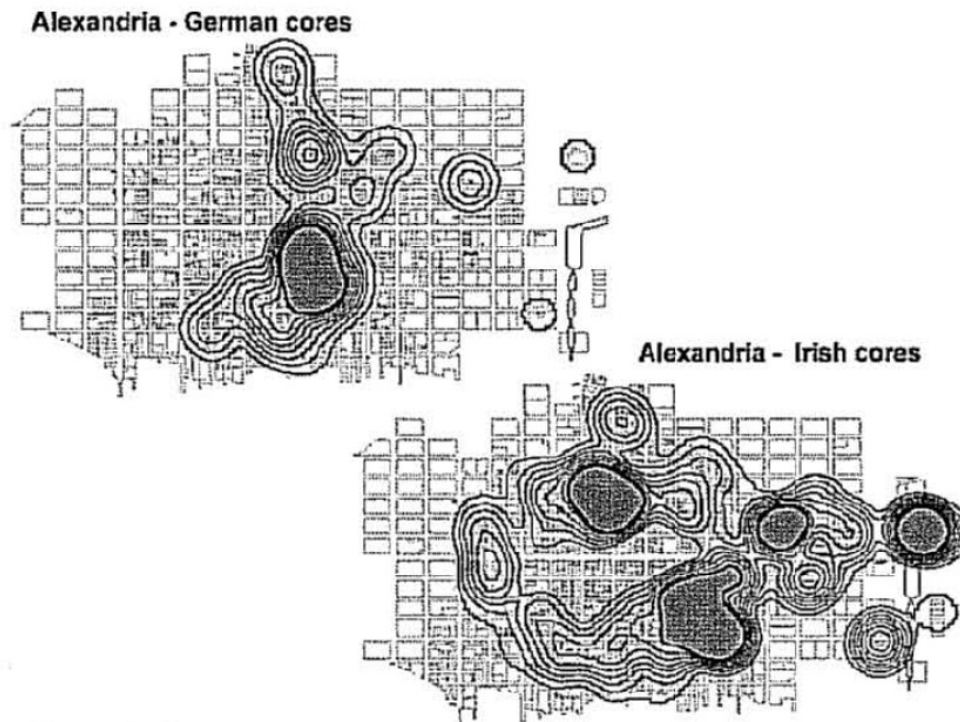


Figure 2.8: Comparison of German and Irish populations in Alexandria (DeBats and Lethbridge 2005)

Extending the use and analytical capabilities of this technique, Harris (2002) demonstrates a temporal approach to visualisation and analysis by using archaeological data of phosphate levels (a good indication of former human habitation) to pinpoint human habitation. The density isolines of phosphate concentrations are given a temporal dimension (or depth). This can be used to gain a sense of change over time by investigating different depths that reflect different moments in time. This idea of depth being used as an axis for time is particularly suited to archaeology for, as Harris explains, “in general, the deeper an artefact or find is in an archaeological series, the older it can be assumed to be” (2002, p. 137). It is therefore possible to be able to *slice* the image to show the density at specific times. The depiction of change over time in isarithmic mapping as demonstrated by Harris is a rare one. Apart from Harris (2002), and Gong and Tiller (2009), who use snapshots of time periods in an image succession, the use of the technique in historical scholarship does not attempt to include a temporal dimension.

Comparison between different areas or different isarithmic values is a difficult task when the chosen approach is to set both images side by side. When multiple images are used, such as in the case of multiple variables, multiple locations, or for many snapshots of time, difficulties of comparison increase. Other issues associated with the technique include the technical issue of choosing the method for interpolation. Interpolating where the isolines rest on the surface can be done in a number of ways both manually and automatically (see the following texts for

details on these and more: Burrough and McDonnell 1998; Davis 2002; Mitas and Mitasova 1999; Slocum et al. 2009) all of which can produce greatly differing results. This can in turn affect the way the data is presented, analysed, and can affect the conclusions drawn from the displays (Slocum et al. 2009).

2.3.3 Ordering and Differential Visual Variables

As discussed above, many of the core aspects of visualisation from Historical GIS projects are based on traditional cartographic design principles. Ordering and differential visual variables are included in this and are used to provide distinction, prominence, and ordering to the basic graphic elements of point, line, and area. The term *visual variables* has been adopted from the work of Jacques Bertin (1983) to describe the different ways in which graphic elements can be altered through shape, size, orientation, and colour (hue, value, and chroma). These visual variables can be applied to point, line, and areal features to create cartographic representations of geographical and related phenomena, and can be used not only to differentiate features from one another (differentiating visual variables) but to create a visual ordering of the elements (ordering visual variables) (Robinson et al. 1995). It is the principles associated with such techniques that form the basis for cartographic products such as the traditional atlas, road network maps, and many interactive web-based mapping products. As a consequence, these techniques also provide a strong grounding for geohistorical projects, for they too rely on the atlas, networks, and web-based interactive services for delivering visualisations that successfully communicate geographical information.

Differentiating visual variables usually involves the use of orientation, shape, and hue (colour) to differentiate feature attribute data for points, lines, and areas. Their use in visualisation is based on their suitability to the data. Orientation refers to the angle at which the symbol is placed on the map and is therefore best to show qualitative differences particularly for points and areas, whilst shape is particularly useful for differentiating between qualitative attributes of point and linear features (Robinson et al. 1995). A number of visualisations showing historical events and landscapes simply require the representation of location and to differentiate between other geographical features. For example, visual variables of shape and colour are used together to reproduce what has become known as the Peutinger Map (Figure 2.9), a map of the world as the Romans knew it in around AD 300

encompassing the Atlantic coast of Europe and North Africa through to Sri Lanka (Talbert and Elliott 2008).

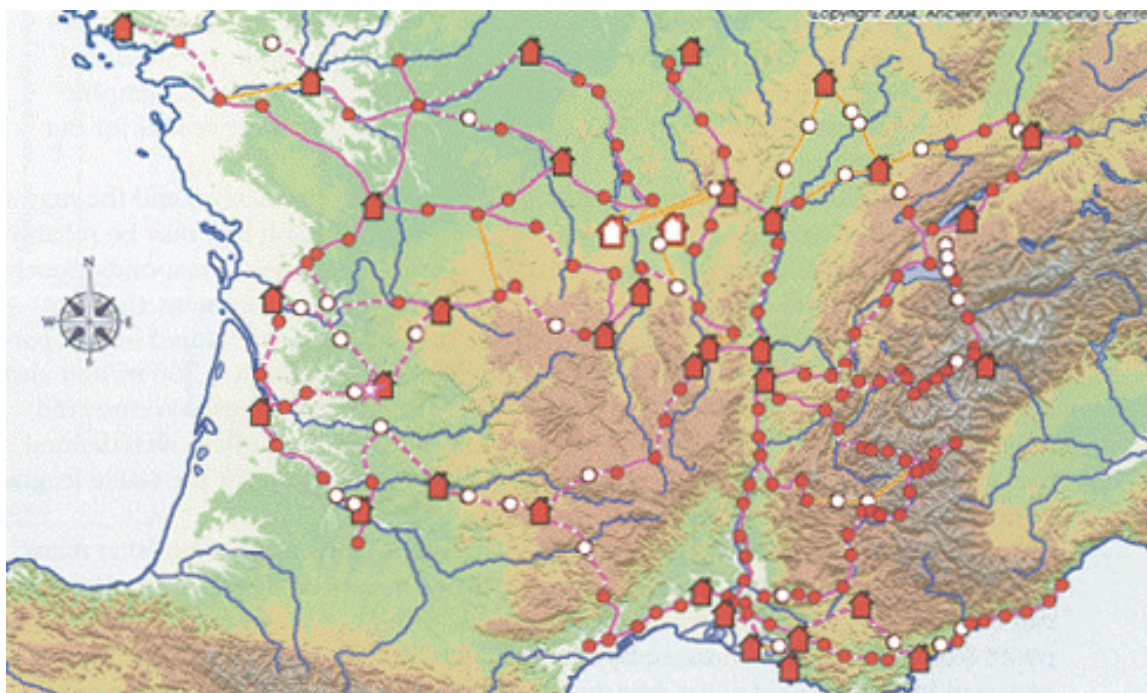


Figure 2.9: The Peutinger Map (Talbert and Elliott 2008)

Features such as sites that appear simply as names on the original map, and those that are represented by a pictorial symbol are differentiated by point symbol shape (dot or “house” respectively), and these are further refined by colour to indicate the preciseness of the location given. Route stretches are represented as linear features and are also differentiated by accuracy, changing the shape or line style of the line from solid (indicating a route whose endpoints can be securely located) to dashed (less reliable in their located endpoints) (Talbert and Elliott 2008). The use of differentiating visual variables to show location of features are found in historical atlas projects (Elliott and Talbert 2002; Lancaster and Bodenhamer 2002), and for the reconstruction of past landscapes (Harris 2002; Schuppert and Dix 2009).

Differentiating visual variables have been applied extensively in the distribution and the representation of the relationships between features, and to distinguish features to aid in comparison. Sheehan-Dean (2002) has utilised point symbols distinguished by colour to differentiate between features and also in proximity analysis by comparing those residences that are more or less than one mile from a town (see Figure 2.10). Research that utilises visual variables in similar ways include: (Armstrong et al. 2009; DeBats 2008, 2009; Piatti et al. 2008; Ray 2002b; Schlichting et al. 2006; Thomas and Ayers 2003). Analytical capabilities of this technique through comparison and spatial relationships have been explored in many areas

of historical social sciences (see: Healey and Stamp 2000; Hillier 2005; Schlichting et al. 2006, to name a few).

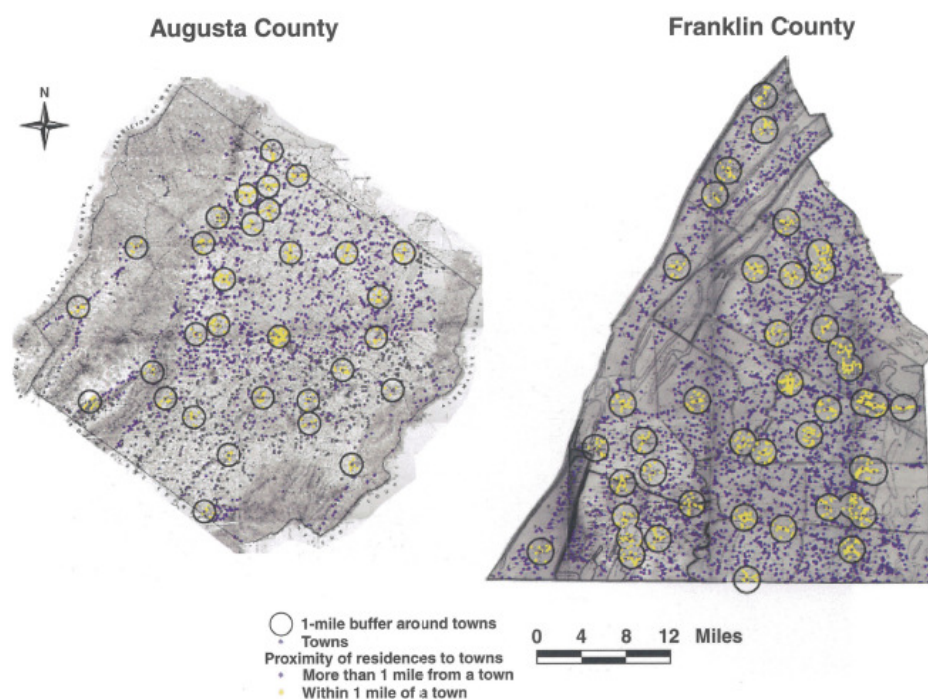


Figure 2.10: Proximity of residences to neighbouring towns (Sheehan-Dean 2002)

Visual variables of shape and colour have also been used extensively to show change of entities and attributes over time, through the use of sequencing static snapshots of instances in time to form a gallery of changing images. Sequencing images have been used to show settlement development (Dobbs 2009), change in land ownership patterns (Donahue 2008), and the differences in grading techniques for real estate evaluation (Hillier 2002). This will be discussed further in section 2.4.2. Donahue (2008) uses point symbol colour to indicate the differences in settlement location between three generations therefore showing the development of land occupation over almost a century in one image.

Ordered visual variables are usually associated with value (the lightness or darkness of a hue/colour, such as from light grey to black), and size (Robinson et al. 1995). Value is particularly useful for showing gradual changes in an attribute, such as the distance of a town from a city centre, and size is used greatly in showing differences in quantities, such as the population of a town compared to a city. Value is applied to areal data in showing the temporal development of Tokyo's harbour areas, classifying the breaks in colour by stages of development, using the visual variable itself to show the gradual change in an image (Siebert 2000). All examples of using size as a visual variable for order in Historical GIS are for point

symbology due to its suitability to the technique and its clear communication of the data. In the same paper by Siebert (2000), point data is used to show the percentage increase and decrease in population from 1940 to 1944, and 1944 to 1945 (Figures 2.11(a) and (b) respectively).

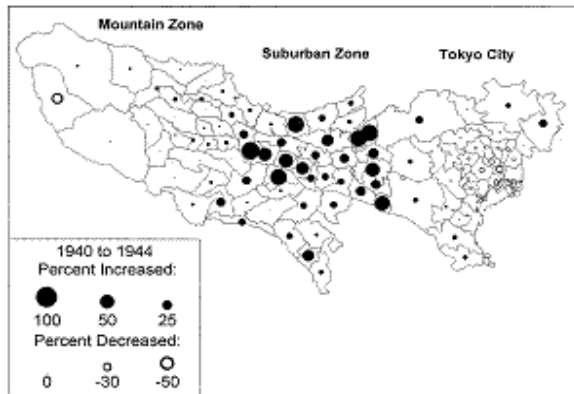


Figure 2.11a: Population percentage change 1940-1944 (Siebert 2000)

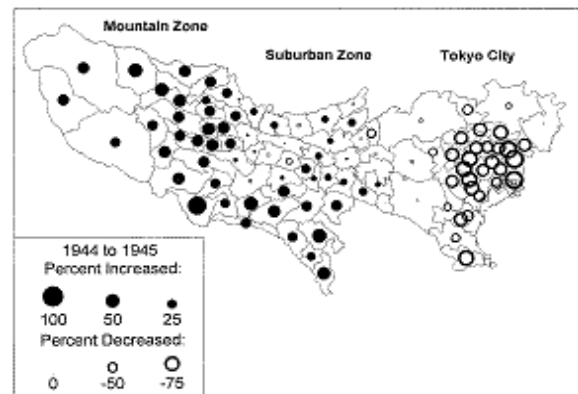


Figure 2.11b: Population percentage change 1944-1945 (Siebert 2000)

This percentage difference is presented in one image by showing not the two states themselves, but the percentage change over the two states. This difference can then be compared to the other period of percentage change to further visually assess change over time. Time has also been represented through animation and use of a sliding time bar in the Salem Witch Project (Ray 2002b), and in the excellent analysis of the causes of the dustbowl by Cunfer, demonstrating the changes in percent cropland in relation to graduated point symbols identifying the period of dust storms from 1879 to 1895 (Cunfer 2008), which will be discussed further in section 2.4.2.

Static visualisations for point graduated symbols have the ability to stress comparisons between locations for values and investigate the spatial distribution of thematic data such as tree diameter (Gong and Tiller 2009), to the number of guests per month at a hotel (Fyfe and Holdsworth 2009) and the number of messages forwarded at metropolitan telegraph stations in 1868 (Wenzlhuemer 2009).

2.3.4 Graphic Depictions

The mapping techniques discussed above can be viewed not only as methods for cartographic representation but as a part of the methods available in the field of data graphics or graphic

representations. All techniques display what Tufte describes as “measured quantities” (2001, p. 9). The measured quantities in our case are ones that are both spatial and historical, and when mapped, the spatial dimension is formed by a coordinate system of latitude and longitude. However, if the coordinate system that Tufte mentions in his definition of data graphics (discussed previously in section 2.2.4) is used to incorporate other variables other than Cartesian coordinates, such as infant mortality rates against average wage, the quantitative and related nature of the data can be emphasised whilst still retaining a spatial focus. A shift from these mapping approaches to relational graphics and time-series representations enables the incorporation of multiple variables (multivariate data) into the visualisation. As a result of this shift an image of clear communication, quantitative importance, and spatial and historical focus is created for the multivariate information at the centre of much geohistorical research.

The use of relational graphs, time-series graphs, and charts to visualise aspects of spatial historical data have been used to present research findings, to support other mapped forms of visualisation, and as a way to analyse results. Their use varies from being a minor role in presenting findings in a research article, to the main form of visualisation for analysis, results, and conclusions. In addition, their treatment of both the spatial and temporal domains varies depending on what is being communicated and the purpose of the image. The spatial significance of their use is what all the following graphs and charts mentioned have in common, and will be discussed in terms of the ways in which this space is aggregated for the visualisation: Individual Locations or Areas; Categories of Space Divided; Location Based on Distance; and Individual Graphs for Individual Locations.

2.3.4.1 Individual Locations or Areas

Graphical depictions that fall under this subject heading area focused on representing individual locations within a graph as either points in a scatter plot, lines or bars in a simple line/bar graph, or pie charts for a given region. Orienting the locations within a spatial coordinate system is no longer the focus, the names of the locations or areas are used instead to provide spatial comparison whilst stressing the attributes or variables. The graphics that are used in geohistorical research are either relational graphics; where multivariate data is graphed against one another to infer relationships between variables and place, or time-series

displays; where one of the axes is a timeline and therefore can show change to a variable over time.

Relational graphics have been used particularly when there is need for two variables to be represented in order to analyse the possible relationships between the two. Figure 2.12 shows a historical record of six hotel guest registers (six individual spatial locations) as lines on a relational graph using ‘percentage of guests’ and ‘distance from hotel’ as the two related variables (Fyfe and Holdsworth 2009).

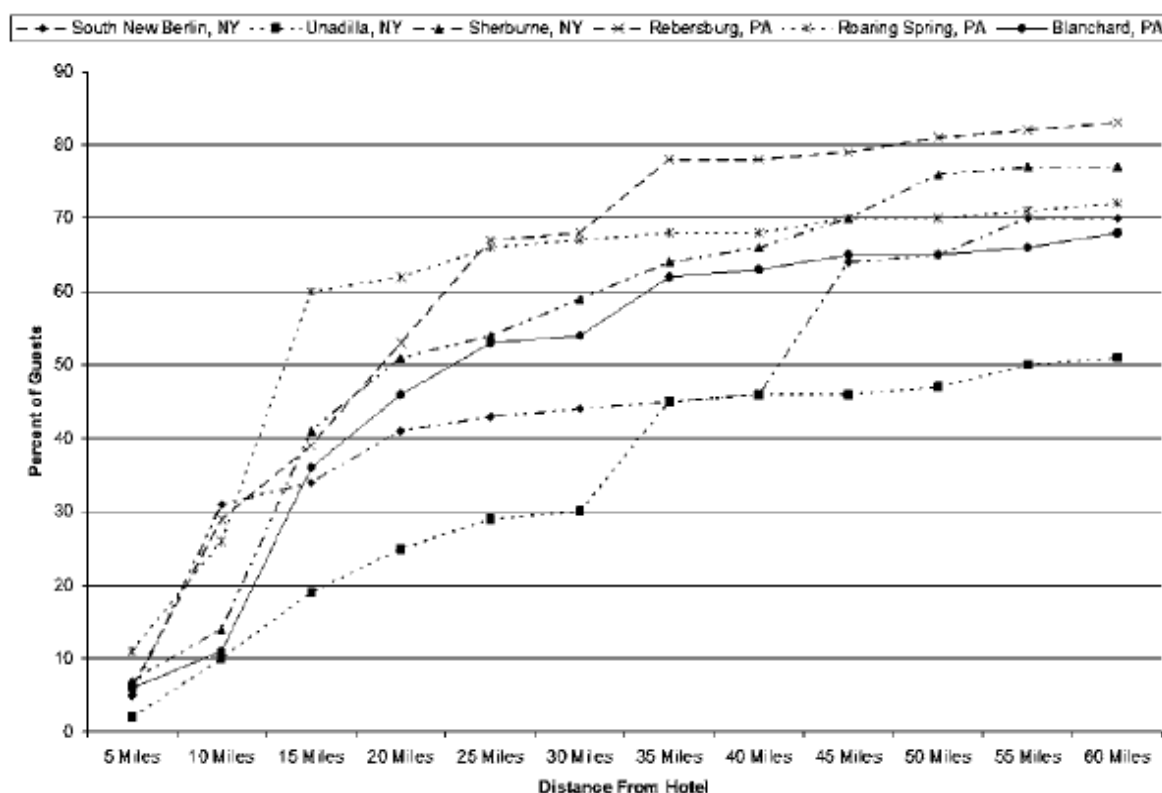


Figure 2.12: Relational graph of six hotel guest registers (Fyfe and Holdsworth 2009)

The article provides a comprehensive interpretation of the trends and patterns found and possible reasons for such findings are discussed. The authors make use of other visualisations (including ordered visual variables), but choose to use relational graphics for multivariate data. This ability to represent multiple variables in one image is also utilised by Gregory (2009) through visualising the relationship between deprivation and mortality in a relational graph. Gregory uses the graphs together with choropleth maps to argue his case (see Figure 2.13). The choropleth maps require two separate images to visualise the multivariate data; one to show deprivation rates and the other mortality levels. As a result, whilst the relational graphs can show the direct relationship between the two variables in a holistic image, the

choropleth maps provide a spatial context to the data, something that is not achievable simply by labelling the graphed points.

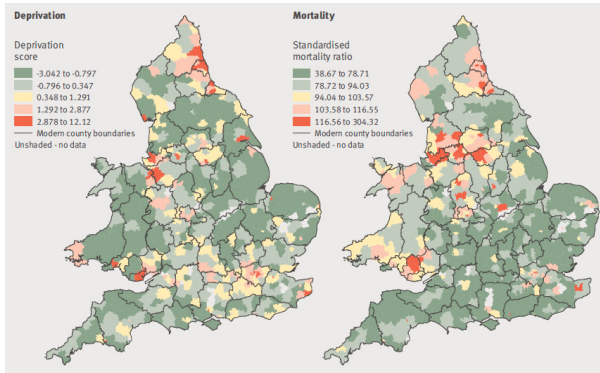


Figure 2.13a: Choropleth map comparison (Gregory 2009)

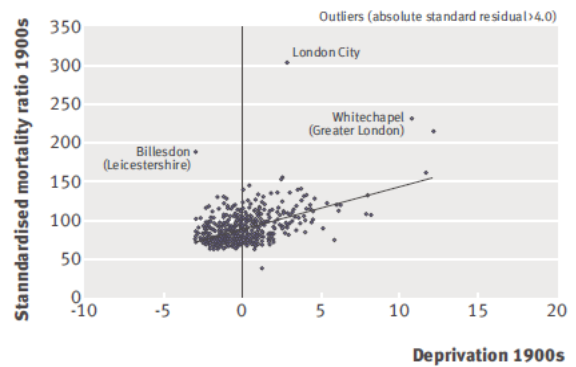


Figure 2.13b: relational graph (Gregory 2009)

Replacing one of these variables with a timeline creates a time-series graph, where the individual locations or areas are still represented as the lines/points/bars, but track a single variable over time. For example, a study into the spatial changes of China’s fertility rates make strong use of time-series graphs, where each line on the graph is an area of interest and can therefore be compared with other lines/areas for the chosen variable over time. Figure 2.14 taken from Skinner (2000) is a time-series graph in which time is divided up into years (1969-1990), the variable is the percentage of women who have had their first child by age 24, and each line is a different area of interest.

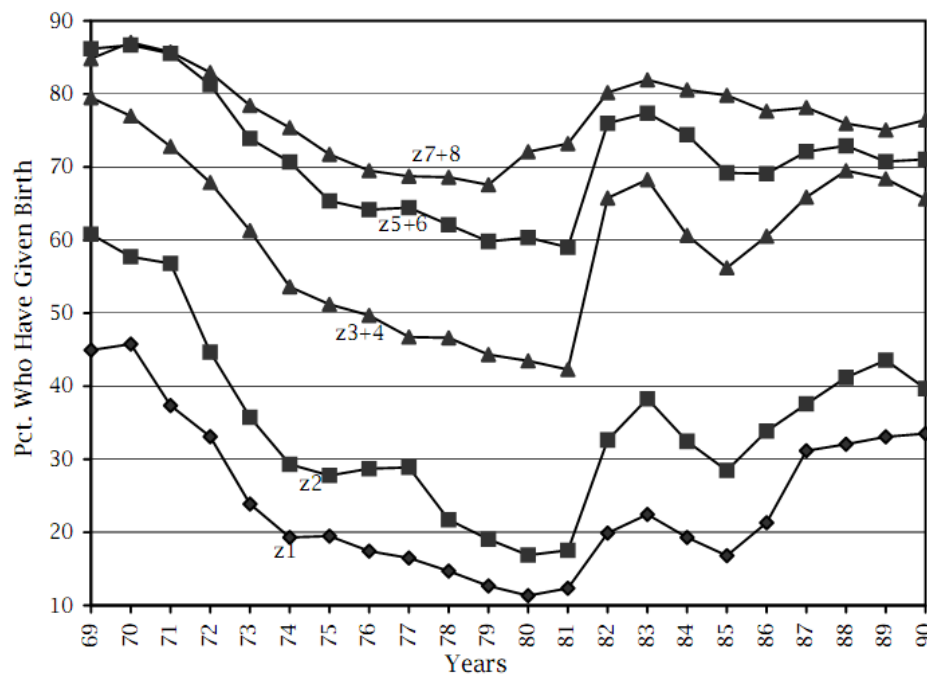


Figure 2.14: Example of a time-series graph (Skinner et al. 2000)

Clear trends can be seen which are common to all areas, however the differences that can be interpreted in the magnitude of the trends and the percentage figures highlights the potential of individual location graphics. As will be discussed in section 2.4.2, time-series graphs are one of the most popular ways in which change in time is represented in historical studies, and has been successful in tracking change over time, comparing different locations, and analysing and presenting relationships for graphed individual locations (Armstrong et al. 2009; Carter 2008; Gregory and Henneberg 2010; Norman et al. 2008).

The final approach for graphically visualising individual location data is through the use of pie charts. Their use in geohistorical research has been given a spatial focus through attributing each location or area on a map to a pie chart, therefore showing the geographical differences between the chosen variable(s). For example, Figure 2.15 shows a map of St. John, US Virgin Islands overlaid with pie charts depicting the production of three different plantations in two temporal snapshots 1780 and 1800 (Armstrong et al. 2009).

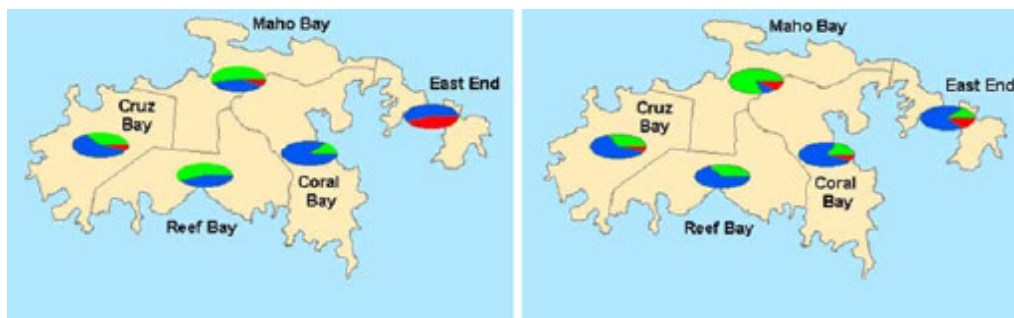


Figure 2.15: Pie charts showing the production of three plantations for 1780 and 1800 (Armstrong et al. 2009)

Each pie chart is overlaid onto the area that the statistics in the chart depict. By creating a map embedded with graphics, the spatial importance and variation in the data is visible and easily interpreted. The pie chart method is also adopted by Sheehan-Dean (2002) and developed further by MacDonald (2000), where one variable is the pie chart divisions (political viewpoint of Canada's newspapers) and the other the relative size of the pie chart symbol itself (total sales per issue). This can therefore be seen as the combination of graphical display and ordered visual variables.

2.3.4.2 Categories of Space Divided

Space can be aggregated to give us certain categories of space. Instead of representing specific individual locations (such as a town) or an area (such as administrative units), space can be divided up into categories that aggregate the data into meaningful divisions. Categories used in geohistorical studies have focused on dividing space into classes from rural to urban, and from inner core to far periphery. By dividing space in such a way, it is possible to gain general views of trends and patterns that can be influenced by the percentage of rural/urban or core/periphery, thereby treating space more as a variable rather than a location where events took place.

A comparison between population and income has been visualised in a study by Beveridge (2002), through the use of a simple time-series bar graph where space is divided into categories of core, near suburbs, and periphery. These divisions act as a strong starting point for analysis and interpretation of generalised areas and can therefore show overall trends and patterns over time. The same advantages are found in a study of the temporal and spatial significance of China's fertility rates, where divisions are based on the combination of both the rural/urban classes and core/periphery zones (Skinner et al. 2000). The development of a Hierarchical Regional Space (HRS) for the area specifies these divisions and is the main focus of the article. Through their use, Skinner argues that the patterns of demographic transition can be more thoroughly understood and it is clear that the time-series graphs play a large role in the effective communication of these patterns. Gregory (2008) has visualised the divisions from the HRS matrix in the original matrix form, using colour to represent the variation in infant mortality rate (see Figure 2.16). Time is also incorporated into the visualisation by displaying the matrix in a series of temporal snapshots.

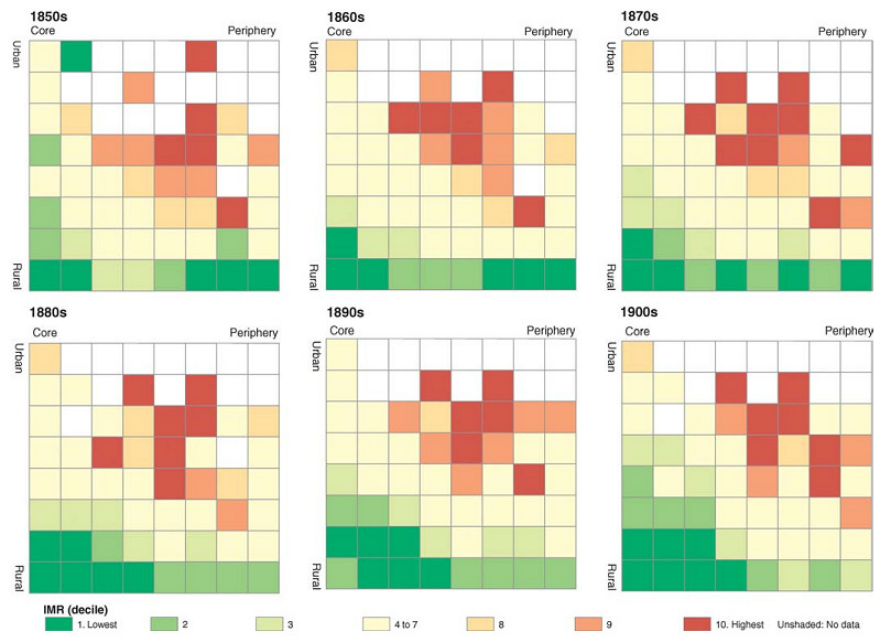


Figure 2.16: HRS matrix showing infant mortality rates (Gregory 2008)

2.3.4.3 Location Based on Distance

The organisation of the spatial component of graphical display can also be aggregated in terms of distance. Distance usually acts as one of the axes in a relational graph and is based on the distance from a significant location. Individual locations and distance have been combined to show the distance guests travel to stay at a hotel, the percentage at each distance interval, and the comparison to other hotel locations (Fyfe and Holdsworth 2009). The research project is the result of much data collection and analysis and is supported greatly by much explanatory text. Distance is treated as the x-axis, whilst the individual hotel locations are depicted by different line styles. A similar approach by Gregory (2008) has been used to show the importance of distance from a central location to the changes in infant mortality (Figure 2.17).

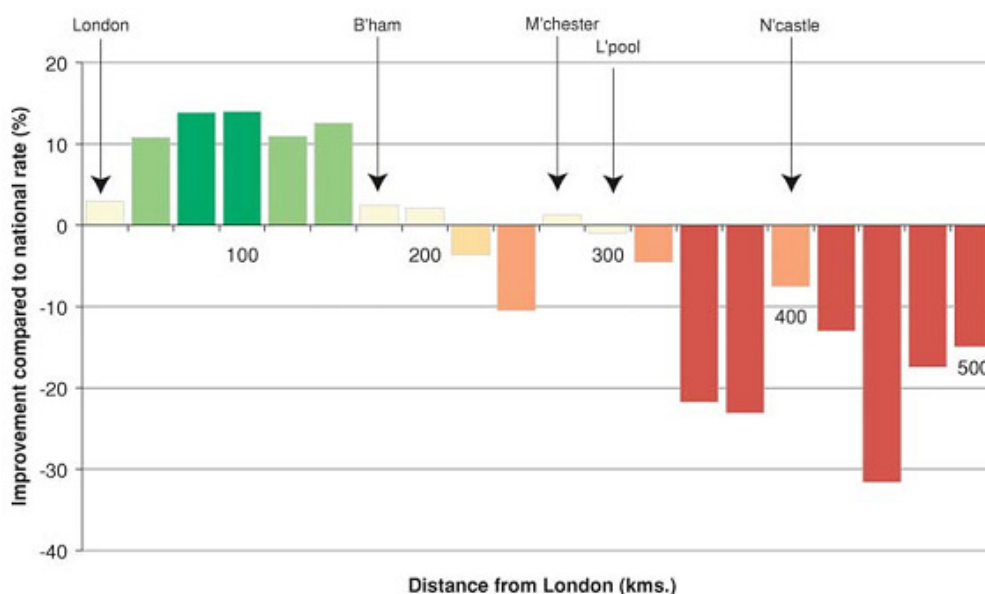


Figure 2.17: Distance in relation to infant mortality rates (Gregory 2008)

Although insights can be gained by this visualisation and categorisation of space, Gregory goes on to suggest that the Hierarchical Regional Settlement matrix discussed above is a more effective model to explain the spatial and temporal patterns associated with infant mortality.

2.3.4.4 Individual graphs for individual locations

In a series of papers authored or co-authored by Gregory (Gregory 2000; Gregory and Ell 2006; Gregory and Southall 2002; Norman et al. 2008), graphs of individual locations or areas are used in succession to provide visualisations that focus on the related variables and the spatial comparison of these variables for specific locations. All centred around British population demographics, Gregory makes good use of relational and time-series graphs for the insights found through their visual comparisons. A series of time-series graphs are used in the study of migration (Gregory 2000; Gregory and Southall 2002), where each graph of a location is placed in succession for comparison (see Figure 2.18).

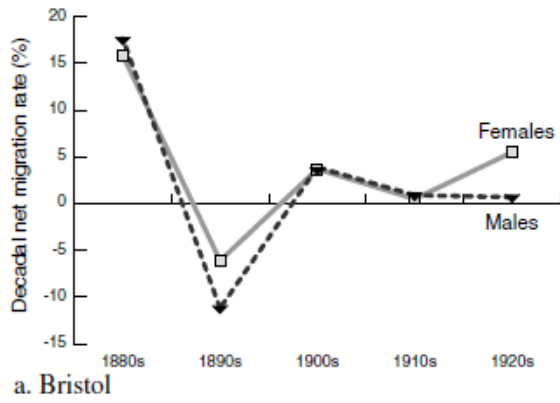


Figure 2.18a: Time-series graph of Bristol (Gregory 2000)

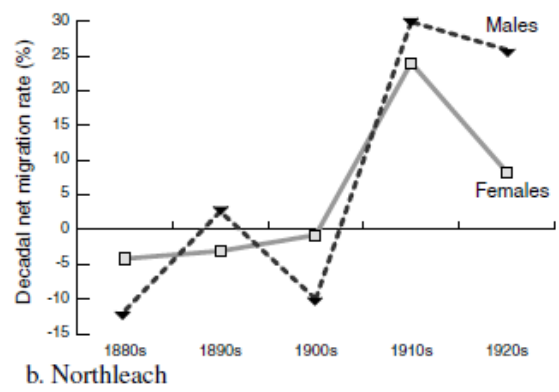


Figure 2.18b: Time-series graph of Northleach (Gregory 2000)

Comparing migration of males and females for Bristol and Northleach is done simply by visually comparing the two graphs and identifying likenesses and differences. The time-series graphic approach when used in this way can allow more variables to be included in the visualisation, for each line can depict a variable instead of location (as in the case of section 2.4.3). Norman et al. (2008) use a similar approach for addressing trends in infant mortality rates, comparing regions of England and Wales through successive time-series graphs of the different regions (Figure 2.19). Further spatial distinction is made by adopting an individual location approach; where each line depicts a certain location. This allows comparison and analyses between locations at two different scales.

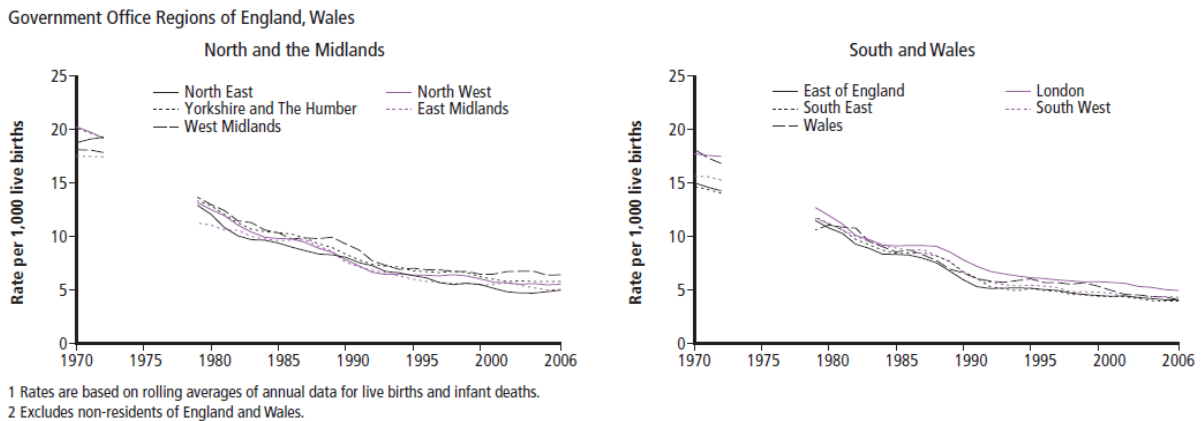


Figure 2.19: Comparison of different regions in England and Wales for trends in infant mortality rates (Norman et al. 2008)

2.3.5 Three-dimensional Representations

The final visualisation technique to be described is the use of historical sources to produce relief mapping, three-dimensional overlays and virtual landscapes – all of which seek to

recreate past landscapes through the added dimension of height. Relief mapping refers to a number of cartographic techniques that can be applied to spatial data with an added height dimension, to represent the three-dimensional surface of the landscape within a two-dimensional image. Techniques used for historical spatial data include contouring and hillshading (Elliott and Talbert 2002; Lancaster and Bodenhamer 2002). The attractive prospect of reconstructing past landscapes has led to a number of applications where historical maps and historical data are overlaid on current landscapes or digital elevation models (Knowles 2008b; Knowles and Healey 2006; Rumsey and Williams 2002). A digital elevation model (DEM) is a three-dimensional surface of elevation points which represent the varying surface of a landscape. The visualisation can have the result of presenting a historical map in the context of what the past landscape looked like (Gregory and Ell 2007). The use of historical maps or other historical records can create not only three-dimensional historical maps, but a far less abstracted recreation of past landscapes – virtual landscapes or simulations (Gregory and Ell 2007; Harris 2002). These three types are discussed below.

Techniques of relief mapping for historical spatial data have been used primarily as backgrounds for additional locational data. Elliott and Talbert (2002) have utilised contouring (lines connecting points of equal elevation) combined with hypsometric colour tinting (determining changes of classes in elevation) as a background for the *Barrington Atlas of the Greek and Roman World* (see Figure 2.20).

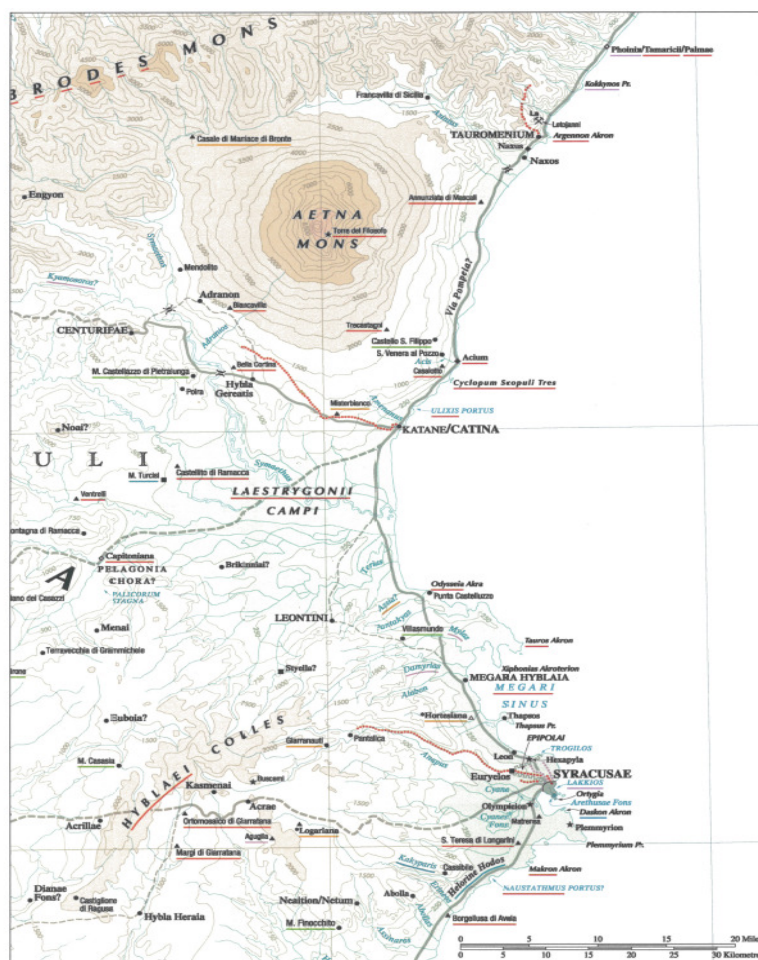


Figure 2.20: Barrington Atlas of the Greek and Roman World (Elliott and Talbert 2002)

The result is a very effective and conventional looking atlas, with a background that provides spatial reference and a broad sense of terrain for historical location data (Elliott and Talbert 2002). As part of the *Electronic Cultural Atlas Initiative* (ECAI), set up to address the problems of using digital technology in cultural studies, the *Sasanian Empire ECAI Publication* uses hillshading most effectively to provide reverence to large geographical areas, and to also act as a background for layers of point location data (Lancaster and Bodenhamer 2002).

Digital elevation models (DEMs) have been applied to the area of historical investigation in research projects ranging from battlefields of Gettysburg in 1863 (Knowles 2008b), to mapping the geographic settings found in literature (Piatti 2007; Piatti et al. 2008), and dissecting archaeologically significant landscapes (Harris 2002). The reason for their use is also varied. Rumsey and Williams (2002) demonstrate the result of overlaying historical maps on DEMs, not only for creating a 3D view of the terrain, but to understand the physical character, and access information that was difficult to perceive in the original format, such as relative heights and a measure of distance and elevation. As with the examples of relief

mapping above, DEMs can be successfully used simply as a background for spatial context of more important location data (Knowles and Healey 2006; Piatti 2007; Piatti et al. 2008; Talbert and Elliott 2008). However, it is in the area of spatial analysis where elevation models have the ability to aid historical investigation significantly. A good example of this is the use of a Triangulated Irregular Network (TIN – another model of surface elevation) to answer the question *what could Lee see at Gettysburg?* (Knowles 2008b). Knowles employs a method of viewshed analysis to evaluate what parts of the historic battlefield would have been visible from certain locations and whether this supports written statements in official reports (see Figure 2.21).



Figure 2.21: Representation of a viewshed analysis (Knowles 2008b)

Another example of the model's ability to aid in spatial analysis of historic events is in the area of archaeology through the location of historically significant mounds and ditches, and the relative locations of archaeological discoveries (Harris 2002).

As Shimizu and Fuse state, “three-dimensional landscapes are more than complements to recorded history. They provide researchers with a new tool for understanding the ancient life pattern of a city” (2006, p. 265). Authors have achieved this using historical maps,

topographic maps, aerial photography, and the less conventional historic wood block landscape prints and pollen analysis studies. Examples include archaeological records that have been combined with modern maps and technology to handsomely recreate the Adena landscape circa 2500 B. P. (Harris 2002), and the reconstruction of Japanese *Edo* and *Meiji* periods from historical maps and artistic representations on wood block prints (Shimizu and Fuse 2006) (see Figure 2.22). Despite such visually pleasing examples, it is important to place these images in relation to extending or aiding historical investigation. As Gregory and Ell warn:

“the problem is the temptation to be overly impressed with the graphic, and forget the scholarly message that the image, be it an animation or a virtual world, is trying to create. This is a temptation for both the creator and the readers” (2007, p. 112).



Figure 2.22: Reproduction of the Adena landscape depicted by Hiroshige's Ukiyo-e (Shimizu and Fuse 2006)

2.4 Visualising the Variation in Historical Spatial Data

Visualisation techniques applied to historical research are used to display varying types of historical spatial data. Whilst all have a historical and geographic focus, they vary in their inclusion or exclusion of representing change over time, and also in the number of variables that are included. A review of the research that was used to determine the dominant styles of visualisation techniques discussed in the previous section 2.3 was used to assess the different types of historical spatial data adopted, the techniques that rest within these variations, and

also the ways in which this data is handled in the visualisations. Four variations could be distinguished and are ordered in the following sub-sections according to complexity. Firstly, historical spatial data with only one or two variables and no change over time is discussed, and is extended in section 2.4.2 to visualise change over time. The final two sub-sections discuss data that is multivariate (more than two variables), and visualisations that combine multivariate data and change over time respectively. This review will contribute to addressing Research Questions 1 and 2 in relation to investigating the ways in which historically changing, multivariate, spatial data have been visualised, focusing particularly on the temporal change of static entities.

2.4.1 Visualising Historical Spatial Data

Data that comes under this heading includes a temporal component – one that does not change over time, but instead represents a snapshot of time past. Visualisations that display such data are only concerned with a single date in time and representing one or two variables (univariate and bivariate) and therefore can focus primarily on representing spatial data and the characteristics attached to spatial objects. All of the visualisation techniques discussed above are used to display historical spatial data of this kind, and the availability and ease in representation of such data ensures that it is the most commonly used for historical investigation out of the four to be discussed in this section.

Visualisations for historical spatial data require a need. What is this data used for? What is the main aim of the visualisation that is applied? A review of the literature reveals a number of uses for static historical spatial data, all of which revolve around the need to support an argument, for analysis, or for the display of results and location data. The main ways in which visualisations are used to support such needs are through representing location - the location of features, distribution, and background; and comparison - comparison of different areas and comparison of different variables over spatial locations. Both of these approaches will be discussed below in relation to the techniques outlined in section 2.3.

The ability to access geographical data that is from historical sources is often a difficult task, and as a result, simply being able to display the location data for the first time, to see the historical information in a spatial context, is often the main aim of the research. It has been observed that the main techniques in displaying location have been ordering and

differentiating visual variables and three-dimensional representations. Ordering and differentiating visual variables, especially of point features, lend themselves well to displaying location – visualising the location of historic towns and residences (DeBats 2008; Elliott and Talbert 2002; Healey and Stamp 2000), and important landmarks (Harris 2002; Knowles and Healey 2006; Lowe 2002).

Three-dimensional representations have been used to create a sense of landscape and provide spatial context to the research data, such as the use of virtual landscapes (Harris 2002; Shimizu and Fuse 2006), and the overlay of historical maps on 3D surfaces (Rumsey and Williams 2002). This technique is often combined with ordering and differentiating visual variables showing individual locations on a three-dimensional surface background. The Literary Atlas of Europe has used this approach to map locations outlined in literary works on a background of historical topographic maps (Piatti 2007; Piatti et al. 2008). Figure 2.23 depicts the locations depicted in fiction writing in an area of Switzerland by foreign authors (marked in violet) and by Swiss authors (marked in orange) between the period 1914 and 2005 with a shaded topographical map in the background (Piatti 2007; Piatti et al. 2008). This is an excellent example of creating spatial context for textual data and at the same time creating a sense of landscape. Other examples include the conventional atlas cartographic style with contours and elevation shading in the *Barrington Atlas of the Greek and Roman World* (Elliott and Talbert 2002) (see Figure 2.20), and the use of digital elevation models coupled with point and linear features for the depiction of ironworks and transportation in north-western Pennsylvania between 1842 and 1858 (Knowles and Healey 2006) (see Figure 2.24). See (Talbert and Elliott 2008) for further examples.

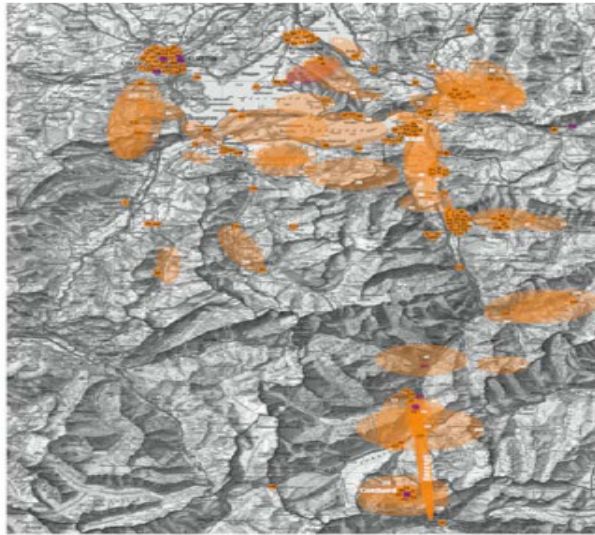


Figure 2.23: Locations depicted in fiction writing (Piatti et al. 2008)

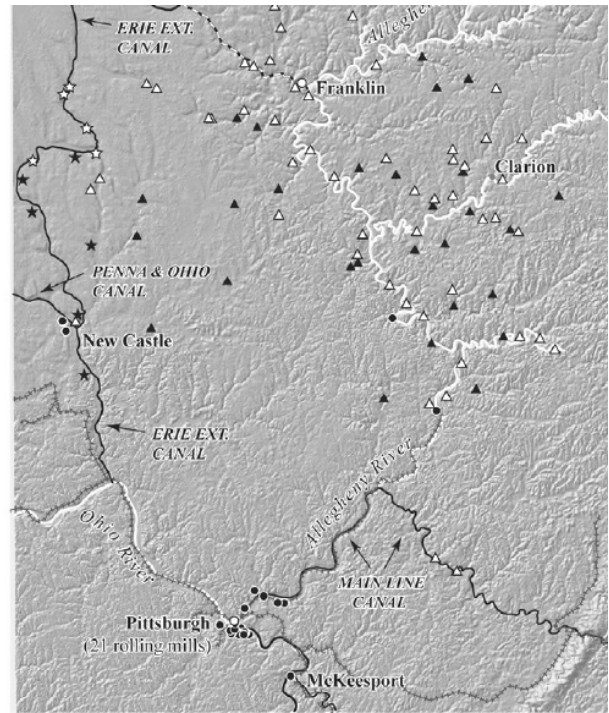


Figure 2.24: Ironworks and transportation in north-western Pennsylvania (Knowles and Healey 2006)

Displaying the distribution of geographic features is an important role for visualisations of historical spatial data. Locational data can be used to plot the distribution of features over a geographic area in order to investigate the relationship between space and selected features, to highlight areas of contrast or similarity, or to aid in the analysis of historical records. Techniques that have been used to achieve this include differentiating and ordering visual variables and isarithmic mapping. However, differentiated symbols dominate the visualisations used to depict distribution since the majority of features represented as a distribution are point based data which lend themselves well to differentiation. When working with only one type of feature, only one symbol is used and therefore there is no need for differentiation. For example, Figure 2.25 shows the distribution of residences of African American heads of households using only one symbol type (Tuckel et al. 2006).

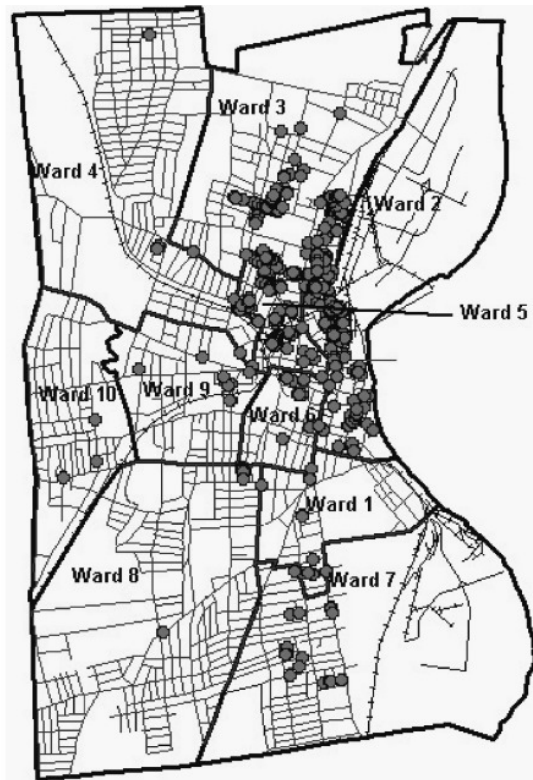


Figure 2.25: Distribution of African American residences (Tuckel et al. 2006)

When two or more types of features are shown, differentiated point symbols can be used to distinguish between the types. For example, Figure 2.26 shows the distribution of slaveholders residences (in black) in relation to non-slaveholders residences (in white) using both colour and shape to distinguish between the two contrasting feature classes (Thomas and Ayers 2003).

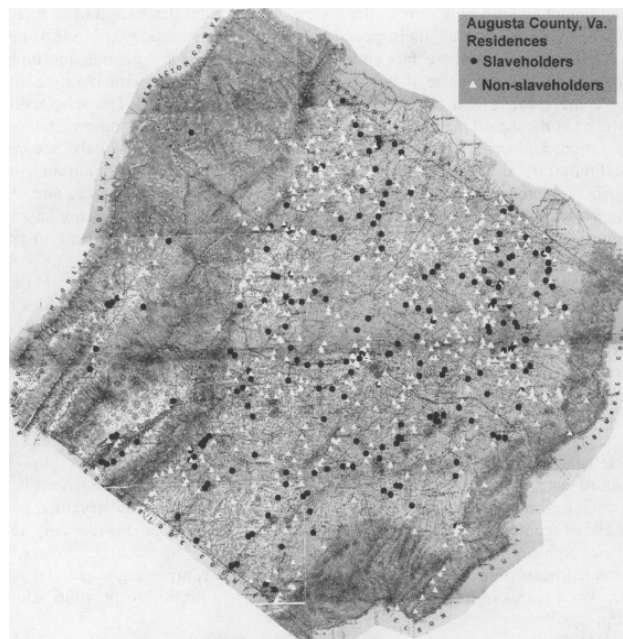


Figure 2.26: The relationship between slaveholders and non-slaveholders residences (Thomas and Ayers 2003)

Such examples have the capacity to also show patterns in distribution. It is possible to look at similarities and differences, clusters, and patterns over an area. In a simple visualisation highlighting neighbourhood types, differentiated point symbols are used to great effect to demonstrate the clustering patterns found in their distribution, and the relationships between the distribution of different neighbourhood types (Longley et al. 2007) (see Figure 2.27).

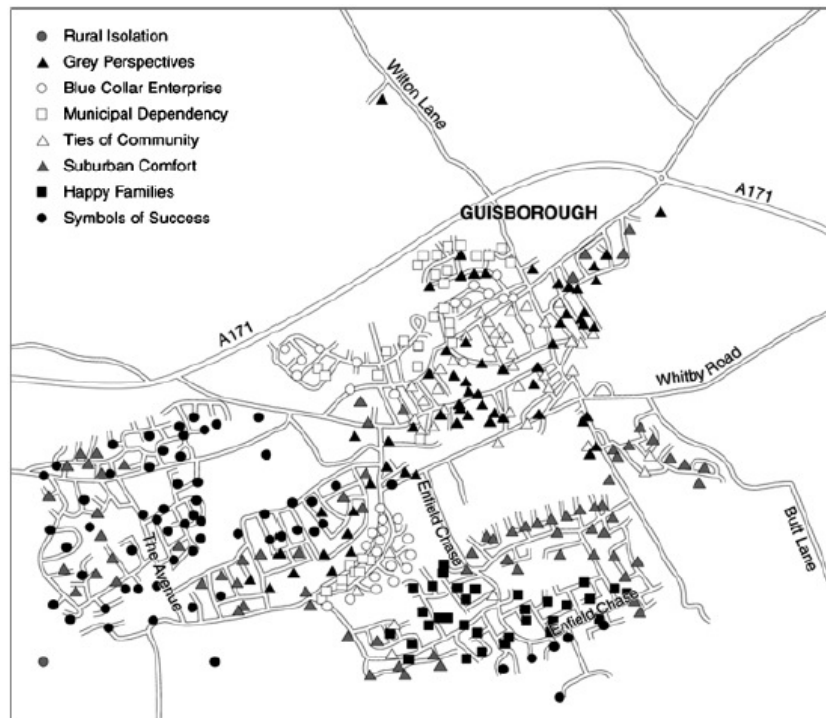


Figure 2.27: The distribution of different neighbourhood types (Longley et al. 2007)

Fyfe and Holdsworth (2009) have utilised ordered visual variables to show the differences in the distribution between the residences of guests at three hotels in New York. Figure 2.28 shows the relationship between patterns of visitation and railroad networks for the three hotels, highlighting the capacity for distinguishing patterns, similarities, and differences for simple distributions. (See: Brown 2005; Dobbs 2009; Gong and Tiller 2009; Gragson and Bolstad 2007; Healey and Stamp 2000; Knowles and Healey 2006; Piatti et al. 2008; Wenzlhuemer 2009, for further examples).

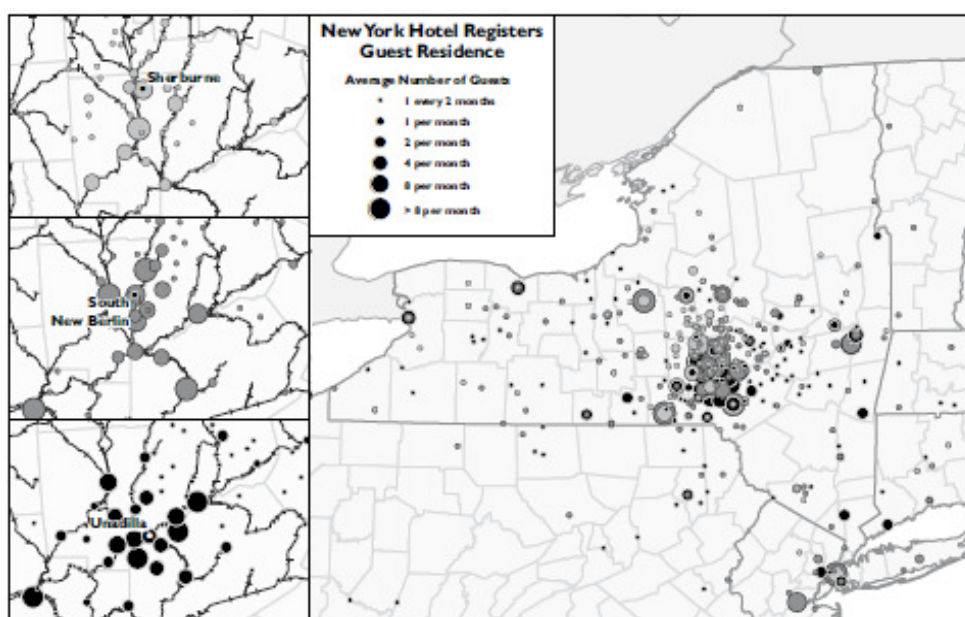


Figure 2.28: Visitation patterns and railroad networks for three hotels (Fyfe and Holdsworth 2009)

Visualisations for historical spatial data that do not show change over time have a greater capacity to be able to focus on the spatial and associated variables. When dealing with such data, a main aim of visualisations has been comparison; comparing variables over different geographic areas, and comparing multiple variables over the same geographic extent. Instead of focusing purely on location and distribution, mapping comparisons demand something different from the visualisations. It demands greater analytical capabilities and, more often than not, attribute data that can be classified either quantitatively or qualitatively in order to take advantage of the visualisations analytical capacity.

A review of the usage of visualisations for historical spatial data in academic works, conducted for this research, has revealed that comparing variables or a number of variables for a geographic area is the most common operation that is performed. This can be done by comparing one variable over a geographic area contained in the one image or over multiple geographic areas in multiple images. Choropleth mapping has been successful in this area due to the technique representing variable values over different areal regions. Therefore, it is not possible for a choropleth map not to invite comparison. Figure 2.29 is a typical example of a choropleth map used to compare one variable over a geographic area within the one image. It shows the relative poverty of different administrative areas in inner London in 1896 (Orford et al. 2002). The author has used this image to demonstrate the east-west split between the rich and the poor (Orford et al. 2002), and has successfully achieved this with the choropleth technique.



Figure 2.29: Relative poverty in inner London in 1896 (Orford et al. 2002)

This approach has also been adopted for visual comparison of the death rate of influenza by wards (Tuckel et al. 2006), and the comparison of religious denominations in Detroit (Stepan-Norris and Southworth 2007) to mention a few.

When a variable is compared over different geographic areas using multiple images, differentiated and ordering visual variables (DeBats 2008, 2009; DeBats and Lethbridge 2005; Sheehan-Dean 2002), graphs (Sheehan-Dean 2002), and isarithmic mapping (DeBats 2008; DeBats and Lethbridge 2005) have been applied successfully. Images are usually placed in sequence and are therefore compared visually side-by-side, such as the isarithmic maps of Alexandria and Newport below (Figure 2.30), comparing core areas of democrat voters between the two areas (DeBats and Lethbridge 2005).

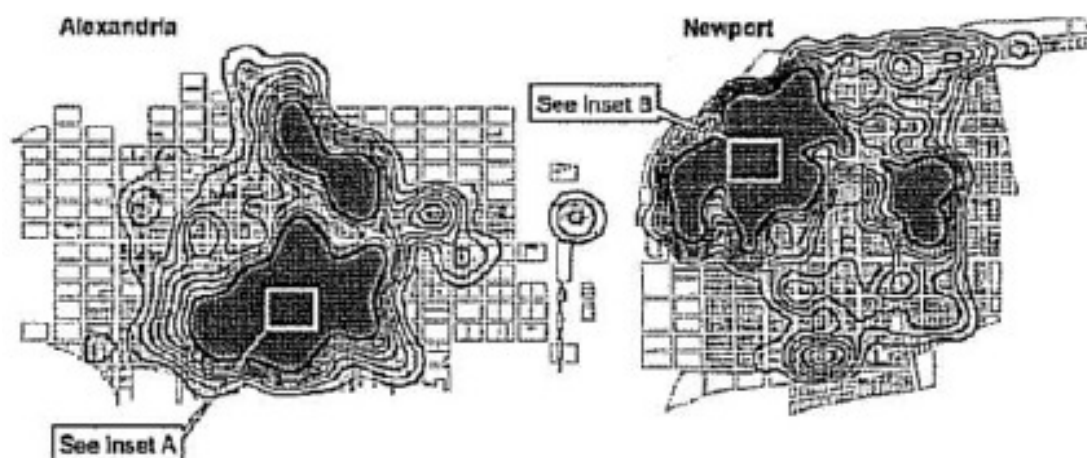


Figure 2.30: Comparison of democrat voters within Alexandria and Newport (DeBats and Lethbridge 2005)

The complexity of the visualisation increases further once we try to incorporate comparison of more than one variable within the same image. To achieve a comparison of an additional

variable within the one image often comes at the expense of the spatial. As a result, the visualisations used tend to abstract the spatial and rely on more graphic forms of communication. Line graphs, such as those employed by Fyfe and Holdsworth (2009) to show both the percent of guests and distance for a number of locations, along with bar graphs (DeBats and Lethbridge 2005) have been used to display simple relational graphs of geographic areas for effective comparison.

2.4.2 Visualising Historical Spatial Data that Change Over Time

When visualisations are used to show not only historical spatial data, but change over time, the focus shifts from spatial to temporal. This section reviews those visualisations that are used to show change over time with one or two variables for historical spatial data and is organised by their treatment of time. There have been four main approaches to representing change over time for the five techniques identified in section 2.3, being: snapshot, time-series graphs, change in two states, and change in visual variables. Each of which will be described below, including a discussion of their respective strengths and weaknesses.

2.4.2.1 Snapshot

A snapshot treatment of time is characterised by representing a single moment in time over the area of interest. When two or more snapshots of different moments in time over the same area are used in a visualisation, it is possible to identify change through comparing each of the snapshots in sequence. This is the most popular treatment of time used for visualising historical spatial data, and is used for many different visualisation techniques. Possible reasons as to why this approach is widely used could include: the simplicity of incorporating change through creating another snapshot of time and not having to adjust the applied technique; and the suitability of much of the historical data used, as many are associated with temporal changes that are uniform across the geographical extent (for example Census data collected at a specific date across the extent of a country).

Snapshot visualisations can very effectively show change for a variable or geographic objects through visual comparison. By viewing snapshot images sequentially, one can identify changes, patterns, similarities, and differences between the two temporal states and can

therefore analyse these characteristics and use the findings to support research. For example, Gregory (2008) uses snapshot images of choropleth maps placed sequentially to show change in infant mortality rates (IMR) between 1850 and 1900 in England (Figure 2.31). The six images used (of which the first and last are shown here) display the state of IMR for each decade and can therefore be used to identify geographical trends and patterns. It is easy to identify the gradual changes in IMR from one image to the next (such as the increased spread of low rates across the country), and when the first and last date images are compared, stark differences can be identified (including the change from dominance of high to low IMR across the majority of the country, and the significant geographical areas of low rates appearing in the south in the 1900s compared to the 1850s).

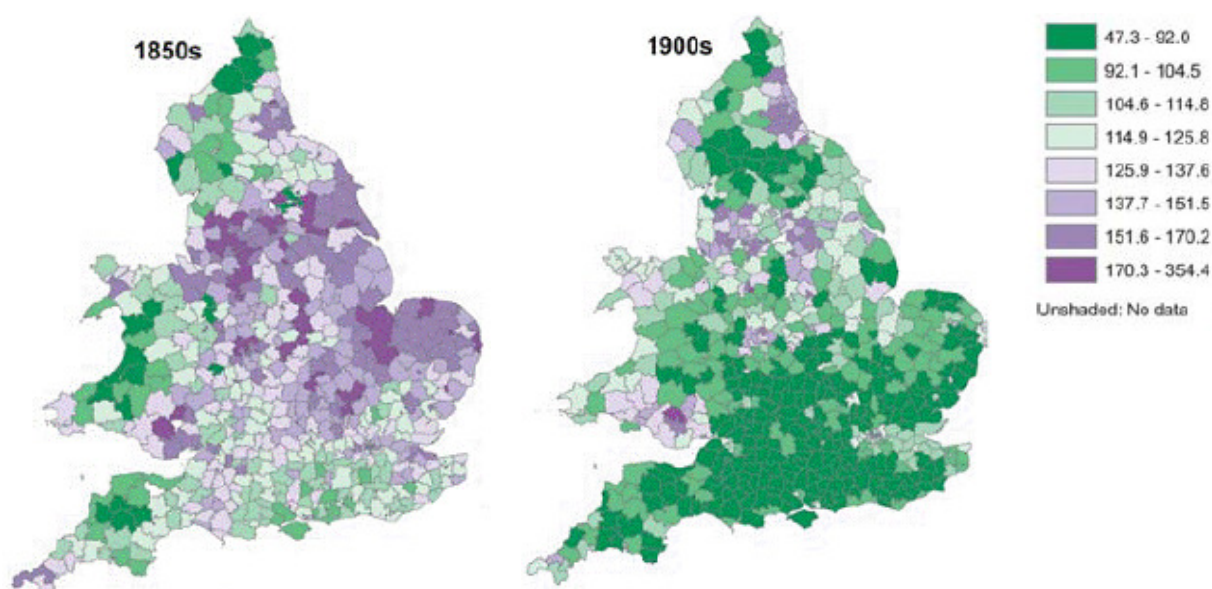


Figure 2.31a: Choropleth map of infant mortality rate 1850s (Gregory 2008)

Figure 2.31b: Choropleth map of infant mortality rate 1900s (Gregory 2008)

A large proportion of studies that incorporate snapshot images using choropleth maps spawn from large infrastructure GIS initiatives such as the Great Britain Historical GIS (GBHGIS) Project and the Electronic Cultural Atlas Initiative. The GBHGIS utilises a net of administrative unit boundaries as the basis for the geographic analysis of population history, and due to this framework, choropleth maps are the choice of visualisation for depicting change over time (Gregory and Southall 1998, 2002). As a result, the GBHGIS has been used as the basis for choropleth snapshot comparisons over time for trends in poverty (Gregory et al. 2001), population (Gregory and Ell 2005), infant mortality (Gregory 2008), and migration (Gregory 2000).

Choropleth maps lend themselves well to a snapshot treatment of time as much of the data used in choropleth maps is collected not just for one date, but for many uniform dates over an area (for example Census data). In addition, comparisons can be made between sequential images for changes in variables or changes in areas as discussed in section 2.5.1, and temporal comparisons are no different. The images now simply depict two different times instead of two different variables. If the thematic data is collected over more dates, more snapshot images can be created and used in subsequent comparison and analysis. Such characteristics can contribute to explaining the dominance of snapshot comparison in choropleth mapping.

Comparisons between two images of two different dates can be easily achieved by using this method - but there is a limit to what is comparable, for as the number of snapshot images increase, the complexity and issues associated with visual comparison also increase. This observation is reflected in the use of snapshot visualisations used in academic publications. Many deal only with a small number of snapshots to communicate their research and findings. Comparative histories utilising a limited number of snapshot images are therefore popular, such as the comparison of 1896 and 1991 for poverty (Dorling et al. 2000); comparison of deprivation and mortality in the 1900s and 2001 (Gregory 2009); and those studies that focus on a smaller time frame such as the 20 year difference in slavery in 1780 and 1800 (Armstrong et al. 2009).

There are of course those that use multiple snapshot images to show not just the difference between two dates but to track multiple changes over time. There are a number of excellent examples where multiple choropleth snapshots are used in this way – studies into infant mortality (Gregory 2008), sex ratio geographies (Boeckel and Otterstrom 2009), and famine (Ell and Gregory 2005) to name a few. This approach is taken further in a study by Geoff Cunfer detailing the causes of the Dust Bowl in America in the 1930s (2002, 2008). Changes in Census districts detailing land use are coupled with digitized boundaries of the Dust Storm regions to highlight changes in land use within the changing boundaries (Figure 2.32).

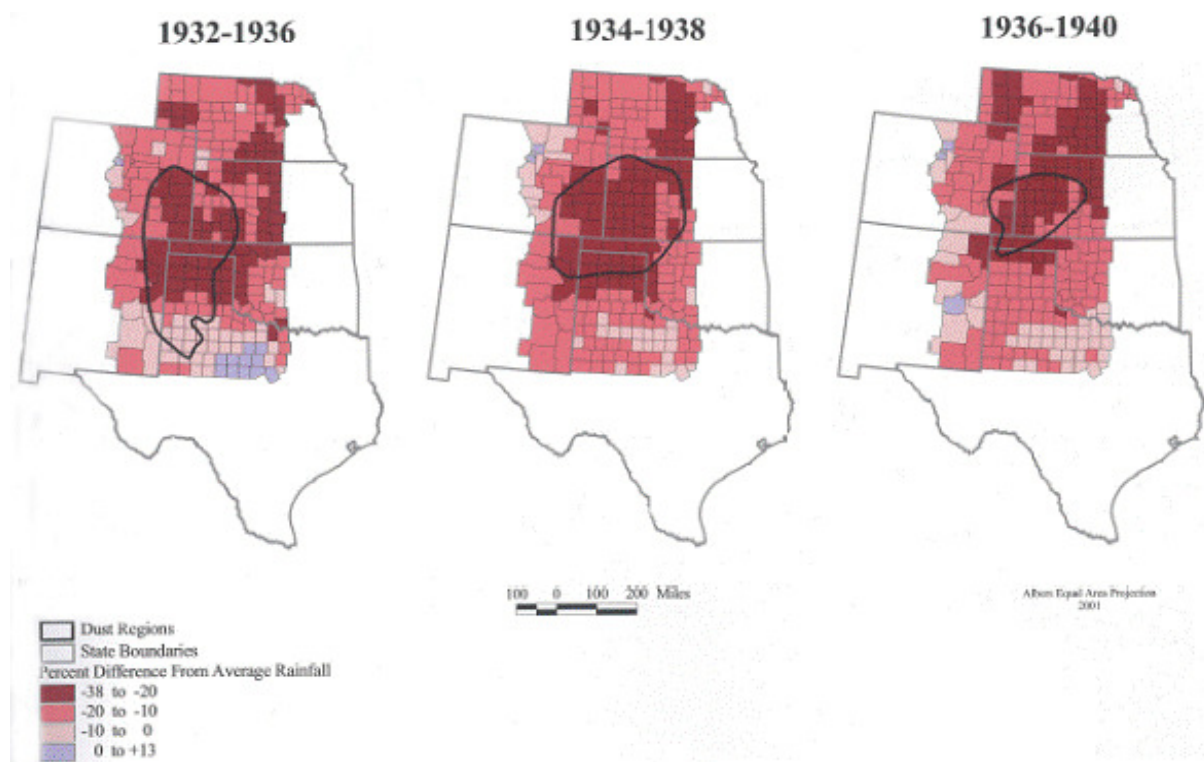


Figure 2.32: The relationship between dust storm region and land use (Cunfer 2002)

A number of these visualisations are taken from animations showing the succession of static images to track patterns of changes over time. When static images are put together to form an array of successive images of a particular area and theme (an animation), changes can be tracked by the user to find general trends and to identify areas of interest. This is a popular approach in large Historical Atlas projects who adopt choropleth maps to show changes in demographics over time and have a large amount of data available for use (Fitch and Ruggles 2003; Lancaster and Bodenhamer 2002; Owens 2007).

The snapshot approach to time treatment has also been applied successfully to differentiated and ordered visual variables in very much the same ways – primarily through a comparison of two dates and tracking change over time for a given temporal period. Figure 2.33 is an example of using differentiated symbols to show the change in population in 1905 and 1940 in relation to public transportation. The visualisation clearly demonstrates, through the use of the two snapshots, the instrumental role that the subways played in shifting the population from Manhattan and northern Brooklyn into southern Brooklyn, Queens, and the Bronx (Beveridge 2002).

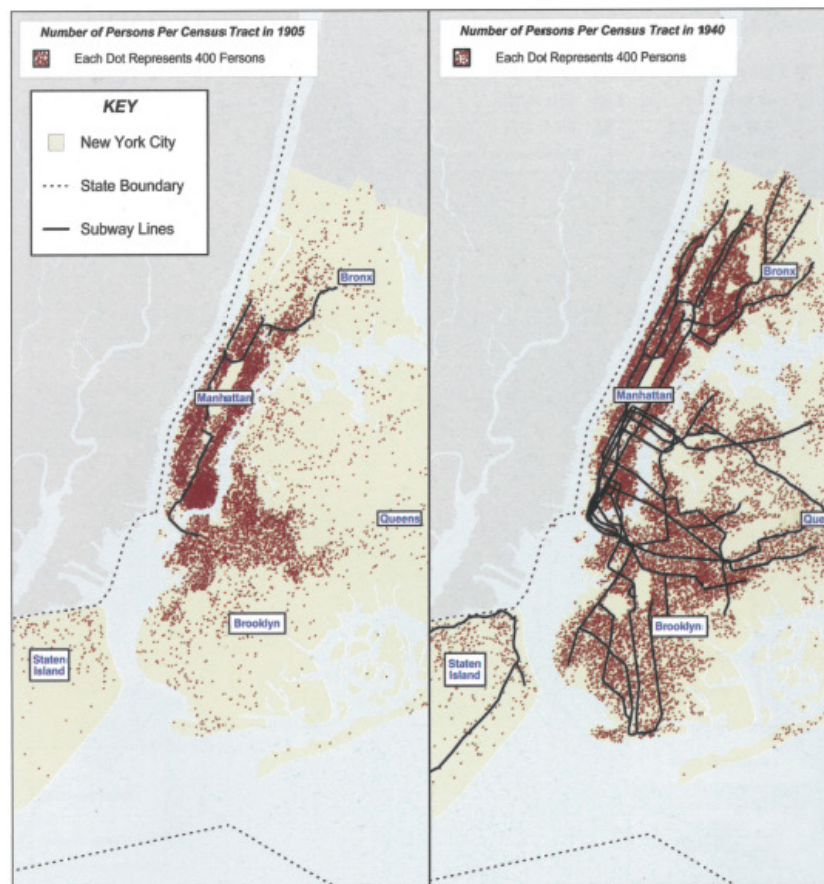


Figure 2.33: Change in population around Manhattan from 1905 to 1940 (Beveridge 2002)

Graphs with a temporal focus have also been used in snapshot comparisons, such as spatially placed pie charts (Armstrong et al. 2009), and relational graphs of geographic locations (Gregory 2009). When tracking change over time for visual variables, multiple images are often used to show variations within the temporal period, thereby tracking gradual changes as seen in a number of studies (Carter 2008; Dobbs 2009; Donahue 2008; Harris 2002; Hillier 2002, 2005), to name a few. Technology can be used to enhance the usability of snapshot images, such as through the control of a sliding time bar in a web environment, or through the use of animation as specified above. Benjamin Ray (2002a) makes use of an interactive web page to display the change in the geographic distribution and incidence of witchcraft accusations involved in the Salem Witch Trials. Whilst each change in accusation sparks a new snapshot image, the treatment of time is enhanced by using a sliding time bar to select specific dates (snapshots) and therefore compare to other dates (Figure 2.34). It also allows the sequence of snapshots to be played as an animation to get an overall idea of change for the period. One pitfall that is often associated with both animations and sliding time bars is the issue of comparison. Whilst it is possible to compare a great number of dates and view change (with often a fine temporal scale) over an entire period, the ability to be able to compare one

snapshot with the next is made difficult due to the fact that only one snapshot is visible at any one time (Gregory and Ell 2007).

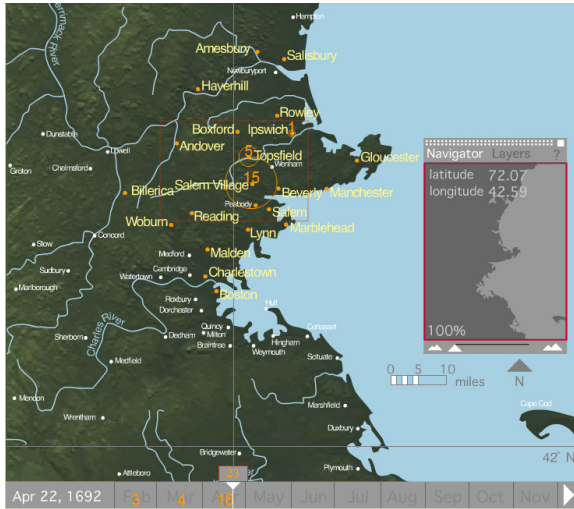


Figure 2.34a: Sliding time bar depicting witch accusations on 22 April (Ray 2002a)

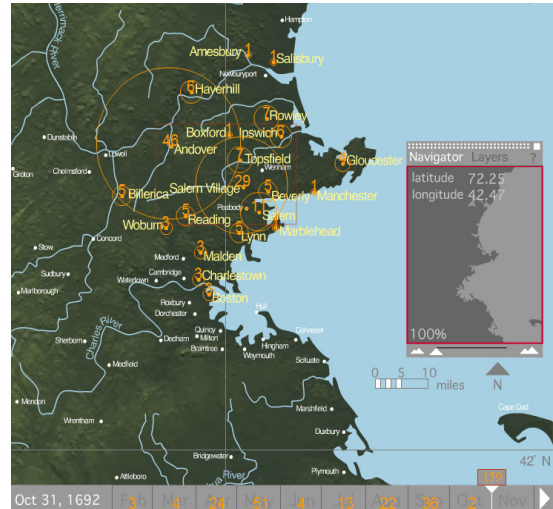


Figure 2.34b: Sliding time bar depicting witch accusations on 31 October (Ray 2002a)

There are a number of issues concerned with the snapshot treatment of time. Whilst it suits data that is available at a uniform date, it does struggle when data is not consistent or if change occurs at a fine temporal scale. For example, if change is minimal but occurs at many different dates (at a fine temporal scale), then to show change over time that depicts all records would require a huge amount of snapshot images, and as a result, comparison and analysis of change would be extremely difficult.

2.4.2.2 Time-series Graphs

The second approach used widely for historical spatial data that change over time is time-series graphs. As discussed in section 2.3.4, time-series graphs can include a spatial component through either representing individual locations or areas as the graphed point/lines/bars, categories of space such as rural to urban or individual graphs for individual locations. Time-series graphs are characterised by a regular division of time along one axis (usually the x-axis), against a variable along the y-axis. Therefore as spatial data is plotted within this temporal/variable frame, it is possible to track change over time through observations at each interval. For example, Figure 2.35 shows the proportion of malaria cases among all hospital admissions against a timeline of months for different hospital locations in Tucuman, Argentina (Carter 2008). At each division it is possible to track the changes in

malaria cases for each of the hospitals and compare the rates in terms of location, malaria case percentage, and time.

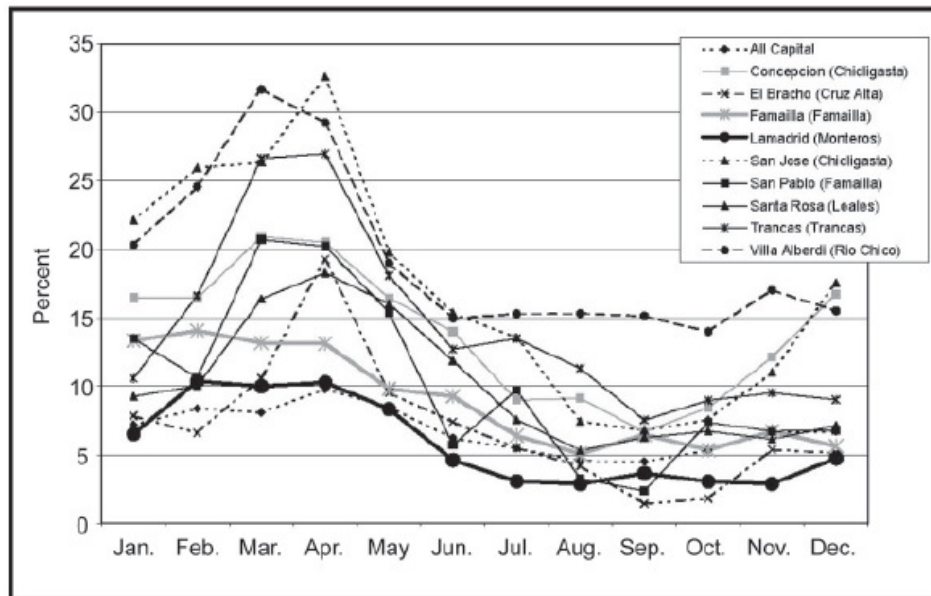


Figure 2.35: Malaria cases over time for different hospital locations in Argentina (Carter 2008)

The treatment of the spatial component in the graph does not affect the treatment of time for each time-series graph. What do change are the temporal divisions. Depending on the type of data used to create the time-series graphs, it is possible to show changes monthly (Carter 2008), yearly (Skinner et al. 2000), every five to ten years (Beveridge 2002; Gregory 2000, 2008; Norman et al. 2008) or greater (Gregory and Southall 2002). Apart from those graphs that depict one individual location for each graphic, time-series graphs are able to track change over time for the entire temporal dimension within the one image. This allows locations to be compared easily over time without resorting to the complex task of comparing multiple images. A main issue with this approach however is the treatment of space. In order to incorporate change over time within one image, the spatial component is often sacrificed, which leads to spatial information that is greatly abstracted. In the case of Figure 2.35, locations are not given a spatial context at all; the locations are simply named. As a result, the ability to interpret any geographical relationships, patterns, or analysis is greatly hindered.

2.4.2.3 Change in States

The depiction of change over time can be approached through representing the rate of change between two dates as a variable for spatial data. In many cases, these changes are depicted in

choropleth maps that show changes over time in one static image, which can then be compared to another. For example, Gregory et al. (2001) focuses on change for a number of themes in a study of social inequality for England and Wales. Figure 2.36 shows one of these maps depicting change from 1901 to 1991 for the ranking of overcrowding.

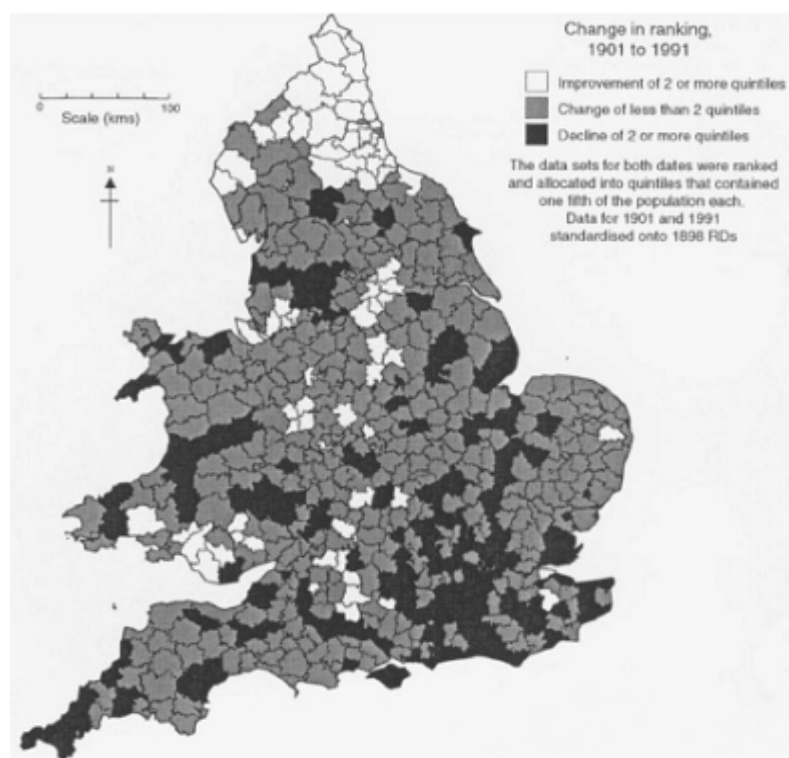


Figure 2.36: Change in the ranking of overcrowding from 1901 to 1991 (Gregory et al. 2001)

It does not represent levels of overcrowding; instead it represents a measure of change in terms of improvement or decline. Through images such as these, it is possible to show change between two states within the one image, highlighting geographical patterns and trends without having to compare two separate maps. Measures of change can also be depicted in relative terms such as standard deviation (Orford et al. 2002), and also compared to other maps of change creating a sequence of changing snapshots (Ell and Gregory 2005). Ordered visual variables have been applied to this technique in an example showing percentage increase and decrease (as indicated by point symbol size and style) of population statistics, demonstrating historical population shifts during World War Two in Tokyo (Siebert 2000) (see Figure 2.37).

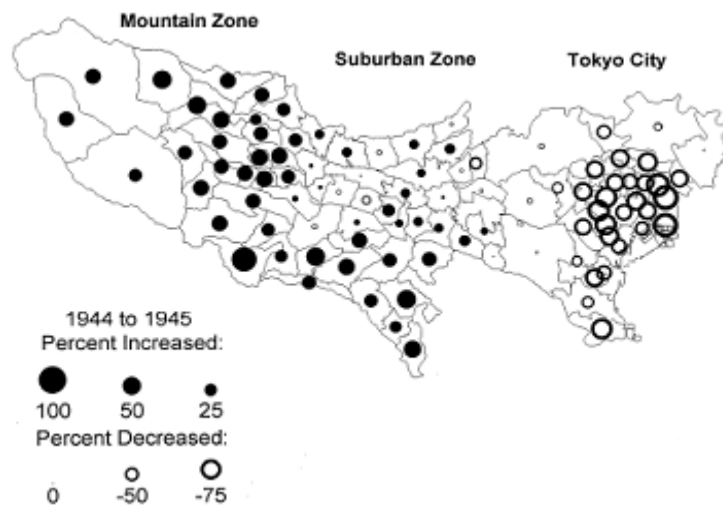


Figure 2.37: Percent increase and decrease in population in Tokyo between 1944 and 1945 (Siebert 2000)

2.4.2.4 Visual Variables

The final category of depicting change over time for historical spatial data is the use of values for visual variables. Each of the values represents a particular moment or period in time, and through their variation (such as colour, size etc.) it is possible to represent multiple periods in the one image. The use of this technique is not as widespread as the others mentioned above as it has a number of limitations which make it suitable for only a select type of data. The technique is best explained through an example. Figure 2.38 shows a map of dust storm locations within the southern and central Great Plains counties in the United States (Cunfer 2002). In this case, time is depicted through the use of the visual variable colour, where each year the location of the dust region is shown as a different coloured areal boundary over a map of the area. The image clearly shows the change to the extent of the dust storm region over the five year period.

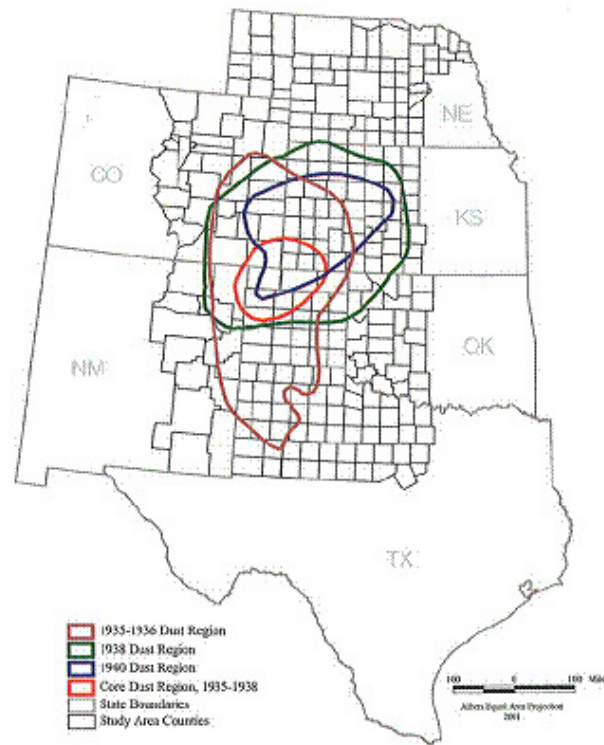


Figure 2.38: Visual variable depiction of dust storm regions over time (Cunfer 2002)

Other cases of this technique being applied to historical spatial data have focused on areal data, such as the development of Tokyo's harbour areas (Siebert 2000), changes in forested areas (Schuppert and Dix 2009), and the temporal acquisition of land (Morel-EdnieBrown 2009). Whilst this technique can effectively show the temporal development of different locations, it is difficult to show change of a specific geographic area for multiple temporal periods. This would require multiple images, or the clever use of overlapping symbols as used by Cunfer (2002) (Figure 2.38). Difficulties also arise when too many temporal dates or periods are displayed as shown in Figure 2.39. Tracking changes using visual variables for a large number of years is very complex and cannot be attempted successfully through visual comparison.

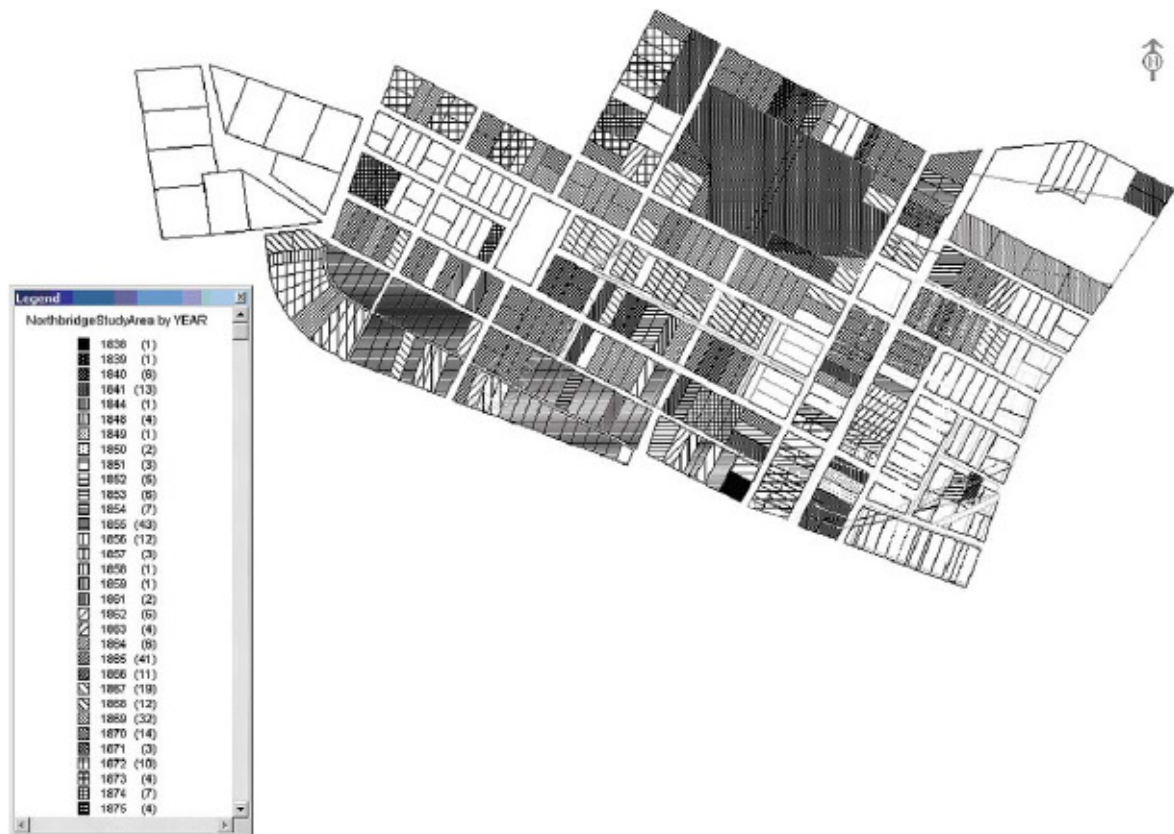


Figure 2.39: An example of when too many temporal classes are visualised (Morel-EdnieBrown 2009)

2.4.3 Visualising Historical Multivariate Spatial Data

Multivariate visualisations or maps display multiple variables. By increasing the number of variables to be visualised, the complexity of the techniques adopted increases, as to the difficulty in effectively displaying and understanding the datasets (Klippel et al. 2009). Whilst challenging, there are a number of ways in which multivariate spatial data can be visualised, ranging from cartographic representations of small multiples and combining all attributes in the one map, to the more technology based interactive display environments. As the collection of ever increasing amounts of data is becoming easier and more common in many disciplines, there is a current need to handle large data volumes with a large number of associated variables (Andrienko et al. 2008; Dykes et al. 2005; Guo et al. 2005). The ability to be able to visualise these data sets is often an integral part in understanding patterns and relationships between them (Guo et al. 2005) and is a focus of the development of a visualisation method in this research. This review will outline the ways in which multivariate data are visualised in geohistorical projects.

One solution to multivariate mapping is to use what Tufte (1990) describes as *small multiples*. This technique involves representing each of the individual attributes on a separate map of the same area, and then placing these *small multiples* in succession to view the dataset as multiple variables. This technique can be seen as a type of snapshot comparison, but using variables instead of time to reproduce the maps. Gregory and Ell (2005) have utilised this technique to visually interpret the patterns of population decline of the 1840s, using housing classes as the variable for the changing index of choropleth maps (Figure 2.40).

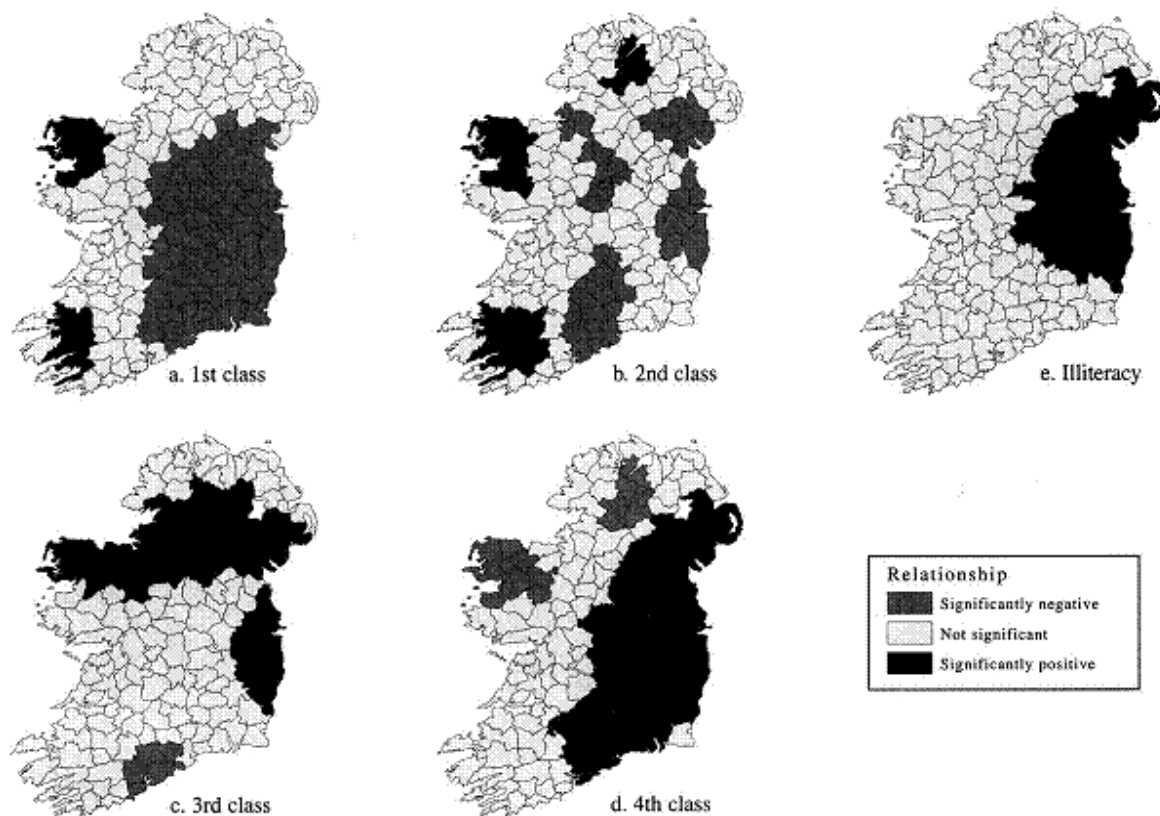


Figure 2.40: Small multiple depiction of the relationship between population decline and class (Gregory and Ell 2005)

Well-designed small multiples can devote attention entirely to the data and can be efficient in interpretation (Tufte 2001), however issues can arise through difficulties in comparing a geographic point or area across a set of attributes, and also in the interpretation of detailed geographic information represented as small images for comparison (Slocum et al. 2009; Steinke and Lloyd 1983).

Difficulties associated with visualising multivariate data are particularly prevalent when combining multiple attributes on the same map, for it challenges the limits of the data graphic and cartographic design for producing understandable images. A review of the literature has revealed a limited use of combining multiple attributes on the same map, but notable

examples are found in the use of trivariate choropleth maps and spatialised pie charts. Trivariate choropleth maps are created by combining three separate coloured choropleth maps, usually from three attributes that add up to 100 percent (Slocum et al. 2009), such as voting data (for example, percent voting Labor, Liberal, and Greens). A trivariate map using a combination of pattern and colour has been developed by Interrante (2000) to show historical data of landuse and farm operation over the USA. Figure 2.41 depicts three attributes in a textured surface across the extent of the country, providing an overall image of trends and individual enumeration districts in particular.

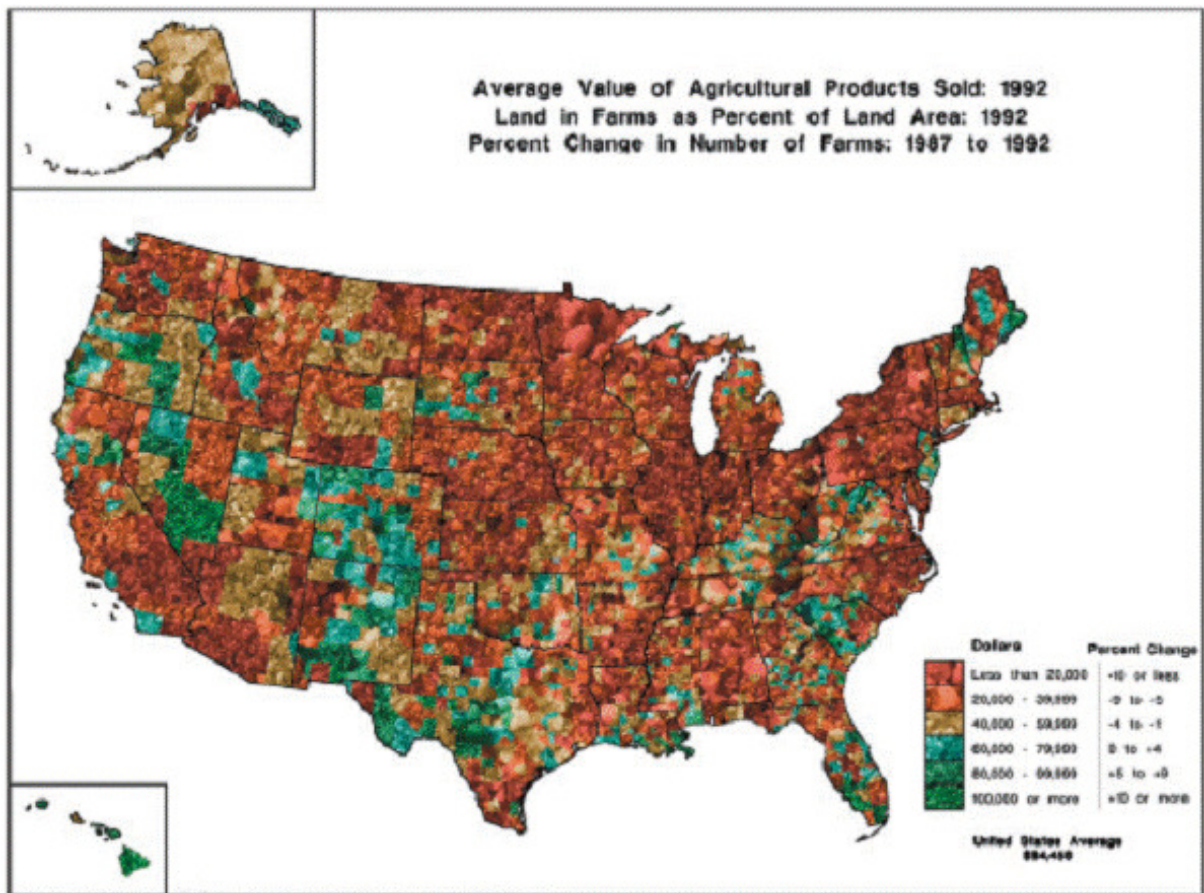


Figure 2.41: Trivariate choropleth map using pattern and colour combinations (Interrante 2000)

Pie charts can be used to present multivariate data geographically by placing a number of pie charts over a simple map to represent either areal classes or cities/towns. This can be seen as an extension of graphic depictions outlined in section 2.3.4, for it can incorporate into the visualisation a less abstracted sense of space. An excellent example of this can be found in the *Historical Atlas of Canada*, taken from Gentilcore (1993) combining ordered visual variables and pie charts divisions over a map of marked areal divisions to show both the number of sales per newspaper issue and the political viewpoint respectively (1993) (Figure 2.42).

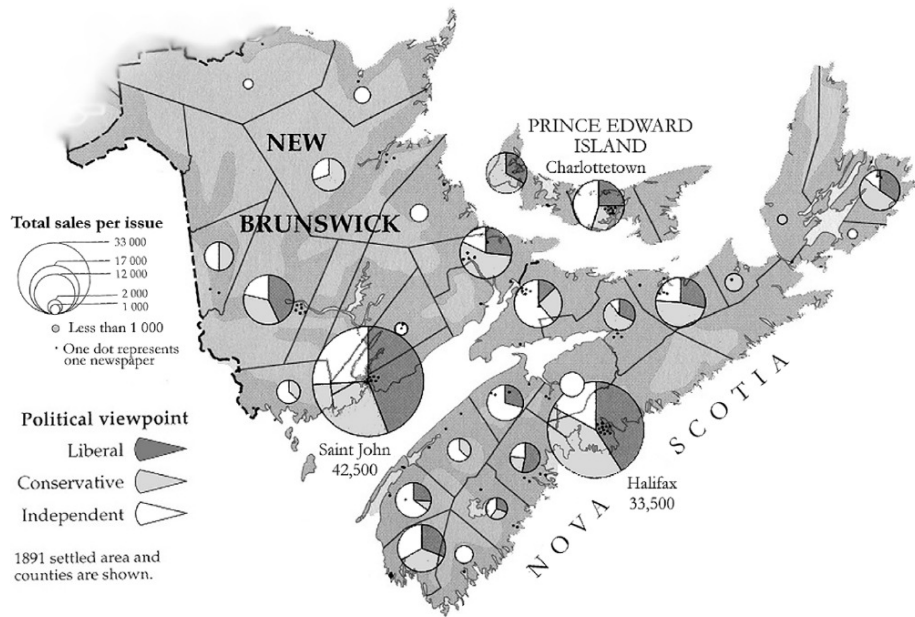


Figure 2.42: Ordered visual variables and pie chart visualisation (Gentilcore 1993)

There are a number of other multivariate same map techniques that, although not used particularly for historical purposes, have had wide application in other disciplines. One area that has been developed quite extensively is the use of multivariate point symbols. The term *glyphs* refer to multivariate point symbols employed to represent nonrelated attributes (Slocum et al. 2009) and have produced symbols in many different forms (see: Forsell et al. 2005; Healey and Enns 1999; Klippel et al. 2009; Ward 2008, for examples). Figure 2.43 depicts two of the most extensively used glyphs for spatial data: Chernoff faces and star glyphs.



Figure 2.43a: Chernoff faces (Slocum et al. 2009)



Figure 2.43b: Star glyphs (Klippel et al. 2009)

Chernoff faces (see Figure 2.43a) make use of distinct facial features to represent certain attributes (Slocum et al. 2009). For example, the size of the eyes may indicate a small to large percentage of unemployment whilst a smile or frown may indicate levels in poverty. Many aspects of the technique have been advanced in recent cartographic research (Dorling 1994; Wang and Lake 1978). Star glyphs (also referred to as metroglyphs (Anderson 1960) and multivariate ray-glyphs (Slocum et al. 2009)), have been used extensively in data visualisation (Chernoff and Rizvi 1975; Lee et al. 2003; Ward 2008) and have been used for spatial data visualisation in particular by placing them in geographical space (Klippel et al. 2009) (see Figure 2.43b). A star glyph depicts a number of variables through the corresponding number of rays emanating from the centre of the plot, where the length of each ray is proportional to the value of the variable it represents (Klippel et al. 2009). Further multivariate same map techniques include: *stick figure* icons used within the visualisation system *Exvis* (Slocum et al. 2009); weighted isolines (Dibiase et al. 1994b); raster display icons (Zhang and Pazner 2004); and parallel coordinate plots (Guo et al. 2005).

Advancements in technology, web technology, and exploratory visual analysis have extended the use of information graphics (such as scatterplots and graphs) and cartographic techniques (such as choropleth maps and isolines) through incorporating dynamic, linked, and often highly interactive displays. Simple choropleth maps can be seen as multivariate displays through the use of selection and query functions within a web-based or desktop application, such as the Great Britain Historical GIS (as discussed previously) and many ECAI supported projects. A simple locator map of historical burial sites can be transformed to access additional information of burial plots once one is selected (Lowe 2002). Complex integrated visualisation and analysis methods often rely on conventional cartographic and data graphic representations as the basis for an integrated system. An excellent example of such an approach is put forward by Guo et al. (2005) which combines a self-organising map (“an artificial neural network used to map multidimensional data onto a space of lower dimensionality – usually a 2D representation” (Koua and Kraak 2005, p. 629)); a parallel coordinate plot (a plot that “organizes the axes of a multi-dimensional space in parallel and thus enables to assess a large number of variables concurrently” (Ahonen-Rainio and Kraak 2005, p. 616)); a geographic mapping component (GeoMap); and a 2D colour design tool (see Figure 2.44). This results in a geographic knowledge discovery environment that is able to, as Guo explains “detect and visualise multivariate spatial patterns within high-dimensional geographic data” (2005, p. 113).

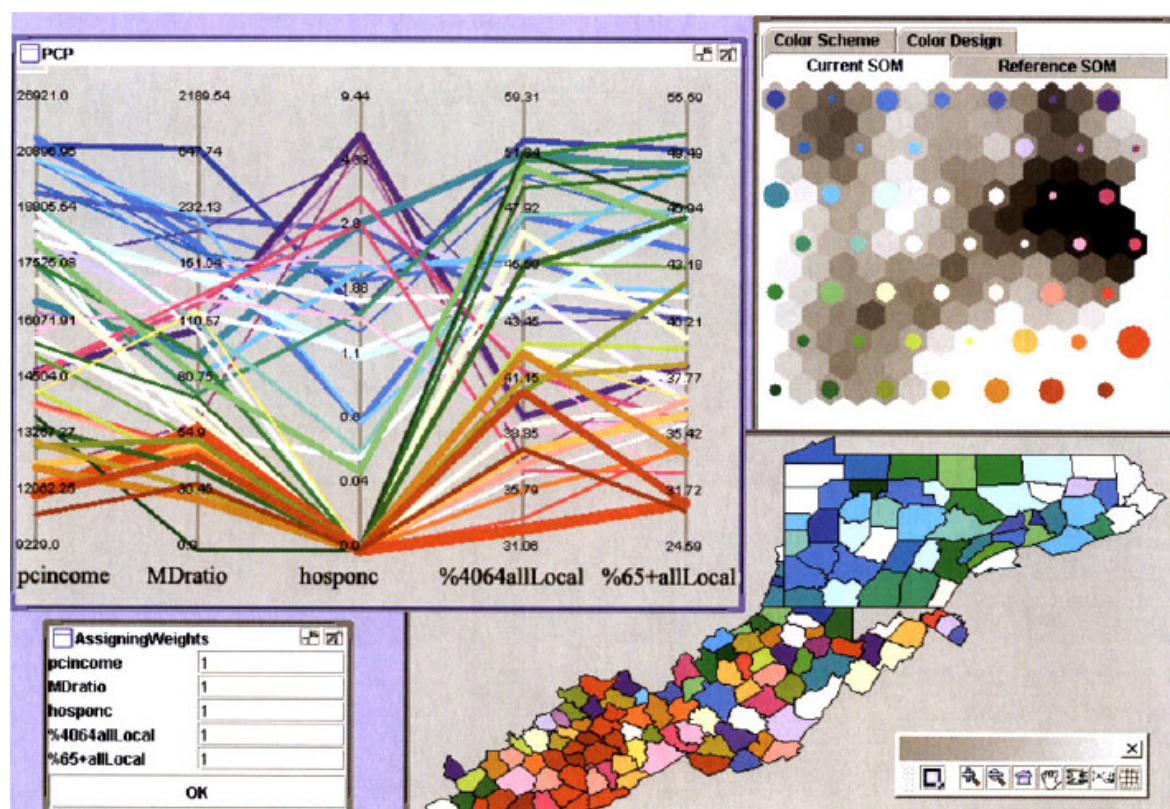


Figure 2.44: An example of a complex visual analytic interactive display (Guo et al. 2005)

There are many other examples of technologically inspired multivariate visualisations that have great potential in historical studies, see the following selection of text for further reading: (Dibiase et al. 1994a; Guo 2009). In review of such techniques, an important distinction is to be made - multivariate visualisation is achieved here by means of technology, not in the technique itself. Whilst equally as relevant and advanced in exploratory data analysis, our focus is on the creation of an alternate cartographic/visualisation technique.

2.4.5 Visualising Historical Multivariate Spatial Data that Change Over Time

The ability to visualise both multivariate data and spatial data that changes over time within the one visualisation is a current challenge in geospatial science (Jern and Franzen 2006) both in design and in communication. Through a review as part of this research, it was found that visualisations that incorporate both of these aspects have been developed predominantly in complex analytical systems. The work of Natalia and Gennady Andrienko has focused on spatio-temporal representations through the use of analytical visualisation systems, and has made multivariate data a key component in a number of research projects (Andrienko and

Andrienko 2005, 2007; Andrienko and Andrienko 2006). Andrienko and Andrienko, along with others, have developed time-series graphs to represent spatial multivariate data that captures change over time (Andrienko and Andrienko 2007; Schroeder 2010). Jern and Franzen (2006) outline a visual analytic interface which include six linked views comprising parallel coordinates, time graphs, and choropleth maps. Parallel coordinates and choropleth maps are also used within the highly interactive and analytical *Visual Inquiry Toolkit* (Chen et al. 2008), together with an introduced concept of a *Pattern Basket* used, as Chen explains, to help “human cognition to identify complex and implicit patterns that may be missed by computational methods” (2008, p. 42). Three-dimensional symbols have been used to visualise time dependent data in the form of pencil and helix icons capable of representing multiple variables within the one icon (Tominski et al. 2005).

Whilst having great potential for historical investigation, these visualisation systems have not as yet made a strong impact in the area. This may be due to the large costs involved in setting up such a system, or the need for reasonably reliable and complete data to be included in such analysis. However, there are a few notable examples where historical scholarship has implemented and benefited greatly from technologically based analytical visualisation systems. A visualisation system utilising a wrapping spreadsheet of calendar dates, tables, histograms, and a location map has been developed specifically for historical investigation – the analysis of historical hotel visitation patterns in the area of Rebersburg, Pennsylvania from 1898 to 1900 (Weaver et al. 2006) (see Figure 2.45).

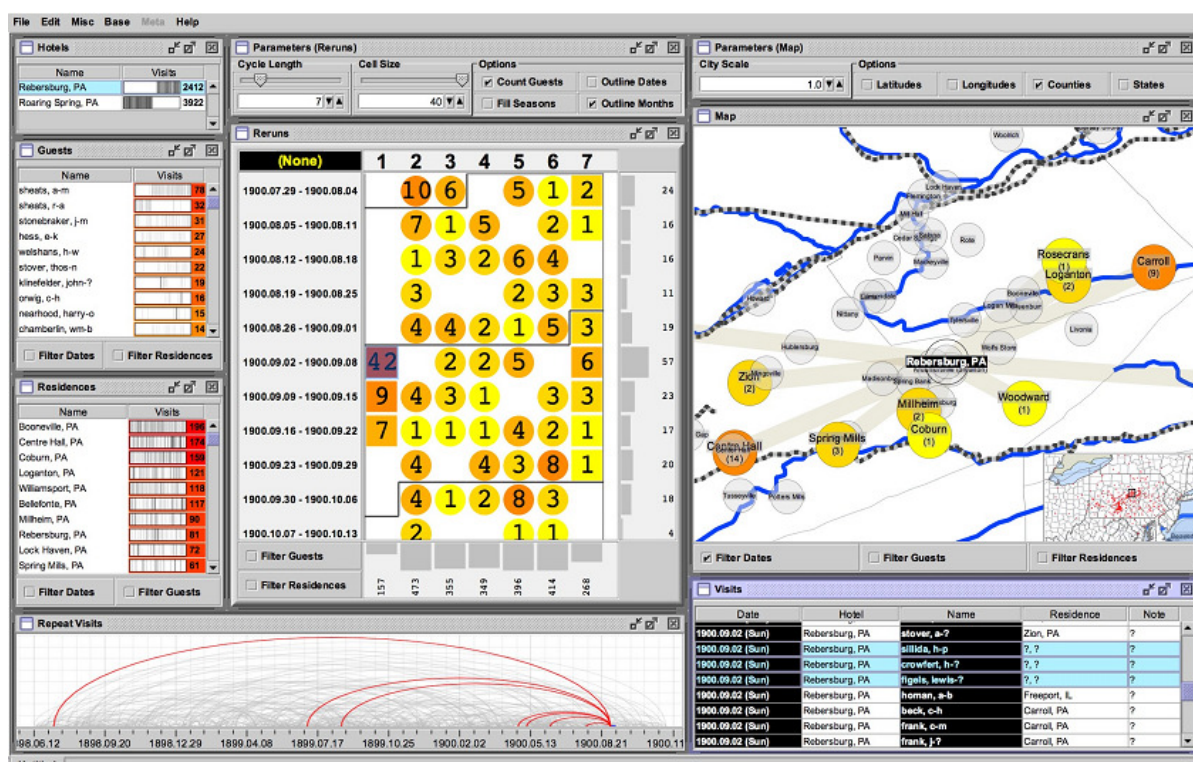


Figure 2.45: multivariate temporal visualisation for the analysis of hotel visitation patterns (Weaver et al. 2006)

Combining multiple attributes and time through a number of visual analytic displays, the visualisation allows “detailed and contextualized queries regarding cyclic temporal patterns (in days, weeks, months, and years), seasonal temporal patterns with corresponding climate indications, social grouping patterns, spatial patterns of travel from particular places or regions, and complex combinations of all of these” (Weaver et al. 2006, p. 7). For the study of travel patterns and social connectivity, the visualisation has uncovered new patterns of travel that have previously gone unrecognised; accelerated hypothesis generation and testing over other traditional techniques; and shaped new Research Questions (Weaver et al. 2006).

As the volumes of data increase through multiple variables and an added temporal dimension, so too do the difficulties in representing all aspects within a single map display, using a single technique. Good examples are rare as most research is directed toward multiple display and interactive visualisations as seen above. One rare and excellent example is used to depict a historical battle, that of Napoleons Russian campaign of 1812, by Charles Joseph Minard (Tufte 2001). Figure 2.46 shows this graphic of space and time, drawn in 1861, in which six variables are plotted in the one graphic: the size of the army, location, direction of the army’s movement, and temperature on various dates during the army’s campaign to and from Moscow. The visual impact of this image is dramatic, delivering the brutal narrative of the loss of life during the lifetime of the campaign. Minard’s graphic of Napoleon’s army (Tufte

2001) incorporates data graphic design into geographic information. It allows the reader to visually explore all the variables that make up the data, and it delivers visual analysis and highly effective presentation of complex geographic data.

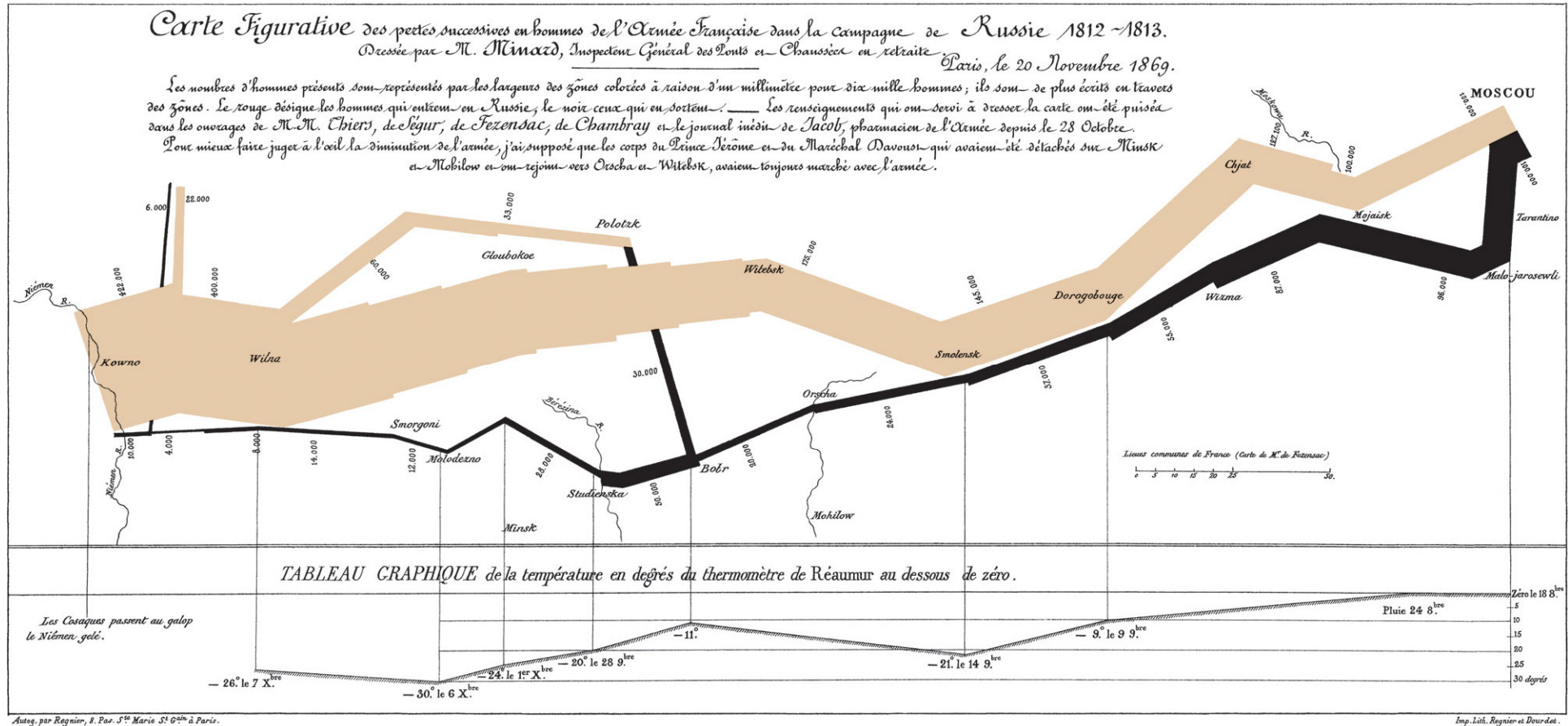


Figure 2.46: The visualisation of Napoleons Russian campaign of 1812 by Charles Joseph Minard (Tufté 2001)

2.5 *Conclusions*

Whilst all of the techniques discussed above have a historical and geographical focus, they vary in their inclusion or exclusion of representing change over time, and number of variables. This review has identified that the vast majority of techniques adopted represent one or two variables in the data. The temporal component is present in all cases, and many visualisations depict change over time. However, a significant outcome of the review of visualisation techniques adopted for historical spatial data is the lack of multivariate techniques, especially when this is coupled with representing change over time. As there are many cases in which such capabilities within a visualisation are necessary for historical spatial data, this chapter has identified a need for further development in this area.

This lack of multivariate techniques may be due to the strong presence of GIS in such projects, and therefore a strong reliance of GIS generated visualisations which are largely based on conventional cartographic techniques. It has been identified that there is a need to consider the suitability of such visualisation techniques for representing historical spatial data. There is also a need to develop visualisation techniques that are specifically tailored toward the characteristics of historical spatial data, toward considering the complex and essential relationship between geography and history, and toward the capacity for historical investigation.

Discussions have significantly contributed to addressing Research Questions 1, 2, and 3, which relate to understanding how historically changing, multivariate, spatial data can be analysed and communicated visually; how can the temporal change of static entities be represented; and understanding the issues involved in working with historical data. The next chapter will add to the discussion of current visualisation techniques by reviewing spatial visualisation methods within the Case Study area, the history of Melbourne's cinema venues between 1946 and 1986. In addition, Chapter 3 will provide a background to the Case Study, including a brief history of cinema in Melbourne and the current move toward studying the spatial nature of cinema.

3 Case Study – Cinema Venues in Melbourne, Australia Between 1946 and 1986

3.1 Introduction

The history of cinema venues provides us with an excellent case study for the development of a visualisation method, as venues can include both spatial and temporal dimensions involving multiple associated variables, such as ownership, screen numbers, and seating capacity. For cinema historians, applying spatial methods and representations to cinema venue data enables a spatial history to be constructed and analysed. This Case Study focuses on the period between 1946 and 1986 in Melbourne, Australia; a city largely neglected by historical cinema research, and a period often ignored by cinema historians (Verhoeven 2006).

This chapter outlines the background to the Case Study specifics, from the use of the term cinema, to the current use of visualisation techniques in the discipline. Visualising the history of Melbourne's cinema venues requires an understanding of the geographic location and settlement patterns of Melbourne, and within this context, the history of Melbourne's cinema industry. It is also necessary to understand the geographic influences that have affected the

city of Melbourne, the cinema industry, and individual cinema venues. This will be discussed in section 3.3. The background to the discipline of cinema studies specifically concerned with cinema venues and the spatial significance of cinema operation will be discussed, including the broader developments within the humanities. Whilst still relatively new, there have been a number of successful studies where spatial visualisations have been applied to cinema data. These will be examined in the final section in relation to the multivariate and temporal capabilities discussed in Chapter 2, and will also provide a discussion of key findings from the literature.

3.2 Cinema

The term *cinema* often goes hand in hand with *film*. However, there is a distinguishable difference between what is referred to as *film* and *cinema* within the discipline of cinema studies. For the purpose of this study, *film* refers to what is exhibited on the screen; the content of the film, and the text. Whilst *cinema* encompasses the commercial activities of film exhibition and distribution, audience, cinema-going, and cinema venue (Allen 2008; Maltby 2007). A history of cinema, as Maltby states, should “engage with economic, industrial, institutional history... and the socio-cultural history of its audiences” (2007, p. 4).

The research specific to this thesis is concerned with the history of cinema venues. There are many views as to what constitutes a venue; whether a new venue is created when a cinema moves location, or if it extends to locations other than movie theatres, such as halls and auditoriums. For the purposes of this study, a cinema venue is a place where films are screened (Verhoeven et al. 2009). More specifically, this study recognises the definition of cinema venue put forward by Robert Allen (2008) as:

“not so much as a fixed place as a process – a “coming together” (as the etymology of the word suggests) of physical location, agency (individuals, groups, and institutions responsible for regulating, arranging, and authorizing a film exhibition), and event (the experience of at least one instance of movie exhibition).”

So although it can be described simply as a place where films are shown, the understanding of these processes are essential in order to realise the history of a cinema venue. Such a definition also includes those cinema venues that do not exist solely for the viewing of films, and as a result this study also includes venues such as Masonic halls, Town halls, Mechanics Institutes, live theatres, art gallery spaces, and drive-in theatres.

The history of cinema venues provides an excellent case study for the visualisation of historically changing, spatial, and multivariate data because of the complexities associated with cinema venues. These three aspects required for the visualisation (historically changing, spatial, and multivariate) can be applied directly to cinema venues:

- 1) Firstly, cinema venues are spatial. Whether they exist as halls or theatres, they exist in space; they can be given a location, and therefore a spatial coordinate.
- 2) Researching cinema venues between 1946 and 1986 involves a temporal understanding, and since data associated with cinema venues changes over time (such as changes in name and the number of screens), cinema venues can be seen as historically changing. Even though venue characteristics change, the spatial location of venues within the Case Study period do not.
- 3) Cinema venues have associated characteristics that can be recorded and tracked over time. These characteristics can be seen as venue attributes or variables, and can also be viewed as multivariate because of the large number of characteristics associated with each cinema venue. Possible attributes that can help in the study of cinema history include: seating capacity, primary purpose of the building, ownership, and number of screens. All of these attributes can change over time and therefore need to have associated dates of change.

Not only do cinema venues provide a perfect case study for developing a method of visualisation, all of these characteristics are important to investigate the history of cinema venues, and the importance of cinema as a cultural practise during a time largely neglected by cinema historians.

3.3 Melbourne's Cinema Industry 1946-1986

The Case Study focuses on the history of Melbourne's cinema venues between the years of 1946 and 1986. This section will provide an introduction to the city of Melbourne, its geography, and those factors that have shaped its pattern of settlement. This section also includes a discussion of cinema, including a brief history and the geographic influences on cinema in Melbourne.

3.3.1 The City of Melbourne

Melbourne is currently the second most populous city in Australia covering a sprawling geographic area. Melbourne is situated in the south-east of the country (see Figure 3.1), and

the metropolitan area is located around the large Port Phillip Bay with the city's CBD situated at the northern most point of the bay at the estuary of the Yarra River (Figure 3.2).



Figure 3.1: Location of Melbourne, Australia

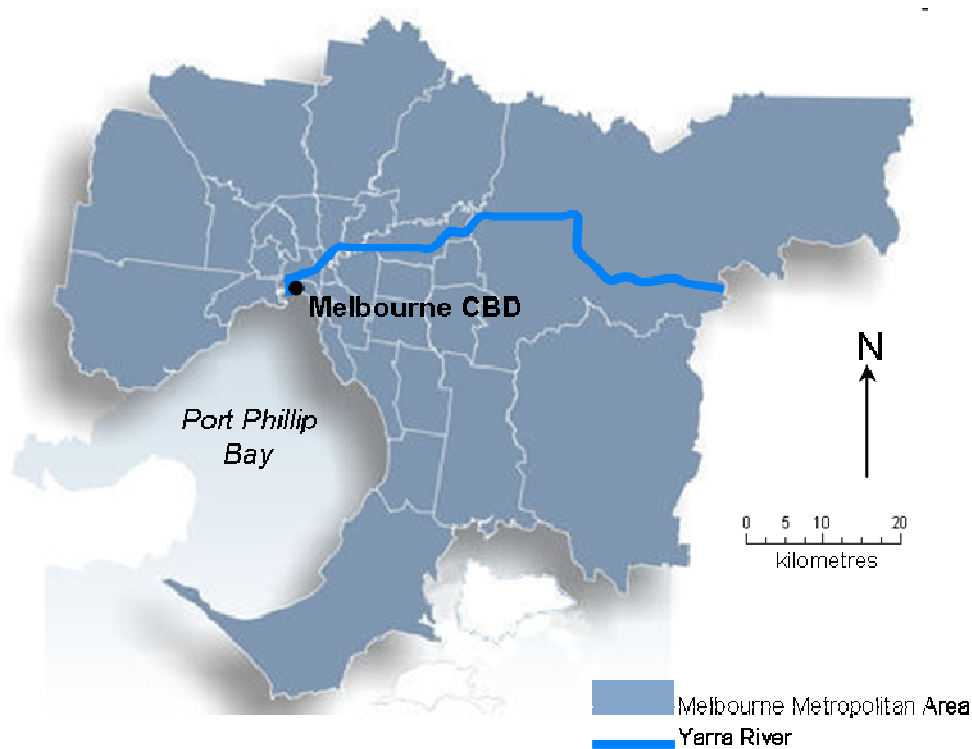


Figure 3.2: Location of Melbourne's suburban extent (Created using image from: State Government of Victoria 2012)

The geographical structure of 1940s Melbourne was dominated by settlement along train and tram lines, low density housing, and the suburban “dream”. The city centre acted as a central point for train and tram services, creating a radial pattern of suburban development clustered around the rail stations and routes (Carroll 2005). This structure of railways still exists today, and although the city is not strictly concentric in its population distribution and development, the city is a central point which causes a concentric pattern for many services (including the train service). Between the years of 1946 and 1986, the metropolitan area of Melbourne expanded from a population of approximately 1,228,000 people in 1947 to 2,968,000 in 1986 (McDonald 2005), and the intervening years witnessed many changes in the development of the city. Suburbanisation expanded beyond and filled the gaps between the train and tram lines as the ownership of cars increased. It is estimated that in 1945, over half of the city’s workers travelled by public transport and only 15% by car. But by 1974 the number of people driving to work had reached 60% (Davison 2005). Migration had also helped shape the structure of Melbourne, creating pockets of cultural distinction and multicultural neighbourhoods. The city’s obsession with suburban living continued post World War Two, as those families that owned or were buying a house increased from one in two to almost three-quarters in the late 1960s (Davison 2005). This ensured the growth of low density detached housing and the continuation of ideals associated with suburban living, such as domestic privacy and middle-class conformity which, as Davison states, is “deeply etched in the city’s consciousness” (2005, p. 692).

The city provides us with an excellent case study to examine the history of cinema venues due to the number of changes associated with the city’s demographics, the cinema industry, and venue operation. There are distinct geographical patterns of distribution and consumption within the metropolitan area (discussed more thoroughly in the proceeding section) which can be used to shed light and validate findings within the data. In addition, a large database covering a number of areas in Australia (including Melbourne) has been developed to cover details about cinema venue existence and operation. This database, titled the *Cinema and Audiences Research Project (CAARP)*, has been compiled over many years of exhaustive research and can provide us with the opportunity to utilise the data collected for an extensive study.

3.3.2 *History and Geography of Melbourne Cinema*

The history of cinema in the city of Melbourne, from the first screenings in the 1890s to the large suburban multiplexes, is a colourful history of technological changes, cinema venue development and growth, economic peaks and troughs, and the influence of social events in Melbourne's history. Just like any other city, cinema in Melbourne is an important social, cultural, and economic practise (Docherty et al. 1987; Jancovich et al. 2003). Unfortunately for Melbourne, there is not a great deal of scholarly writing (and analysis almost none) of Melbourne cinema venues, with the rare and notable exceptions of Catrice (1991), and Verhoeven (2009a).

Catrice (1991) has written about the history of cinemas in Melbourne between 1896 and 1942, and Verhoeven (2009a) has explored the distribution, exhibition, and migrant audiences of Greek cinema in Melbourne. There have also been aspects of Melbourne cinema history in particular that have been examined based on individual venue historical accounts and amateur histories. For example, Trevor Walters (2003) has written a thorough historical account of the picture palaces of Melbourne, creating a full history of the *Regent*, *State*, and *Capitol Theatres* from their inception and height of popularity in the 1920s through to the final days of the last operating palace, the *Regent Theatre*, in 1970.

Cinema venue distribution centred around population distribution. Figure 3.3 shows a series of maps that were created within this study using data from the CAARP database. The maps depict the location of cinema venues in Melbourne between 1946 and 1986, displaying cinema geographic distribution in 1946, 1956, 1966, 1976, and 1986 within 50km of the CBD. Melbourne's suburban population was growing extensively in the east of the city during the 1940s, and Figure 3.3a shows a large number of venues in the inner and outer suburbs in this area. Cinema venues are also distributed quite heavily in the inner suburbs north and southwest of the city, and in response to a heavy reliance on the train network, venues are found dotted along the train lines extending from the city. The population expansion that began to *fill in the gaps* between settlements along the train lines can be seen in the appearance of cinema venues in these areas from 1956 onwards.

Within the GIS, this study revealed that of the 162 cinemas that existed in 1946, only 28 survived the 40 year span to 1986, and overall venue numbers fell from 162 to 61 during the same period. There is a large difference in the number of cinemas between 1956 and 1966, as

indicated by Figures 3.3b and c. Catrice (2005) has reported that attendances fell by 52% in less than three years from 1956, and these findings are reflected in this study, using the CAARP data, with a large decrease in cinema venue numbers between 1956 and 1966 (figures 3.3b and 3.3c). By comparing the two figures, the closures can be seen over the entire expanse of Melbourne, especially in the east and southeast between 5 and 20 kilometres from the city centre. From 1966 onwards, the distribution of cinema venues is much more sparse, with a steady decline in the western suburbs and a thinning out of suburban venues seen in 1986 (Figure 3.3e). During the last decade span, cinema venue numbers decreased from 101 in 1976 to 61 in 1986.

In investigating the history and geographical distribution of Melbourne's cinema venues, two main factors affecting their operation became apparent: the cinema industry itself and the greater social events.

First and possibly most importantly in terms of geography, was the influence of distribution practises and the domination of the city centre. For most urbanised areas over the last century, movie distribution/exhibition was organised into a progression of runs which determined the stage of film release in sequence of first, second, third runs etc. (Verhoeven 2009a). For post-war Melbourne, the geography of film distribution has been described as:

“turning on a garden sprinkler. First turn of the tap covered the city theatres, another turn covered the inner suburbs and each subsequent turn reached further out until suburban Melbourne was saturated”
(Miller 2006, p. 26).

The city acted as the origin of a type of concentric expansion of distribution, and these runs not only influenced the spatial arrangement of markets, but also the ranking and priority of markets (Verhoeven 2009a). The suburban theatres were therefore often sacrificed in favour of the higher ranked city venues. During a time of massive cinema closure, between 1958 and the early 1962, much of the investments went into the city cinema's fight for survival at the expense of the smaller and later run suburban venues (Verhoeven 2009a).

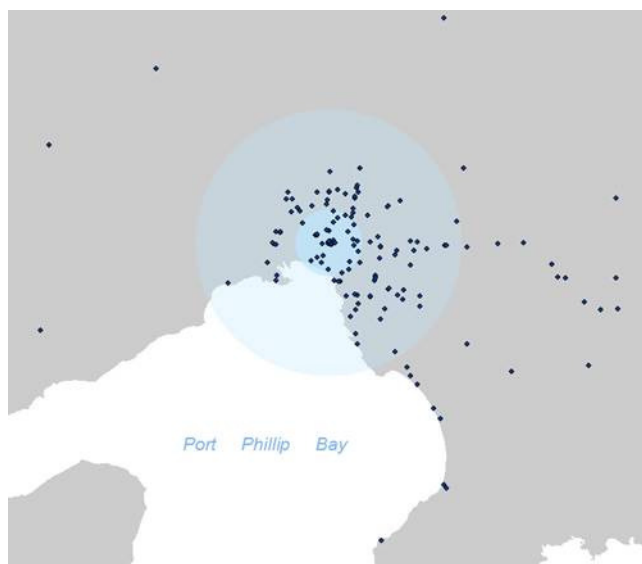


Figure 3.3a: Cinema Distribution 1946

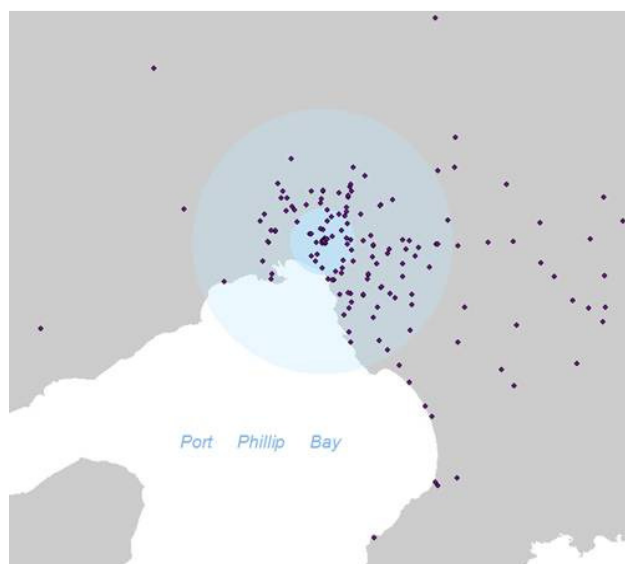


Figure 3.3b: Cinema Distribution 1956

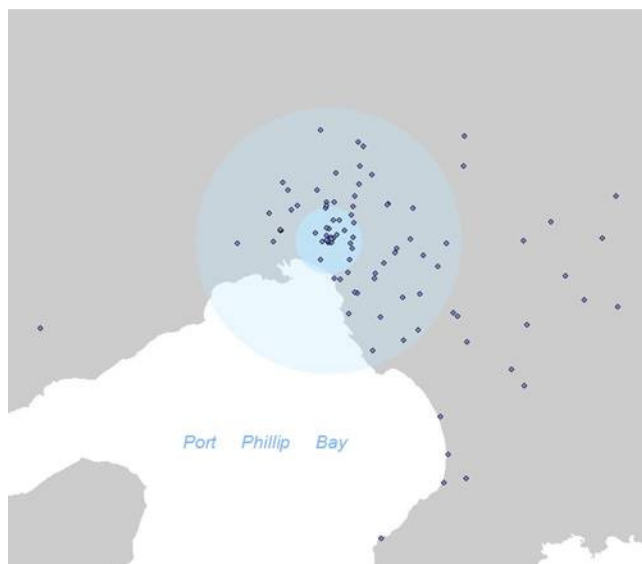


Figure 3.3c: Cinema Distribution 1966

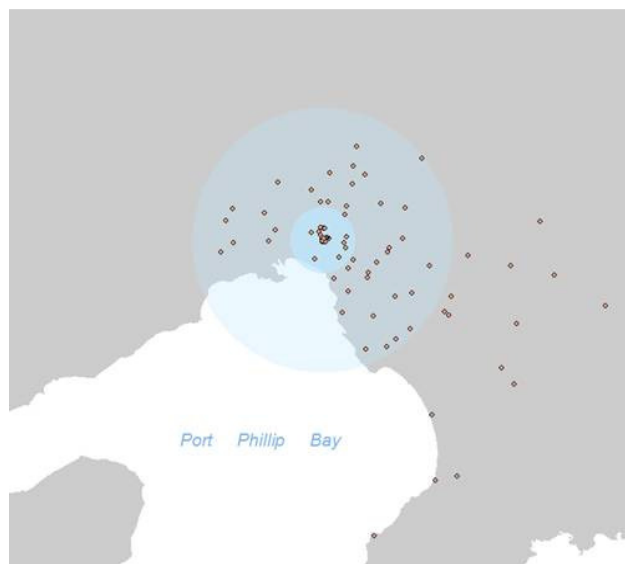


Figure 3.3d: Cinema Distribution 1976

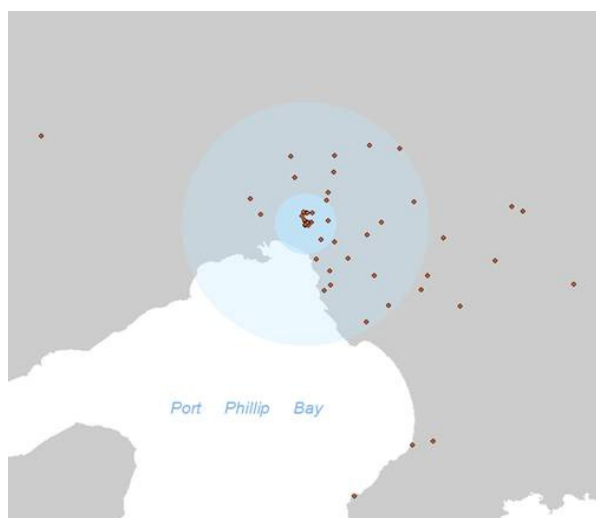


Figure 3.3e: Cinema Distribution 1986

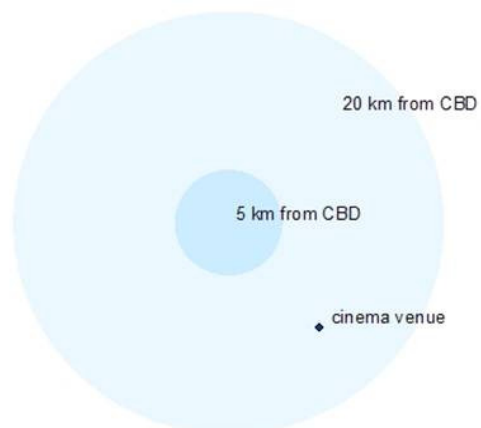


Figure 3.3f: Legend

Figure 3.3 Distribution of Melbourne's cinema venues from 1946 to 1986

Another change to the cinema industry which had an impact on venue distribution and operation was changes in technology. Wide screen formats were introduced in the 1950s. Cinemascope launched in Melbourne in December 1953, Cinerama in December 1958, and 70mm in 1959 (Verhoeven et al. 2010). These new screens and projection facilities were expensive to install and usually required venue renovations and the removal of seating (Verhoeven et al. 2010). New technologies were an integral component of a move towards cinema that emphasised the prestige event of cinema attendance in the more luxurious city venues, drawing audiences away from the local suburban theatres. Technology favoured the city venues. The decline in venue numbers seen in Figure 3.3 may be partially attributed to the competition for audiences between the suburban and city cinemas during a time of declining attendance in the late 1940s and early 1950s (Collins 1987).

The introduction of television in Melbourne, starting in November 1956, has often been held accountable for the period of mass cinema closure between 1958 and 1962. By 1960, more than 70 percent of Melbourne's population owned a television set (Collins 1987), arguing that there can be no doubt of the competition television provided to the movie theatre. This research goes a long way to demonstrate that the closures during this period cannot simply be described as "indiscriminate" as has been widely believed (see Collins 1987), but that there were a number of variables that help to explain the survival of cinemas over others in particular locations.

Distribution of cinema venues has been strongly influenced by the growth of car ownership. The increase from 15% of workers travelling to work by car in 1945 to 60% in 1974 also led to the suburban development of areas between train lines. This can help to explain the appearance of new cinema venues in these areas, especially from 1966 onwards (see Figure 3.3c, d, and e). A large portion of these new cinemas were Drive-in theatres, born from Melbourne's love affair with the car. The first drive-in theatre in Australia opened in Melbourne's eastern suburb of Burwood in 1954, and according to Catrice (2005), there were 20 drive-ins operating in Melbourne by 1970, mainly in the outer suburbs due to the large amount of land needed.

The growth in the population of Melbourne was helped largely by post-war migration which had a large impact on film distribution, the origin and the type of films exhibited, and also the

geographical distribution and survival of cinema venues. For example, between the years of 1952 and 1974, over 220 000 Greeks came to Australia, and by 1971 there were more than 98 000 Greeks in Melbourne alone (Verhoeven 2009a). With this influx in Greek demographics came a Greek cinema circuit which comprised 30 inner-city and suburban venues in Melbourne (Verhoeven 2009a), often taking over older cinemas that would have most likely been destroyed or converted. Such a large circuit made a strong contribution to the cinema industry at the time and also demonstrates the impact of migration on the social, cultural, and economic practise of cinema.

3.4 Cinema Studies and Geography

The lack of historical research into the history of Melbourne's cinema venues, especially geographically speaking, is found not only in Melbourne, but in most areas around the world. Until recently, cinema studies have focused largely on film content. Examining the geography, audiences, and operation of cinema venues is a relatively new area of research in cinema studies. Through this change in emphasis and the move towards alternative methods of communication and interpretation, the spatial significance of cinema venues is a rising influence in cinema studies. This section will include a background to these new areas of research and will include a review of the style of work currently being undertaken.

3.4.1 New Cinema History

Cinema or film studies, is a far reaching discipline that seeks to investigate the significance, history, and practice of film and cinema. However, it has not been until recently (mainly over the last decade) that the significance, history and practice of *cinema*, rather than the content of films, has been examined in detail (Maltby 2007). The dominance of the study of film content has overshadowed the significance of the cinema to the extent that the histories, cultural meanings, and socio-cultural impact can be drawn (or claim to be) only from the films themselves.

What has become known as the *New Cinema History* questions this assumption through focusing instead on, as Bowles and Maltby state, "questions of the circulation and

consumption of cinema – on the commercial activities of film distribution and exhibition, and the political and legal matrix that underpinned them – and on writing the histories of cinema’s specific local audiences” (2008, p. 7). This new history argues that it is impossible to recognise the cultural significance or impact of cinema solely through the content of the films themselves. As Richard Maltby argues:

“...cinema is not the history of its products any more than the history of railroads is the history of locomotives. The development of locomotive design forms part of the history of railroads, but so, far more substantially, do government land policies and patterns of agricultural settlement. To write a history of text and call it a history of Hollywood involves omitting the social process and cultural function of cinema, and denies the contextual significance of the material conditions under which movies were produced and consumed” (2007, p. 3).

In addition, the significance of film content has been questioned in oral histories of cinema experiences, where “who sat where each week, and with whom, and what they wore” were deemed more important and memorable to local audiences than what was on the screen (Huggett and Bowles 2004, p. 68). The change in focus from film to cinema in order to recognise such histories invites new questions to be asked, for new methods of investigation and analysis to be applied, and for new accounts and conclusions of cinema history to be sought (Bowles and Maltby 2008; Docherty et al. 1987; Jancovich et al. 2003; Maltby 2007; Verhoeven et al. 2009).

One important issue associated with conducting this new research is the spatial nature of much of its subjects. The circulation, consumption, film distribution and exhibition, and the behaviour of cinema audiences are all spatial in one way or another. As Robert Allen notes “the most notable and enduring characteristics of cinema as a cultural form have been its mobility and geographic reach”, that distribution involves “not just the physical transportation of cans of films, but a much more complex economic, cultural, technological, and social circulation and exchange – of people, technologies, ideas, stories, images, identities, places, practices, and values” (2006, pp. 24-25). To investigate the spatial significance of cinema venue operation in Melbourne, we therefore need to consider space and spatial theories to explore and understand the complex relationships between such practices. This requires a disciplinary shift from the analysis of film texts and written communication to spatial and

quantitative data sources, digital databases, geographic information systems (GIS), and spatial methods of communication (Allen 2006; Klenotic 2011; Maltby 2007; Verhoeven et al. 2009).

3.4.2 The Spatial Turn in the Humanities and Cinema Studies

As a result of the interest in this *new cinema history* and the spatial influences on cinema, there has been a spur of activity in spatial analysis, mapping, and GIS. In addition, there has been a rebirth in geography as other disciplines have increasingly become spatial in their orientation to reflect the importance of space for their own inquiry (Warf and Arias 2009). This spatial interest has been dubbed the *spatial turn* and has been reflected in many humanities areas such as literature (Moretti 2007; Piatti et al. 2008), and the social sciences (DeBats 2008; Donahue 2008; Gregory and Henneberg 2010; Knowles and Healey 2006; Skinner et al. 2000).

Why this *spatial turn*? And why is it of importance to humanities scholars? Commenting on what he considered to be of great importance to research, Harvey (1995, p. 161) remarked that “the geographical imagination is far too pervasive and important a fact of intellectual life to be left alone to geographers.” It has also been argued that the influence of geography goes beyond the fact that everything happens somewhere in space, that geography matters because “where things happen is critical to knowing *how* and *why* they happen” (Warf and Arias 2009, p. 1). Such a view of space can inspire humanities research to incorporate spatial meaning, spatial analysis, and to create visual access to geographically significant data. This in turn can often lead to greater understanding of the subject under investigation and inspire new insights and possible Research Questions.

Despite these advantages, there has been a relatively slow uptake of spatial techniques within the humanities, especially concerning the use of GIS. There are many contributing factors which can go some way to explaining the inhibition of geographical information in the humanities. Jessop (2008) suggests there are four factors that affect this inhibition: 1) the implications of using data visualisation and images within a discourse-based research methodology of the humanities; 2) the suitability of existing methods and tools for performing humanities research with spatial data; 3) the nature and collection of humanities data; and 4) the issues associated with current research practice and scholarly institutions. On top of such

issues are the differences when working at the junction of two disparate disciplines; spatial sciences and the humanities. In the context of academia, Couclelis (2004) introduces the problems associated with incorporating spatial analysis into disciplines with their own analytical tools, and believes that the inhibition of spatial technology in other disciplines is due to the techniques falling outside the “traditional explanatory frameworks” used within other disciplines. However, as more research is conducted that combines the disparate areas of geospatial sciences and the humanities, these issues are gradually being overcome.

One area of study that has embraced the idea of a spatial turn has been cinema. Interest in mapping and spatial techniques has manifested itself in a variety of ways under the umbrella of cinema studies, both metaphorically and technically speaking. The terms *mapping* and *cartography* in cinema studies do not always correspond to the geographer’s understanding of the terms. These terms are often embedded in the language metaphorically, such as referring to a “cartography of relations” to describe the linkages in the film *The 39 Steps* (Conley 2009a, p. 139), or to quote scholar Giuliana Bruno’s (2002, p. 71) reference to an *Atlas of Emotion*; “by way of filmic representation, geography itself is being transformed and (e)mobilized... A frame for cultural mappings, film is *modern cartography*.” Several authors have attempted to explain this “spatial turn” in cinema through the term *Cinematic Cartography* which is characterised loosely by the ways in which cinema and cartography have converged (Roberts 2010), creating a hybrid form of cartography (Caquard and Fraser Taylor 2009). Roberts (2010) provides a typology of the greatly varying thematic areas within cinematic cartography and has included the more metaphorical areas of which he calls *Cognitive and Emotional Mapping* which includes the work of Bruno (2002) and Conley (2007). However, it is within the more practical and technical use of geographic techniques that this research lies. Roberts typology outlines aspects of such research through the thematic areas of map use in films (Caquard 2009a; Conley 2009a, 2009b; Mills 2010), the economic impact of *film or movie-induced tourism* (Beeton 2005; Kim and Richardson 2003), and mapping film consumption and production (Allen 2006; Klenotic 2007; Verhoeven et al. 2010; Verhoeven et al. 2009).

A consequence of this *spatial turn* is the acceptance of mapping and spatial analysis in cinema studies, in particular dealing with cinema and spatial data to address geographical questions. These practical aspects of creating maps and performing spatial analysis are mainly concerned with the aspects of mapping the geographies of film production and consumption (Caquard 2009b; Naud 2010; The University Library 2008), and in the analysis of geographical patterns

of cinema operation and influence (Caquard 2009b; Hallam and Roberts 2009; Klenotic 2007; Verhoeven et al. 2010; Verhoeven et al. 2009). Studies have explored the use of cartographic representations, spatial analysis, and GIS to expand the scope of cinema studies to incorporate geographical enquiry and influence. It was through the work of Jeffrey Klenotic that geographical inquiry in cinema studies first came to light using mapping and GIS (1998, 2001). Klenotic's (1998, 2001) pioneering research into the relationships between cinemas in Springfield, Massachusetts, in 1926 and the neighbourhoods that surrounded them was performed using spatial demographic data and spatial coordinates of cinema venue locations within a GIS. Since this beginning, scholars have mapped cinema geographies using digitised versions of historical maps (Allen 2008; Klenotic 1998, 2001), census statistics and boundaries (Klenotic 1998, 2001, 2011; Verhoeven et al. 2009), cinema venue street addresses (Klenotic 1998, 2001), location and success of film screenings and festivals (Caquard 2009b), spatial revenue comparison (Caquard 2009b), cinema venue opening and closing (Klenotic 1998, 2001; Verhoeven et al. 2010; Verhoeven et al. 2009), and many more. The interest in GIS and other forms of spatial analysis and representation in current cinema research is the result of the success of such projects. As Klenotic (2011, p. 9) claims:

“The introduction of GIS into the landscape of cinema history inquiry brings questions of cinema’s spatial positioning, dispersion and historical representation to the fore; it also affords a means of interactively and iteratively exploring such questions in keen detail.”

Such positive views on the use of spatial technology to enhance cinema history inquiry will ensure that it continues to be an effective method within cinema studies.

Whilst Roberts (2010, p. 21) admits the idea of a *spatial turn* in cinema studies, has “become rather redundant in terms of ‘orientating’ oneself within the subject area (critically, theoretically, practically)”, it is the data associated with the above studies that clearly identifies a unique thematic area of research. Cinema studies therefore requires different kinds of data to be collected beyond the conventional film studies databases, such as social and physical data concerning cinema location, distribution, and audiences (Verhoeven et al. 2009); vital quantitative information that can reach beyond a “history without people” (Maltby 2007, p. 8).

3.5 *Visualising Cinema Data*

The shift from a textual based discipline to the inclusion of visual communication requires the consideration of suitable visualisation techniques that complement historical investigation. Reviewing the techniques adopted for historical spatial data, as discussed in Chapter 2, revealed the strong reliance on traditional cartographic representations, which in the most part do not emphasise temporal characteristics or change over time, and also revealed the lack of multivariate analysis capabilities. The visualisation of spatial cinema data is a result of the need to locate people and places, to combine information from many sources, to investigate historical aspects of cinema operation and influence, and to discover new insights and geographic and temporal patterns within cinema data. Spatial cinema data shares many characteristics with historical spatial data, and as a result the visualisation of such datasets shares many of the same issues. The majority of visualisation techniques used for spatial cinema data discussed in this section are the same as those outlined in Chapter 2 and therefore do not require a technical explanation. Instead, these techniques are reviewed in relation to the type of data they utilise and the complexity and temporal capabilities they deliver. The following section is organised into a literature review of two sections that discuss the visualisation of spatial cinema data and those that handle change over time respectively. Within each sub-section, multivariate studies are reviewed in contrast to those that focus on univariate or bivariate representations. The section concludes with a discussion of the key findings from the literature.

3.5.1 *Visualisation of Spatial Cinema Data*

The majority of visualisations currently used for spatial cinema data do not consider change over time. Instead, they are used to locate geographic features or provide a spatial context to cinema research. A review of visualisation techniques for univariate or bivariate data has identified the use of ordering and differentiating visual variables, choropleth mapping, and statistical graphics. These techniques are used much in the same way as other historical spatial data (as reviewed in Chapter 2). Differentiating and ordering visual variables are used primarily to differentiate between different geographic entities or to show a more gradual difference or order between entities. Snickars and Bjorkin (2002), have used ordered visual variables in a simple manner to locate shooting positions in the film *Bilder fran Hernosand* in

the city of Hernösand, Sweden. Arrows have been used and, with the addition of numbers, show the order in which these locations appear in the film. Order has also been represented as simple point locations differentiated using the names of cinema venues, and animated using both *Flash* and *GoogleEarth* to show the order of distribution of specific films from first release to final release (Verhoeven et al. 2010). Differentiating visual variables for point features have been used to represent different attributes of cinema venues (Verhoeven 2009a), and have been combined with choropleth mapping for both orienting cinema locations within administrative boundaries (Hallam and Roberts 2009), and providing local demographic statistics that underlie venue location (Klenotic 1998, 2001, 2011). Verhoeven et al. (2010) have adopted a unique technique of *Markov Chain* analysis to establish the most popular distribution practises of certain films through calculating probabilities. The resultant tree graph of venue probabilities has been used to aid in the analysis and visual presentation of results (see Figure 3.4).

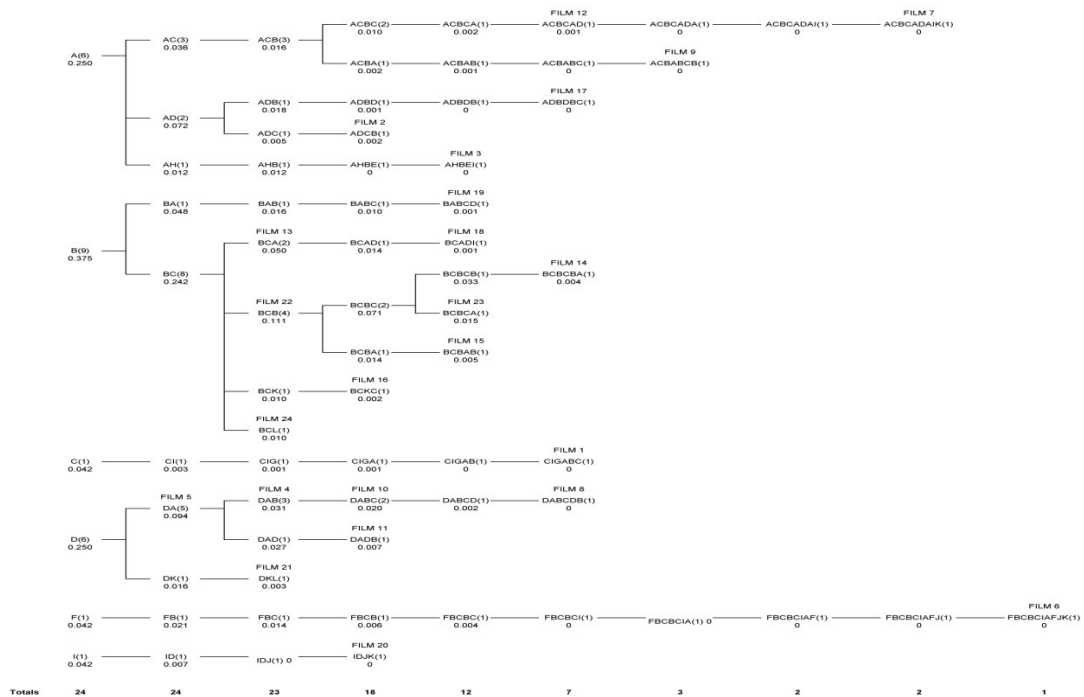


Figure 3.4: Tree graph of venue probabilities for 12 films using Markov Chain analysis (Verhoeven et al. 2010)

The dominance of ordering and differentiating visual variables is also found when representing multiple variables of cinema venue characteristics and local demographics. The ability to be able to interact with a web-based application through selection choices and highlighting features for more information, or query a GIS database to access additional data has allowed multiple variables to be utilised when investigating information. This has been

demonstrated effectively with the web-application *Going to the Show*, allowing users to click on differentiated point symbols of venue locations and access multiple variables about a venue (The University Library 2008), and through the Canadian online atlas of cinema (Naud 2010), representing ordered point variables with selected attributes such as film and cinema company. Each geographic point can also be selected to view more multivariate information about the location. Klenotic (2011) has combined point location data of cinema venues with choropleth mapping within a GIS to compare venues with local demographic data whilst still being able to query each venue for additional information.

A more graphic approach and abstract treatment of space has been used to create the *Cybercartogramme* as part of the Canadian online atlas of cinema (Naud 2010). This method uses ordered visual variables, not for a variable at a location, but through a type of relational graph. For example, Figure 3.5 shows the revenue of the film *Atanarjuat* at a number of venues throughout Canada. The size of the point symbol represents the relative amount of revenue and the symbols position on the axis radiating from the centre of the semi-circle represents the percent of the population that is French. This can then be used to compare different areas and examine the influence that location and demographics can have on film revenue. This excellent example of simple graphic design principles highlights the data rather than the geographic location of the cinemas, as often it is the dynamics associated with the cinema venues that are the most important aspect of the data.

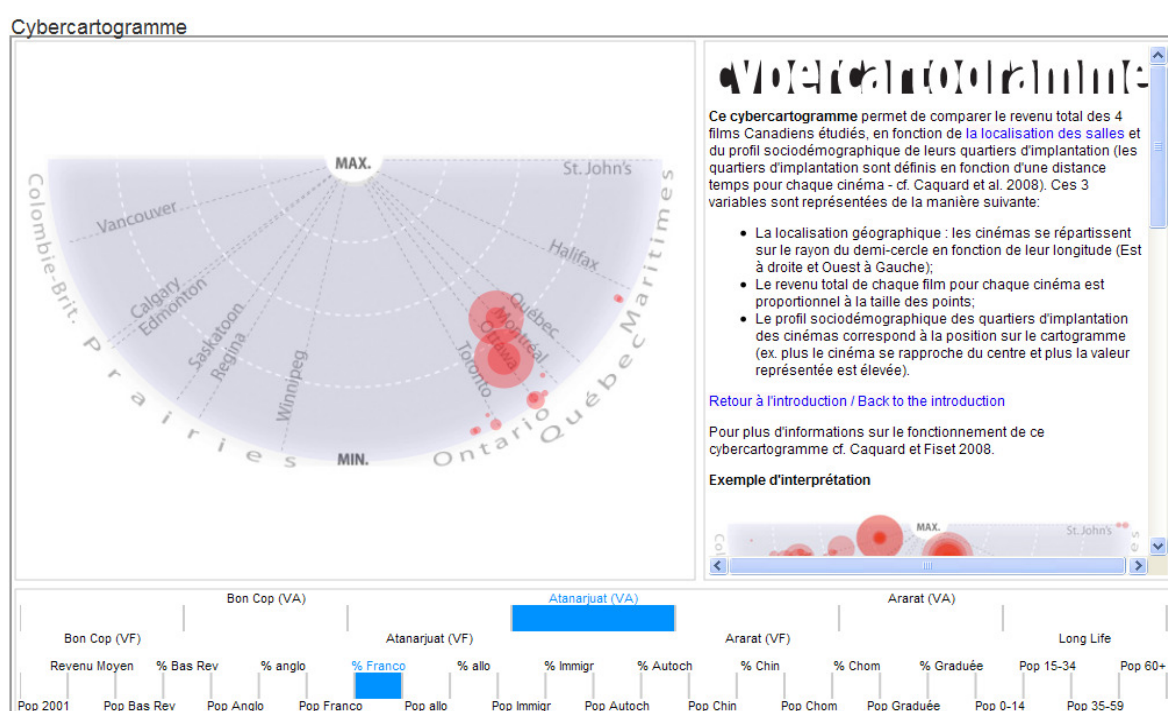


Figure 3.5: Cybercartogramme showing revenue and the French percentage of the population (Naud 2010)

Yet, it can be argued that these are not true multivariate representations. The multivariate capabilities seen here have stemmed from the technology rather than the technique itself – it is through the use of selection, pop-up windows, and queries that the visualisation can work with multiple variables. The previous example from the *Cybercartogramme* has many variables that can be utilised, however it is only the values along the axes (percent of population) and the size of the point symbol (revenue) that provide a visual representation for the values associated with an attribute. Film is shown, but only one can be chosen at any one time, and therefore cannot represent the values associated under the attribute of *film title*. For all of the multivariate approaches discussed above, it is not possible to look at multiple variables at the same time across the dataset. This can only be achieved individually, i.e. for each single venue not over the entire range, by selection, pop-up windows, or hyper-linking to additional information. As a result, comparisons are difficult and analysis is hindered.

3.5.2 Visualisation of Spatial Cinema Data that Change Over Time

A review of techniques used to show change over time of geographic entities using cinema data reveals a very limited number of approaches. Some studies discussed in the previous section 3.5.1 have a temporal aspect either through order of events, or through a temporal attribute. What they do not show however, and what is essential in examining most aspects of history, is change over time. To investigate how things changed over the historical period one is examining.

Of the few techniques used, they mirror those found in other historical studies looking at space and change as discussed in Chapter 2. Change, as represented through the change in two states, is a technique used to show cinema openings and closures between 1950 and 1970 (Verhoeven et al. 2010). This is displayed using four snapshots of change in five year intervals (see Figure 3.6). When arranged in sequence, it is possible to also show changes over time for the 20 year period. Extending the use of time to show changes of multiple variables, the Canadian online atlas of cinema (Naud 2010) has incorporated a sequential timeline broken down into temporal periods, such as weeks and months, for the user to select and therefore view change over time through sequential snapshot images. It is possible to select individual venues to view multiple variables, as discussed above in section 3.5.1, and shown in Figure 3.7. Again, ordered visual variables are used to display the range of a

variable. And as with multivariate approaches for non-temporal change data, multiple variables are only accessed individually or through selection. It is not possible to look at multiple values for multiple attributes over an entire dataset concurrently.

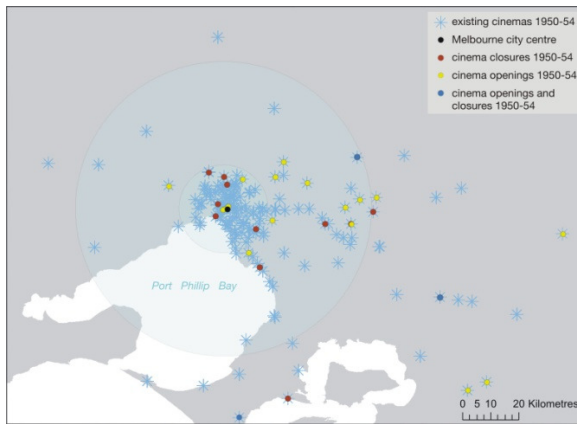


Figure 3.6a: 1950-54

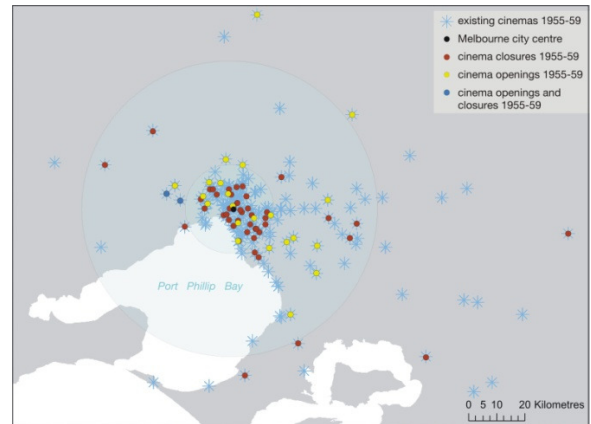


Figure 3.6b: 1955-59

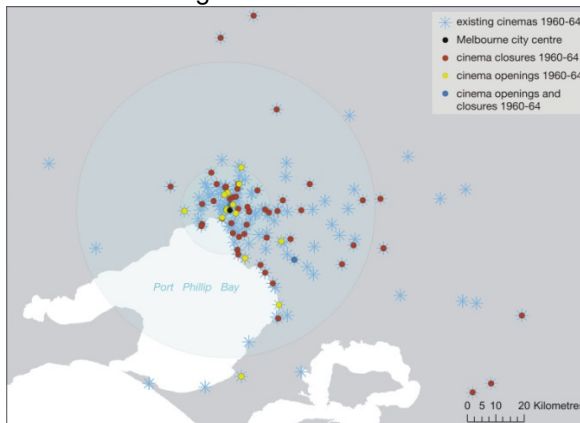


Figure 3.6c: 1960-64

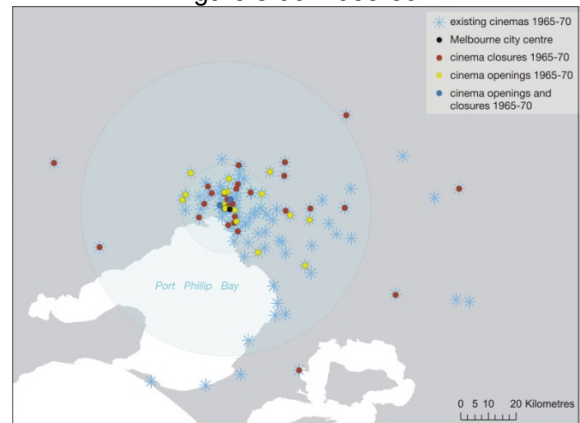


Figure 3.6d: 1965-70

Figure 3.6: Cinema Venue Openings and Closures Between 1950 and 1970 (Verhoeven et al. 2010)

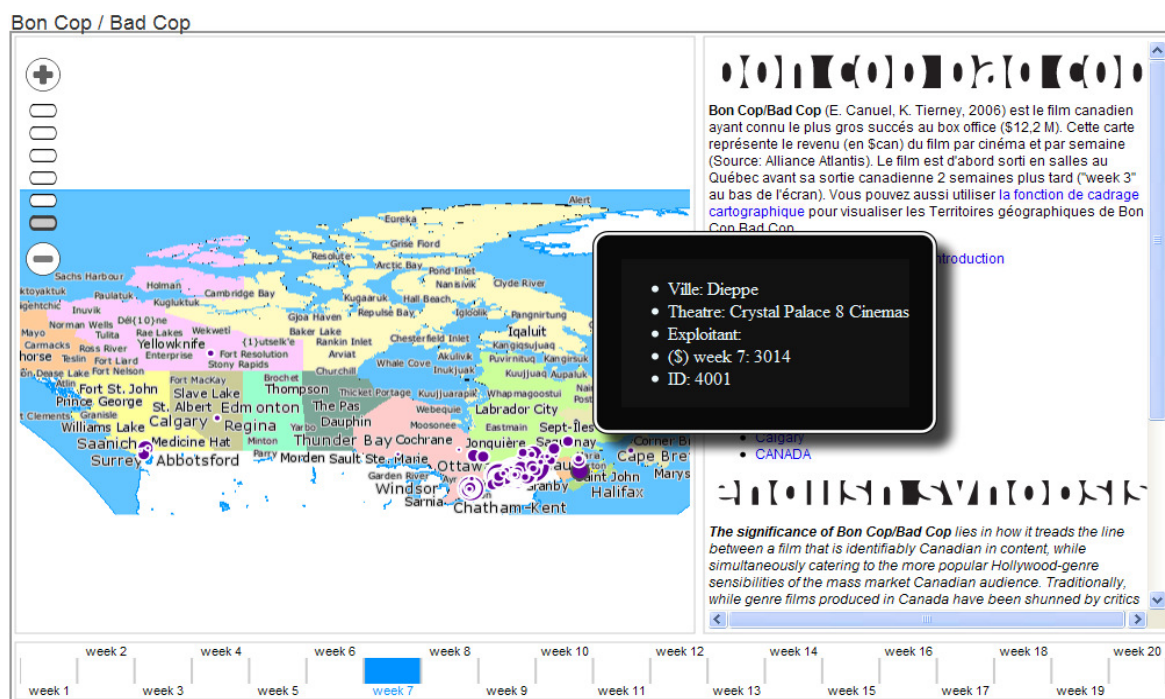


Figure 3.7: Timeline visualisation of venues exhibiting *Bon Cop* (Naud 2010)

3.6 Conclusions

In her paper titled “*Limit of Maps? Locality and Cinema-going in Australia*”, Kate Bowles (2009) discusses the limits associated with using representations of quantitative and spatial data for cinema research. It is true that maps or other forms of spatial representation cannot provide us with all the answers, it cannot always tell us why. But they can be used to examine multiple data sources at once, analyse relationships, distributions and patterns, and it can present and communicate findings in an effective visual way. The current use of visualisations of spatial cinema data all present information in a way that is different to the conventional mode of communication in cinema studies, the written word. Many use these visualisations to analyse data and present new findings, and others to simply spatialise data.

There is however, a lack of visualisations that have the capacity to deal with change over time. Of those projects that have, change over time is not something that can be analysed or tracked effectively – it is a result of sequential images viewed either side by side or one snapshot of time replaced by another. There are a number of issues with representing time in this way. The tracking of changes of a geographic entity over time is cumbersome as it relies on memory to make connections and form patterns. The temporal scale cannot be fine since there are only a certain number of snapshots that can be used to represent a period of time;

otherwise the numbers are so great that it renders interpretation impossible. Analysis of changes to distribution, geographic patterns, and patterns of associated variables are also difficult because all information is not present. It is hidden behind pop-up windows, or in the next snapshot of time. This of course does not mean that such use of time does not have its place. It can effectively show general changes over time and allow comparisons of the state of the subject at different times. What is greatly hindered is the ability to visually analyse changes over time. A visualisation that looks at the historical change of cinema data over time needs to be able to handle visual analysis if it is to be used to aid in historical investigation.

Another challenge identified in the literature is representing multiple variables of the one entity at the same time for a dataset. As shown in Figure 3.7 (Naud 2010), and the project *Going to the Show* (The University Library 2008), it is possible to access multiple variables about a venue through a pop-up window, but only one at a time. This is almost impossible to analyse. Multiple attributes of a venue can also be represented with the help of selection. For example, the *Cybercartogramme* (Naud 2010) goes a long way in terms of analysis, however for the third variable (see Figure 3.5), only one value under the heading of this variable (in this case *Film Title*) can be selected at any one time, therefore limiting analysis.

There are many reasons as to why visualisations are used in such research. Bowles (2009, p. 91) argues that “spatial data can only aspire to be a starting point for research”, yet visual access to spatial data can be more than a starting point, it may be the most important point; the one method that discovers new patterns and relationships. The question of *why* is not always the aim of research. The discovery of geographic patterns, temporal and characteristic changes, and geographic differentiations is research in itself. Not all of the visualisations used for cinema research are used for analysis of change for multiple variables. But techniques that are able to handle these characteristics have the ability to extend the use and possible outcomes of visualisations in cinema studies and the humanities. The following chapter will expand on the Case Study outlined in this chapter by addressing the data needs and specifications and the requirements of handling historically changing, spatial, multivariate information. This discussion will aid in the development of the visualisation technique through the creation of a number of questions that will assess the flexibility and suitability of the method.

4 Exploring the Relevant Geographic Questions Relating to Cinema Studies

4.1 Introduction

In review of the visualisation techniques discussed in chapters 2 and 3, it was found that there is a lack of techniques that can represent historically changing, spatial, multivariate data. Chapter 4 addresses this deficit by investigating the data associated with the Case Study of Melbourne's cinema venues. The nature of this data, the data sources, and data analysis all play a major role in the visualization concept. Chapter 4 outlines three Geographic Questions that were developed to validate the success and flexibility of the visualization technique. In support of these Geographic Questions, the data sources, specifics, compilation, and inclusion criteria of the required data is discussed. This data is handled within a GIS which has required the development of a number of customized tools to query the temporal dimension of the historical data. In conclusion, the chapter will discuss the analysis involved in determining the data specifics of the temporal, spatial, and attribute dimensions.

4.2 Formation of Cinema Geographic Questions

The history of Melbourne's cinema venues between 1946 and 1986 is extensive. Changes associated with 40 years of operation for 289 cinemas are impossible to portray in one visualisation since the attribute and temporal information associated with each venue can serve many purposes depending on what is asked of the data. For example, an investigation into the longevity of cinemas would require very different characteristics compared to an analysis of the geographic distribution of large cinema chains.

For this reason, the topic of cinema venue operation was discussed with cinema historians to gain an understanding of the important aspects concerning venue operation and those aspects which would be of interest to cinema historians. These aspects formed a number of geographical questions of the data, all of which were required to meet certain criteria in order to aid in the development of a single visualisation method that can be used for all queries. The two main criteria were: 1) to include an aspect of change over time; and 2) to have multiple variables associated with each cinema venue. The result of this discussion has produced three geographical questions which focus on exploring the varied histories of Melbourne's cinema venues. These are:

- 1) The longevity of Melbourne cinemas operating in 1946 – why did some cinemas survive the 40 year span to 1986 and others closed?
- 2) The openings and closures of cinema venues between 1950 and 1970, a particular period of cinema decline – what were the characteristic and geographical aspects of cinemas operating during this period?
- 3) The operation of large cinema companies with multiple venues (cinema chains) within Melbourne's cinema industry – how successful were large cinema companies between 1946 and 1986 and what were the characteristic, spatial and temporal differences between the different companies?

Each of these geographical questions will be discussed in detail, including the data needed to address the questions, in the sub-sections below.

4.2.1 The Longevity of Cinemas Operating in 1946

The question regarding the difference between cinemas that survived and those that failed is of particular interest to historians, not only cinema historians but others interested in the cultural, economic, and social impact of the cinema industry. By looking at the different characteristics, temporal lifespan, and geographic distribution of cinemas operating in 1946, such analysis can lead to new findings. Such new findings include detecting patterns of change, understanding the possible reasons for closures and survival in different location, and assess the different variables that have an impact on a cinemas lifetime.

As noted in Chapter 3, of the 162 cinemas that existed in 1946, only 28 survived the 40 year span to 1986. Of the few cinemas that survived, they operated through a post-war period of extensive change; changes in cinema industry practise and technology; changes in suburban expansion; the impacts of migration; the growth of car ownership; and the introduction of television. Those that did not survive did not necessarily stumble at one of these hurdles, but may have been particularly susceptible to failure because of management or business decisions, or were geographically or characteristically disadvantaged compared to other venues. Such influencing factors can be addressed through applying an appropriate visualisation method to the question.

To investigate the question of longevity there are a number of aspects that are important to consider, such as differences, similarities, spatial and temporal patterns, and relationships. As a result it is essential to look at where these cinemas are, their distribution and extent; what type of cinemas they are, whether they are theatres, halls etc.; what characteristics they have, including the differences and similarities between different venues; and the temporal, spatial, and attribute relationships between the different venues. This requires specific data. First of all, there needs to be records collected of the operation of historical venues that existed in 1946, many of which do not exist today, including venues such as halls and Mechanics Institutes. All venues need spatial information in order for geographic coordinates to be determined. Different attributes associated with the cinema venues (such as ownership and seating capacity) are needed in order to assess the different characteristics that can affect the operation of a cinema. And lastly, data is required that records changes to the cinema venues, therefore the type of change and the date of change. This data is essential in order to accurately assess the question of longevity.

4.2.2 The Openings and Closures of Cinema Venues Between 1950 and 1970

What has been viewed as a period of wholesale decline in cinema venues, the cinema industry suffered greatly between the years of 1950 and 1970, especially during the late 1950s and early 1960s. Studies have labelled cinema closures during this time as “indiscriminate” (Collins 1987) and have singled out the introduction of television as the reason for such mass closures (Catrice 2005; Collins 1987). But the question still remains as to why some cinemas failed and others survived and in contrast, what were the characteristics of cinemas that were opening during this period? In addition, what were the important factors influencing cinema venues at this time and were these geographic in nature? By analysing the geographic, temporal, and attribute information associated with each venue that opened or closed during this period, it is possible to aid in the understanding of such questions, whether these closures were in fact indiscriminate, and to reveal relationships and patterns that can be further investigated.

Between 1950 and 1970, many changes occurred. There were changes in cinema technology such as the introduction of widescreen and drive-in theatres, growth in car ownership, competition between city and suburban theatres, suburban expansion as the population relied less on the train and tram networks, and the large cultural and social change associated with the uptake of television in homes. From the 162 venues that existed in 1946, this figure rose to 181 by 1950. However, these numbers dropped dramatically to 117 by 1970, a decrease of approximately 35 percent. A simple explanation of the catastrophic impact of television does not explain the reasons why these particular cinemas failed, for there are other factors and influences that need to be taken into account. It is hoped that by putting together venue specific information in both a temporal and geographic context, and visualising the data effectively, can help to reveal and understand these factors.

An appropriate visualisation method needs to be able to take those aspects that are important to the study of cinema decline, and communicate them in a way that encourages patterns, differences, similarities, and relationships to be established. Important aspects include: looking at where these cinemas are located, their proximity to neighbouring cinemas and distribution; when these cinemas closed and what was the rate of closure at different periods; what were some of the characteristics of these venues; and what kind of cinemas opened

during this period, when and where? Just as the longevity question requires specific data, so does this particular Geographic Question. The data specifically covers temporal, spatial, and attribute information. Records are required of all openings and closures during the period between 1946 and 1986, including their address to ascertain geographic coordinates, and the date of closure or opening. In addition, associated variables for all venues are needed to investigate the characteristics of the cinemas that closed and those that opened. And lastly, data concerning the type of change and the date of change of cinema attributes, such as the date of change from a single screen to multiple screen venue, are required to accurately assess and understand this period of cinema decline.

4.2.3 The Operation of Large Cinema Chains

There were a number of large cinema chains operating in Melbourne between 1946 and 1986 that had a dictating role when it came to venue ownership, distribution practises and cinema growth. Cinema chains are therefore of great interest to cinema historians as their operation and history is of great significance to the industry and the economic state of Melbourne. This question will address the success of large cinema chains, their geographic dispersal, temporal peaks and troughs of operation, and the competition between one another.

There were established cinema chains in Melbourne before 1946. The two major players in the industry in the 1950s were *Hoyts Theatres* and *Greater Union Theatres*, originally starting in 1908 and 1911 respectively. During this time there was also a strong presence of *Cosmopolitan Theatres*, *Kirby's Theatres*, and a number owned by *Robert McLeish Theatres*. The majority of cinema venues, especially in the suburbs, were under independent control; however these large cinema chains still dominated the industry and owned or built the majority of prominent cinema venues in Melbourne. In 1954, *Village Cinemas* was founded and would go on to become a dominant chain in the cinema industry of Melbourne. Since records of larger companies are easier to come by, examining their operation may help to explain changes in the cinema industry in addition to the behaviour and success of the individual companies.

In order to successfully communicate the history of Melbourne's cinema chains, a number of important aspects should be considered, including: the location, distribution, and concentration of the cinema venues; the venue characteristics; changes within the lifetime of

the cinemas; and the differences between the cinema chains in terms of venue operation characteristics, geography, and longevity. The data needed to investigate these points include: information on the large cinema companies operating during the period, including names, ownership and management, and spatial location of venues occupied; a number of venue variables to assess the operational differences between companies and within each company; and a measure of change, an accurate temporal record of the type of change and the date at which it occurred. This will, for the first time, look not at the revenues and marketing of cinema chains in order to understand their success, but study the geography and attributes of the venues to help understand the differences, similarities and patterns of their success and geographical distribution.

4.3 Data

From the formation of the Case Study questions until they are addressed, the data influences the scope, accuracy, analysis, and final conclusions made. In order to meet the requirements of the research and address the geographical questions, the data needed to be temporal, geographic, and exhibit change of multiple variables. This section will address the process of data sourcing through to the final inclusion criteria in a number of sub-sections. The first two sub-sections will discuss the main database used for the Case Study and the large number of sources that were used in its creation. It will also outline the spatial, attribute, and temporal specifics of the acquired data. The final two sub-sections will outline the process of extracting the data, compiling the information into what was needed for the Case Study, the inclusion criteria for the data, and the minimum criteria the venues needed to make in order to create a geo-historical record of a venue.

4.3.1 Data Sources

For any historical study, the analysis, findings and conclusions must rely on historical sources of information. As mentioned previously in Chapter 2, this inherently comes with a number of issues concerning accuracy and completeness, which are also present in other non-historical sources, but particularly amplified in historical studies. This Case Study requires data that can address the three geographical questions outlined in the previous subsection, namely: the

longevity of Melbourne cinemas operating in 1946; the openings and closures of cinema venues between 1950 and 1970; and the operation of cinema chains within Melbourne's cinema industry. With these questions in mind, the data required to construct these individual histories of cinema venue operation can be summarised from the previous subsection and must include the following:

- 1) *Spatial Data*: in the form of geographic coordinates of cinema venues in order to examine the location, distribution and extent of the venues.
- 2) *Attribute Data*: including venue characteristics for each individual cinema such as number of screens and name.
- 3) *Temporal Data*: in the form of dates of change. This will recognise the time of change between one value of an attribute to another, and therefore will need to be associated with each attribute entry.

To meet these criteria, data was taken from the Cinema and Audiences Research Projects (CAARP) database (*CAARP Database* 2010) developed through an Australian Research Council funded project on which a number of academics worked. The lead developer was Deb Verhoeven and it was built by an IT consultancy, *Strategic Data* (*Strategic Data: the Intelligent Application of Information Technology* 2011). The CAARP database includes information on film screenings, companies, and venues within Australia. Information can be added and queried via a wiki-style interface that is specific to a venue, company, or film. In the context of cinema venues, the CAARP database stores information about every venue where films were exhibited in the greater Melbourne area. It includes data collected for dates of operation, name, address, geographic coordinates, seating capacity, number of screens, ownership, management, and primary purpose for each of the venues recorded. Each of these entries is given a time stamp, and the change of an entry is called an event. An example of this is shown in Figure 4.1. This figure shows the resultant search for the *Adelphi Theatre* in Melbourne, and shows a number of changes to name, capacity, operation dates, and different roles each with their own event date up until its closure in 1967. As a result, it is possible to see all events that took place over a lifetime for a cinema venue, track when these changes occurred, and therefore see the change over time of each venue.

home	film	company	venue	login				
Venue Name : Jubilee Palace / Adelphi, Carlton								
Event Date	Name	Address	Suburb	State	Postcode	Latitude	Longitude	Capacity
1913-01-01	Jubilee Palace	367 Nicholson Street	Carlton	Victoria	3054	-37.786677	144.972497	
1925-01-01	Adelphi Theatre	365 Nicholson Street	Carlton North			-37.791419	144.97574	1850
1951-01-01								1890
1954-01-01								1600
1963-01-01								1800
Summary	Adelphi Theatre	365 Nicholson Street	Carlton North	Victoria	3054	-37.791419	144.97574	1800

Suburban	Purpose	Screens	Operation Dates	Roles
Suburb	Cinema	1	1913-01-01 - 1923-01-01	1925-01-01 - 1958-01-01 : Exhibitor : Adelphi Theatres Pty Ltd
				1959-01-01 - 1961-01-01 : Exhibitor : Johnson, W. & Sluce, L.
			1925-01-01 - 1967-01-01	1963-01-01 - 1965-01-01 : Exhibitor : Johnson, W. A.
				1964-04-01 - 1967-04-24 : Exhibitor : Vitali, C.
Suburb	Cinema	1		

Figure 4.1: CAARP database showing the *Adelphi Theatre* (CAARP Database 2010)

The CAARP database includes data from many historical sources to ensure the data is cross-referenced and therefore deemed to be correct or as accurate as possible. This data came from a variety of sources: from newspapers and journals, directories, books, unpublished theses/papers, websites, the Australian Bureau of Statistics (ABS), local historical societies, and public libraries. The full list of sources is shown below in Table 4.1.

Source Type	Source
<i>Newspapers and Journals</i>	Age Argus Australasian Exhibitor Bulletin Building Cinema Record Everyones Film Reporter and Show World Film Weekly Herald Kino Lone Hand Picture Show Sun Table Talk Truth Victorian Theatre Trust
<i>Directories</i>	Australian Motion Picture Yearbook Film Weekly Motion Picture Directories Melbourne Telephone Directories Sands & McDougall Directory of Victoria Broadcasting and Television Year Book 1958-1974, Greater Union Group of Companies, Annual Reports. Greater Union Group of Companies, Sydney. -1962 Hoyts Theatres. Directors' report and accounts, Hoyts Theatres, Melbourne.
<i>Books</i>	Building a City: 100 Years of Melbourne Architecture Frame by Frame: a History of Brunswick's Picture Theatres Cinemas of Australia Via USA Picture Palaces and Flea Pits Hollywood Downunder. Australia at the movies 1896 to the present day.
<i>Unpublished Theses/Papers</i>	"The Social Impact of Television in Melbourne: 1956-1960" BA Thesis, Dept of History. Monash 1984. Catrice, D. "Cinemas in Melbourne 1896-1942" MA Thesis, Dept of History, Monash 1991.
	Smyth, M 1976, Economic Aspects of Film Distribution and Exhibition in Australia, Unpublished thesis for Master of Commerce (hons) at University of NSW, Sydney.
<i>Websites</i>	Kilderry, D 1999, Drive-ins downunder: http://www.drive-insdownunder.com.au/

	Screen Australia 'Research and Statistics: Australian film industry statistics'. http://www.screenaustralia.gov.au/research_and_statistics/GW_Research-And-Statistics.asp
<i>ABS</i>	Australian Bureau of Statistics. Census of the Commonwealth of Australia, 1947-1986 Australian Bureau of Statistics. Victorian Yearbooks. 1946-1981
<i>Local Historical Societies and Public Libraries</i>	In order to capture a more complete dataset I also referred to some local suburb newspapers and publications, public record files as well as resources and files located at CATHS and PROV.

Table 4.1: Data sources of the CAARP database

It is not always possible to find every piece of information required to put together a full history of a cinema venue. Sometimes, records simply do not exist to outline specific facts and changes. Despite these challenges, the CAARP database is the most comprehensive collection of venue specific details for cinemas in Melbourne.

All of the data sources listed above were used to create the records for each of the cinema venues. The three main aspects of the data needed to address the geographical questions (temporal, spatial, and attribute) are used below in Table 4.2 to show how the CAARP data can be utilised in the context of this Case Study.

Case Study Category	Venue Data taken from CAARP	Example
<i>Spatial</i>	Suburb Address Postcode Geographic Coordinates	Collingwood 20 Albion St 3183 -37.830573, 145.055837
<i>Attribute</i>	Name Seating Capacity Number of Screens Primary Purpose Role (management, ownership, lease) Operation	Astor Theatre 1200 1 Cinema Village Theatres 01/01/1946 – 24/06/1960
<i>Temporal</i>	Operation Period (between two dates) Role Period (between two dates) Change of Event (date of change)	01/01/1946 – 24/06/1960 01/01/1946 – 24/06/1960 01/01/1946

Table 4.2: CAARP data example

Additional information was also sourced for historical events that were influential to Melbourne's society and the cinema industry within Melbourne. Whilst approximately 99%

of the data used in this research is venue specific, this additional information was collected to provide context to the operation of cinema venues and to aid in the analysis of the venue data. The information was sourced from a timeline of historical events in Australia depicted in the book detailing the life of contemporary film maker Jane Campion (Verhoeven 2009b). Information that was found to be relevant was transferred to an Excel spreadsheet with the date of each event. Such events included: the introduction of television in 1956; and the opening of the first drive-in theatre in 1954. With the addition of these events, the history of cinema venues in Melbourne can be viewed through three different contexts: Melbourne's social events, events that directly effect Melbourne's cinema industry, and the operation of cinema venues. These three levels will be discussed in relation to the development of the visualisation in Chapter 5. However, the remainder of this chapter will be concerned only with the cinema venue data, as this is the focus of the analysis and visualisation conducted as part of the research.

4.3.2 Data Specifics: Spatial, Temporal, and Attribute

In order for the extracted data to suit the needs of the Case Study, it was essential to maintain the links between the three data requirements (spatial, temporal and attribute) because each component is integral to the history of a venue. Each venue exists in space and the relationships between other spatial features and the venues geographic location is important to the operation of a cinema. Each venue also has a number of associated characteristics or attributes that can change over time, along with a temporal lifespan. In addition, venues are affected by events in society and the cinema industry. It is not possible to understand the history of a cinema venue by disregarding any of these components, and therefore the links between these components must be maintained to properly address the Case Study geographical questions.

The data extracted from the CAARP database is venue specific and therefore all attribute, temporal, and spatial records relate specifically to each venue. However, the data used is described below in terms of the three components, not each venue.

Spatial information is attributed to a venue's location, and therefore a single venue is one geographic coordinate pair. If a venue changes location, this is recorded as a new venue. As outlined in Table 4.2, the spatial data extracted from CAARP included: Suburb, Address,

Postcode, and Geographic Coordinates. This was enough information to satisfy the requirements for the spatial component. The data specifics of each spatial component are:

- 1) *Geographic Coordinates:* This is the most essential attribute for location. It provides a consistent base for the geographic analysis of venues and is based on the supporting spatial attribute information. Each coordinate pair is stored in decimal degrees in an international coordinate system WGS84 (for example [-37.830573, 145.055837]), and can therefore be used in association with any other spatial data of the same system, such as train line data or postcode boundaries.
- 2) *Suburb:* This attribute contains information of the suburb in which the geographic coordinates of each venue lies. It is based on current suburb names and can be used to aggregate results. An example would be Frankston or Camberwell.
- 3) *Address:* This attribute refers to the street address of the cinema venue and can be used to identify streets of high cinema density. This attribute was used as the main source to create the geographic coordinates. An example would be 131 Sydney Rd.
- 4) *Postcode:* Similar to suburb, this attribute contains information of the administrative boundary in which the geographic coordinates of each venue lie and can also be used to aid in aggregation. Each is stored as a four digit number (for example 3183).

All attribute data was extracted from the CAARP database and all original values were maintained. Some attribute entries were recorded at a very fine scale and therefore it was important to be able to keep this level of detail. Table 4.2 outlined all the attribute data components extracted for the Case Study and the specifics for each are:

- 1) *Name:* This contains the name of the venue and the changes to name at specific dates, such as *Rivoli Cinemas*.
- 2) *Seating Capacity:* This refers to the number of seats available at a venue. This value often changes due to renovations and new technology and is therefore recorded at specific dates of change.

- 3) *Screens*: The attribute of screens contains the number of screens present at a venue. As some cinemas changed from single to multiple screens, the changes are recorded along with a date.
- 4) *Primary Purpose*: Each cinema venue is not necessarily a theatre designed specifically for screening movies. As stated in Chapter 3, this Case Study includes all venues that screened a movie, including less conventional venues such as Town halls and Mechanics Institutes. The data from CAARP uses the term *venue* in the same way and therefore records the type of venue and the change in venue for each cinema. This attribute contains a number of pre-determined types. These are: cinema, live theatre, hall, Mechanics Institute, and art gallery.
- 5) *Role*: This attribute refers to three sub-attributes of management, ownership, and lease. A venue may only have one or many values for role. Each value for management, ownership, and lease has a corresponding name, such as Hoyts Theatres, or L. Brown. These can change many times, but instead of being time-stamped, each record is given a time period between two dates, as often this type of information is not known and therefore cannot be replaced by another value. As a result, there are periods where this attribute is not filled.
- 6) *Operation*: This refers to simply the dates of operation of a cinema venue, and therefore is shown as a group of two dates that define a period. Sometimes this can be just two dates, the opening and closing. But it can often be a set of periods as in many cases venues will close for periods of time for renovation or changing hands etc.

Temporal data consists of time stamped dates of change, the initial dates of existence for each attribute, and the concluding dates of operation. For every attribute record there is an associated temporal record of a date, and has been described in Table 4.2 (page 107) as a *Change of Event*. Each attribute came into existence, in most cases, when the cinema opened, as there cannot be a cinema without seating or a screen, but in some cases this may not be the case due to missing data. Each subsequent change to an attribute is given a new date of change. These dates are depicted in the format of *day/month/year*, for example 01/01/1976 refers to the 1st of January 1976. An example of the temporal record for changes in seating capacity is shown in Table 4.3.

Date of Change	Seating Capacity
01/01/1976	1200
15/07/1980	500
24/07/1981	467

Table 4.3: Seating capacity change example

Operation Dates
12/12/1946 - 12/04/1954
14/07/1954 - 01/01/1964
01/01/1968 - 14/08/1968

Table 4.4: Operation dates example

Operation and Role periods are defined temporally by two dates, depicting a period of operation or a period under a certain role of a particular company/individual. As a result, the dates are shown as pairs in the format *day/month/year - day/month/year*. For example, Table 4.4 outlines the operation of a cinema venue, showing three periods of operation over its lifetime. Opening in 1946 it closed briefly in 1954 for three months and then operated for approximately ten years. There was a long period of closure between 1964 and 1968, and a final closure shortly afterwards on 14/08/1968.

4.3.3 Acquisition and Compilation

The acquisition and compilation of the data from the CAARP database was a straightforward process once the needs were specified for each geographical question. The CAARP database now has the functionality of being able to download tables of queries directly from the website. However, this was not the case at the time the data was extracted for this research. The extraction was performed in a more manual sense. Each venue table for every cinema venue in Melbourne was searched individually and all event data was simply copied from the table into an Excel spreadsheet, of which a sample is shown below in Table 4.5.

Event Date	Name	Address	Suburb	Postcode	Latitude	Longitude
01/01/1913	Elster	9 Gordon Street	Elsternwick	3185	-37.884055	145.000824
01/01/1946	Esquire, Elsternwick					
01/01/1969	Sharon Theatre, Elsternwick					
01/01/1971	Classic, Elsternwick					
Event Date	Capacity	Purpose	Screens	Operation Dates	Roles	
01/01/1913	800	Unknown		1913-01-01 - 1946-01-01	1946-01-01 - 1967-01-01 : Management :	
01/01/1946		Cinema	1	1946-01-01 - 1967-01-01	Howard, W. J., Investments Pty Ltd	
01/01/1969	559			1969-01-01 - 1971-01-01	1969-01-01 - 1971-01-01 : Management :	
01/01/1971			5	1971-01-01 - 9999-12-31	Sharon Theatres Pty Ltd	

Table 4.5: An example of an Excel spreadsheet of a single cinema venue

Once all venues in Melbourne were collected, each venue was given a unique ID, since the name (or any other attribute) could not be used to identify the venue as this sometimes changed. Using the venue ID, the data was arranged in separate tables according to the headings outlined in Table 4.2 to help simplify the format and investigate the nature of the data. All spatial data (address, suburb, postcode, latitude, and longitude) were included in the one table as shown in Table 4.6, with the venue ID used to differentiate each location. Attribute data were divided up into each of the headings identified in Table 4.2 and included both the date of the event and the venue ID which was used to associate the records with the specific venue. Table 4.7 is an example of the Name attribute, showing venue ID, event date, and the name of a number of venues. The temporal data was incorporated into each of the records giving each one a time stamp.

Venue ID	Address	Suburb	Postcode	Latitude	Longitude
1	200 Camberwell Rd	Camberwell	3124	-37.8305733	145.0558374
135	156 Collins Street	Melbourne	3000	-37.8147810	144.9682070
136	1 Chapel Street	St Kilda	3182	-37.8579060	144.9919940
137	235 Faraday Street	Carlton	3053	-37.7987760	144.9662970

Table 4.6: The venue table

Venue ID	Event Date	Name
162	14/10/1978	Universal Theatre
163	01/01/1946	Newmarket
163	01/05/1959	Vesuvio
164	01/01/1946	Victoria, Richmond
164	16/06/1976	Valhalla
165	01/01/1946	Westgarth Pictures
165	01/01/1987	Valhalla, Westgarth

Table 4.7: The name table

The following section will outline the inclusion criteria used to review each record for inclusion in the database, and the formatting of each table is then discussed in section 4.4.

4.3.4 Inclusion Criteria

As it is the case with all historical data, the data is incomplete. As more research is performed and more historical documents are scrutinised, historical information can develop; it changes and evolves. Being able to deal with incomplete, inconsistent, and inaccurate data is a consequence of this research. Many pieces of information are missing from the CAARP database; however these are constantly being updated. Such issues involving the accuracy and completeness of the data have led to the development of a number of inclusion criteria to ensure each venue meets a minimum criterion in order to be included in the database. This criterion was based on being able to locate the cinema venue in space and time. Without such basic requirements, it would be impossible to create a geo-historical record of a venue.

However, before this could be addressed, it was required that the venues were within the scope of the Case Study in both geographic extent and temporal period. This research, as stated in Chapter 1, has a specified geographical and temporal extent. To recap on the scope outlined in Chapter 1, the geographical extent refers to those venues that are classified as either *city* or *suburban* theatres in the CAARP database within the entire extent of greater Melbourne. This has created a geographical extent that is largely within 50km of the CBD; however, there are also a number of venues that lie outside this distance. These are also included. The temporal extent refers to the period between 1946 and 1986. The resultant geographical and temporal criteria for inclusion are:

Geographical Extent

- 1) Only those venues that are classed as either *city* or *suburban* in the CAARP database within Melbourne can be included in the database.

Temporal Extent

- 1) Venues must have existed at some point in the period between 1946 and 1986.
- 2) Records of change for a venue are only included if they lie within the period between 1946 and 1986.

- 3) Venues that existed before 1946 but operated during the Case Study period were given an operation date starting on 01/01/1946.
- 4) Records prior to 1946 that showed the state of an attribute in that year were maintained but given a date of 01/01/1946. For example, if a venue had a recorded seating capacity of 120 in 1934, and then changed to 300 in 1950, the first record will be 120 in 1946 as this was the status at the beginning of the Case Study period.

All venues and venue records that did not meet this initial criterion were disregarded.

The inclusion criteria based on accuracy and completeness of data is structured around a minimum requirement of spatial information and operation dates. For a venue to be included in the database after meeting the initial Case Study extent, it must have the following:

Spatial Criteria:

- 1) All venues must have a geographic coordinate.
- 2) If coordinates are not given, coordinates must be able to be determined by other spatial data such as address, or suburb. This varies on the type of information available and the proximity to the city centre.
 - a. Where an approximate address was given such as a street name or the intersection of two roads, coordinates were assigned as an approximate if the street was small and an intersection of the two roads could be established.
 - b. For more rural locations, often only the town name was listed in the spatial information, therefore the coordinates of the centre of the town (based on the main street) was used.
 - c. If old addresses that have since changed names are used for spatial information (such as old roads or suburbs), old directories of the city were used to approximate the location. Coordinates were then determined using the new address or suburb.

Operation Date Criteria:

- 1) Each venue must have at least one set of operation dates to determine a temporal lifespan.

Of those venues where geographic coordinates were determined by address, the coordinates were taken from Google Earth (*Google Earth* 2009). This allowed addresses to be searched and the location of town centres to be determined visually. All venues that did not meet the inclusion criteria were disregarded.

4.4 Data Handling

This section discusses the process of data handling including; data management design, integrating the data into the GIS program used, and the design of new tools for investigating all dimensions of the cinema information. Each of the tables are linked in a simple manner to the venue table and are used within the GIS program *ArcGIS 9* (Esri 2010) to display and analyse the data. Because GIS is largely a static technology, two custom tools were designed to incorporate the important temporal dimension within *ArcGIS*, enabling querying and analysis of change over time.

4.4.1 Data Management Design

Each of the tables are arranged so each variable is kept separate which has the advantage of investigating variables individually, but also being able to link tables to combine details for further analysis. Figure 4.2 graphically depicts the arrangement of each of the tables and their relationships to one another in an entity relationship (ER) diagram.

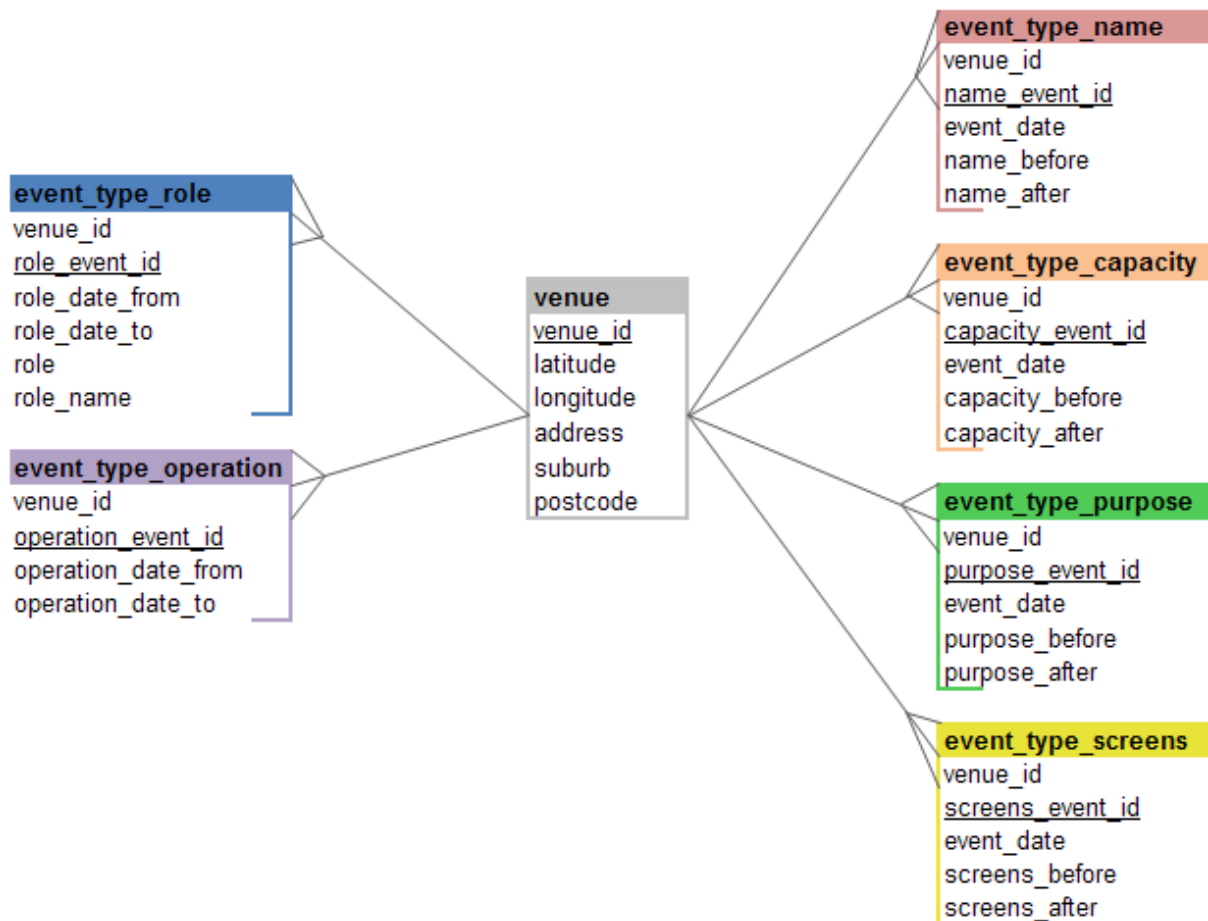


Figure 4.2: Database entity-relationship diagram

The central location of the venue table (or entity) reflects its importance to each of the attribute tables, as each record includes the venue ID from the venue table. To distinguish each of the attribute records a unique identifier in the form of an event ID is included. For those tables on the right of the image (name, capacity, purpose, and screens), each record also includes an attribute which lists the event prior to the current record, allowing greater ease in distinguishing change and tracing previous record events. The two remaining tables, operation and role, do not have this attribute, for one event does not necessarily replace the other. Instead of an event date, they have a *from* and *to* date to show periods of operation or roles. There are times when the cinema is not in operation, or when there are no details about management or ownership and therefore no records exist at this time in either of the tables.

4.4.2 *ArcGIS Data Integration*

The software program used for data integration and analysis of the historical cinema data was *ArcGIS 9*, a suite of geographic information system (GIS) software products which is produced by *Esri* (Esri 2011). *ArcGIS* is capable of performing a number of tasks, such as mapping, geographic analysis, data editing and compilation, data management, visualisation, and geoprocessing (Chang 2004). One of the main reasons why *ArcGIS* was used is due to its wide application in academia and industry, and its ability to store, manipulate, and analyse spatial information. It can easily and effectively perform all the data handling, analysis, and display operations required for this project. Other GIS packages were considered, including open-source software, however *ArcGIS* was chosen over these because of its ease in customising tools and manipulating the data.

Within the GIS environment, the two most common forms of spatial data types are vector and raster. Vector data works with what are known as the *graphic primitives* of point, line, and polygon (or area) features (see Figure 4.3).

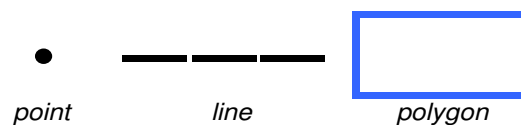


Figure 4.3: Vector data graphic primitives

The graphic primitives are used to represent all geographic features within the GIS. For example, a point feature may be used to represent the location of a city, a line to represent a river, and a polygon an administrative area. Raster data is used primarily with satellite imagery such as infrared images of landscapes.

In this case, the entire geographical extent is made up of a matrix of pixels or cells that contain a quantitative value which represent the continual geographic surface (Chang 2004). The Case Study cinema venue data was recorded as a set of coordinate pairs (latitude and longitude). To represent this type of information in a raster format, it would be necessary to have a value for every pixel for the entire geographical extent of Melbourne. This is not possible because cinema venues are not everywhere, the data is not continuous. Instead, the

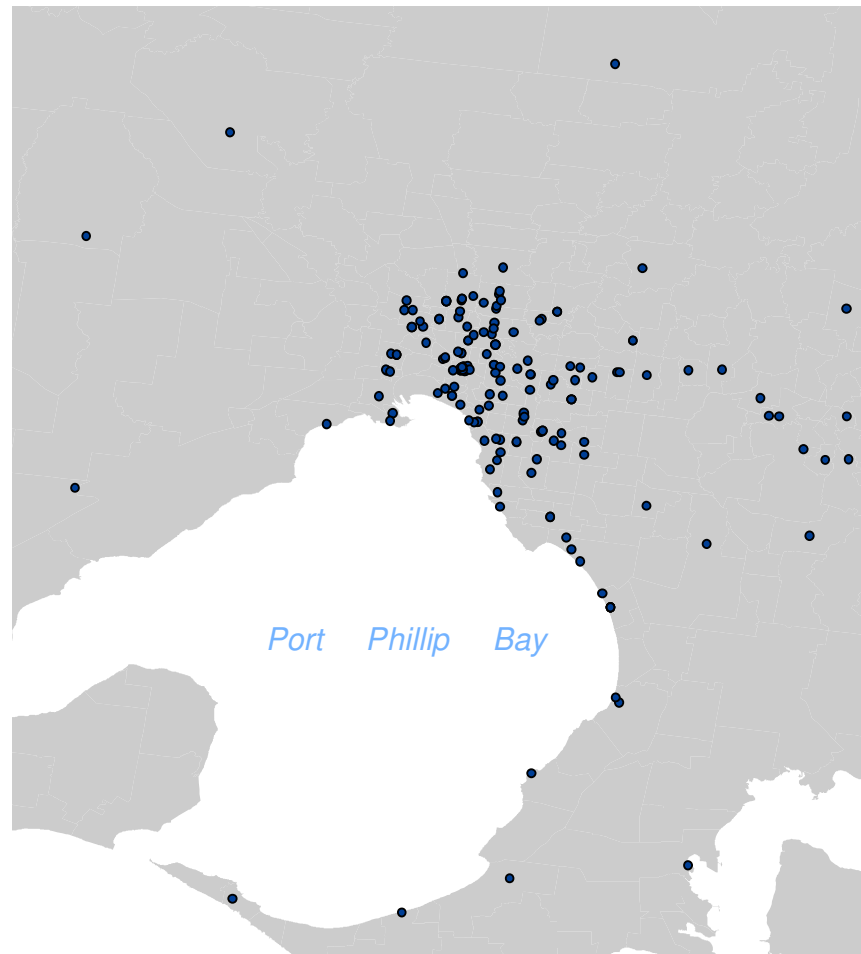
vector data format was used because venue locations can be best represented as point features.

The tables were incorporated into the *ArcGIS* program by importing them directly as tables. A Microsoft Access database file (.mdb file) was created to store the tables, which includes the database structure, which can be accessed within the *ArcMap* application of *ArcGIS*, the main application for display, querying, and data output (Chang 2004). Each of the attribute tables were linked to the venue table containing the spatial data using the simple *Relate* function which connects tables via the Venue ID whilst keeping them separate (Chang 2004). This enabled each table to be queried based on attribute values as well as spatial location. An example of an attribute table is shown below in Figure 4.4.

OID	name_event	name_eve_1	name_befor	name_after	venue_id
30	32	1946.004107		Newmarket	163
31	33	1959.331964	Newmarket	Vesuvio	163
32	35	1946.004107		Victoria, Richmond	164
33	36	1976.459959	Victoria, Richmond	Valhalla	164
34	37	1946.004107		Westgarth Pictures	165
35	41	1946.004107		Ascot Vale	191
36	42	1969.007529	Ascot Vale	Cinema Colosesso	191
37	43	1946.004107		Century Theatre, Melbourne	192
38	44	1965.998631	Century Theatre, Melbourne	New Century	192
39	45	1971.003422	New Century	Swanston	192
40	46	1979.282683	Swanston	Capitol Two	192
41	47	1946.004107		Clifton Theatre	193
42	48	1959.003422	Clifton Theatre	Cinema Italia	193
43	49	1965.883641		Liberty Theatre, Brunswick	194
44	50	1966.595483		Orient	195
45	51	1946.004107		Tatler Theatrette	196
46	52	1961.242984	Tatler Theatrette	Curzon, Melbourne	196
47	53	1968.643395	Curzon, Melbourne	Australia Twin Two, Melbourne	196
48	55	1946.004107		Windsor	199

Figure 4.4: Example of an attribute table in ArcMap

To visualise the venue locations, the venue table was spatialised to display the recorded latitude and longitude columns as spatial coordinates. This was achieved through the creation of a *shapefile*, an *Esri* data format especially useful for individual non-related geographic features (Chang 2004). This created our point based data of all cinema venues operating between 1946 and 1986 in Melbourne for which all spatial analysis and querying was directed (see Figure 4.5).



Legend: ● cinema venue location

Figure 4.5: The location of all cinema venues operating between 1946 and 1986

4.4.3 ArcGIS Tool Design and Implementation

In order to investigate the cinema data, two customised tools were designed to incorporate temporal queries into the analysis. The majority of GIS are inherently static – their focus is on the spatial, not the temporal. Temporal capabilities are improving in GIS, and there is a large amount of research effort directed towards this issue, especially in the area of database management and spatio-temporal visualisation (for examples see: Andrienko and Andrienko 2006; Chen et al. 2008; Hornsby and Egenhofer 2000; Le 2005; Lohfink et al. 2007; Peuquet and Duan 1995). Since the data was contained in a number of linked tables, time was treated simply through time stamps and was analysed through the two customised tools in order to extract the type of information needed.

ArcObjects is the development environment that is used to create customised tools within *ArcMap* (Esri 2010). The environment uses *Visual Basic for Applications* (VBA) which was applied to create a new *UIToolControl* (used for data and display interaction) in *ArcMap* and edited within *Microsoft's Visual Basic* editor. When the code is written in the *Visual Basic* editor, it can then be saved and the tool can be run within *ArcMap*. The two tools created were the *Status Query Tool*, and the *Event Tool*; each of which will be discussed in the following sub-sections.

4.4.3.1 Status Query Tool

This tool was designed to return the status of all cinema venues at any chosen date. As the tables are made up of records with a corresponding date stamp, previously it was not possible to query the venues for any date because each date is not recorded for every venue. For example, if we wanted to know the status of all cinema venues in 1960, it would not be possible to simply query the data tables as this data does not exist. Instead, what was needed was the ability to search through the records and find the last event that took place for each attribute of each venue before the date in question – these event dates would therefore provide us with the status for each of the variables associated with the cinemas for the chosen date. The tool queried the tables and created a new table of results through the following method:

- 1) Firstly, the tool is designed for the user to input the chosen date and also select what attributes are to be queried and included in the results table.
- 2) After selection, the tool script investigates to see if the venue is operational at this time by looking up each of the venue IDs in the *operation* table and determining whether or not the chosen date lies within an operation period. For example, if the date 01/01/1960 was chosen as the status query date, venue ID 163 (shown in Table 4.8) would be included in the results because the chosen date lies within the first operation period recorded. In comparison, venue ID 164 would not be included in the results as the operation dates show that it was closed during the chosen date.

Venue ID	Operation From	Operation To
163	01/01/1946	01/01/1966
163	17/06/1968	04/12/1977
164	01/01/1948	23/02/1959
164	08/05/1966	30/12/1985

Table 4.8: Example of operation table

3) If the venue is operational, the tool then proceeds to recall the latest entries before that date for each of the attributes of the venues.

4) The tool creates cursors for each table and points them to the first record in each of the corresponding tables. The tool then creates a list of all venue IDs of those cinemas operating on the status query date from the operation table, record by record until the end of the list.

5) The relevant information is retrieved from the correct tables and placed in the new table of results. The information from the source tables is checked for matching venue IDs and dates to ensure the data in the results table is correct.

6) After the required data has been collected and stored in the new table the tool is now able to create a layer from the results table. This was achieved by using the *XY Event* tool included in *ArcMap* which takes the latitude and longitude in each record and converts them into a new layer of point data to be visualised. A copy of the code used to create the *Status Query Tool* is provided in Appendix A.

4.4.3.2 Event Tool

The *Event Tool* is used to deliver those events that occur between two chosen dates. This includes the opening and closing of cinema venues and also changes to any of the variables. Initially it was not possible to query records that rested within a temporal period. What was needed was the ability to query each of the tables and determine whether or not each record rested within the chosen temporal period. These records would therefore result in a table of events that took place between two dates of interest.

The tool queried the tables and created a new table of results through the following method:

1) The tool was designed for the user to input a *from* and *to* date which will specify the temporal period. The user can also select which events to query, and therefore which tables are to be investigated (see Figure 4.6).

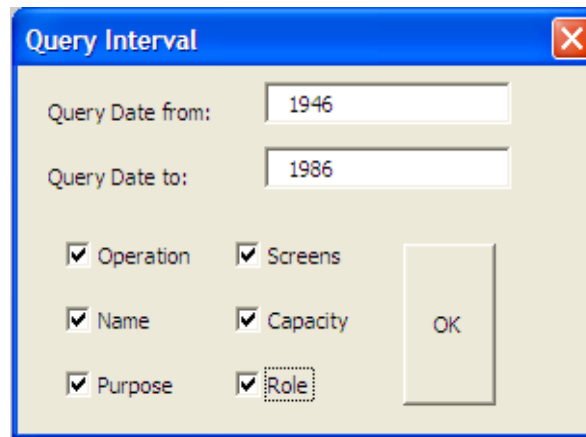


Figure 4.6: User selection interface for the customised tool

2) The tool script scans each table and extracts those records that have a date within the temporal period.

3) These records are included in an output table containing an event ID, venue ID, date from, date to, event type, and the event before and after (if available).

4) The output table also includes the venues spatial information which allows an *XY Event* layer to be created and therefore the location of venues with associated events can be visualised. A copy of the code used to create the *Event Tool* is provided in Appendix B.

4.5 *Data Analysis*

Each of the Geographic Questions required something different from the data, in terms of the venues used, the temporal period, and chosen attributes. To determine the variables used in each of the Geographic Questions a number of aspects were considered. Firstly, discussions held with cinema historians over the formation of the Geographic Questions also concerned what characteristics of the data they would like to investigate and what would possibly yield interesting and useable results for each of the questions. The results from these discussions were then combined with those aspects that would technically test the visualisation and evaluate its generic capabilities. Variables were chosen to allow a wider variety of attributes and values to be visualised and therefore show the flexibility and ability to deal with different types of data using the one visualisation technique. The GIS

was used to help in determining those variables that exhibited many changes, a small number of changes, those that were quantitative and those that were qualitative. Results from the analysis enabled a number of variables to be determined that would evaluate the visualisations flexibility, ability to handle change of varying degrees, ability to communicate both quantitative and qualitative data, and address all of the Geographic Questions.

The following sub-sections will discuss the data specifics for each of the Geographic Questions in terms of the temporal, attribute, and spatial components needed for the visualisation.

4.5.1 Temporal

The temporal dimension dictates much of the data that is included for each of the Geographic Questions. As noted in section 4.3, every entry for each attribute in the database contains an associated temporal record; a date stamp of when the event took place. These date stamps of each record can be used to determine the period of the question, those cinemas that were operating within the period, the status of each attribute for a given date, and all events that took place between two dates. Each of the Geographic Questions is concerned with a certain time period and therefore this governs the temporal specifics and which venues are used in the visualisation. The temporal specifics are defined below in relation to the three Geographic Questions. To recap, the three Geographic Questions are: 1) The longevity of Melbourne cinemas operating in 1946 – why did some cinemas survive the 40 year span and others closed?; 2) The openings and closures of cinema venues between 1950 and 1970, a particular period of cinema decline – what were the characteristic and geographical aspects of cinemas operating during this period?; and 3) The operation of large cinema chains within Melbourne’s cinema industry – how successful were cinema chains between 1946 and 1986 and what were the characteristic, spatial, and temporal differences between the different companies?

1) *The longevity of Melbourne cinemas operating in 1946*

The temporal characteristics of this question are centred around the year of 1946. All of those cinemas that were operating in 1946 were included in this question, and since the Case Study is between 1946 and 1986, all events were maintained up until the end of 1986. The status of each venue in terms of attributes and operation was determined for 1946 by using the *Status Query Tool*. This first confirmed those cinemas that were operating in 1946 and then provided a status for each venue at this date. These records were then used as the initial values, deleting all history prior to 1946. To determine all events that took place (and therefore change over time) for these cinemas between 1946 and 1986, the *Event Query Tool* was used, providing a time stamped record of each event change.

2) *The openings and closures of cinema venues between 1950 and 1970*

The temporal period of interest in this case is between 1950 and 1970. However, the question does not require all venues that were operating within this period, only those that closed or opened between the two dates. Therefore, operation dates were analysed and those that had their first entry (opening date) or last entry (closing date) within the period were included. The *Status Query Tool* was used to provide the current values for all attributes for 1950, and the *Event Query Tool* determined a time stamped record of each event that took place between the two dates.

3) *The operation of large cinema chains within Melbourne's cinema industry*

The temporal data required for the third Geographic Question was determined in the same way as question 1. The main difference being that in this case all venues were included that operated at some point between 1946 and 1986, not just those that existed in 1946. Status and event data were determined using the same techniques as the previous two questions. As this question concerned only those venues that could be characterised as belonging to a large cinema chain, all other venues were not included, as will be discussed in detail in the following section.

4.5.2 Attribute

All relevant records of attributes that were to be included in the visualisations were determined through the use of the *Status* and *Event Query Tools*, and were therefore included based on the temporal requirements. Each of the attributes chosen to be visualised are detailed below.

1) *The longevity of Melbourne cinemas operating in 1946*

The attributes included to address the question of longevity are listed in Table 4.9.

Attribute	Description
<i>Number of Screens</i>	The number of screens present within a venue
<i>Primary Purpose</i>	The primary purpose of the venue based on venue type. Includes the classification of cinema, live theatre, hall, Mechanics Institute, and art gallery
<i>Seating Capacity</i>	The number of seats present within a venue

Table 4.9: Attributes of Geographical Question 1

All of the values for each attribute were the original values recorded in the database.

2) *The openings and closures of cinema venues between 1950 and 1970*

The attributes included addressing the question of openings and closures are listed in Table 4.10.

Attribute	Description
<i>Size of Cinema Company</i>	The size of the cinema company is determined by the number of venues under ownership or management. Therefore if a company owns or manages only one cinema venue it is classed as small, and if the company owns or manages two or more it is classified as large
<i>Primary Purpose</i>	The primary purpose of the venue based on venue type. Includes the classification of cinema, live theatre, hall, Mechanics Institute, and art gallery
<i>Seating Capacity</i>	The number of seats present within a venue

Table 4.10: Attributes of Geographical Question 2

Values for the *Primary Purpose* and *Seating Capacity* attributes were maintained as the original values recorded in the database. There was no record for the size of a cinema company. This information was determined by the number of venues under the same operation as specified in Table 4.10.

3) *The operation of large cinema chains within Melbourne’s cinema industry*

The attributes included to address the question of large cinema company operation are listed in Table 4.11.

Attribute	Description
<i>Role</i>	The role under which the company acted. Includes the classification of owned, managed, and leased
<i>Number of Changes</i>	The total number of changes that took place between 1946 and 1986 over all attributes
<i>Cinema Chain Name</i>	The name of the large cinema chain. Includes the classification of Hoyts, Village, Greater Union, Cosmopolitan, Kirby’s Theatres, and Robert McLeish Theatres

Table 4.11: Attributes of Geographical Question 3

Each of the companies chosen for this question had the greatest number of entries in the database under role name. The values for the *Role* and *Role Name* attribute were maintained as the original values recorded in the database. The values for *Number of Changes* were determined by combining the number of changes or events that took place for an individual cinema between 1946 and 1986.

4.5.3 *Spatial*

Based on the data requirements determined for the temporal and attribute characteristics, the only spatial data needed was the location of each of the venues that met these requirements in the form of geographic coordinates. Question 1 required the location of all venues that were operating in Melbourne in 1946, Question 2 required the location of only those venues that opened or closed between 1950 and 1970, and Question 3 required those venues that

were run by one of the six largest cinema chains in Melbourne operating sometime during the period between 1946 and 1986.

4.6 *Conclusions*

This chapter has outlined all aspects concerning the data involved in the Case Study application and the development of the visualisation method. By working directly with historical spatial data, it was found that in order for the data to be compatible with the exacting technology of GIS, a number of criteria needed to be enforced to ensure the data met both the requirements of the research and the GIS. The CAARP database was found to be an excellent source of information for the research and provided a relatively simple transformation of data to be incorporated into the GIS. Through the creation of the three Geographical Questions that address different aspects of cinema venue history, the cinema venue data was analysed in order to identify aspects that were relevant to the questions investigation and also those aspects that would meet the multivariate, change over time, and spatial requirements of the visualisations method. It was found that through the creation of customised tools (the *Status Query Tool* and the *Event Tool*), analysing the temporal data within the static environment of the GIS was simple and effective.

The final spatial, temporal, and attribute components for each Geographic Question will be used in the development of the visualisation method discussed in the following chapter. Chapter 5 will also outline the concept behind the visualisation method and technique and will present the specifics and functions of the final visualisation product.

5 Developing a Visualisation Approach to Historical Spatial Data

5.1 Introduction

To create a visual representation for historical multivariate data that change over time, an approach has been developed that addresses those aspects that are significant to the understanding of most historical events: multivariate representation and analyses, the detection of change over time, and the geographical significance of the events. The specific requirements of the Geographical Questions outlined in Chapter 4 were considered in the concept and development, not because of the final application to the Case Study, but because they provided an insight to the practical issues present in the main aspects mentioned above.

This chapter outlines the background and methods implemented from concept to creation. In order to make the leap from visualising data to a visual representation that is an integral component in interpretation, analysis, and communication, this research has found three

core issues that need to be addressed. These are: the treatment of time and space; multivariate analysis and interpretation; and the importance of visual communication. Each of these issues will be discussed in relation to the concept. The treatment of time in historical studies will be explored and the implications of these alternate temporal concepts for geographic historical data will be examined in relation to the Case Study. The development of the visualisation has been achieved through the consideration of these implications and the importance of visual communication (discussed in section 5.2.3 and 5.3.2), influencing the temporal, spatial and attribute components of the final product. The final section of this chapter will present the visualisation approach; the components of the visual representation and the functionalities and capabilities of the method.

5.2 The Concept of the Visualisation Approach

The developments in spatial technology and visualisation for historical investigation provide us with the opportunity to develop a visualisation approach that recognises the limitations of both areas whilst incorporating positive aspects that will contribute to the growth of an interdisciplinary field. In review of the techniques used in the visualisation of historical spatial data, their adaption is largely centred on the type and limitations of the data. The data can greatly influence the treatment of the spatial and temporal dimensions; it can limit the opportunities of classification and aggregation; and can play a big role in the selection of the visualisation method adopted. This is true too for the data used in this study. Chapter 4 outlined the characteristics of the data and it was noted that all the spatial, temporal, and attribute information available was included in the database. The reason for this is it allows for greater flexibility in the treatment of time, space, and variables and therefore opens up the opportunities to create more varied visualisations.

Whilst the data is a major component of any geohistorical study, it has the ability to dictate the overall concept of the visualisation. Of the projects discussed in Chapters 2 and 3, there research found that there is very little discussion on the decision to use a certain visualisation technique. This of course does not mean that each decision was made without thought. But it does seem to indicate that the visualisation is not a main focus of the study and generally the visualisation is seen more as a secondary thought or supplementary evidence in support of an argument. Visualisations can be much more than this. It will be argued that their role as a communicator of information, as an exploratory analysis tool, as a method to illustrate a story, and as a catalyst for raising questions in traditional fields associated with geospatial technology can also have their place in historical studies.

The overall limited role of visualisations in geohistorical studies has hindered the development of new visualisations specifically designed for historical spatial data. New visualisations that consider in more depth the ways in which spatial and temporal data should be treated, the need for a multivariate approach to relational attribute data, the design concepts for successful visual communication of data, and the relationships between geography and history. As a result, the developed visualisation concept of this study has

focused on these aspects of research, and has identified three core issues that need to be addressed in order for geohistorical visualisations to make the leap from visualising data to an integral component in interpretation, analysis, and communication. These are: the treatment of time and space; multivariate analysis and interpretation; and the importance of visual communication. The remainder of this section will address each component in depth.

5.2.1 The Treatment of Time and Space

Historical time and spatial data are the two necessary components of geohistorical studies and their resultant visualisations. Of those techniques used in geohistorical projects (see Chapters 2 and 3), the majority rely on temporal and spatial approaches that have a strong grounding in geography and conventional cartographic representations. Looking beyond these techniques, the concept for the visualisation aims to enhance the capabilities of visualisation in geohistorical studies by considering alternate approaches to the treatment of both space and time.

In this study, the treatment of space is a core component in the concept for visualising historical spatial data, and is based on the question, *how can we organise space more effectively?* Visualising the locations of geographical entities on a map through representing the entities using their geographic coordinates is the most common approach to spatial organisation in cartographic representations, especially for point based features. Because of its extensive use, the representation of spatial entities as they are located in space is not challenged greatly in cartography. Yet it is important to consider whether to visualise the exact coordinate positions is necessary and if their true location is important in order to communicate the spatial aspects of the data effectively. As discussed in Chapter 2, graphs that include a spatial dimension such as the names of locations or the distances from a central point do not attempt to represent places as coordinates in space but they still communicate spatial information. This study proposes that there are advantages to be gained by combining elements of cartographic and graphic communication and representations. This is achieved by classifying the data in a meaningful way and avoiding the aggregation present in most cartographic and graphic representations. But most importantly, it creates a more position oriented view in graphic representations whilst incorporating graphic

principles to spatial representations. The development of this concept is discussed in section 5.4.1.

Time is inherent in geohistorical studies, whether through the investigation into a past time of historical significance or a study into the changes over time. As discussed in Chapters 2 and 3, time treatment in the visualisation of historical spatial data has focused primarily on time-series and snap-shot methods which are common in most fields where spatial visualisations are applied. This core component in the concept for the visualisation invites a shift from the dominance of geographical time in geohistorical visualisations to incorporating the ways in which historians view time for a more effective way of communicating the temporal dimension. Whilst many historical studies also use methods of chronological time like the time-series and snap-shot found in geography, there are also many alternate views on historical time that can be considered. These will be discussed in section 5.3 along with their implications for visualising historical spatial data.

5.2.2 Multivariate Analysis

The second core component of the visualisation concept is the need for a multivariate approach to relational attribute data. Many spatial visualisations have the effect of neglecting the importance of associated attribute data in order to stress the geographic. Historical spatial data, especially in the humanities, is often attribute rich because of the details required for thorough historical investigation. As a result, there is a need to consider multiple attributes at the same time, and be able to compare and visualise the relationships between them. Certain attributes and their influence and association with others can be a key historical question, as well as the spatial relationships between differing attributes. Their importance in the Case Study of Melbourne's cinema venues is even more prevalent, as it is the changes to these variables over time, such as ownership and venue name, that gives us historical change. The ability to represent multivariate data is therefore an essential component in the concept for the visualisation and its adoption is discussed in section 5.4.3.

5.2.3 *The Visual Communication of Data*

The third and most influential core component of the visualisation concept is the successful visual communication of data. This reflects one of the main aims of the study; to create visual access to information. As discussed in Chapters 1 and 2, visualisations have been largely associated with graphical representations because graphical representations can very effectively make “data and the corresponding phenomena perceptible to the mind or imagination of the explorer” (Andrienko and Andrienko 2006, p. 166). The visual communication of information through graphical representations is thus central to all of the decisions made in relation to the visualisation of the data and the way the information is organised; without considering this we are often left with a visualisation that does not serve a specific purpose. To be able to communicate the data and ideas effectively in this study the purpose to create a visualisation that allows for interpretation and analyses of data, patterns and results, and to raise questions drives the design and technical decisions.

Approaches such as choropleth mapping, isarithmic maps, and graphs invite the reader to make interpretations, distinguish patterns, raise questions, and form relational links. However the snap-shot treatment of time, the spatial classification, and the lack of multivariate treatment has meant that interpreting the data is challenging, requiring analysis of multiple images to present the complex information. Therefore, in order to make the shift from visualising data and the complex analysis of multiple images to a visualisation that is integral to interpretation, analysis, and communication, certain characteristics from the fields of Data Graphics and Exploratory Data Analysis (EDA) are incorporated.

Data Graphics, also referred to as *Info Graphics* “visually display measured quantities by means of the combined use of points, lines, a coordinate system, numbers, symbols, words, shading, and colour” (Tufté 2001, p. 9). As discussed in section 2.2.4, the work of graphic experts such as J. H. Lambert, William Playfair, and Jacques Bertin have laid the foundations for the majority of data graphic, info graphic, information visualisation, and visualisation techniques. One such technique that is common in visualising historical spatial data is time-series displays.

Tufte (2001) argues that the use of time-series displays coupled with the spatial dimension, so that the data are moving over space as well as over time, is especially effective for enhancing the explanatory power of time-series displays. Time-series graphs have been used extensively in Historical GIS to display information, and there are a number of ways in which the spatial dimension is included such as: defining individual locations or areas by individual points, lines, or graphs (Armstrong et al. 2009; Carter 2008; Groote et al. 2009); using spatial categories or distance to define space (Beveridge 2002; Gregory 2008); or through separate graphs for different individual locations (Gregory and Southall 2002; Norman et al. 2008) (see section 2.3.4). Each of these methods does not convey the data in their geographical context; they are not given a coordinate in geographical space. Instead, their treatment of location or of the spatial dimension is more abstract. This can allow for greater flexibility in the treatment of temporal and attribute dimensions, bringing a stronger focus to multivariate display. This view of the spatial dimension for time-series graphs has been extended in this research to create a more geographic oriented spatial dimension by incorporating spatial classifications of distance and direction. The classification and development of this will be discussed in section 5.4.1.

Being able to create visual representations of multivariate, spatial, and temporal data has many advantages, and can be used at many stages of a study. One point that is clear through the review of relevant literature in Chapter 2 is that visual representations of historical spatial data are not limited to a final representation of results. However, the ability to use visual representations for the exploration and analysis of data is relatively new in historical studies. Exploratory Data Analysis (EDA) is a field that is focused on exploring data to see what it might tell us, not working with the data to answer a specific question (Andrienko and Andrienko 2006). As a result, EDA is about hypothesis generation rather than hypothesis testing and does this largely through the use of graphical representations of the data (Andrienko and Andrienko 2006).

The ability to be able to not only display the data or the results of analysis, but to use visual representations in a way that encourages analysis, interpretation, the ability to explore the relationships between variables, and form new Research Questions is at the core of this research. All of these functions are supported by EDA techniques. A number of approaches for dealing with the issues present when visualising large spatial and temporal data have

been identified by Andrienko et al. (2008), and categorised into three approaches to exploratory and analytical visualisation, being:

1. Direct depiction and visualisation of the data collected
2. Derivation, depiction, and visualisation of abstract data summaries – aggregates, generalisation, samples
3. Extraction, depiction, and visualisation of computationally extracted patterns

For the visual representations of historical cinema venues in this research, characteristics have been adopted from the first two approaches to form the analytical capabilities of the data. The traditional visualisation approach of *direct depiction* allows the data to speak for itself by enabling the user to extract patterns based on the original integrity of the individual measurements recorded in the data set. This approach has been applied to the treatment of the temporal and attribute data, as well as the existence of the individual venues themselves. The spatial classification of the data is based on representing data summaries that are formed from the original data. Instead of directly mapping the location of cinema venues, the classification presents the data in way that allow patterns to be extracted. This has meant that visual clutter and confusion has been reduced which in turn has led to greater freedom in the treatment of those aspects that are directly depicted. Whilst aspects of EDA are incorporated into the visualisation for the aid in analysis, it should be noted that it is not used to explain the data. Instead, the visualisation explores the data in relation to specific questions.

5.3 Time Treatment in Historical Studies

‘Understanding place requires a historical perspective, and understanding periods requires a geographical perspective. Each needs the other; each is impoverished without the other. More importantly, each is enriched by the other’ (Baker 2003).

Geohistorical data provides us with the unique opportunity to enrich both historical and spatial perspectives. It encourages greater collaboration and understanding between the two. Geohistorical data also encourages us to consider the differences between the temporal dimension of both fields and the potential benefits of adopting alternative views of time. Previous studies working with historical spatial data have been dominated by a geographers view of the temporal dimension; one that is driven by causation; chronological time. Chronological time is also very popular in historical scholarship, yet there are many other ways in which historians view the temporal dimension.

This section will address the possibility of improving visualisation for historical spatial data through collaboration with historical thought by incorporating an alternate historical view of time. The first part of this section will outline the main approaches to time treatment in historical scholarship. These will be further discussed in relation to visualising historical spatial data and their potential for improving the communication of information to historians. In particular, the main characteristics of the new concept adopted for the historical time treatment within the developed visualisation will be discussed in detail.

5.3.1 Concepts and Background

There are many different views on the nature of time itself. Historians have explored the concepts of objective, subjective, and relative time (Hall 1980; Von Leyden 1963) as well as other alternative views. For example, Collingwood's principle of minimum time suggests that every historical event requires a minimum amount of time in order to exist (Von Leyden 1963). However, this research focuses not on answering the question *what is time?*, but instead focuses on addressing the main approaches to time treatment and the different ways in which the notion of time is communicated in historical scholarship.

Starr (1966) identifies that the historians view of time fall within five main categories – *cycles, retrogression, even flow, swift movement, and slow movement*. Cyclical time has been adopted to understand the cyclical nature of histories such as art and economics, where one feels they often return to the point at which they began (Starr 1966). Retrogression concerns the sense of a reversal of times, in which Starr explains “generations seek to

revivify an earlier isolation or simpler ways” (1966, p. 31). In Starr’s discussion of the different categories of historical time the dominance of chronological time cannot be overlooked. The categories of swift and slow movement as well as an even flow of events all stem from linear chronology, or as Hall describes as the “march of events” (1980, p. 113). Indeed, the categories of cycles and retrogression can also be built upon a period of chronological time treatment. On the one hand, there are moments in history when time can be said to stand still, whilst on the other, the swift movement of time seems riddled with great events (Starr 1966). However, it is the regularly measured chronology or even flow that is the dominant concept in modern studies, despite the complications involved in dealing with the differing tempos of swift and slow historical movement that can be identified within this framework (Starr 1966). In many cases, history does not conform to the chronological placement of events, and as Kracauer observes: “history consists of events whose chronology tells us but little about their relationships and meanings” (1966, p. 68).

As a result of the issues concerned with chronology, its dominance has been challenged by two alternative developments: objective and subjective time (Hall 1980). The concept of the relativity of multiple scales of objective time has been identified largely with the *Annales* school of historiography, through the works of scholars such as Lucien Febvre, Marc Bloch, and Fernand Braudel (Hall 1980). Fernand Braudel especially has placed an emphasis on the treatment of time for historical analysis through the development of his theory *The Plurality of Social Time*. Commenting on what he considered to be a dominance of nineteenth century emphasis on events that deal only with brief moments in history (Hall 1980), Braudel remarks that these are merely “surface disturbances, crests of foam that the tides of history carry on their strong backs” (1972, p. 27). In response to this, Braudel’s *Plurality of Social Time* presents a temporal structure in which history moves on different planes, each with its own tempo, thereby introducing two other scales of objective time which rest under these surface disturbances (Hall 1980; Jessop 2004).

The three planes or tiers of Braudel’s *Plurality of Social Time* consist of short, medium, and long term changes (seen in Figure 5.1), and are described as:

1. **Long-term** – reveals the fundamental conditions of material life, states of mind and the impact of the natural environment

2. **Medium-term** – in which the forms of social, economic, and political organization have their life span
3. **Short-term** – the time of the individual (Tosh 2006).

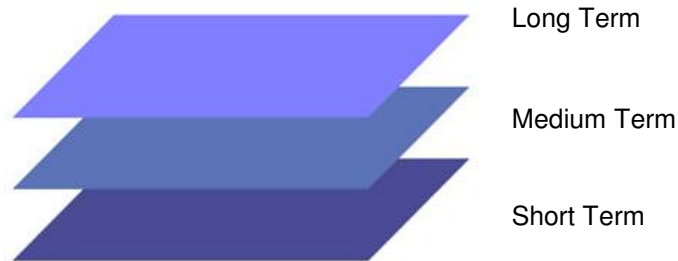


Figure 5.1: Braudel's three tier structure

Each tier has its own tempo of change and through their co-existence can provide association and relation to the whole.

5.3.2 Implications for Geographic Historical Data

This research has aimed to improve visual interpretation and analysis through considering notions of historical time treatment and adopting them for visualisation. Whilst many theories have potential to do so, alternate views of historical time treatment have yet to be adopted in Historical GIS projects and the visualisation of geohistorical data. The benefits of incorporating such views on time treatment has been discussed briefly by Jessop (2004); suggesting that the mapping of migration patterns would need to move from a unilinear approach to one which accommodates the ideas put forward by Braudel if it were to be developed further. But how does one communicate the coexistence of these different tiers? Tosh (2006) identifies this problem as a fundamental issue for contemporary historians, stating that “the problem... is how to convey the coexistence of these different levels in a single moment of historical time – how to elucidate their interaction in a coherent exposition...” (2006). The developed visualisation discussed below attempts to provide historians with a way of addressing this fundamental issue through visual communication instead of written explanation.

Braudel's theory of multiple scales of objective time has been loosely adopted for this research because it can provide a temporal framework for visual analysis and interpretation of any event-driven historical data. This is due to three factors:

1. The ability to provide greater historical context for the event based data through two supportive levels/tiers of historical information
2. The meaningful separation of events into three levels/tiers to decrease complexity and organise data more effectively
3. Relationships between different events and possible causation to be explored and to spark further questions of the data

These three factors are used in the development of the visualisation method for the Case Study of Melbourne's cinema venues, as discussed in section 5.4.2.

5.4 Development of the Visualisation

In order to realise the concept of the visualisation it has been found that the treatment of those aspects that shape the development of the visualisation need to be addressed. An important aspect discussed above in relation to the visualisation method was the shift from traditional cartographic representations to a visualisation that integrates data communication driven information graphics and historical time treatment. In response to this shift, the treatment and organisation of the spatial, temporal, and attribute dimensions need to reflect the characteristics of the concepts discussed above. All three dimensions need to be handled in such a way that emphasises the relationships between them and their influence and association with one another.

This section will discuss the treatment of the spatial dimension and the classification used to optimise the interpretation of the operation of cinemas. Due to the historical nature of the project, the method adopted to handle the temporal aspects of the data will hold great significance. Therefore the background to the choice of the treatment of time will be explored. In addition, this section will outline the concepts surrounding the organisation and

treatment of attribute data and the importance of the temporal aspects of attribute data in capturing change.

5.4.1 Spatial Classification

The spatial classification of the data used in the visualisation is centred on maintaining the individual venue records and stressing the spatial aspects of the data that are important for analysis and historical interpretation. This is achieved by focusing on meaningful classification of the information and avoiding the use of spatial aggregation to represent the data. The geographical distribution and the different variables associated with each venue vary significantly, and it is the dynamic nature of the venues that is of importance to a study of their history. As a result, a visualisation is needed that reflects these differences and maintains the individual characteristics of each separate cinema venue.

The majority of visualisation approaches discussed in Chapter 2 for large datasets rely on aggregation in some capacity. For instance, choropleth mapping aggregates the spatial distribution of the data into administrative boundaries (Gregory 2000; Gregory and Southall 2002), differentiating and ordering visual variables can also correspond to representing statistics of aggregated areas (Siebert 2000), and dot maps contain aggregated information where each dot represents a certain number of individual records (Beveridge 2002; Robinson et al. 1995). Statistically, aggregation can cause a highly abstracted representation of the data, can lead to inaccuracies in the information being presented along with what can be interpreted, and smooths out an area that can contain much variety by eliminating outliers that may be of importance. Although in many cases aggregation suits the data used, the benefits gained by maintaining each individual location is highly suitable for the type of data that can deliver integrity, variability, and accurate interpretation.

The spatial organisation of each individual venue is based on the variables of distance and direction. This classification method reduces visual complexity in a meaningful way by taking the spatial coordinate values, street addresses and suburbs and transforming them into classes of direction and distance from Melbourne CBD (more specifically the Melbourne General Post Office). Therefore, classification is given to a venue based on where their

coordinates fall within the distance/direction grid. For example, based on the classes to be described below, the *Progress Cinema* situated on Colby Drive in suburban Melbourne with spatial coordinates (-37.924144, 145.352709) would be represented as being in the distance class of between 20-50km from the CBD and in a east south east direction (Figure 5.2). The following discussion of the use of distance and direction for classification highlights the natural geography of the city of Melbourne and the spatial patterns of cinema distribution and exhibition.

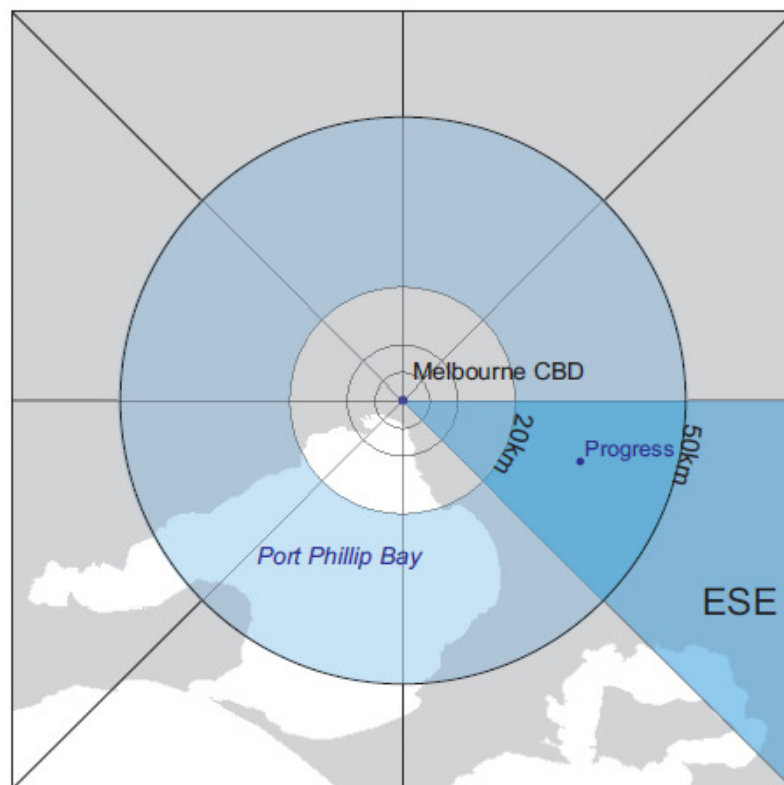


Figure 5.2: *Progress Cinema* location

Distance has been used in classification for the visualisation of historical spatial data in the area of relational graphics discussed in section 2.3.4 (Fyfe and Holdsworth 2009; Gregory 2008). The method has been adopted for forming part of the classification for Melbourne's cinema venues due to the central location of the city and the influence of distance from the CBD on cinema distribution and exhibition practises. The extent of Melbourne (shown in Figure 5.3) is centred around the CBD, and although the population distribution of the city is not considered strictly concentric, the CBD acts as the centre for many services such as the rail service and roads (Carroll 2005). Such services radiate out from the centre of the city and their density generally decreases as the distance from the CBD increases.

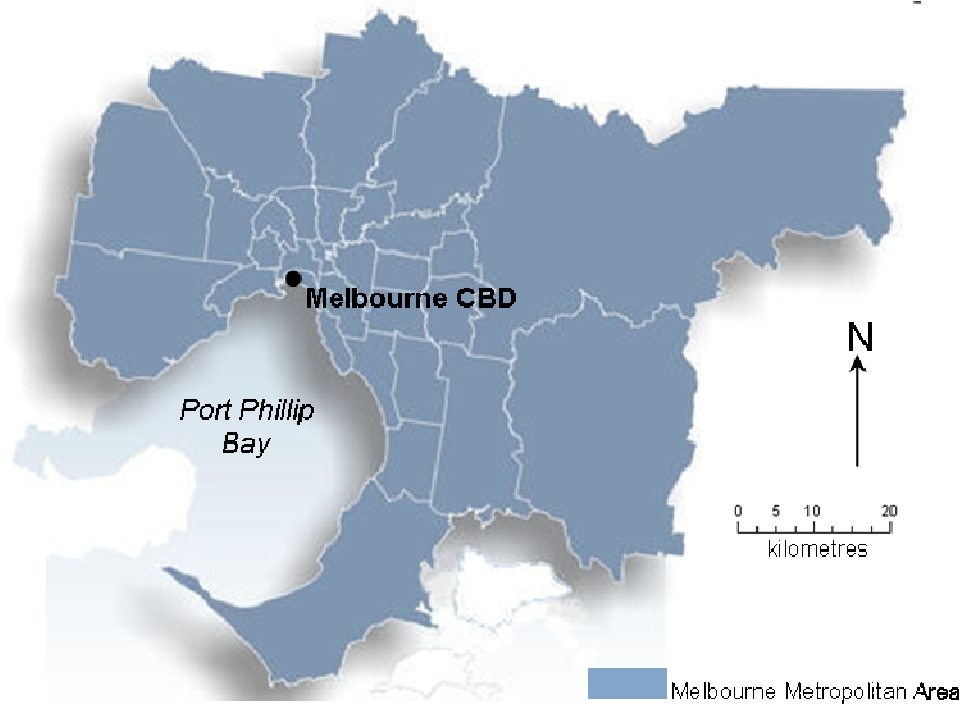


Figure 5.3: Geographical extent of Melbourne's suburbs (Created using image from: State Government of Victoria 2012)

The cinema industry between 1946 and 1986 behaved in very much the same way as these services. Exhibition and distribution patterns were dictated by the development of the CBD, where the inner and outer suburban theatres were controlled and influenced almost concentrically from the cinemas located in the middle of the city. As discussed in section 3.3.2, the city acted as the origin of a type of concentric expansion of distribution, that not only influenced the spatial distribution of markets, but also the ranking and priority of markets (Verhoeven 2009a). For post-war Melbourne, the geography of film distribution has been described as “turning on a garden sprinkler. First turn of the tap covered the city theatres, another turn covered the inner suburbs and each subsequent turn reached further out until suburban Melbourne was saturated” (Miller 2006, p. 26). Distance from the CBD also played an important role in the survival of a cinema venue. For example, the suburban theatres were often sacrificed in favour of city venues. During a time of massive cinema closure, between 1958 and the early 1962, much of the investments went into the city cinema's fight for survival at the expense of the smaller and later run suburban venues.

Distance is thus a dominant factor in the geographic distribution and character of Melbourne's cinema venues, and using the variable of distance from the CBD to classify the location of the venues creates a visualisation that reflects this distribution. The classes

adopted for the visualisation divide the geography of Melbourne into six radial divisions from the CBD to a distance of greater than 50km and are shown in Table 5.1, and graphically in Figure 5.4. Distances are based on the geography of the city, reflecting the natural divisions between inner and outer suburbs, the influence of the CBD, population density and distribution, and the density of services. Six distance classes were chosen because of the way they logically divided the geographic extent of Melbourne and because four to six classes is the most common number used in mapping for ease of interpretation (Gilmertin and Shelton 1989; Monmonier 1977; Tyner 1992). Normally, no more than ten classes are used in thematic mapping and this limit is based on human perceptual abilities (Tyner 1992). However, in practice, usually no more than six classes are recommended (Gilmertin and Shelton 1989; Monmonier 1977). Distance Class 1 (0 – 1km) is based on the clearly defined CBD of Melbourne which is characterised by a formal grid pattern. Distance Class 2 (1 – 5km) is defined by the inner suburbs of Melbourne which are generally small property lots and dominated by dense development and population. Distance banding of 5 – 10km is characterised largely by a thinning out of population and heavily built-up environments but still retaining relatively small property lots. At the distance banding of 10 – 20km, Melbourne’s suburbs is the dominant theme, characterised by larger lots and mainly single storey dwellings. Beyond this at a distance of 20 – 50km, Melbourne’s outer suburbs are characterised by larger lots and the appearance of rural properties. The distance class of 50km+ is concerned mainly with rural towns on the periphery of Melbourne, but those that are still influenced by the city itself. Although such characteristics and dynamics change over time and have therefore changed between the Case Study period of 1946 to 1986, only one set of distance classifications has been used due to simplicity. It should also be noted that divisions are not based on classifications such as “rural” or “inner suburban”, but instead a distance interval and number, therefore making no generalisations or assumptions about classes that change name and their spatial arrangement temporally. As a result, the classes are transferable for any given year as they have no restrictions on their definitions.

Distance Class Number	1	2	3	4	5	6
Distance Interval From CBD (Kms)	0 - 1	1 - 5	5 - 10	10 - 20	20 - 50	50+

Table 5.1: The six radial division classes for distance

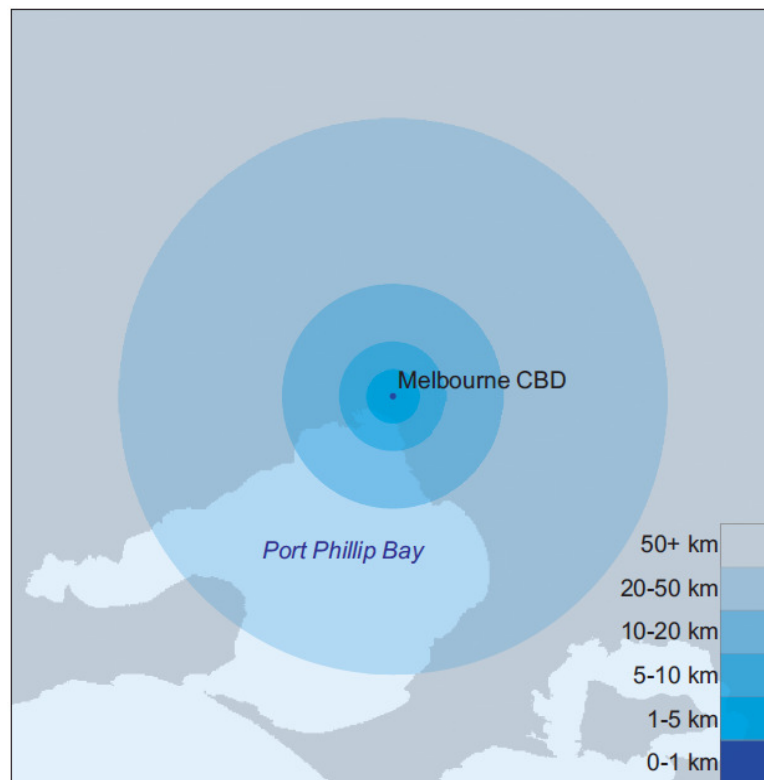


Figure 5.4: The six radial division classes for distance

Combining classifications of distance and direction enables a more position oriented classification to be created, as well as one that reflects the distribution and characteristics of cinema venues. Just as distance is an influential geographical variable for cinema spatial distribution, so too is the directional location of cinemas from the CBD. Population distribution, cultural characteristics, migration, and historical settlement patterns all vary in response to an area's cardinal (north/south) position from the CBD and this in turn influences the characteristics and location of cinema venues. Demographic variables such as population distribution and density differences between east and west have greatly influenced the number and location of cinema venues. For example, large numbers of cinemas are located in the eastern suburbs in order to service the demands of a large and growing population.

It is clear that a method of classification should incorporate the cardinal direction of venues from the CBD due to its spatial significance in population and the geography of cinema locations. Neglecting this significance will reject the city's underlying geographical and historical patterns. Figure 5.5 shows the eight chosen directional classes used for the

visualisation. Each class is based on their cardinal direction from the CBD and divides the geographical extent of Melbourne into eight equal divisions of 45 degrees radiating from the CBD.

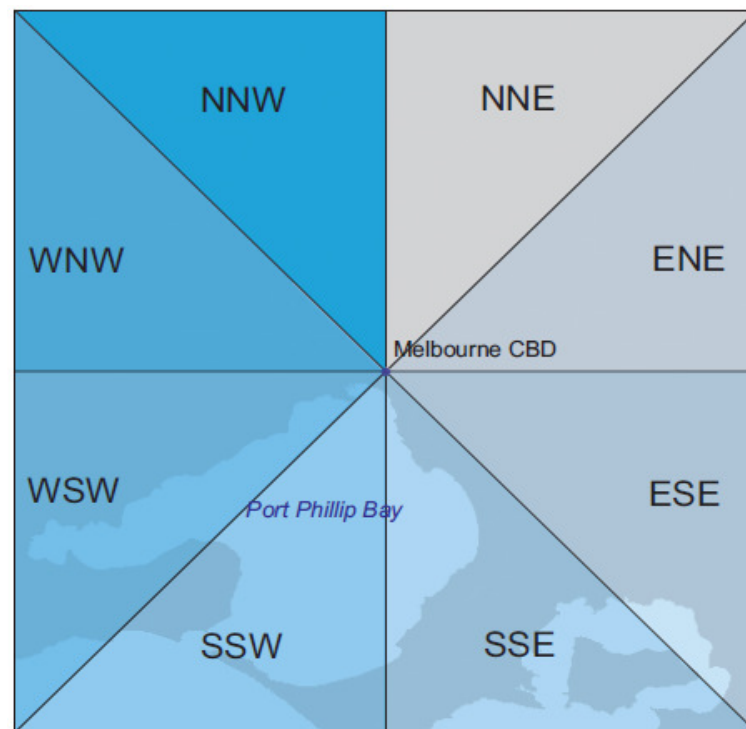


Figure 5.5: The eight cardinal direction classes

Spatial divides of the four cardinal directions of north, south, east, and west were considered for the classification, but it was found that it created data that was too generalised in order to gain insights. The eight divisions are more granular in their representation of the data and allow more detail to be viewed without becoming too complex. Population pockets such as the Mornington Peninsula on the east coast of Port Phillip Bay can be distinguished at this level of classification, and so too can the general differences between east and west.

The classifications of distance and direction have been combined to create two venue variables based around the spatial dimension. By not strictly mapping individual venue coordinates, the treatment of space is more flexible and can be utilised in much the same way as any other variable, such as seating capacity or ownership. The spatial classification has the advantages of reflecting the geographical nature of cinema operation and suburban expansion whilst still maintaining a position oriented view.

5.4.2 *Time Treatment*

The presence of time is a prominent aspect of geohistorical studies, and is true too for the treatment of time in geohistorical visualisations. The developed visualisation method incorporates two approaches to time treatment, Braudel's *Plurality of Social Time* and time-series graphs. Both approaches have a strong standing in historical scholarship, whilst only time-series graphs are particularly evident in spatial and geohistorical visualisation.

In addition to the venue data, the different sources of historical events that influence the cinema industry and Melbourne's society during the time period have been identified in Chapter 4. These three "levels" of data have been incorporated into the temporal framework inspired by Braudel's temporal structure. This has been achieved by presenting three levels of history; Melbourne's society, the cinema industry, and the venue history itself, as the three *tempos* of time put forward by Braudel; long term, medium term, and short term (shown in Table 5.2). Each temporal level discussed by Braudel behaves at a different tempo and the changes associated with each level are given context through the coexistence of all three levels. The long-term level of social change is shown as the top layer in Table 5.2 as it affects the other layers beneath. The medium-term level of industry change rests between the long and short-term levels as it is influenced greatly by changes in society and in turn affects the history and development of the individual cinema venues. The short-term level of venue change is shown as the bottom layer, indicating the presence of both the medium and long-term influences on its operation.

Level	Braudel’s “Plurality of Social Time”	Historical Layers of Change
Level 1	Long-term – reveals the fundamental conditions of material life, states of mind and the impact of the natural environment	Social Change – those events that change general society, such as: migration, employment, taxes, television etc.
Level 2	Medium-term – in which the forms of social, economic, and political organisation have their life span	Industry Change – those events that change the operation of the cinema industry, such as: entertainment taxes, admission prices, specialty cinemas, wide-screens etc.
Level 3	Short-term – the time of the individual	Venue Change – those events within the venue itself that change the operation of the venue, such as: change in seating capacity, ownership, screen numbers etc.

Table 5.2: Showing the adoption of Braudel’s theory for temporal structure

The classification of the temporal dimension in this way enables the data concerning cinema venues, the cinema industry, and Melbourne’s society to be seen as three distinct historical levels of change, changing at different tempos and magnitudes, whilst bringing attention to their influences on each other through their coexistence and integral place in the temporal structure of the visualisation.

Changes within each of the temporal levels are distinguished by date and arranged in a manner that highlights the sequential order of events; a time-series graph. This approach is popular in historical theory and also in current geohistorical visualisations (for a review see section 2.3.4) due to its suitability in displaying and tracking the sequence of events. The subject of cinema history also suits such an approach. Each event has a recorded time stamp associated with it, and this event signals a new change in history or it signals that a new state has replaced a previous state. When all events are put in order on a particular subject such as a cinema venue, it is clear to see the lifetime of the subject; its changes, the number and sequence of changes, times riddled with events and those that stand still. The sequence, position, and type of events on a graph are all significant in relaying the history of a time or entity, and they too can offer insights into those events that act as a catalyst for change. In addition, the sequence, position, and type of events can highlight the temporal and thematic

patterns of events and can spark new questions, insights, and explanations of such events and entities.

Through the use of a time-series graph, it is possible to maintain the dates as recorded, therefore acknowledging the integrity of the original data and avoiding classification and aggregation. A snapshot or animation view of time could not include the fine granularity of the original dates without producing a snapshot image of time for each individual record; possibly leading to hundreds of individual images that create a vast amount of reproduced redundant data. As discussed in section 4.3.3, most of the recorded dates correspond to the first date of the year, as often the year and not a precise date is known. But where there is a case in which the exact date is known this information is preserved.

Combining two very different approaches to time treatment within the one visualisation for this research has created a new and innovative technique to successfully communicate multi-level temporal data. Each level of historical time contains a time-series graphic of the events, where each level can be combined or layered to create a visual framework of association and influence, as will be discussed in section 5.6. This allows for greater comparison of the temporal relationships between varying social events and the ability to simplify the analysis and interpretation of each layer through their divisions.

5.4.3 Attribute Classification

One of the main advantages of working with a graphic approach to visualisation is the importance of not only the geographic location of the data, but of the attribute data associated with the spatial data. Mapping inherently stresses the geographical aspects of data, but often this can compromise the importance of the relationships between multivariable data. As a result, the attribute data in the proposed geovisualisation have been organised in a way that highlights the relationships between different attributes and to thereby create a visualisation that encourages multivariable comparison together with a geographic and temporal focus.

Each of the variables used in the visualisation are attributed to the venue to which it belongs, therefore avoiding aggregated units. There is also no classification imposed on the attribute data because it is possible to maintain each individual record through the fine granularity of the visualisation developed. This ensures the same benefits as keeping the original temporal records for each venue; creating a more detailed and accurate perspective of the attribute data for a densely informative visualisation.

5.4.4 Capturing Change

One of the main components in developing the geohistorical project is the visualisation of events, and how to represent the change from one state to another dictated by these historical events. Since the location of the individual venues are always the same and do not change temporally, it is the visualisation of historical attribute change that is required.

Each of the attribute changes associated with the venues has a time stamp, and can therefore be seen as a record of change. As a result, the way that change is captured in the visualisation is simplistic as it is already embedded in each attribute as a record of change. By sequencing these records in a time-series graph, as discussed above, the lifetime of each venue is created through the change from one state to another. This also produces an accurate depiction of change because it is possible to avoid classification and aggregation for both the temporal and attribute data that form the record of change.

5.5 The Visualisation Approach

By creatively applying those aspects developed in the previous sections, a method has been developed for the visual representation of historical multivariate data; one that communicates data holistically and effectively, stressing the historically significant geographic, temporal, and multivariate aspects of event-driven information. The visualisation approach achieves this through a conscious awareness of the effectiveness of simplistic and efficient data graphics to create a clear portrayal of the subtleties and complexities within the data. This section will outline the steps taken to create the visual

representation. The temporal and spatial framework for the visualisation will be discussed along with the visual treatment of the venue coordinates. The section will outline the main functionalities and capabilities of the approach which include the detection of change, visual analysis and comparison, and the three levels temporal structure for greater historical perspectives. It will also highlight the flexibility of the method which will aid in the application to the three Geographic Questions and their requirements.

This section will significantly contribute to addressing Research Questions 1 and 2 by addressing the questions of *how can historically changing, multivariate, spatial data be analysed and communicated visually? And how can temporal change of static entities be represented using spatial technology?*

5.5.1 Framework

The framework for the visualisation is based around the needs of the venue data. The treatment of space and time (discussed in sections 5.4.1 and 5.4.2 respectively) are brought together to form a visual representation that is both holistic and simplistic for interpretation. Just as the spatial data uses direction from the CBD as one of two methods of classification, direction is also used as a platform for the framework, where the visualisation is divided into eight cardinal segments all radiating from the centre of the image. Each of these eight directional segments is placed radially from the centre of the image creating a visualisation that is circular and reflects the directional classification of the data (see Figure 5.6).

By taking an abstracted view of space, this research has extended the time-series graphic technique to create a more position oriented representation. The temporal dimension within the framework is a chronological time-series graph of regular spaced divisions and is applied to each of the directional segments. This produced a framework of eight time-series graphs placed radially for the eight cardinal directions, where each graph depicts those venues that fall within the 45 degree divisions (Figure 5.6). The beginning of the temporal period rests at the centre of the image and radiates out in regular divisions until reaching the boundaries of the visual representation, or the end of the temporal period.

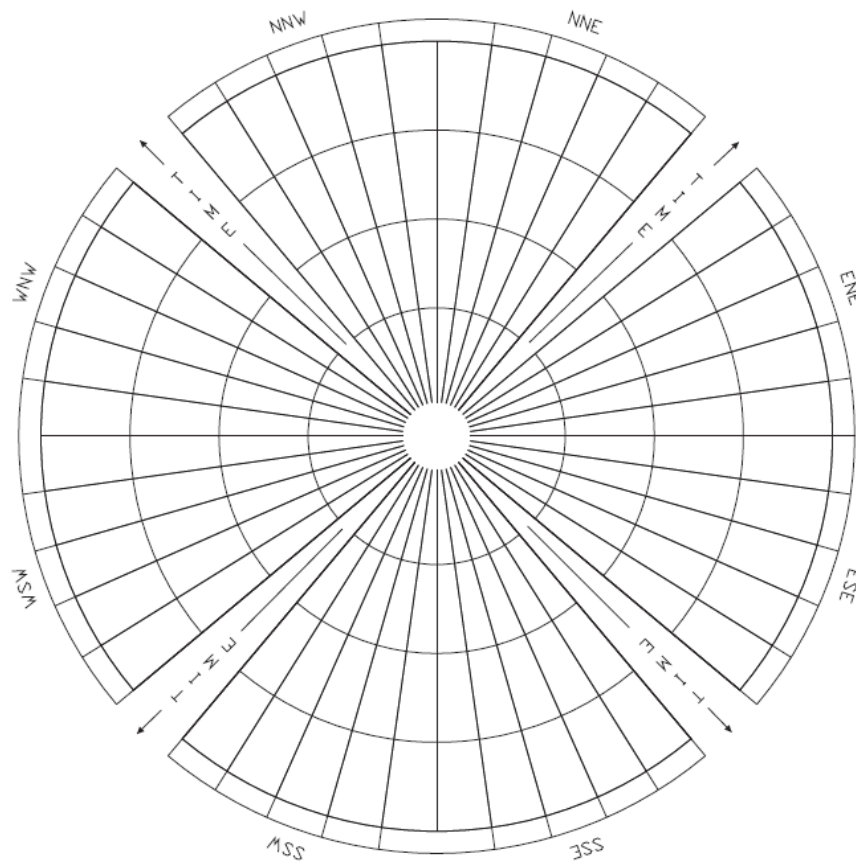


Figure 5.6: The graphic framework of the combined time-series graphs

The time-series graphs of the visualisation are used to track a variable associated with cinema venues against time such as capacity, number of screens, or distance from the CBD, and can therefore (in the case of capacity and screen numbers) show the change to these variables over time. By placing the time-series graphs radially for the eight cardinal directions, the simplistic graphic depictions are enhanced to represent an important spatial component of the data and therefore provide greater meaning for the data and subsequent interpretation and analysis. The time-series approach to the framework holds many benefits, including allowing the entire period of interest to be presented in one holistic image, to track the progression of a cinema over time, and view a cinema's lifetime in its entirety.

5.5.2 From Point to Line

The locations of the cinema venues were collected as point coordinates and stored in the database as coordinate pairs (see Chapter 4). For each individual cinema venue, after the coordinates are used for the spatial classification, the exact location of the venue is no

longer required. This is because the point based event data has not been represented as point features, instead these positions are transformed into lines that rest within the spatial framework. As a result, each line in the visualisation represents an individual cinema venue. There are a number of reasons for this transformation. Because of its continual nature, a line can be tracked through a time-series far more effectively than a point which results in tracking the progression of a cinema throughout its lifetime. Another advantage of using lines instead of points for representing the venues is the capacity for greater variability. Just as a point can vary the primary visual variables of size, shape, and colour, so too can a line through line width, style, and colour. When these graphic elements are transferred onto the graphic space, a linear feature can vary in its shape (through changes in direction and curves) and length however, a point cannot. This means greater flexibility in use and also greater capacity for representing and communicating multivariate data.

This approach is not new for time-series graphs. For example, countries or regional areas are compared in terms of demographic statistics such as population, percent rural, crude death rates etc, and this is often done graphically over time using time-series graphs (Beveridge 2002; Carter 2008; Norman et al. 2008). Geographically, countries are usually represented as points or area features, but when transferred to a graph, they are represented as lines in order to effectively track changes. However, these lines rarely have a spatial component apart from a location name, and when trying to graph a large dataset, the graph becomes cluttered and hard to interpret. This research has improved the spatial dimension of time-series graphs by creating a more position oriented graph using distance classification and representing the lines over a spatial directional framework. Each line, or in this case each cinema, is given geographic context and the ability to be compared to a large number of entities.

By combining the graphic framework and visual variables, it is possible to represent multiple variables in the one display and depict the time in which each of these variables changed. For example, Figure 5.7 depicts the history of a cinema venue between 1946 and 1985. The length of the line indicates the lifetime of the cinema, and we can see that it closes in 1985. The central axis shows capacity, and therefore any change in the direction of the curve indicates a change in capacity (a change occurred in 1962, showing a large decrease in capacity and then again in 1981, showing an increase to approximately 1500). The colour, line style and line width indicate additional variables; distance, primary

purpose, and number of screens respectively. By considering a cinema venue not as a location but as a historical lifetime, it is possible to embrace a more abstracted view of space and achieve a more holistic and multivariate representation for comparison.

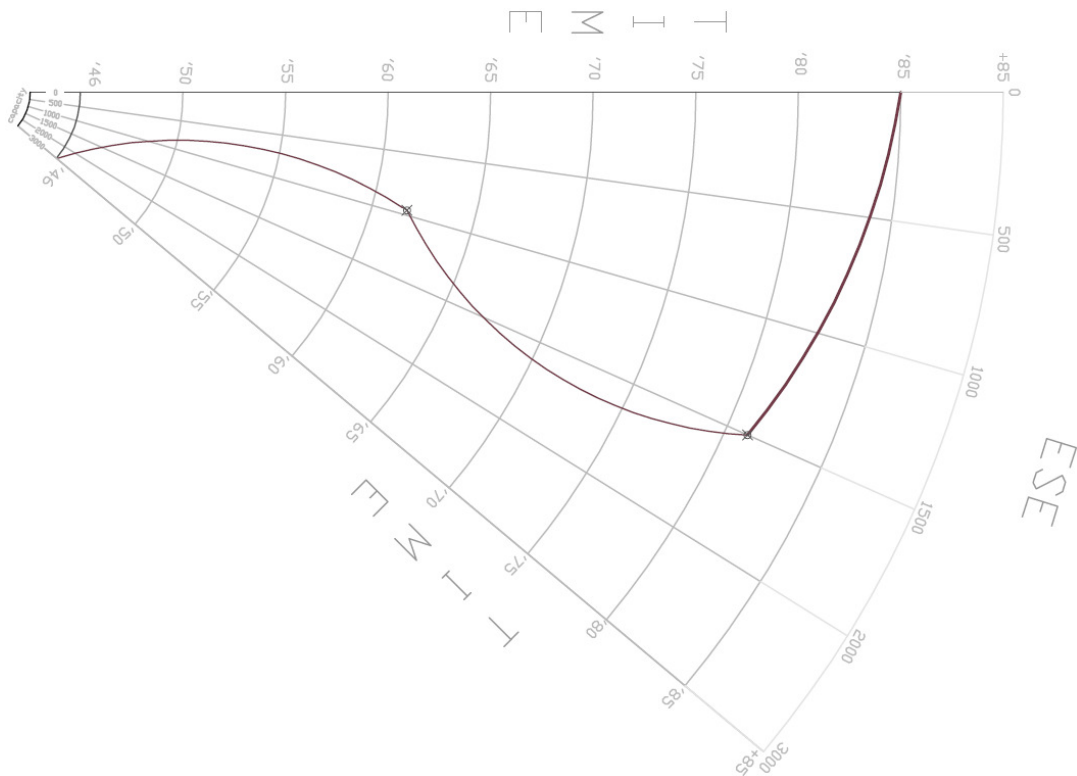


Figure 5.7: The history of a single cinema venue

5.5.3 Length and Change

Due to the importance of change over time for historical research, the ability to visually communicate change of historical spatial data is of great importance. Detecting change, the type of change, and the time of change is possible because of the holistic display using time-series graphs, and representing each venue as a line. Indeed, it is possible to track every individual cinema venue separately throughout the expanse of the time-series graph and identify the time of change and the type of change that took place.

The length of the line represents the lifetime of the cinema. A short line indicates a cinema that only operated for a short period of time, whilst a long line indicates a cinema that has a greater lifespan. Therefore length is a variable that is always applied to cinema longevity;

for a venue to exist they must operate for a period of time, even if it is brief. Where a line ends on the time-series graph corresponds to its closing date and always ends at the timeline axis. The reason for this is to emphasise that it is a closure and for the ease in visual comparison of different geographic areas. It does not mean that the variable that dictates the shape of the line changes. For instance, it doesn't mean that the capacity is now at zero, or that a venue 20 kilometres away from the city relocates to the CBD. Instead, it simply means that it no longer exists as a cinema venue and therefore no variables can be applied to it.

Changes to variables over the lifetime of the cinema (or length of the line) are indicated by changes in the visual variables used to depict them. For example, the visual variable of colour can vary to indicate a change in a venue variable such as ownership or number of screens. Line width may change to indicate a change in capacity, or line style change from dotted to continuous may indicate a change from live theatre to cinema. Where these changes occur in relation to the time-series graphs indicate the time of change.

Change can also be detected in the shape of the line itself and reflects a change in the variable applied to the axis as plotted against time. A curved shape is always used to indicate this variable because it can eliminate clutter of straight lines and can also highlight whether the change is increasing or decreasing from the previous value. For example, Figure 5.7 shows a single cinema venue between 1946 and 1985. During the cinema's lifetime there are many associated changes as discussed in the previous subsection. The axis of capacity shows an original value of 3000. If this value did not change throughout the operation of the cinema it would simply show a curved line from 1946 to 1985 on the timeline axis. If this line was straight, then another venue of the same capacity and the same closing date would not be seen as one would be on top of the other. The curved line has greater flexibility for it allows the shape to be manipulated slightly so both cinemas can be seen. The changes to the curves indicate a change in capacity. Again, curves are used because it prevents visual clutter, but it can also indicate the type of change. An outward curve indicates an increase whilst an inward curve indicates a decrease. This is useful in times where the value only changes marginally and would be difficult to decipher visually if the line was straight. The line would not change enough to detect change. But since the line is curved, we know whether the value either decreases or increases slightly, which can make a big difference in analysis.

5.5.4 Geographic and Temporal Analysis

The ability to create a single display for the analysis of the multivariate data was identified in Chapter 2 as a current challenge in visualisation research (Jern and Franzen 2006; Klippel et al. 2009). One of the main advantages of doing so is the simplification of analysis over time. Within the developed visualisation, the main functions of analysis and comparison can be achieved in a single display due to combining multiple variables, the spatial dimension, and the entire temporal span. It is possible to visually analyse the changes and characteristics of individual venues and to compare individual venues to other venues in the same area. Visual comparisons and pattern detection can be made for geographic, attribute, and temporal characteristics; we can look at geographic and temporal patterns of change, temporal relationships between variables, and differences and similarities over different areas. An additional analysis process involves the manipulation of the main display through selection and filtering those venues based on attribute and spatial classification. This allows certain aspects to be investigated more thoroughly and relationships between variables to be viewed clearly and simply. Figure 5.8 shows a set of data depicting two selections. In this case, the user has specified to view only those cinemas with a capacity of 0 to 500 (Figure 5.8a) and a capacity of 500 to 1000 (Figure 5.8b) in order to simplify the results and make the interpretation of patterns clearer.

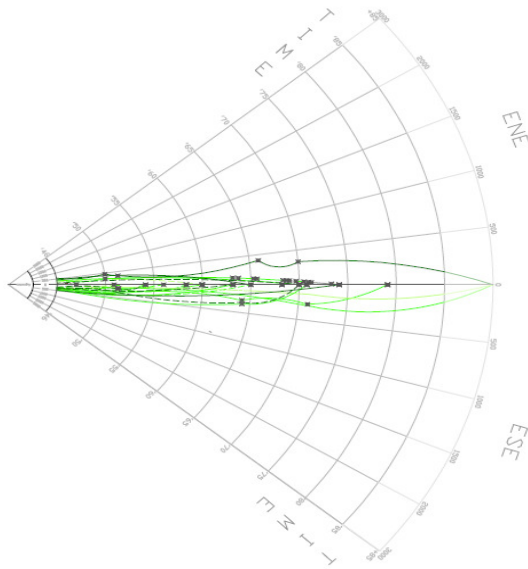


Figure 5.8a: Eastern venues with a capacity of 0 to 500

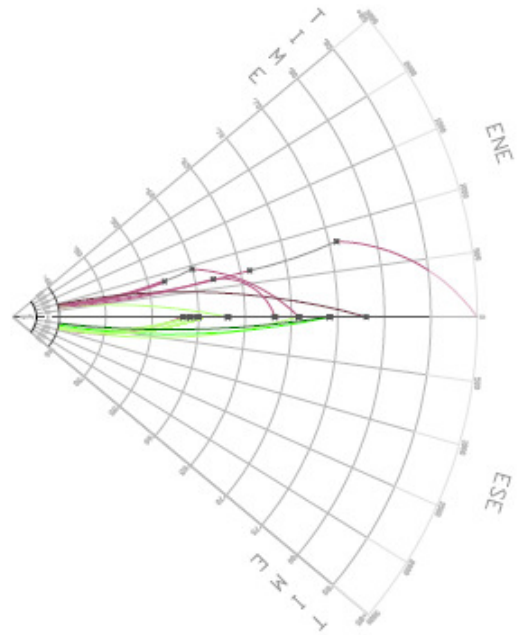


Figure 5.8b: Eastern venues with a capacity of 500 to 1000

5.5.5 The Three Level Visualisation

The venue data level is the main focus of the visualisation and analysis concerning roughly 99% of the data. This section (section 5.5) has addressed only those developments concerning the venue level. The other two levels of data, industry and social events, exist within the same framework but act as additional tools for aiding in the analysis process. The *temporal* framework discussed here outlines the three level approach to the visualisation structured around the temporal theory of historian Fernand Braudel.

As discussed in section 5.4.2, each level of information (venue, industry, and society) corresponds to a separate level in the visualisation resulting in a display of three planes which can be superimposed upon one another when needed. The supporting two levels of cinema industry and social events have been given the functionality of being able to be “turned on and off” when the information is needed and to compare events across the different levels for different times. These two levels contain a time-series graph of the events; however they are not given any spatial context because they relate to the entire geographical extent of Melbourne. As a result, each event sits on the time-series graph and is displayed concentrically around the graphic (Figure 5.9).

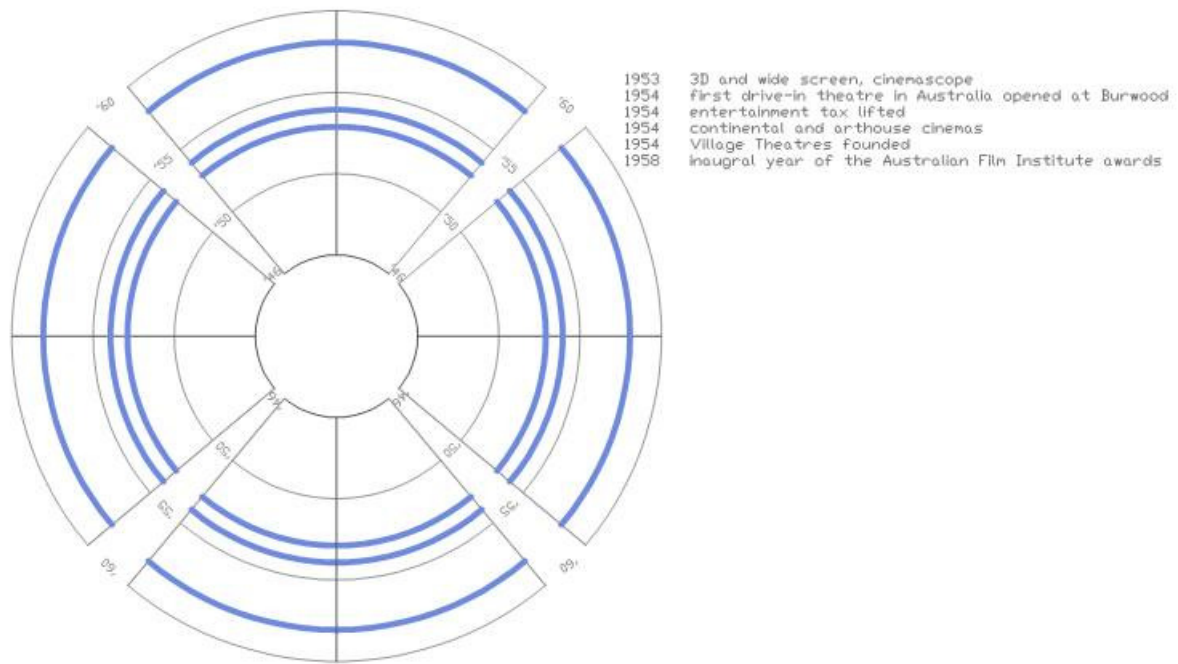


Figure 5.9: The visual representation of the cinema industry tier

Such functionality ensures that temporal associations can be made between events over each of the layers and can be visually distinguished by where they sit in relation to each other. This can assist in the analysis of the venue data, can lead to further investigation of interesting findings, produce more questions to be asked of the data, and demand more details of possible causation.

5.6 Conclusions

The resultant visualisation method provides the capabilities of communicating and visually analysing historical multivariate point data in a holistic view. The development of this final output has been outlined in this chapter from concept to creation. It has been found that in order to successfully communicate and visually analyse historical spatial data, it is necessary to stress the temporal aspects of the information without disregarding the geographic. By incorporating time-series graphs into the visualisation and extending the ability to represent spatial information more effectively, it has been identified that the tracking of historical events and entities over time is achievable. Considering the different ways in which historians handle time within historical scholarship led to the inclusion of

Braudel's *Plurality of Social Time*, which formed the temporal structure for the three levels of history. This not only provided context for the venue data, but has also demonstrated that differing concepts of time can be incorporated into spatial visualisations.

Within this chapter, the research has answered the question put forward by Tosh (2006) in relation to the three levels within Braudel's theory, who specified that "the problem... is how to convey the coexistence of these different levels in a single moment of historical time". This question has been answered by developing a visualisation which provides an alternate approach to the problem of conveying the coexistence of the different levels – by turning to visual communication in abstract graphic form instead of the written word.

The developed visualisation method has addressed the first Research Question which asks *how can historically changing, multivariate, spatial data be analysed and communicated visually?* through an innovative approach to visualisation. This question has been developed further within this research by answering it in a way that challenges all aspects – by representing all components within one holistic display and with the one technique. As identified in Chapter 2, this has been tackled by only a rare few. However, the technique developed in this chapter has provided an alternate method for visualising such data without the reliance on complex interactive computer displays. The following chapter provides a means to validate the success of this visualisation through applying the method to each of the geographical questions.

6 *Application and Evaluation of the Visualisation Method*

6.1 *Introduction*

Assessing Research Questions 1 and 2 that ask “how can historically changing, multivariate, spatial data be analysed and communicated visually?” and “how can temporal change of static entities be represented using spatial technology?” requires not only the development of a visualisation method, but the validation of the visualisation method to successfully represent, communicate, and analyse the geohistorical information. This is assessed by applying the method developed in Chapter 5 to the Case Study of the history of Melbourne’s cinema venues between 1946 and 1986. In particular, the developed visualisation method is applied to each of the three Geographical Questions outlined in Chapter 4, which are:

- 1) *The longevity of Melbourne cinemas operating in 1946*
- 2) *The openings and closures of cinema venues between 1950 and 1970*

3) *The operation of large cinema chains*

Each of the visualisations tailored to the Geographic Questions are created using the relevant cinema venue data (spatial, temporal, and associated variables) and their representation is discussed in section 6.2. The visualisation method is then assessed for the ability to analyse and identify patterns and relationships that the data hold through visual interpretation.

6.2 Applying the Visualisation to the Cinema Geographic Questions

The multivariate, temporal, and spatial capabilities of the visualisation method have been developed for historically changing data, as discussed in Chapter 5. But without applying the method to existing collections of historical information, it is not possible to show that the method is suitable or that it can provide us with an alternative to written explanation for understanding history. The Case Study of the history of Melbourne's cinema venues offers an excellent source of multivariate, temporal, and spatial data to evaluate the suitability of the developed method. The three Geographic Questions identified in Chapter 4 provide three different scenarios for which the data may be applied and evaluated, all of which ask something different of the data, thereby testing the visualisation's flexibility and ability to adapt to different historical variables, time scales, and spatial distributions.

Cinema venue locations, as specified for each question in Chapter 4, were placed within the spatial direction and distance framework in order to classify the data as outlined in section 5.4.1. This took all venue geographic coordinate locations and transformed them into classes of cardinal direction and distance from the CBD. All venues were queried in *ArcGIS 9* and relevant attribute information was extracted for applying to the visualisation. Each of the Case Study visualisations were created using *AutoCAD 2007*, a computer aided design (CAD) software application for 2D and 3D design and drafting (2011). Once all relevant data was extracted from the GIS, each venue was transformed to a line and all variables were assigned a visual variable or framework dimension based on data suitability. The process of creating each of the visualisations for the specific Geographic Questions is addressed below in the following sub-sections.

6.2.1 Question 1: The longevity of Melbourne cinemas operating in 1946

The question of the longevity of Melbourne's cinema venues includes a large temporal span of 40 years, 140 venues, and both numerical and type classification. As specified in Chapter

4, the three data components needed for the visualisation (spatial, temporal, and attribute), are specific to each Geographic Question, although they are all applied to the same technique. The radial axis component of the visualisation framework was adjusted for the specifics of the Case Study scenario, resulting in radial time divisions spaced at five year intervals and spanning the 40 year period from 1946 to 1986. Distance classification was treated like all other attribute variables for the cinema venues as explained below.

Converting each of the venues to linear symbols required representing each of the attribute values using linear visual variables (style, width, and colour) and the central axis (line shape). Table 6.1 lists all attribute values and their associated representation. Since a change in shape is instantly recognisable in the visualisation, the capacity attribute was assigned the central axis divisions as this was an attribute that changed the most out of the variables. The number of screens was chosen to be represented by line width as a numerical number can be easily interpreted with the thickness of a line (the thicker the line the greater number of screens). Colour is attributed to distance from the CBD because of the suitability of graduated distance classification to graduated colour classes. Graduated colours for the six classes were obtained using the colour principles developed by Cynthia Brewer (1994) as a guide to colour choice for maps. The six colours were chosen with the aid of an interactive website developed by Harrower and Brewer (2003), designed for users to choose the number of divisions and the nature of the data, whether it be divergent, sequential, or qualitative (see Brewer and Harrower 2009). In this case, six sequential classes were selected ranging from a dark purple through to a dark green. Table 6.1 also outlines each of classes within each variable and the symbol assigned to each.



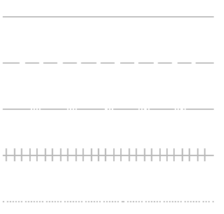
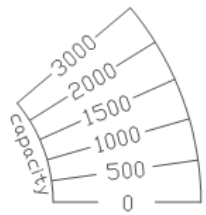

Visual Variable	Cinema Variable	Values
<i>Colour</i>	Distance from the CBD	 <ul style="list-style-type: none"> 0 - 1 km 1 - 5 km 5 - 10 km 10 - 20 km 20 - 50 km 50+ km
<i>Line Width</i>	Number of Screens	 <ul style="list-style-type: none"> 1 screen 2 screens 5 screens 6 screens
<i>Line Style</i>	Primary Purpose	 <ul style="list-style-type: none"> cinema live theatre hall/institute gallery unknown
<i>Central Axis (Line Shape)</i>	Seating Capacity	
<i>Point Symbol</i>	Time of Change	 <ul style="list-style-type: none"> time of change

Table 6.1: Geographic Question 1 - representation of variables

Once each of the variables was assigned a visual representation, each venue (line) was drawn onto the framework with the relevant styles using *AutoCAD*. Figure 6.1 shows an example of a venue drawn on the framework with the characteristics of the longevity Case Study. Operating in 1946 and in the ESE direction of the city, the colour indicates that the venue is within the city's CBD and operates primarily as a cinema (as indicated by the solid line style). There are a number of changes to the shape of the curve occurring at two dates. This refers to changes in the central axis which in this case represents changes in seating capacity. From a venue of large seating capacity of approximately 3000, this was reduced as indicated by the inward curve to approximately 950 in 1962. During the year of 1981, capacity again changed, increasing to 1500 seats due to the instalment of an additional

screen (shown in the increased line width). The cinema however closed soon afterwards in 1985 as can be seen by the final position of the curve at the central line.

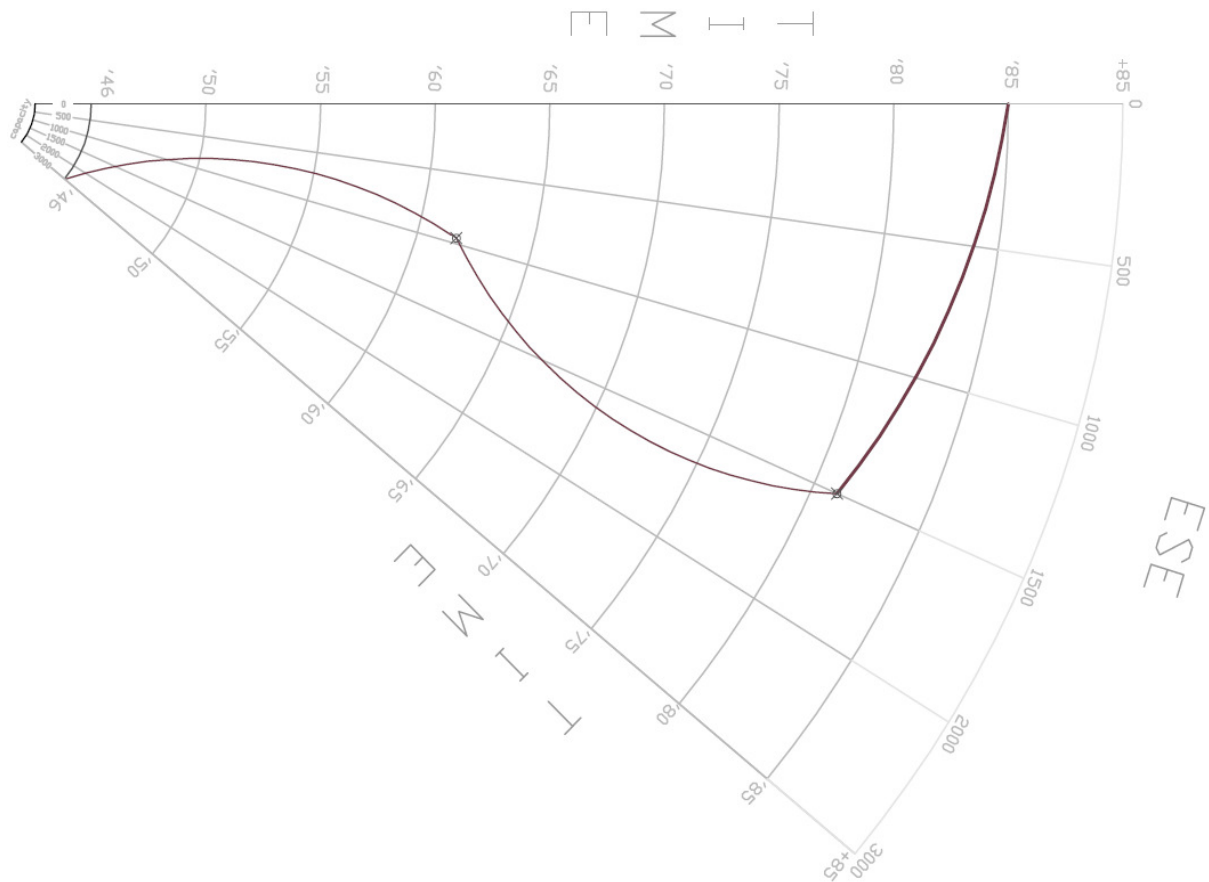


Figure 6.1: Single venue with Geographic Question 1 characteristics

The resultant visualisation provides a holistic representation of all 140 venues that were operating in 1946 (Figure 6.2 along with a larger format visualisation in Appendix C) all with the same detail that can be gained from looking at a single venue as in the example shown above. It is possible to view all attributes simultaneously and therefore analyse patterns and relationships between different variables over time. A sense of space is maintained due to the cardinal divisions of the framework, and through the design considerations applied in Chapter 5 it is possible to investigate spatial relationships, distribution, and differentiation through visual analysis.

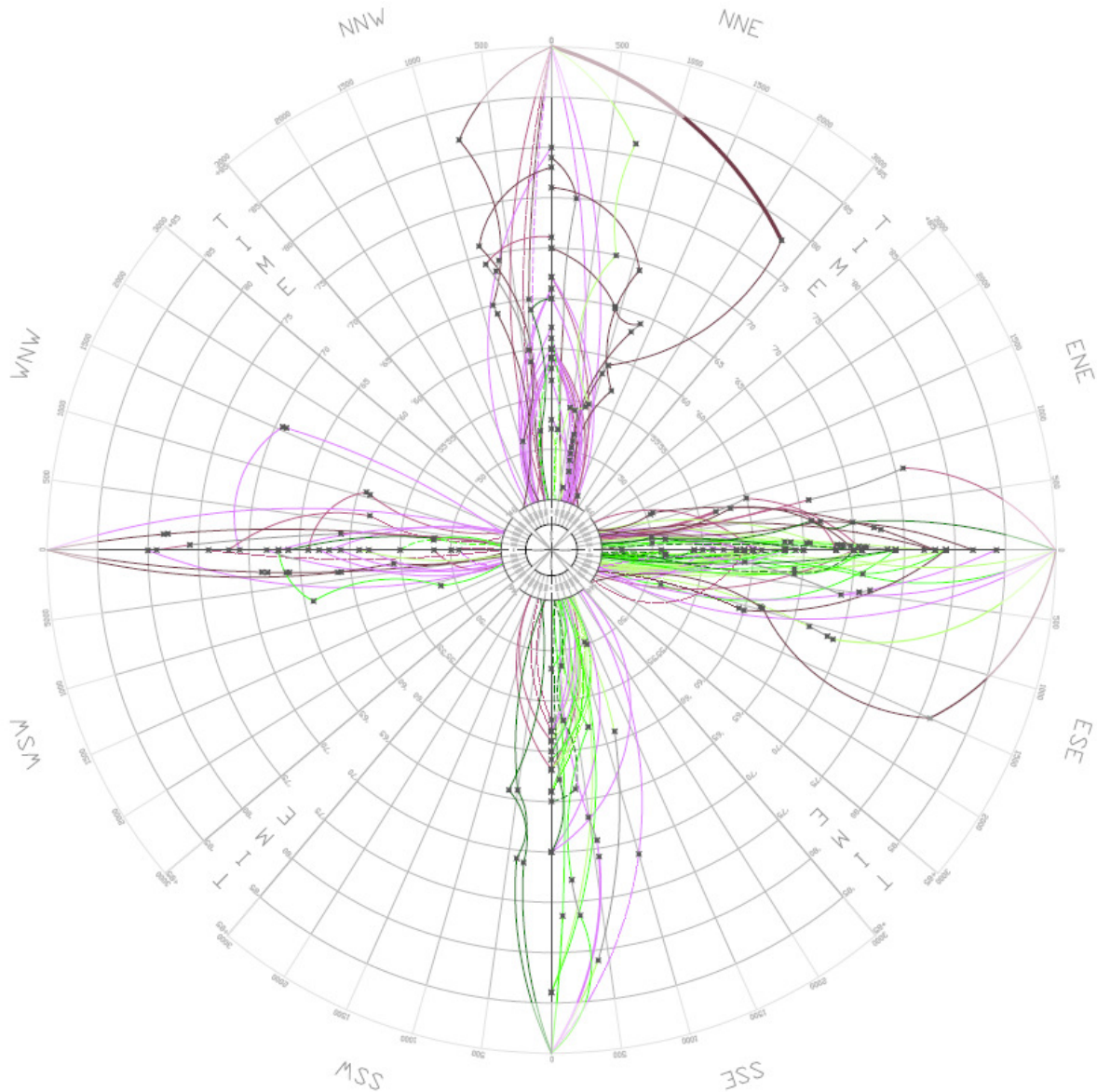


Figure 6.2: Visualisation of Geographic Question 1

6.2.2 Question 2: The openings and closures of cinema venues between 1950 and 1970

The visualisation framework of radial axis and cardinal division was adjusted to show time divisions of five year intervals and a period of 20 years from 1950 to 1970. As with the longevity question, the cardinal divisions formed the direction classification and were maintained from the original framework design of eight classes. Table 6.2 lists all the variables and their associated values and representation, and is based on the data requirements set out in section 4.5.

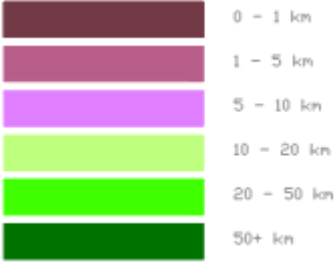


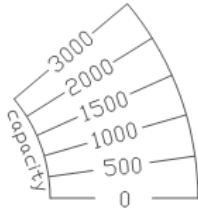

Visual Variable	Cinema Variable	Values
<i>Colour</i>	Distance from the CBD	
<i>Line Width</i>	Size of Cinema Company	
<i>Line Style</i>	Primary Purpose	
<i>Central Axis (Line Shape)</i>	Seating Capacity	
<i>Point Symbol</i>	Time of Change	

Table 6.2: Geographic Question 2 - representation of variables

The variables and representation styles used for Questions 1 and 2 are similar for they demanded similar aspects of the data. The main differences lie in the line width (in this case it corresponds to size of the cinema company), the temporal period, and the differentiation between openings and closures. To emphasise the differences between opening and closures, all openings were drawn as straight lines that projected out from the axis to the boundary of the visualisation, instead of curves (used in this case to represent closures). On the rare occasion where a cinema opened during the period but also changed capacity before the end of the temporal span, this was shown as a curve up until the point of change, and then a straight line until the boundary of the temporal span (see Figure 6.3).

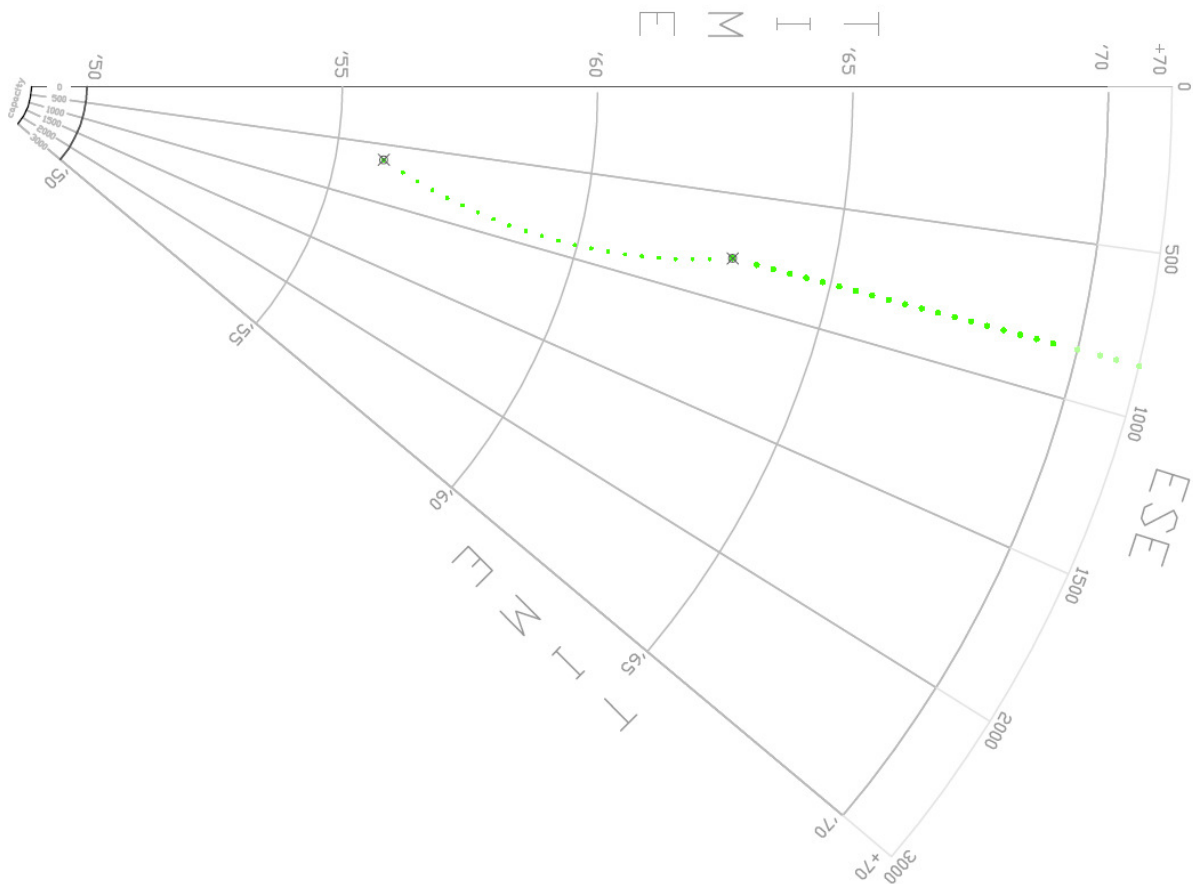


Figure 6.3: Single venue showing opening and capacity change

By placing each of the venues as lines on the framework, the resultant visualisation represents change over time, temporal spans, spatial location, and multiple variables with their associated change over time for all venues individually. An example of a venue opening and closure with the chosen characteristics of Question 2 is shown in Figure 6.4a and 6.4b respectively. The straight line depicted in Figure 6.4a represents a single cinema venue with an opening date of 1966 located between 1 to 5km of the city's CBD (as indicated by the colour) and in the ESE direction. The line style and thickness shows that the venue primarily operated as a cinema under a large cinema company. The lines position on the framework indicates a capacity of approximately 950, and all venue characteristics remain unchanged up until the end of the Case Study period in 1970. Figure 6.4b depicts a venue operating in 1950 and closing in 1962. The colour, width, and line style of the curve indicate that the cinema is located within 10 to 20km of the CBD, is operated privately, and exists primarily as a cinema venue respectively. The initial position of the curve in relation to the central axis shows a seating capacity of approximately 1600, and there are no changes to venue characteristics between 1950 and its time of closure.

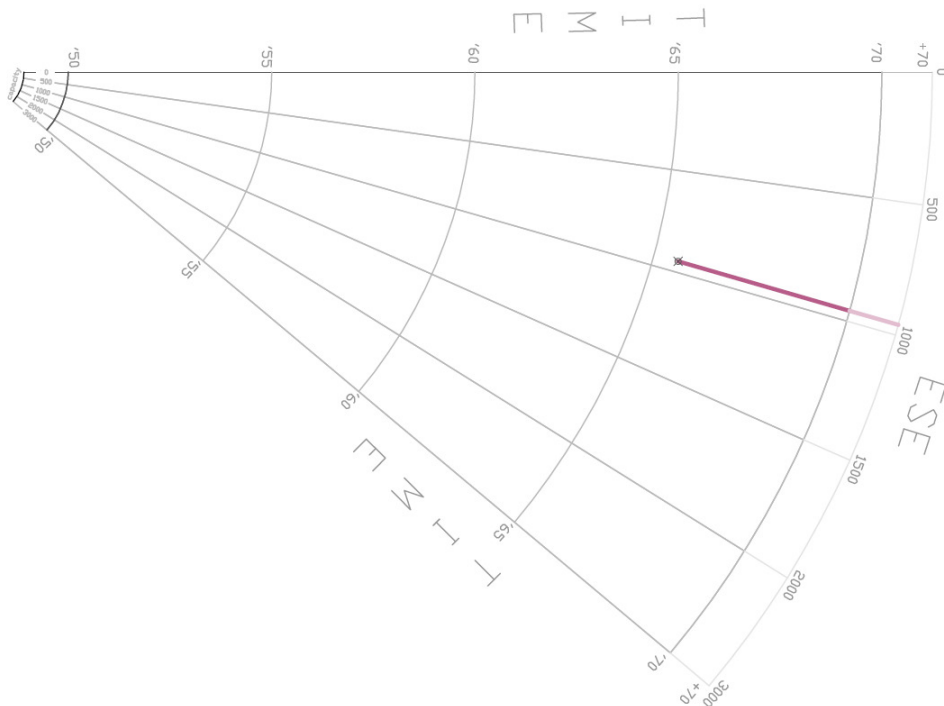


Figure 6.4a: single venue with Geographic Question 2 characteristics (Opening)

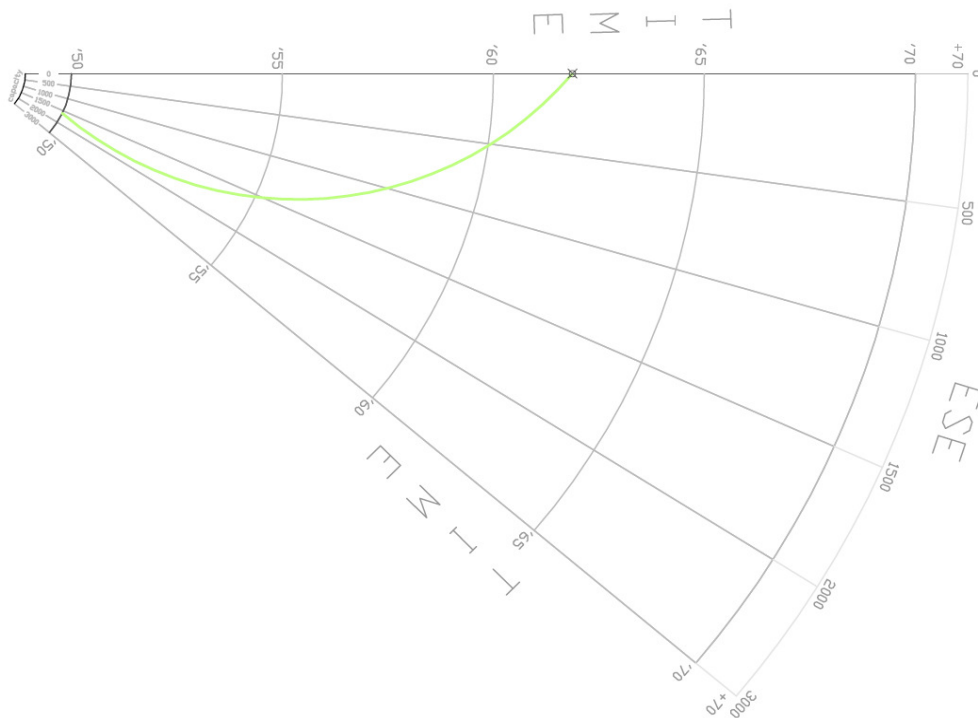


Figure 6.4b: Single venue with Geographic Question 2 characteristics (Closure)

When all venues are drawn on the framework, the final visualisation (as seen in Figure 6.5 and in larger format in Appendix D) reflects the stark differences between openings and closures during a time of great cinematic change, all of which are depicted in the one image. The degree of change, closure, and opening can be easily distinguished and compared both temporally and spatially.

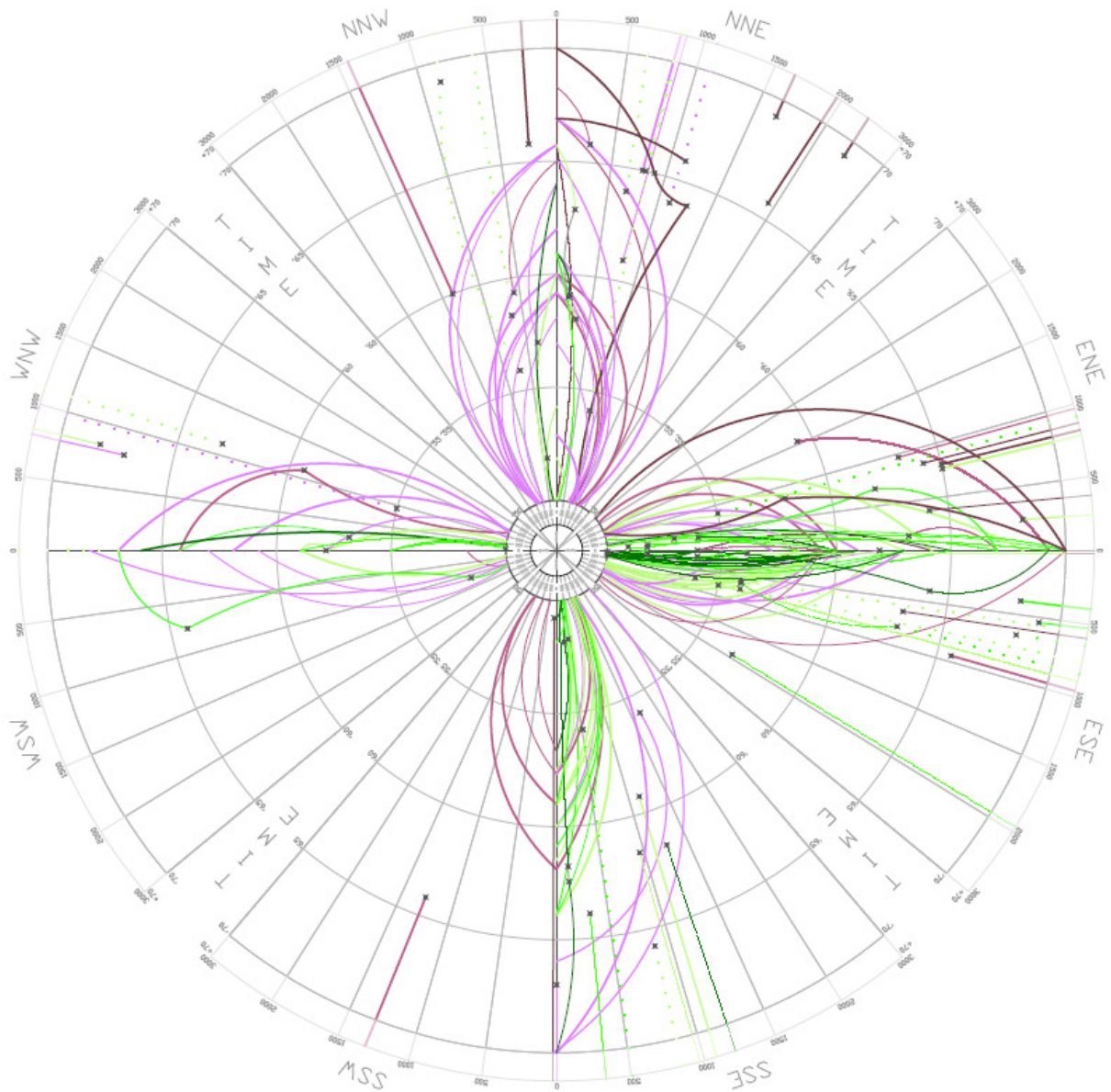


Figure 6.5: Visualisation of Geographic Question 2

6.2.3 Question 3: The operation of large cinema chains within Melbourne's cinema industry

In order to address the question of the success of Melbourne's large cinema chains, the visualisation focused on the visual differentiation of the cinema venue companies and the number of changes that took place within the lifetime of the cinema. The radial axis component of the visualisation framework was adjusted for the specifics of the Geographic Question to show five year divisions spanning the 40 year period from 1946 to 1986.

The chosen variables outlined in section 4.5 were transformed to linear visual variables of style, width, colour, and shape and are listed in Table 6.3.




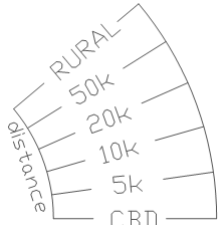

Visual Variable	Cinema Variable	Values
Colour	Name of Cinema Company	
Line Width	Number of Changes	
Line Style	Main Role	
Central Axis (Line Shape)	Distance from the CBD	
Point Symbol	Time of Change	

Table 6.3: Geographic Question 3 - representation of variables

Colour was attributed to the different cinema chains since the ease of visually detecting colour differentiation reflects the importance of differentiating between the chains. Since colour is one of the most visually dominating variables within the framework, the ability to distinguish between the different companies is very effective, and is based on the divergent colour Brewer principles designed for this purpose (Brewer and Harrower 2009) which are in opposition to sequential principles used in Questions 1 and 2. Line width was assigned to

represent the number of changes to a cinema venue, as a numerical number can be easily interpreted with the thickness of a line (the thicker the line the greater number of changes that took place). Whether the cinema venue was owned, managed, or leased by the company was represented by line style, and is suited especially for closer examination and analysis. The central axis of the framework is defined by distance from the CBD. As with Questions 1 and 2, a graduated visual representation was required for distance as it is itself a graduated variable. Sequential classes of colour were used in the previous case studies; however, colour in this case was used to distinguish the different companies. Instead, the central axis was deemed appropriate for representing distance as it could show the gradual change in classification; the closer to the central line the closer to the CBD. As a result, the shape of a line does not change in this case, as the location of a cinema venue does not change. This has therefore resulted in six divisions radiating out from the centre of the visualisation from the closest classification of CBD to 50km+. This highlights the flexibility of the visualisation to handle different types of data for each visual variable used.

Once each of the attributes was assigned a visual representation, each venue (each line) was drawn onto the framework with the relevant styles. Figure 6.6 shows an example of a venue drawn on the framework with the specifics of the cinema chain question.

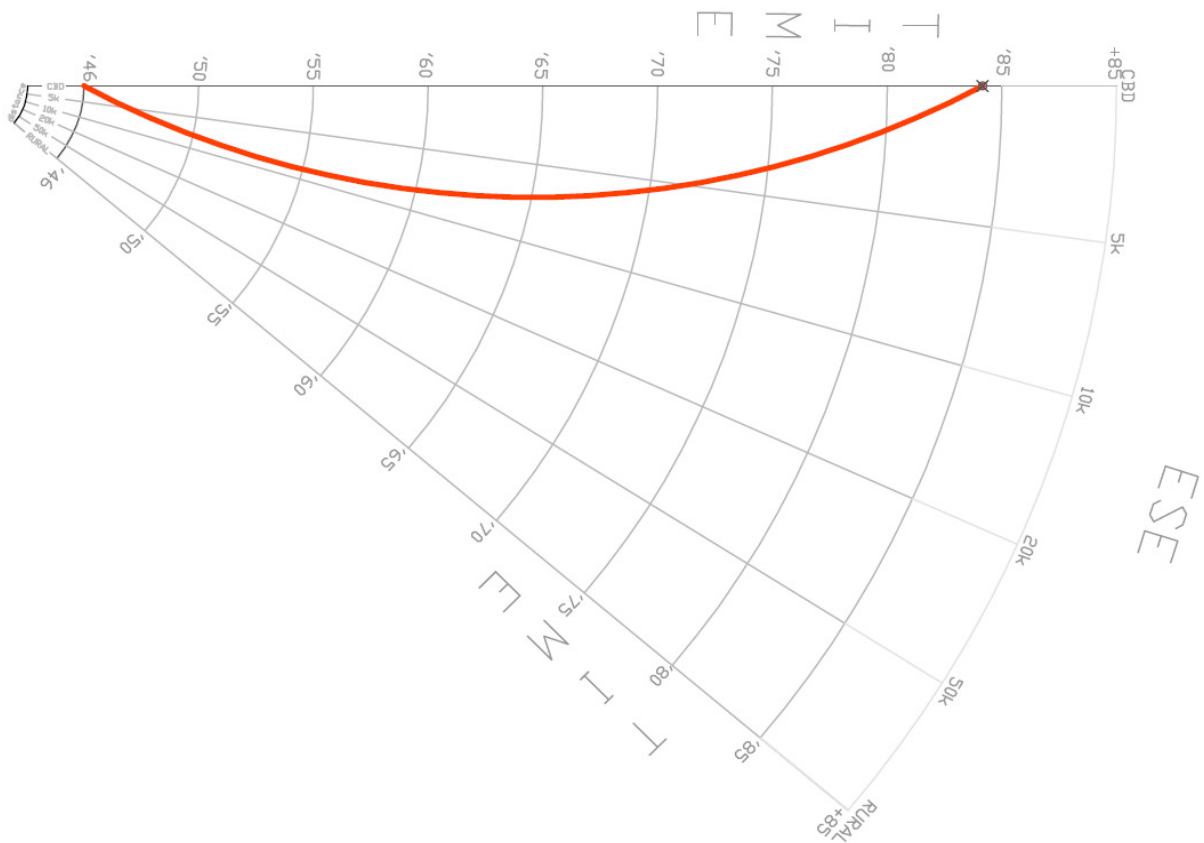


Figure 6.6: Single venue with Geographic Question 3 characteristics

Operating in 1946, the length of the line depicts the lifetime of the venue, up until its closure in 1984. During this time the cinema experiences four changes as indicated by the width of the line and is owned by the Greater Union Theatres as represented by the line style and colour respectively. The position of the curve on the framework provides us with the distance from the CBD (in this case it is located in the CBD itself) and lies within the ESE direction of the city. The final visualisation of all venues for Question 3 (see Figure 6.7 and larger format shown in Appendix E) provides a holistic display of venue locations, multiple variables, temporal span, and change over time. The visualisation allows you to visually analyse the chosen variables for all venues in both a geographic and temporal sense without resorting to complicated analysis of multiple images of differing geographic and temporal scales.

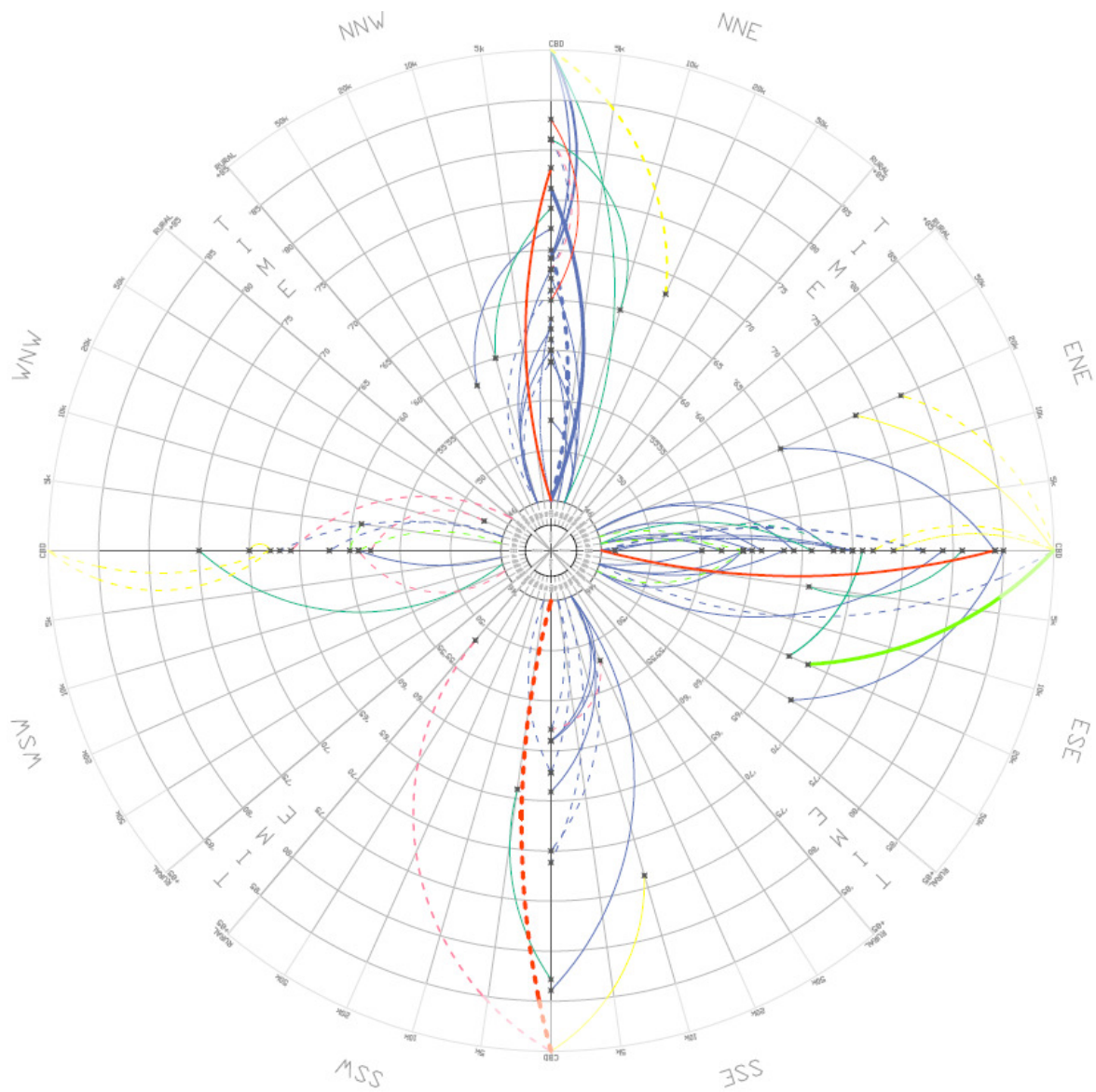


Figure 6.7: Visualisation of Geographic Question 3

6.3 *Evaluation of the Visualisation Method for Understanding the Spatial History of Melbourne's Cinema Venues*

The final visualisations addressing each of the geographical questions demonstrate that it is possible to incorporate all chosen elements of the data and depict each individual venue within the one visualisation. Yet, in order to evaluate the effectiveness of the visualisation for understanding the spatial history of Melbourne's cinema venues, and addressing the main aim of the research for representing and analysing historically changing, multivariate,

spatial information, the three visualisations will be examined to interpret patterns, trends, similarities, and differences within the data. Each geographical question will be examined separately and will also demonstrate the ability to incorporate other layers of event information and to visualise only selected and relevant data for enhancing interpretation. The three sub-sections below do not attempt to provide an interpretation of all the findings that can be made using the visualisations; instead they provide a summary of the type of information that can be extracted from the visualisations through careful observation and analysis.

6.3.1 Question 1: The longevity of Melbourne cinemas operating in 1946

Applying the visualisation to the question of longevity creates an overall picture of cinema venue distribution in 1946 (see Figure 6.2 and Appendix C). This is highly reflective of population distribution across the city, with a strong presence of cinemas within 10-20km and 20-50km of the CBD in the east and south eastern suburbs and within 5-10km in the north. The less populated western suburbs do not have a large number of cinemas which is also true of the south west. Yet, this pattern of spatial differentiation across Melbourne is not maintained once we look at these same cinemas in 1986. Only 28 of the original 162 cinemas lasted the 40 year span, and these cinemas produced a very different picture of geographic distribution. The once dominant cinemas located within 20-50km in the east and south east did not dominate those that survived, and the closer suburbs did not make up a high percentage after the 40 years compared to the first 20. Therefore, the spatial distribution and characteristics of cinemas change dramatically over 40 years of cinema operation and closure.

Focusing on the visualisation (Figure 6.2) to show cinema longevity it is possible to depict (amongst the highly varying lifetime of cinemas) patterns of longevity and cinema closure for historical venues. The convergence of lines for the period 1958 to 1962 show a peak in cinema closures during this time, and this is evident throughout the extent of Melbourne. Prior to this, there is very little change in cinema venue operation, with all cardinal segments showing very little cinema closures, especially in the north and south. When the

large number of cinemas in the eastern suburbs are plotted, smaller clusters of cinema closures in 1963, 65, 70-71, and 78-79 can be depicted. These small clusters are not evident in the other quadrants. Southern venues had small clusters in 1964 and 1970; the north shows a small cluster between 1965 and 1967; whilst the west does not show any further particular closure clusters.

These clusters invite the question of *what were the differences between those that survived to 1986 and those that did not last beyond 10, 20, or 30 years?* The peak period of cinema closures between 1958 and 1962 occurred at different distances from the CBD depending on direction. The majority of those that closed during this time in the east and south east were outer suburban theatres between 10 to 50km from the CBD, and the north and west were predominantly within 1 to 10km from the city centre. The vast majority of these venues (approximately 95%) experienced no change between 1946 and their time of closure – no changes to capacity, number of screens, primary purpose of venue, and no periods of temporary closure. In contrast, change occurred more readily in those venues that survived past this period of cinema decline. Of those cinemas that lasted until at least 1986, 21 of the 28 changed in some manner. These changes occurred at different times, but the majority take place either during the time of peak closures or after. Very few of these venues experience any change prior to this. The lack of change can therefore not be seen as a reason for failure, as the majority of those cinemas that survived the 40 year period did not change until either during or after this time, more in response to the closure around them.

What are the changes that occur to venues that survived past this period of peak cinema closure? The number of screens at a cinema venue (as indicated by line thickness) does not change from a single screen until the late 1960s. The visualisation clearly depicts that those cinemas that increased the number of screens survived past 1986, no multiple screen venues failed during this period. There is a dominance of inward curves, indicating that many of the venues decreased their seating capacity. This is particularly evident in the venues within the city's CBD. Those that decreased their seating capacity were single screen venues and survived past the period of mass closure, through until 1970 and beyond. The very large single screen city theatres with capacities greater than 2000 decreased their seating numbers dramatically in the late 1950s and 1960s. Those that increased their seating capacity in the city did so because of the addition of more screens as indicated by the change in line thickness and curve direction coinciding (see Figure 6.8). All city venues experienced some

change apart from one, and all survived at least until the 1970s. This high level of change in the CBD coupled with greater longevity seems to support the claim that much of the investments went into the city cinema's fight for survival at the expense of the smaller and later run suburban venues (Verhoeven 2009a). This investment manifests itself in the visualisation through changes in seating capacity, screen numbers, primary purpose, and temporary closures possibly for renovations as these usually occurred leading up to times of change.

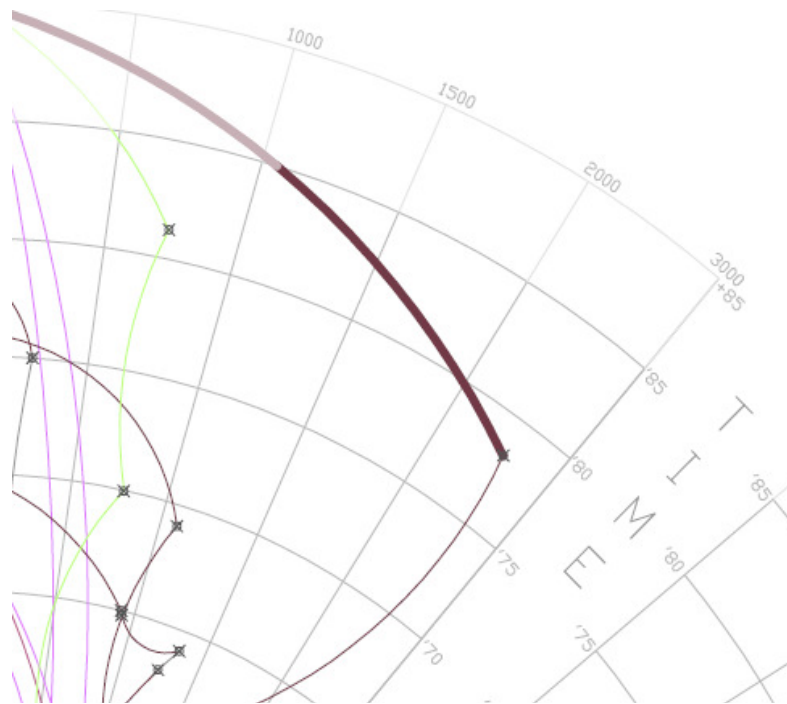


Figure 6.8: The relationship between increased seating capacity and screen numbers

Changes in capacity are easy to distinguish in the visualisation; however it is more difficult to ascertain whether capacity values had any relationship with longevity. It is possible to look at this relationship by selecting certain classes of capacity for comparison. For example, Figure 6.9 shows a comparison between those venues in the east that have a capacity of less than 500, between 500 and 1000, and greater than 1000. This does not change the data in any way; it simply makes it easier to read if some characteristics are difficult to distinguish once there are many records involved. Using the visualisation to explore the relationship between cinema capacity and longevity, it can be seen that each classification of capacity classes shown below depict very different characteristics.

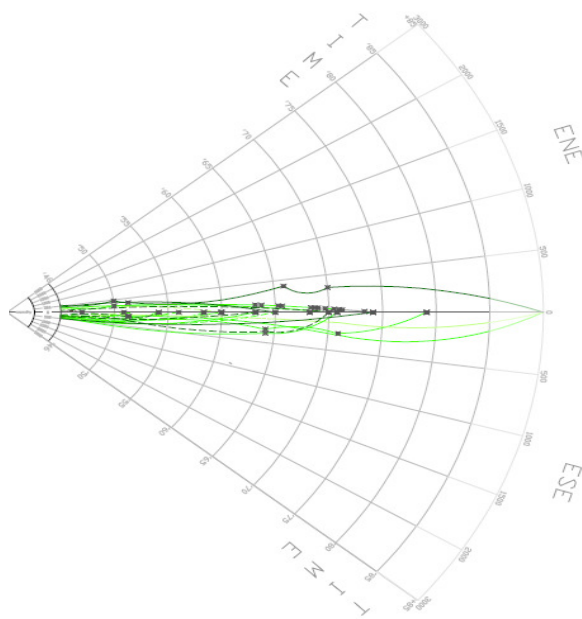


Figure 6.9a: Capacity of 0-500

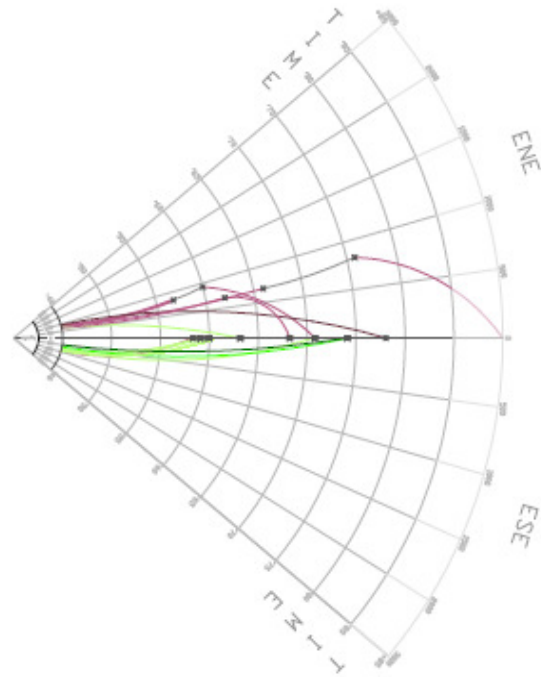


Figure 6.9b: Capacity of 500-1000

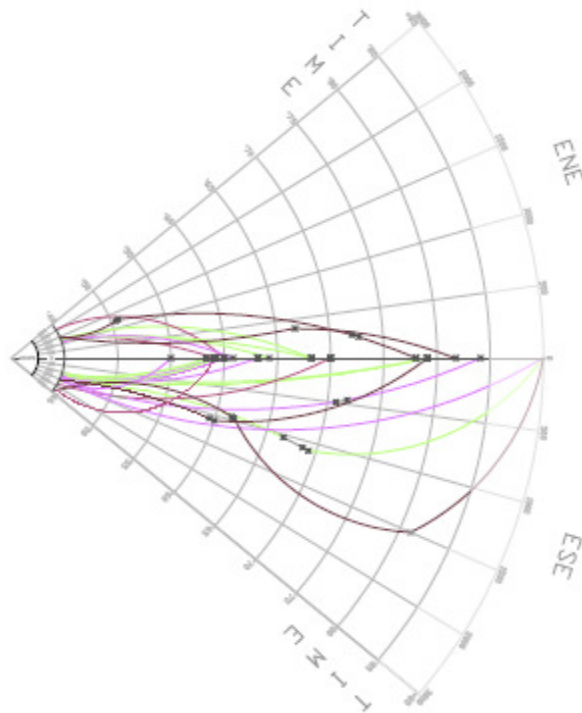


Figure 6.9c: Capacity of 1000+

Figure 6.9a of venues with a seating capacity of between 0-500 are mainly situated in the outer suburban areas of Melbourne and if there is a change in capacity, it is only minor. Only three go on to last the full 40 years, whilst most close prior to 1970 with a large number closing in the 1950s. Figure 6.9b on the other hand also includes venues that are closer to the CBD and show a number of closure clusters, in the late 1950s and around 1974.

However the inner suburban venues tend to last longer at this capacity but only one until 1986. Those venues with a capacity of over 1000 (Figure 6.9c) are a lot more varied, yet none are found in the outer suburbs. There are still a large number closing between 1958 and 1962, but there is a stronger presence of those closing after this in the 1970s and 1980s. The venues in this capacity class experience mainly large changes to capacity if change occurs. For both Figure 6.9b and c, only one venue is found to close before the peak period of 1958-1962, which is in contrast to Figure 6.9a where many close during this time.

By looking at the cinema venue data in relation to other layers of influence, it is possible to provide the interpretations with context and possibly greater understanding to develop reasons for patterns and relationships. For example, if we were to investigate more closely the devastating number of cinema closures in the outer suburbs in the east and south east over a 20 year span, the visualisation allows the inclusion of additional information in the form of influential events in the cinema industry and Melbourne's society. By combining these layers of information, it can be seen that the first drive-in theatre for Melbourne opened in Burwood in 1954 (see Figure 6.10).

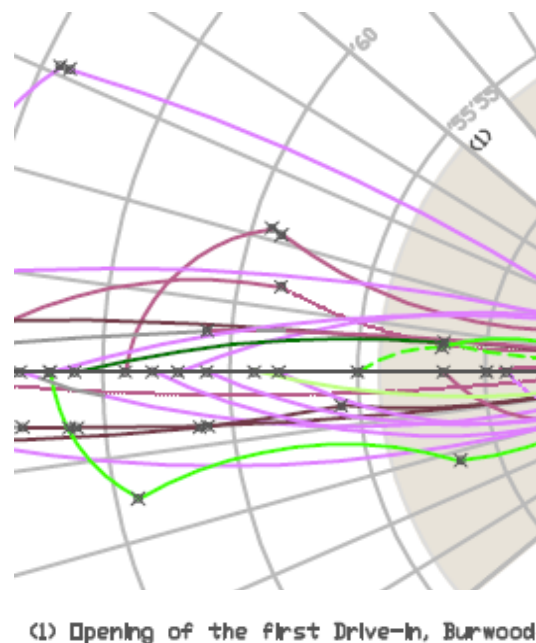


Figure 6.10: Venue and cinema event layers showing the first drive-in theatre in 1954

This outer suburban drive-in located in Melbourne's east was the first of many drive-ins to occupy large areas of land. Was it possible that drive-in theatre's in the outer suburbs created competition for the theatres in these areas, therefore contributing to their closures?

This additional piece of information can therefore be used to examine the relationship between drive-in theatre locations and suburban theatre decline through further research or the development of a visualisation that addresses this issue.

6.3.2 Question 2: The openings and closures of cinema venues between 1950 and 1970

The years between 1950 and 1970 have been identified as a period of wholesale decline in cinema venue operation (Collins 1987) (see Figure 3.3.2). By applying the visualisation to the openings and closures during this time, it is possible to investigate the different characteristics of these cinemas and identify spatial and temporal patterns for cinema venue operation (see Figure 6.5 and Appendix D). Most significantly, the visualisation shows a large number of closures over the 20 year period, but is dominated by closures between 1958 and 1962. This period of decline was also identified in the previous visualisation, but in this case shows not only the closures of those cinemas that were operating in 1946, but all those that opened after this time. The spatial arrangement is also very similar, with large numbers of outer suburban theatres closing in the east and south east, and inner suburban theatres in the north and west. By combining this period of closure with the layer of social events, it is possible to analyse the data in relation to the introduction of television, which many cinema historians believe was the reason for the large number of closures (Collins 1987). The visualisation can therefore be used to assess the temporal relationship between a number of related events and the venue data (as shown in Figure 6.11).

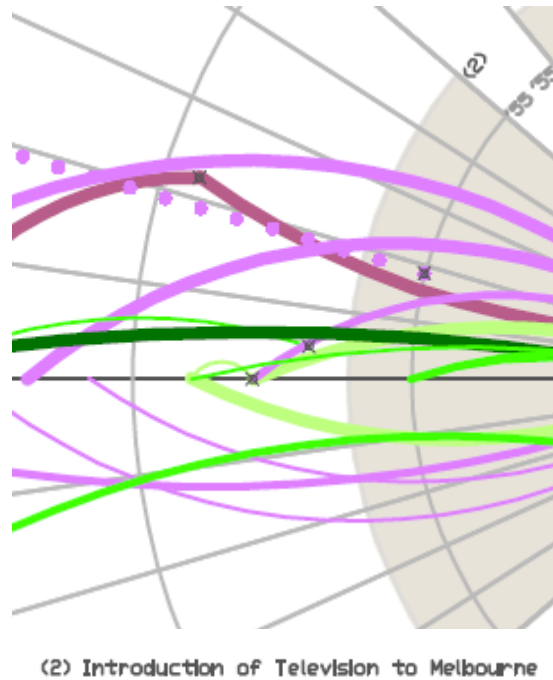


Figure 6.11: Venue and social event layers showing the introduction of television in 1956

Those cinemas that closed between 1950 and 1970 experienced very little to no change. For the majority of those that did change, they survived the peak period of closure. The visualisation shows that closures occurred amongst the privately owned cinemas as well as those owned by large cinema companies (as indicated by line thickness). The east shows a large number of halls closing in the outer suburbs, a pattern which is not obvious in other areas of Melbourne. Large capacity venues that closed during this period do not show any change in variables, however the majority of which last until 1970.

The number of cinema closures far outweighs the number of cinema openings. There is a temporal pattern throughout the extent of Melbourne that shows a stream of openings between 1963 and the late 1960s. These cinemas are found at all distances from the CBD. Prior to this, cinema venue openings are largely limited to drive-in theatres, the first of which appears in 1954 in the outer east. All of these drive-ins occupy outer suburban areas because of the need for space and are largely operated by large cinema companies. Many of the theatres that start to operate in the 1960s have capacities of below 1000. This is in contrast to many of those that closed, where capacities for many were between 1000 and 1500. This contrast is particularly evident in the east. A notable exception to this is the three large cinemas opening up in the CBD shown in the visualisation north of the city, all of which are owned by large cinema companies.

Comparisons between certain attributes can be made more effectively with the use of the selection/querying capabilities within the visualisation technique. This can be useful simply in eliminating unwanted information. For example, comparing results from two particular classes of distance is possible by placing two snapshots side by side or by only including the relevant information in the one visualisation. Figure 6.12 is an example where this would be useful. It depicts two visualisations comparing two distance classes of 1-5km and 20-50km of venues. This same data is also depicted in Figure 6.13, showing both classes in the same visualisation. By eliminating all other venues, both approaches ensure that the focus can be given to the relevant data and comparisons can be made more readily.

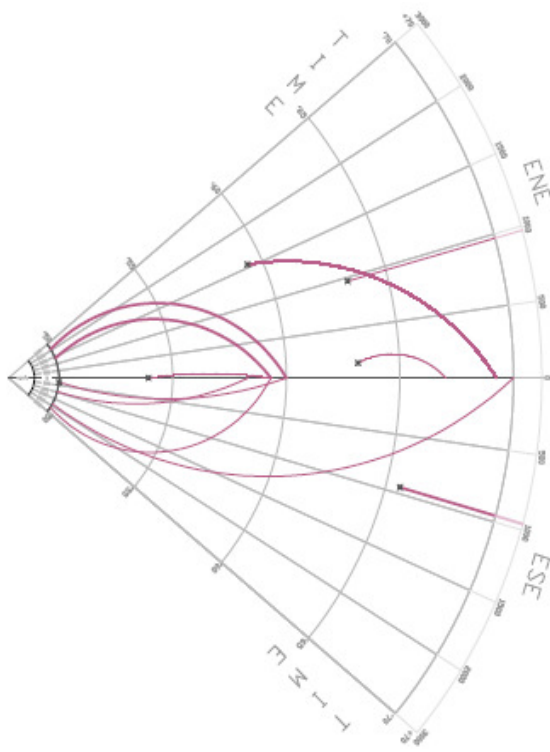


Figure 6.12a: Venues within 1-5km of CBD

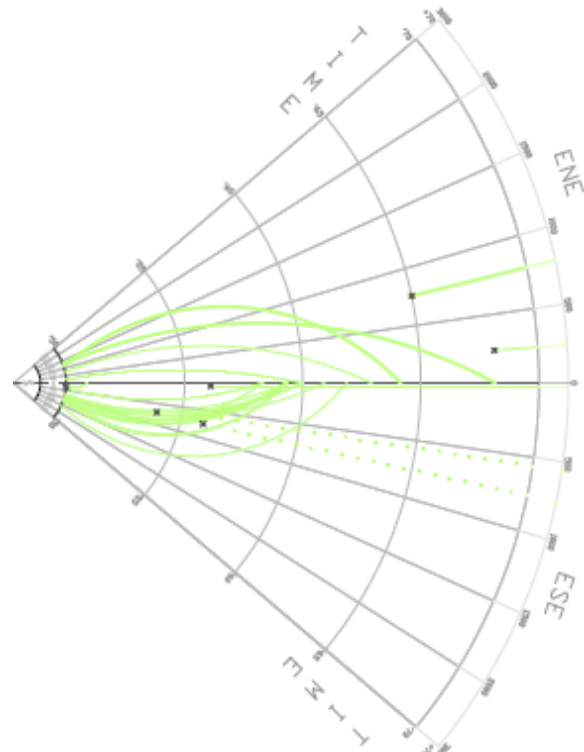


Figure 6.12b: Venues within 20-50km of CBD

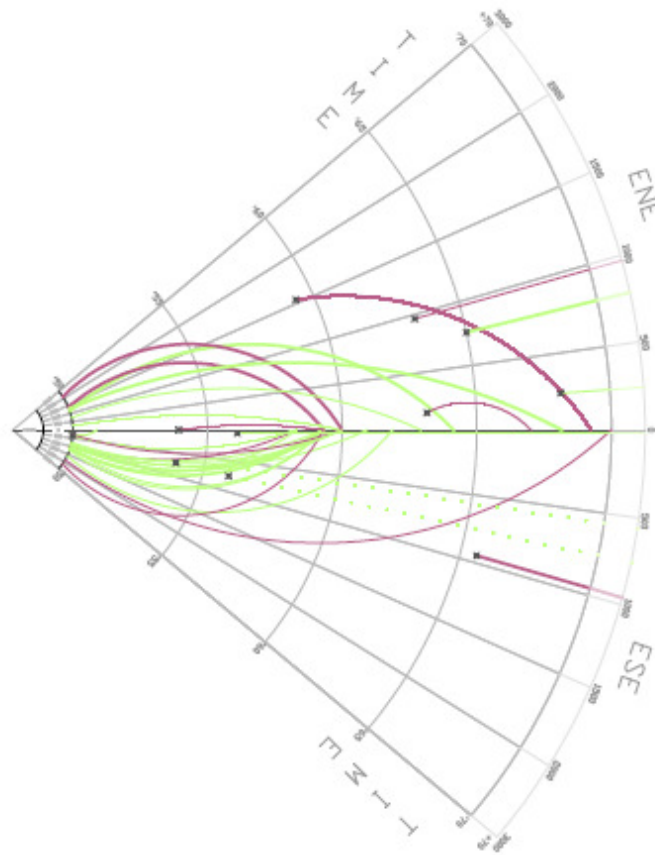


Figure 6.13: Visualisation showing venues within 1-5km and 20-50km of CBD

6.3.3 Question 3: The operation of large cinema chains within Melbourne's cinema industry

The operation of large cinema chains, their success or failure, had a strong influence on cinema practice in Melbourne for they were a strong presence in the industry. Plotting all venues for six cinema chains on the visualisation framework creates a picture of cinema chain geographic distribution over 40 years of operation (see Figure 6.7 and Appendix E). The more densely populated north and east of the city have a strong presence of large cinema chains, the majority of which are found within 20km of the city centre. In the north, there are only two cinema venues that are located outside the 10km mark of the CBD, and these do not appear until 1958 and 1968 respectively. The only rural cinemas operated by large cinema companies are found in the less populated regions of the west and south. The extensive period of closures already highlighted in Questions 1 and 2 (see Figure 6.2 and 6.5) are also easily distinguished in the visualisation for Question 3. The sheer number of closures is also evident if we look at the longevity of those cinemas that were operating in

1946; for only a handful of these cinemas lasted past 1986. We can see a cluster of new cinemas opening between 1965 and 1975, occurring after a short break from the peak of closures, distributed mainly in the east and north of the city (see Figure 6.14 for eastern cluster). The lack of new cinemas opening in the west outside of the CBD is clearly shown. In fact, there are no large cinema chains operating in this area past 1975.

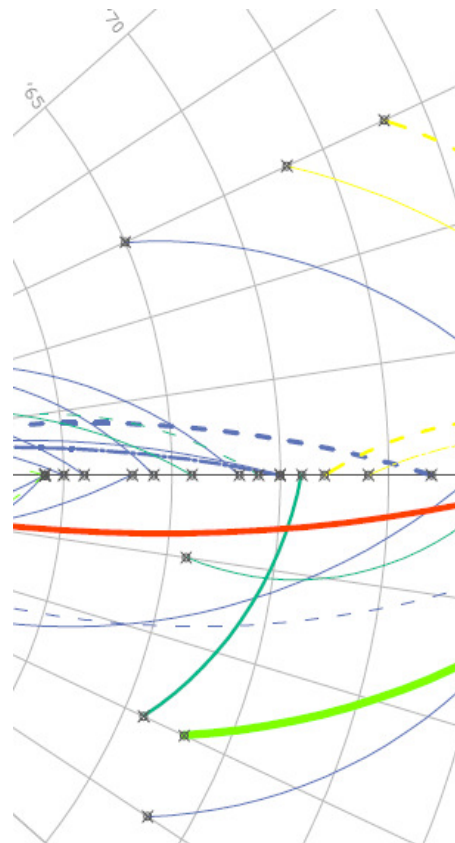


Figure 6.14: Cinema venue openings in the east

Further associations and findings can be found when we interpret the data in relation to the other variables of change, name, and company role. The dominance of the blue curves is indicative of the dominance of *Hoyts* cinema venues. The large numbers of *Hoyts* cinemas are found throughout Melbourne and at varying distances from the CBD. However, the majority of these cinemas do not survive past 1970, and of those that do they experience some form of change indicated by the width of the line. This suggests that a *Hoyts* cinema operating in 1946 would most likely not last past 1970 unless they made adjustments to their cinema such as adding another screen or decreasing seating capacity. Another interesting association is the comparison between *Hoyts* and the *Greater Union Theatres*. All *Greater Union Theatres*, represented in red, that existed in 1946 adjusted to the times and had a longer lifespan than the average *Hoyts*; making a possible association between change and

longevity. The cinema chain *Cosmopolitan* is also a company that made little changes to their venues and were also not very successful in terms of longevity. For those venues that opened up after 1946, none of them survived even 20 years of operation.

The areas in which the cinema companies operate also differs. *Greater Union Theatres* did not operate outside the CBD whilst others such as *Kirby's Theatres* are located mainly in the outer suburban areas. The south east is dominated by *Hoyts* cinemas, all of which were operating in 1946 and at a range of between 1 and 20km of the CBD. The emergence of the *Village* cinema company in the late 1960s made its mark in the CBD as well as outer suburban locations, and all survived past 1986. The outer suburban theatres took up operation in these areas with very little competition. Most cinemas that were operating in similar proximity (in the same direction and distance classifications) either closed prior to their opening or soon afterwards. The visualisation makes it possible to focus more closely on just one cinema chain by eliminating all other venues as shown in Figure 6.15, depicting only *Cosmopolitan* theatres.

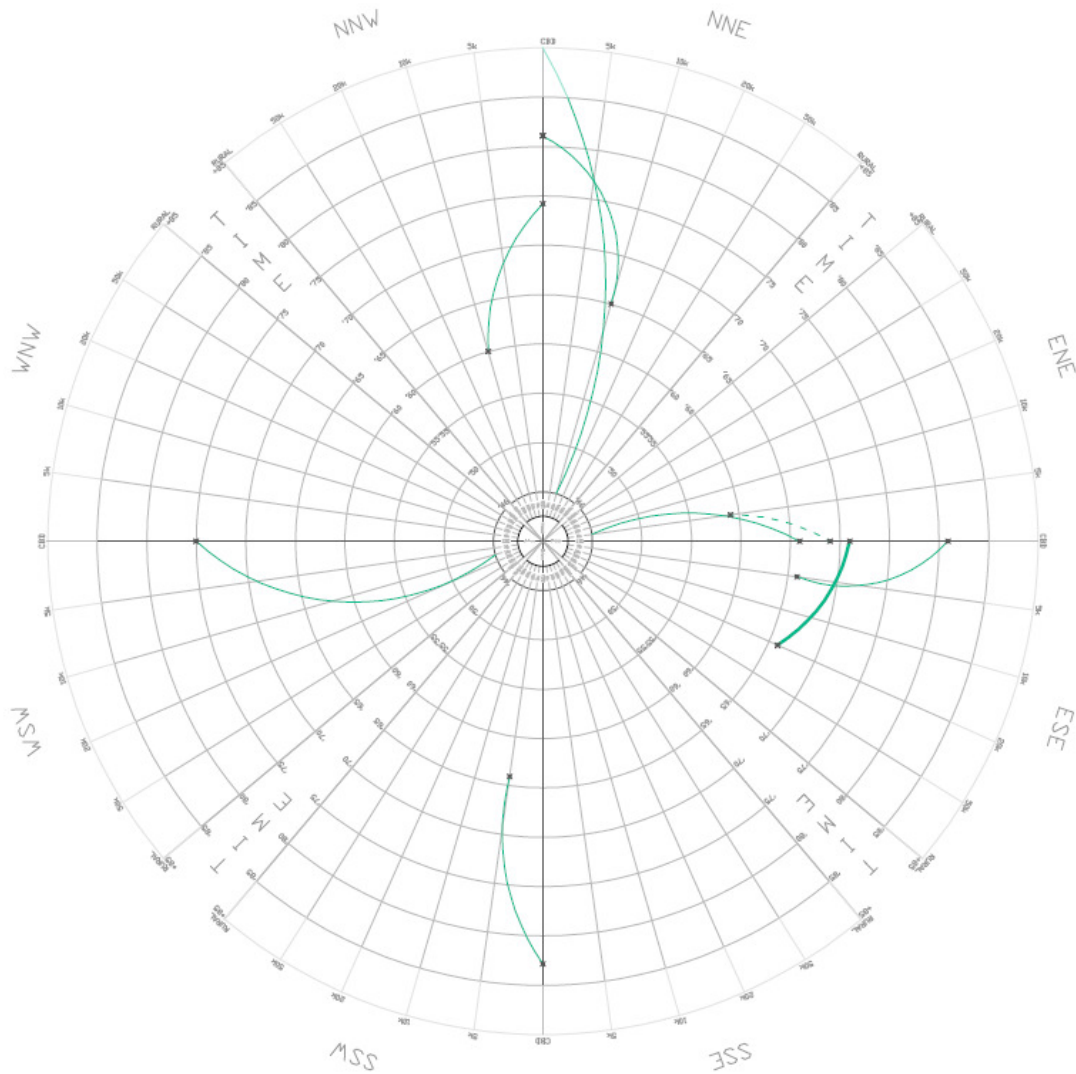


Figure 6.15: The operation of *Cosmopolitan Theatres*

6.4 Conclusions

This chapter has identified that the visualisation method can effectively communicate and provide visual analysis for the cinema venue data within each Geographic Question. This has been demonstrated through the creation of each visualisation with the differing temporal, spatial, and variable aspects each with differing representation specifics. It was possible to plot all venues within the spatial/temporal framework and assign the representation values to each venue characteristic required.

By investigating the information displayed in the visualisations, a number of interpretations could be made for the spatial, temporal, attribute, and changing aspects of the data. This

verifies the success of the visualisation through the ability to analyse and identify patterns and relationships that the data hold. These findings could be developed with further analysis of the visualisation, and through the use of selection, querying, and the three level temporal framework. Areas of cinema history have been identified that have not been examined previously and therefore addresses Research Question 5, showing that a visual mode of communication can enhance the history of Melbourne's cinema venues. The visualisation method is validated further by successfully creating visual access to information typically reserved for the written word.

The final chapter will discuss the success of the research by assessing whether each of the Research Questions and the main objective were answered throughout the thesis. The final chapter will also outline limitations associated with the research that have been identified, and will suggest aspects for future research.

7 Conclusion

7.1 Introduction

This chapter will provide a summary of the research project by evaluating the developed visualisation method and research method through assessing whether the visualisation and research met the original Research Questions and main objective outlined in Chapter 1. A number of limitations with both the visualisation technique and Case Study have been identified and are outlined in section 7.3. The chapter concludes by looking at suggestions for future research that have been raised throughout the thesis and in addressing the research main objective.

7.2 *Evaluation of the Visualisation Method and Research*

Making an evaluation of the visualisation method and overall objective of the research is not possible without addressing each of the Research Questions specified in Chapter 1. Whilst the Research Questions relate to particular aspects of the study, each contribute to the overall objective either directly in the background and development of the visualisation method, or indirectly through the application of the visualisation to the Case Study. The following two sub-sections will therefore firstly address whether the thesis addressed each of the Research Questions, and secondly assess if the study achieved its main objective: to develop a method for analysing and representing historically changing, multivariate, spatial information by creating visual access to information typically reserved for the written word.

7.2.1 *Research Questions*

The five Research Questions specified in Chapter 1 included three dedicated to the visualisation of historical spatial data and an additional two relating to the Case Study. This section is organised in these two respective groups: *Visualising Historical Spatial Data*, and *Case Study*.

Visualising Historical Spatial Data

- 1) *How can historically changing, multivariate, spatial data be analysed and communicated visually?*

The literature review identified a number of visualisation techniques used for historical investigation: choropleth mapping, differentiated and ordered visual variables, isarithmic mapping, graphic depictions, and three-dimensional representations. Whilst their application is varied, their dominant use is in representing data that usually involves only one or two variables at a time, and are shown as either temporally static or as changes to the attribute values over time. In review of these techniques used to visualise spatial historical data, combining historically changing, multivariate, spatial data is challenging and rarely

attempted. In response to the first Research Question, it has been identified that there is a lack of multivariate approaches to visualising historical data, especially when attempting to show change over time of these variables. Of those cases that represent and analyse such complex data, they do so with the aid of complex analytical systems and with linked and interactive computer displays, such as those developed by Andrienko and Andrienko (2005, 2007; 2006), Jern and Franzen (2006), Schroeder (2010), Chen (2008), and Tominski (2005).

Whilst having great potential for historical investigation, these visualisations have been developed primarily for spatio-temporal data, not for historically sourced data specifically, and therefore have not as yet made a strong presence in the area of historical investigation. However, there are examples of how historically changing, multivariate, spatial data can be visually communicated and analysed. For example, Weaver et al. (2006) has developed an analytical visualisation system comprising of a “wrapping spreadsheet” made up of calendar dates, tables, histograms, and a location map for the analysis of historical hotel visitation patterns in the area of Rebersburg, Pennsylvania from 1898 to 1900.

The developed visualisation addressed the challenge of visualising multiple variables that change over time within the one visualisation technique. The visualisation has addressed the challenge put forward by Klippel (2009) who highlights the increased difficulty in “sensibly” displaying multivariate data sets. This research has found inspiration for addressing this challenge in the work by Joseph Minard; representing Napoleons plight to Moscow in 1812 within the one image (see Tufte 2001). By turning toward principles of data graphics and information visualisation as opposed to conventional cartographic techniques, the developed method has resulted in a visualisation that incorporates historically changing, multivariate, spatial data holistically through one visualisation technique. The technique (as discussed in Chapter 5) has been developed by extending the spatial dimension of time-series graphs, meaningful classification, and by utilising the capacity to show change and variability in linear spatial objects. Chapter 6 has clearly shown how this type of complex data can be communicated and analysed visually by applying it to cinema venue data over the period of 1946 to 1986. The research has demonstrated the ability of the method to analyse and display the data by interpreting three visualisations that address the separate Geographic Questions. This was achieved by visually identifying patterns, trends, differences, and similarities within the data. The analytical process was enhanced by the addition of querying capabilities to highlight certain aspects of the data which can then be used as comparison for other aspects. Further analysis can be performed when layers of historical cinema industry and social events

are incorporated into the visualisation, thereby providing historical context to patterns of change.

2) *How can temporal change of static entities be represented using spatial technology?*

The review of visualisation techniques undertaken and discussed in Chapter 2 identified that the majority of techniques used in historical research display change over time of variables or the change of the distribution of certain geographic features. Techniques do not track the change of spatial location of a geographic entity, but instead are used to show the temporal change of static entities; of entities that do not change in their location. Examples include the change of variables of a particular town or city (Carter 2008; Ray 2002a), administrative boundaries (Boeckel and Otterstrom 2009; Dorling et al. 2000; Gregory 2008; Gregory and Southall 2002), building or residence (Donahue 2008; Fyfe et al. 2009), or change to the distribution of population and localities (Beveridge 2002; Gong and Tiller 2009). This small selection of examples show that the temporal change of static entities are all visualised through traditional cartographic techniques, the majority of which are the result of GIS databases, analysis, and query. Spatial technology, whether through GIS, cartographic techniques, or other sources such as remote sensing imagery or aerial photographs, can be used to show the temporal change of static entities.

This research has found that GIS can be used successfully in exploring temporal data for patterns of change, whilst the developed visualisation demonstrates the capacity to display change through the development of a new cartographic technique. The technique depicts change through values of visual variables. Changes to the visual variables of colour, shape, width, and style all indicate changes to associated variables, and when combined with a time-series graph, it is possible to determine when these changes took place. It is possible to represent the temporal change of static entities in an effective manner, designed for the analysis of such changes and ease in interpretation. The additional challenge put forward by Tosh identifies the problem of communicating Braudel's *Plurality of Social Time* as a fundamental issue for contemporary historians, stating that "the problem... is how to convey the coexistence of these different levels in a single moment of historical time – how to elucidate their interaction in a coherent exposition..." (2006). This research provides a solution to this challenge, not through conventional written communication, but through visual communication. This research has delivered a unique approach to representing the

temporal change of geographic static entities utilising spatial technology in the form of a new cartographic technique.

3) *What are the issues related to working with historical data?*

The Literature Review identified a number of issues relating to working with historical data, particularly in a geographical context. One of the main issues is the differences between the disciplines of history and geography. History's main mode of communication is textual, whilst Geography is dominated by the visual through maps, graphs, and interactive visual displays. Other differences can be found in the data sources of both disciplines, the focus of either temporal or spatial concepts, and in the accuracies associated with the data sources. This last point of accuracy has been particularly prevalent in this research due to working directly with historical data in the development of the visualisation method and application to cinema venue data.

As outlined in Chapter 4, GIS technology and the majority of cartographic techniques are not designed for the incomplete, inaccurate, and unreliable data often found in historical sources. In order to handle this type of data within the GIS, a number of inclusion criteria were specified which created a minimum requirement for the data if it were to be included in the database. This limited the amount of problems that had to be addressed within the GIS itself. The developed visualisation allows the inclusion of inaccurate and unknown data by classifying the spatial and temporal aspects of the data in such a way that does not require accurate records (such as locating the venues within a certain distance and direction classification from the CBD). The treatment of variables can also handle such data by assigning a visual variable value, whether it is colour, line style etc., to the attribute value of *unknown*.

Case Study

- 4) *What are the important spatial and temporal aspects, and associated attributes related to cinema venue operation?*

Chapter 3 reveals a number of important aspects related to current trends in cinema studies. The emergence of the *New Cinema History* and the *spatial turn* in cinema has encouraged a change in focus from film content to circulation and consumption of cinema and the spatial significance of these aspects. Investigating the operation of cinema venues in a geographic context is an extension of this shift. As this thesis demonstrates, the history of cinema venues involves investigating not only the temporal history, but also the geography of cinema venues and change to their associated variables.

Through the aid of the Case Study, the research has identified a number of important aspects related to the spatial, temporal, and associated attribute dimensions through working directly with historical data of cinema venue operation. Examining and analysing the data within the GIS through exploratory data analysis and with the aid of customary tools to incorporate the temporal dimension, highlighted a number of aspects that were important to cinema venue operation. All aspects were further supported by discussions with cinema historians and are outlined in Chapters 4 and 6. Important aspects included: the geographical distribution of cinema venues, seating capacity, ownership, number of screens, distance and direction from the CBD, and time of attribute change. Using the three geographical questions, it was possible to investigate many of these aspects by applying them to the visualisation method (outlined in Chapter 6). The visualisation also allowed further examination of the aspects in determining their importance and impact on cinema venue operation through displaying the temporal, spatial, and attribute dimensions concurrently and also through the aid of visual analysis.

- 5) *Can a visual mode of communication enhance the understanding of the history of Melbourne's cinema venues?*

The final Research Question is addressed in Chapter 6, where the visualisations for each of the three Geographic Questions are examined in order to extract understanding of specific aspects of the history of Melbourne's cinema venues. The visualisation method allows the Case Study to be examined visually and for patterns and relationships to be communicated in

a visual sense rather than through text. This research has revealed a number of insights that have not been examined previously and are found in the interpretations that were a result of analysing the visualisations (as outlined in Chapter 6). These insights and understandings cover aspects of the temporal, geographic, and attribute dimensions of the data. Such interpretations would have been difficult to ascertain without visual communication and without the aid of the developed visualisation specifically. Therefore, there can be no doubt that the visualisations have enhanced the understanding of the history of cinema venues in Melbourne and made a significant and original contribution to visual communication in cinema studies.

7.2.2 Research Objective

The research objective was to *develop a method for analysing and representing historically changing, multivariate, spatial information by creating visual access to information typically reserved for written communication*. By addressing each of the Research Questions above, their results contribute greatly to this main objective. This is especially true for Research Question 1, as it asks: *how can historically changing, multivariate, spatial data be analysed and communicated visually?* By focusing purely on the method of the developed visualisation, this question directly reflects the aim of the research. To assess whether the research objective has been met, the objective is broken down into three segments which will be addressed separately. These three sections are: *1) how has the method incorporated historically changing, multivariate, spatial information? 2) can the method both analyse and represent this complex information?; and 3) has the method created access for information typically reserved for written communication?* Each of these questions is addressed below in the following sub-sections.

1) How has the method incorporated historically changing, multivariate, spatial information?

The developed method consists of a visualisation technique that has the ability to incorporate historically changing, multivariate, spatial information. This has been achieved by developing a visualisation that allows all elements to be visualised concurrently without the need for multiple snapshots, animation, or multiple visualisation techniques. Spatial information is

handled within the visualisation through the classification of distance and direction and has been incorporated through the use of visual variables, and cardinally oriented time-series graphs. The capacity to handle multivariate data has been achieved by transforming point locations into lines that rest within the spatial framework. The advantage of doing so is that linear features have the ability to represent multivariate data more effectively than point features, due to the fact that in addition to the visual variables of width, colour, and style, linear features can vary in their shape (through changes in direction and curves) and length. An additional advantage can be seen in a lines continual nature; a line can be tracked through a time-series graph far more effectively than a point. By using time-series graphs and linear features, it is possible to depict historical change of the attribute information over time. This is because it is possible to show when changes to attributes occurred by the relative location of the visual variable change within the time-series graph.

The resultant visualisation presents an alternate approach to visualising this complex information in one holistic display. It also provides an original contribution to research into visualisation techniques and concepts by creating a new visualisation technique that can be used for historical, spatial, and multivariate data.

2) Can the method both analyse and represent this complex information?

The method has been developed to represent and analyse all aspects of the complex historical information described above. It has achieved this by creating a holistic display of the data so the visualisation of the data and subsequent analysis is contained within the one image, thereby eliminating the need to refer to sequential snapshot images or compare elements over differing techniques. The method represents the temporal and attribute data in *as close the original form* as possible, avoiding aggregation and bold classifications, in order to present the information clearly and without manipulation. To achieve this, the spatial component of the data has been sacrificed. Instead of representing the geographic coordinates of the location, classifications of distance and direction have been used in their place. This more closely reflects the accuracies of the spatial data and also the spatial components that are particularly relevant to geographic phenomena that have a central point of influence, as discussed in Chapter 5.

Analysis of the data is possible by visually examining the data presented in the visualisation. Attributes and geographic characteristics can be compared over different geographic areas or over different time periods, which can allow patterns, trends, differences, and similarities within the data to be identified. Through the use of a Case Study, Chapter 6 demonstrates that the analytical process can be enhanced by the addition of querying capabilities to highlight certain aspects of the data which can then be used for comparison to other aspects, time periods, or geographies. Further analysis can be performed when layers of historical cinema industry and social events are incorporated into the visualisation, thereby providing historical context to patterns of change. By analysing the data contained in the visualisations, one thing is clear: there is no immediacy to interpretation. Instead, the visualisations reward careful study.

This research makes an original and significant contribution to stressing the geographical aspects of historical data through representation and analysis. It provides an alternate approach to current visualisation techniques utilised in the field, and enhances their suitability for historical data by focusing on historical change over time.

3) Has the method created visual access to information typically reserved for written communication?

As discussed in Chapter 2 and in response to Research Question 3, historical data is usually communicated through text. This research has shown that by creating a visualisation that allows this same data to be communicated visually, new patterns, relationships, and insights can be gained. Visual access to historical data has been achieved by creating a visualisation that communicates all important aspects of the temporal, attribute, and spatial dimensions in one holistic display.

The research has demonstrated the ability of the visualisation to create access to information usually reserved for written communication by applying the technique to the Case Study of cinema venues. Cinema studies is a discipline that is also dominated by the written word. However, the results outlined in Chapter 6 show that the visualisation succeeds in delivering the information visually. This assessment has been supported by positive preliminary feedback from a number of cinema historians through prototype interpretations. However,

whilst initial feedback has supported the visualisation method for visual interpretation, formal usability testing is required in order to validate the method.

Through the investigation into each aspect of the main objective, it can be seen that the objective of developing a method for analysing and representing historically changing, multivariate, spatial information by creating visual access to information typically reserved for written communication has been successfully achieved.

7.3 Limitations

The following two sections will address the limitations associated with the visualisation technique and the Case Study.

7.3.1 Limitations with the Visualisation Technique

Representing spatial, temporal, and attribute values concurrently is a challenging task when the visualisation is to be used for historical investigation. The design of the visualisation needs to be effective in communicating this data and the patterns and relationships embedded within the different elements. Visualising change over time of multiple variables has placed emphasis on the temporal and the attribute dimensions of the data by keeping the original records from collection through to the visualisation. As a result, this focus has had to come at the expense of the spatial in order for the data to be effectively communicated. This has led to highly classified spatial data which therefore generalises and degrades the accuracy of the geographic component of the data. This however has not sacrificed the importance of the geographic component. It was possible to turn to spatial classification due to the importance of distance and direction over geographic location. As discussed in Chapter 5, it was found that the distance and direction from the CBD was a more influencing spatial element than the exact geographic coordinates of the cinema venues. So whilst spatial accuracy is lost, the decision to use alternate and abstract representations of space is justified by examining the data and understanding the operation of cinema venues. It should also be noted that although space is generalised, it has not been aggregated. This means that the venues within a particular spatial class are still depicted as separate entities, not as an aggregate.

In order to still maintain a visual sense of the geographic space of Melbourne, the spatial class of direction was used to place each of the time-series graphs in the cardinal directions of the eight cardinal classes. The resultant radial visualisation is possible because of the centre point of influence embedded in the data; the CBD. Because the CBD acts as a central point not only for cinema operation, but for other geographic features as well such as the train and road networks (as discussed in Chapter 3 and 5), Melbourne is a perfect case study for the visualisation. Yet, what happens when the city's cinema operations or other industries that could be applied to the technique cannot be organised in such a way? There is no reason why the visualisation cannot be manipulated to suit different geographic patterns. For example, a city may be situated along a coast line, and the city is influenced by the distance and proximity to the coast line instead of a central point. In this case, the visualisation can be used to represent this arc-like city pattern by arranging the time-series graphs in the pattern of an arc stemming from the coast line. Applying the visualisation becomes more difficult if there is not a clear pattern to the city's geography. There has been no attempt to apply the data to such situations.

Since the successful interpretation of the data is paramount, anything that can affect the ability to visually extract the information from the visualisation needs to be reduced. One limitation with interpretation is the tendency toward visual clutter if too many geographic entities are used. Whilst large numbers can show general trends and patterns, it is impossible to investigate each individual entity separately, which can affect the success of the visualisation process. Therefore, with the aid of simple usability testing, the number of geographic entities should be limited to fewer than 150 in order to utilise the visualisation in the most efficient and effective manner. This in turn raises another limitation. To interpret the data effectively, the visualisation must be a high resolution image. Due to the large number of graphic objects, a large format printed copy (as seen in Appendix C, D, and E) or large display with the ability to zoom into specific areas is preferred to extract the information needed. Without such specifications, the visualisation is limited in its interpretation of the data.

7.3.2 Limitations with the Case Study

By applying the visualisation to the Case Study, a number of limitations were found with the data and scope of the application. Currently, only cinema data has been applied to the

visualisation method. This research has not made an attempt to apply the visualisation method to other industries or other locations, but with manipulation there is a strong possibility that the method is transferable. This will be discussed further in section 7.4.1 and 7.4.2 as areas of further research.

The cinema venue data used in the Case Study was limited to cinema venue characteristics that could be assigned to individual cinemas. This data consisted of records of spatial location, seating capacity, screen numbers, name, role, primary purpose, closing date, and opening date. All of this data can be used to investigate the history of the operation of cinema venues. However, it cannot tell the whole story. The research has focused purely on the data concerning cinema venues with the addition of historical events over the period. But with the addition of other relevant data such as distribution patterns, revenue, or attendance, different insights could be sought along with a more holistic investigation to reveal possible conclusions. There are many additional sources of information that could be applied to the history of cinema venues. For example, film historian Robert Allen has stated that film distribution involves “not just the physical transportation of cans of films, but a much more complex economic, cultural, technological, and social circulation and exchange – of people, technologies, ideas, stories, images, identities, places, practices, and values” (2006, pp. 24-25). However, it is impossible to achieve this within the one visualisation, as is the case with the entire history of venue operation.

It was not the intent of this research to simply ignore additional influences; however it is beyond the scope of the research. The visualisation cannot incorporate such information for the resulting complexity would have to lead to analytical and interactive computer interfaces that involve multiple techniques and linked views. As discussed throughout the thesis, this was not the intent of the research. The focus of the study was not on the incorporation of all relevant data to paint a picture of everything that is known, instead it was to create visual access to data and allow certain aspects to be analysed and interpreted in a way not previously explored.

A final limitation with the Case Study data is the changing nature of historical sources. The database used as the main data source for the Case Study, CAARP, is constantly evolving as new pieces of information are found and updated. As a result, the interpretations and conclusions drawn from this research are relevant at the time of when the data was extracted. Data that has been updated after this time has not been included.

7.4 Areas of Further Research

This thesis has uncovered a number of areas where further research can be explored. In order to validate the visualisation method, further application is required for other locations, temporal periods, and industries. This can be seen as not only validation, but also as an extension for areas of further use in which the visualisation method could provide a tool for analysis and develop new insights. Throughout this thesis, the benefits of developing new visualisations through extending aspects of data graphics as opposed to relying on conventional cartographic techniques have been explored. There is potential for these aspects to be expanded through further research and application for the benefit of effective visual communication. Areas of cinema research that can be further explored and developed have been identified throughout the research project. This section will address each of these areas in the following sub-sections.

7.4.1 Applying the Method to Other Locations and Temporal Periods

This research has focused on applying the method to cinema venues in Melbourne between 1946 and 1986. Whilst this has been an excellent case study for the visualisation, this research has not been applied to other locations or other temporal periods for cinema venues. In order to validate the method of the visualisation, it is imperative that the method be applied to other locations and other temporal periods. For example, it could be applied to other cities in Australia or international locations. Temporally, the method could be assigned to periods in history that exhibit different patterns of change and geographies, such as the period concerning the initial uptake of cinema in Melbourne. Not only can further application validate the method, it has potential to also provide a tool to enhance the current knowledge concerning different cinema histories.

7.4.2 Applying the Method to Other Industries and Histories

Whilst the visualisation method has only been applied to the cinema industry, a potential area of further research is the application to other industries. The method could, with simple manipulation, be potentially applied to any point sourced data that exhibit attribute change and are of temporal and geographic significance. In particular, the method would be suited to historical data that has a central point of influence. Potential application areas could include the analysis of other entertainment industries, retail industries, parks and recreational services, and business development.

7.4.3 Further Extension of Data Graphic Principles within Historical GIS and Geo-visualisation

This research has focused on the successful communication of data through visualisation. The research has drawn upon concepts of data graphics and information visualisation in order to move beyond conventional cartographic techniques that were not suited to the complex data and historical investigation. This research has demonstrated the benefits to be gained from representing the geographic aspects of the data in a more abstract form. There is a tendency to rely on pre-existing cartographic techniques as soon as geographic information is to be visualised. However, thought must be given to the suitability of such techniques and what the user hopes to get out of the visualisation. If this cannot be achieved effectively through the use of a more conventional cartographic technique that focuses more on locating geographic entities, then thought should be given to other forms of visualisation or the development of new data specific techniques. This can have particular relevance to historical spatial data and the field of Historical GIS, as the main aim is to aid in historical investigation, not the representation of location data. To quote Tufte (2001, p. 191):

“What is to be sought in designs for the display of information is the clear portrayal of complexity. Not the complication of the simple; rather the task of the designer is to give visual access to the subtle and the difficult – that is the revelation of the complex.”

The often automatic turn to conventional cartographic methods can complicate what is actually wanted from the data and what really needs to be communicated.

Many complex geo-analytical and geo-visualisation systems involve techniques that stem more from data graphics and information visualisation than cartography, however there is great potential for further research into holistic displays utilising single graphic display techniques as opposed to multiple linked techniques and displays. Further possible sources for expanding the spatial presence of data graphics and integrating data graphic design principles for spatial data can be found in research that explores aspects of graphic design, info graphics, data communication, and art. See the following references for examples: (Cartwright et al. 2009; Klanten et al. 2009; McCandless 2009).

7.4.4 Research into Neglected Areas of Australian Cinema Research and Cinema Visualisation Development

It was noted in section 3.3.2 that this research has found very little previous study into cinema distribution and exhibition practises (especially during the post-war period in Australia) (Verhoeven 2006), and the history of cinema venues (particularly in regards to their geographical distribution). There is great potential for further research in these areas. There are also many possibilities to advance the spatial presence in many areas of cinema research and expand on the range of visualisation techniques currently utilised by cinema scholars described in section 3.4 and 3.5. Investigating the nature of openings and closures, longevity, and the geography of venue operation has led to new insights into periods of cinema history that can be further developed. Visualisations can reveal patterns and trends within data, but they cannot explain these findings. Further research is required in order to explain the reasons for such findings and to investigate possible sources of causation.

7.4.5 The Development of an Interactive Computer-based Application

If this particular visualisation method is to be expanded further to aid in historical investigation, the automation of the visualisation process for screen display is required in

order to provide a method that is interactive and question specific. This will allow the analytical capabilities of the method to be fully realised. It would allow the temporal period and attributes to be specified, along with the choice of visual variables for representation. Querying directly with the visualisation and selecting and filtering those venues based on attribute and spatial classification allows patterns and relationships to be easily identified and comparisons to be made as discussed in section 5.6.4 and assessed in Chapter 6. Yet in contrast, one of the main benefits of creating a holistic visual representation is the ability to work with hardcopy paper representations. Hard copies allow the entirety of the data to be viewed whilst particular areas can be examined. It gives the option of highlighting interesting patterns and differences for later inspection. Therefore, even though computer-based applications have the ability to generate interactive visualisations based on queries, hardcopy representations can still be seen as a highly interactive product.

7.4.6 Formal Usability Testing

If this visualisation method is to be applied for wider use and adopted by the cinema historian community, formal usability testing would be required to ensure that the method is successful in achieving the desired results. Whilst preliminary testing has been performed and has been successful, formal testing would ensure that the desired results are achievable for all intended users.

7.5 Conclusions

This thesis has established a visualisation method for investigating and analysing the temporal and geographical nature of historical events. In particular, it has focused on addressing the importance of visualising historical change of multivariate data over time, with the aid of a Historical GIS and data graphics, for understanding the patterns and relationships within geohistorical information. The visualisation method was developed through the aid of a Case Study application; the history of Melbourne's cinema venues between 1946 and 1986. This historical study provided inspiration for a number of design, communication, and analytical capabilities developed throughout the research, along with a complex history which tested the flexibility and the ability to stress both the temporal and geographic aspects of historic events.

The visualisation method enabled these temporal and geographic aspects, along with multivariate capabilities, to be incorporated effectively by extending the spatial dimension of time-series graphs, meaningful classification, and by utilising the capacity to show change and variability in linear spatial objects. Thereby creating an alternate visualisation technique that can be adapted to many different histories and geographies.

This research has enabled data that is usually reserved for written communication to be visually analysed, interpreted, and displayed in a way not previously explored. It has been found that by creating visual access to multivariate and temporal spatial information it is possible to produce new insights into the geographic and temporal patterns and relationships present in historical data.

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Appendix A – Status Query Customised Tool Script


```
Private Function UIToolControl2_ToolTip() As String

UIToolControl2_ToolTip = "Status Query Date"

End Function

Private Sub UIToolControl2_Select()

Dim pMxDoc As IMxDocument
Dim pMap As IMap
Dim pFilter As ISpatialFilter
Dim shapefield As String
Dim pDoc As IMxDocument
Dim pDataSet As IDataset

Dim filePath As String
Dim operationST As String
Dim nameST As String
Dim capacityST As String
Dim purposeST As String
Dim roleST As String
Dim screensST As String
Dim newTST As String
Dim venueST As String
Dim xyST As String

    filePath = "D:\Cinemas\GIS"
    venueST = "venue.dbf"
    operationST = "operation.dbf"
    nameST = "name.dbf"
    capacityST = "capacity.dbf"
    purposeST = "purpose.dbf"
    roleST = "role.dbf"
    screensST = "screens.dbf"
    newTST = "newT.dbf"

Dim pWorkspace As IWorkspace
Dim pFact As IWorkspaceFactory
    Set pFact = New ShapefileWorkspaceFactory
    Set pWorkspace = pFact.OpenFromFile(filePath, 0)
Dim pFWorkspace As IFeatureWorkspace
    Set pFWorkspace = pWorkspace
Dim operationT As ITable
Dim nameT As ITable
Dim capacityT As ITable
Dim purposeT As ITable
Dim roleT As ITable
Dim screensT As ITable
Dim venueT As ITable
Dim newT As ITable 'newT is the new created table

Dim oRow As IRow
Dim nRow As IRow
Dim cRow As IRow
Dim pRow As IRow
Dim rRow As IRow
Dim sRow As IRow
Dim vRow As IRow
Dim newTRow As IRow
Dim newTRowTemp As IRow
```

```
Dim oCurs As ICursor
Dim nCurs As ICursor
Dim cCurs As ICursor
Dim pCurs As ICursor
Dim rCurs As ICursor
Dim sCurs As ICursor
Dim vCurs As ICursor
Dim newTCurs As ICursor

Dim jumpOut As Integer
Dim Qdate As Double
Dim vidList() As Integer
Dim ocount As Integer
Dim roleCount As Integer
Dim position As Integer
Dim listLength As Integer
Dim operationBool As Boolean
Dim nameBool As Boolean
Dim purposeBool As Boolean
Dim screensBool As Boolean
Dim capacityBool As Boolean
Dim roleBool As Boolean

    listLength = 2
    ocount = 0
    position = 0
ReDim vidList(listLength)
    TestForm.Show
    Qdate = TestForm.txtQdate.Value
    operationBool = TestForm.operationBox.Value
    nameBool = TestForm.nameBox.Value
    purposeBool = TestForm.purposeBox.Value
    screensBool = TestForm.screensBox.Value
    capacityBool = TestForm.capacityBox.Value
    roleBool = TestForm.roleBox.Value

    XYform.Show
    xyST = XYform.xyEventbox.Value

Set venueT = pFWorkspace.OpenTable(venueST)
Set operationT = pFWorkspace.OpenTable(operationST)
Set nameT = pFWorkspace.OpenTable(nameST)
Set capacityT = pFWorkspace.OpenTable(capacityST)
Set purposeT = pFWorkspace.OpenTable(purposeST)
Set roleT = pFWorkspace.OpenTable(roleST)
Set screensT = pFWorkspace.OpenTable(screensST)
Set newT = pFWorkspace.OpenTable(newTST)
    newT.CreateRow

'these lines set each cursor to point to the corresponding table
Set vCurs = venueT.Search(Nothing, False)
Set oCurs = operationT.Search(Nothing, False)
Set nCurs = nameT.Search(Nothing, False)
Set cCurs = capacityT.Search(Nothing, False)
Set pCurs = purposeT.Search(Nothing, False)
Set rCurs = roleT.Search(Nothing, False)
Set sCurs = screensT.Search(Nothing, False)
Set newTCurs = newT.Search(Nothing, False)
Set oRow = oCurs.NextRow
```

```
Set nRow = nCurs.NextRow
Set cRow = cCurs.NextRow
Set pRow = pCurs.NextRow
Set rRow = rCurs.NextRow
Set sRow = sCurs.NextRow
Set newTRow = newTCurs.NextRow
Set newTRowTemp = newTRow

'the following is to get a list of venue_ids from the querydate
and the operation table
Do Until oRow Is Nothing
    If oRow.Value(2) <= Qdate And oRow.Value(3) > Qdate Then
        ReDim Preserve vidList(listLength)
        vidList(ocount) = oRow.Value(4)
        ocount = ocount + 1
        listLength = listLength + 1
    End If
    Set oRow = oCurs.NextRow
Loop

ocount = 0
newT.DeleteSearchedRows Nothing
Set newTCurs = newT.Search(Nothing, False)

Do Until ocount >= listLength - 2
    Set vCurs = venueT.Search(Nothing, False)
    Set oCurs = operationT.Search(Nothing, False)
    Set nCurs = nameT.Search(Nothing, False)
    Set cCurs = capacityT.Search(Nothing, False)
    Set pCurs = purposeT.Search(Nothing, False)
    Set rCurs = roleT.Search(Nothing, False)
    Set sCurs = screensT.Search(Nothing, False)
    Set vRow = vCurs.NextRow
    Set oRow = oCurs.NextRow
    Set nRow = nCurs.NextRow
    Set cRow = cCurs.NextRow
    Set pRow = pCurs.NextRow
    Set rRow = rCurs.NextRow
    Set sRow = sCurs.NextRow

    Set newTRow = newT.CreateRow
    newTRow.Value(1) = vidList(ocount)
    newTRow.Store

    'venue
    Do Until vRow Is Nothing
        If vRow.Value(1) = vidList(ocount) Then
            newTRow.Value(2) = vRow.Value(2)
            newTRow.Store
            newTRow.Value(3) = vRow.Value(3)
            newTRow.Store
            newTRow.Value(4) = vRow.Value(4)
            newTRow.Store
            newTRow.Value(5) = vRow.Value(5)
            newTRow.Store
            newTRow.Value(6) = vRow.Value(6)
            newTRow.Store
        End If
        Set vRow = vCurs.NextRow
    Loop
Loop
```

```
'operation
If operationBool = True Then
  Do Until oRow Is Nothing
    If oRow.Value(2) < Qdate And oRow.Value(3) > Qdate And
oRow.Value(4) = vidList(ocount) Then
      newRow.Value(7) = oRow.Value(1)
      newRow.Store
      newRow.Value(8) = oRow.Value(2)
      newRow.Store
      newRow.Value(9) = oRow.Value(3)
      newRow.Store
    End If
    Set oRow = oCurs.NextRow
  Loop
End If

'name
If nameBool = True Then
  Do Until nRow Is Nothing
    If nRow.Value(2) < Qdate And nRow.Value(5) =
vidList(ocount) Then
      newRow.Value(10) = nRow.Value(1)
      newRow.Store
      newRow.Value(11) = nRow.Value(2)
      newRow.Store
      newRow.Value(12) = nRow.Value(3)
      newRow.Store
      newRow.Value(13) = nRow.Value(4)
      newRow.Store
    End If
    Set nRow = nCurs.NextRow
  Loop
End If

'purpose
If purposeBool = True Then
  Do Until pRow Is Nothing
    If pRow.Value(2) < Qdate And pRow.Value(5) =
vidList(ocount) Then
      newRow.Value(14) = pRow.Value(1)
      newRow.Store
      newRow.Value(15) = pRow.Value(2)
      newRow.Store
      newRow.Value(16) = pRow.Value(3)
      newRow.Store
      newRow.Value(17) = pRow.Value(4)
      newRow.Store
    End If
    Set pRow = pCurs.NextRow
  Loop
End If

'Screens
If screensBool = True Then
  Do Until sRow Is Nothing
    If sRow.Value(2) < Qdate And sRow.Value(5) =
vidList(ocount) Then
      newRow.Value(18) = sRow.Value(1)
      newRow.Store
      newRow.Value(19) = sRow.Value(2)
      newRow.Store
```

```
        newTRow.Value(20) = sRow.Value(3)
        newTRow.Store
        newTRow.Value(21) = sRow.Value(4)
        newTRow.Store
    End If
    Set sRow = sCurs.NextRow
Loop
End If

'capacity
If capacityBool = True Then
    Do Until cRow Is Nothing
        If cRow.Value(2) < Qdate And cRow.Value(5) =
vidList(ocount) Then
            newTRow.Value(22) = cRow.Value(1)
            newTRow.Store
            newTRow.Value(23) = cRow.Value(2)
            newTRow.Store
            newTRow.Value(24) = cRow.Value(3)
            newTRow.Store
            newTRow.Value(25) = cRow.Value(4)
            newTRow.Store
        End If
        Set cRow = cCurs.NextRow
    Loop
End If

'role
If roleBool = True Then
    role = 0
    Do Until rRow Is Nothing
        If rRow.Value(2) < Qdate And rRow.Value(3) > Qdate And
rRow.Value(6) = vidList(ocount) Then
            newTRow.Value(26) = rRow.Value(1)
            newTRow.Store
            newTRow.Value(27) = rRow.Value(2)
            newTRow.Store
            newTRow.Value(28) = rRow.Value(3)
            newTRow.Store
            newTRow.Value(29) = rRow.Value(4)
            newTRow.Store
            newTRow.Value(30) = rRow.Value(5)
            newTRow.Store
            If role >= 1 Then
                newTRow.Value(1) = newTRowTemp.Value(1)
                newTRow.Store
                newTRow.Value(2) = newTRowTemp.Value(2)
                newTRow.Store
                newTRow.Value(3) = newTRowTemp.Value(3)
                newTRow.Store
                newTRow.Value(4) = newTRowTemp.Value(4)
                newTRow.Store
                newTRow.Value(5) = newTRowTemp.Value(5)
                newTRow.Store
                newTRow.Value(6) = newTRowTemp.Value(6)
                newTRow.Store
            End If
            role = role + 1
            Set newTRowTemp = newTRow
            Set newTRow = newT.CreateRow
        End If
    Loop
End If
```

```
        Set rRow = rCurs.NextRow
    Loop
    If role >= 1 Then
        newTRow.Delete
    End If
End If
ocount = ocount + 1
Loop

Dim piDoc As IMxDocument
Dim piMap As IMap
Set piDoc = ThisDocument
Set piMap = piDoc.FocusMap

Dim pTable As ITable
Set pTable = newT

Dim piDataSet As IDataset
Dim pTableName As IName
Set piDataSet = pTable
Set pTableName = piDataSet.FullName

    ' Specify the X and Y fields
Dim pXYEvent2FieldsProperties As IXEvent2FieldsProperties
Set pXYEvent2FieldsProperties = New XYEvent2FieldsProperties
With pXYEvent2FieldsProperties
    .XFieldName = "longitude"
    .YFieldName = "latitude"
    .ZFieldName = ""
End With

    ' Specify the projection
Dim pSpatialReferenceFactory As ISpatialReferenceFactory
Dim pProjectedCoordinateSystem As IProjectedCoordinateSystem
Set pSpatialReferenceFactory = New SpatialReferenceEnvironment
Set pProjectedCoordinateSystem =
pSpatialReferenceFactory.CreateProjectedCoordinateSystem(esriSRProjCS_GDA1
994MGA_55)

    ' Create the XY name object and set it's properties
Dim pXYEventSourceName As IXEventSourceName
Dim pXYName As IName
Dim pXYEventSource As IXEventSource
Set pXYEventSourceName = New XYEventSourceName
With pXYEventSourceName
    Set .EventProperties = pXYEvent2FieldsProperties
    Set .SpatialReference = pProjectedCoordinateSystem
    Set .EventTableName = pTableName
End With
Set pXYName = pXYEventSourceName
Set pXYEventSource = pXYName.Open

    ' Create a new Map Layer
Dim pPlayer As IFeatureLayer
Set pPlayer = New FeatureLayer
Set pPlayer.FeatureClass = pXYEventSource
pPlayer.name = xyST "Status Query XY"

    'Add the layer extension (this is done so that when you edit
    'the layer's Source properties and click the Set Data Source
    'button, the Add XY Events Dialog appears)
```

```
Dim pLayerExt As ILayerExtensions
Dim pRESPageExt As New XYDataSourcePageExtension
    Set pLayerExt = pFlayer
        pLayerExt.AddExtension pRESPageExt

        piMap.AddLayer pFlayer

MsgBox "There are " & listLength - 2 & " venues which were operating in "
& Qdate

End Sub
```

Appendix B – Event Customised Tool Script


```
Private Function UIToolControl3_ToolTip() As String

UIToolControl3_ToolTip = "Query Time Interval"

End Function
Private Sub UIToolControl3_Select()

Dim pMxDoc As IMxDocument
Dim pMap As IMap
Dim pFilter As ISpatialFilter
Dim shapefield As String
Dim pDoc As IMxDocument
Dim pDataSet As IDataset

Dim filePath As String
Dim operationST As String
Dim nameST As String
Dim capacityST As String
Dim purposeST As String
Dim roleST As String
Dim screensST As String
Dim intervalTST As String
Dim venueST As String
Dim xyST As String

    filePath = "D:\Cinemas\GIS"
    venueST = "venue.dbf"
    operationST = "operation.dbf"
    nameST = "name.dbf"
    capacityST = "capacity.dbf"
    purposeST = "purpose.dbf"
    roleST = "role.dbf"
    screensST = "screens.dbf"
    intervalTST = "intervalT.dbf"

Dim pWorkspace As IWorkspace
Dim pFact As IWorkspaceFactory
    Set pFact = New ShapefileWorkspaceFactory
    Set pWorkspace = pFact.OpenFromFile(filePath, 0)
Dim pFWorkspace As IFeatureWorkspace
    Set pFWorkspace = pWorkspace
Dim operationT As ITable
Dim nameT As ITable
Dim capacityT As ITable
Dim purposeT As ITable
Dim roleT As ITable
Dim screensT As ITable
Dim venueT As ITable
Dim intervalT As ITable 'intervalT is the new created table

Dim oRow As IRow
Dim nRow As IRow
Dim cRow As IRow
Dim pRow As IRow
Dim rRow As IRow
Dim sRow As IRow
Dim vRow As IRow
Dim intervalTRow As IRow
Dim intervalTRowTemp As IRow
```

```
Dim oCurs As ICursor
Dim nCurs As ICursor
Dim cCurs As ICursor
Dim pCurs As ICursor
Dim rCurs As ICursor
Dim sCurs As ICursor
Dim vCurs As ICursor
Dim intervalTCurs As ICursor

Dim jumpOut As Integer
Dim QdateF As Double
Dim QdateT As Double
Dim venueList() As Double
Dim operationList() As Integer
Dim ocount As Integer
Dim roleCount As Integer
Dim position As Integer
Dim listLength As Integer
Dim operationBool As Boolean
Dim nameBool As Boolean
Dim purposeBool As Boolean
Dim screensBool As Boolean
Dim capacityBool As Boolean
Dim roleBool As Boolean

    jumpOut = 0
    listLength = 2
    ocount = 0
    position = 0
ReDim venueList(listLength)
ReDim operationList(listLength)

    Qinterval.Show
    QdateF = Qinterval.txtQdateF.Value
    QdateT = Qinterval.txtQdateT.Value
    operationBool = Qinterval.operationBox.Value
    nameBool = Qinterval.nameBox.Value
    purposeBool = Qinterval.purposeBox.Value
    screensBool = Qinterval.screensBox.Value
    capacityBool = Qinterval.capacityBox.Value
    roleBool = Qinterval.roleBox.Value

    XYform.Show
    xyST = XYform.xyEventbox.Value

Set venueT = pFWorkspace.OpenTable(venueST)
Set operationT = pFWorkspace.OpenTable(operationST)
Set nameT = pFWorkspace.OpenTable(nameST)
Set capacityT = pFWorkspace.OpenTable(capacityST)
Set purposeT = pFWorkspace.OpenTable(purposeST)
Set roleT = pFWorkspace.OpenTable(roleST)
Set screensT = pFWorkspace.OpenTable(screensST)
Set intervalT = pFWorkspace.OpenTable(intervalTST)
    intervalT.CreateRow

Set vCurs = Nothing
Set oCurs = Nothing
Set nCurs = Nothing
Set cCurs = Nothing
Set pCurs = Nothing
Set rCurs = Nothing
```

```
Set sCurs = Nothing
Set intervalTCurs = Nothing
Set oRow = Nothing
Set nRow = Nothing
Set cRow = Nothing
Set pRow = Nothing
Set rRow = Nothing
Set sRow = Nothing
Set intervalTRow = Nothing

'these lines set each cursor to point to the corresponding table
Set vCurs = venueT.Search(Nothing, False)
Set oCurs = operationT.Search(Nothing, False)
Set nCurs = nameT.Search(Nothing, False)
Set cCurs = capacityT.Search(Nothing, False)
Set pCurs = purposeT.Search(Nothing, False)
Set rCurs = roleT.Search(Nothing, False)
Set sCurs = screensT.Search(Nothing, False)
Set intervalTCurs = intervalT.Search(Nothing, False)
Set oRow = oCurs.NextRow
Set nRow = nCurs.NextRow
Set cRow = cCurs.NextRow
Set pRow = pCurs.NextRow
Set rRow = rCurs.NextRow
Set sRow = sCurs.NextRow
Set intervalTRow = intervalTCurs.NextRow
Set intervalTRowTemp = intervalTRow

Do Until oRow Is Nothing
  If Not (oRow.Value(3) <= QdateF Or oRow.Value(2) > QdateT)
Then
  ReDim Preserve venueList(listLength)
  venueList(ocount) = oRow.Value(4)
  ocount = ocount + 1
  listLength = listLength + 1
  'MsgBox ocount
  'MsgBox "venue is " & oRow.Value(4)
  'MsgBox venueList(ocount - 1)
  End If
  Set oRow = oCurs.NextRow
Loop

ocount = 0

intervalT.DeleteSearchedRows Nothing
Set intervalTCurs = intervalT.Search(Nothing, False)

Set vCurs = venueT.Search(Nothing, False)
Set oCurs = operationT.Search(Nothing, False)
Set nCurs = nameT.Search(Nothing, False)
Set cCurs = capacityT.Search(Nothing, False)
Set pCurs = purposeT.Search(Nothing, False)
Set rCurs = roleT.Search(Nothing, False)
Set sCurs = screensT.Search(Nothing, False)
Set vRow = vCurs.NextRow
Set oRow = oCurs.NextRow
Set nRow = nCurs.NextRow
Set cRow = cCurs.NextRow
Set pRow = pCurs.NextRow
Set rRow = rCurs.NextRow
Set sRow = sCurs.NextRow
```

```
Set intervalTRow = intervalT.CreateRow

Dim pQueryFilter As IQueryFilter
Set pQueryFilter = New QueryFilter

'operation
If operationBool = True Then
  Do Until oRow Is Nothing
    If (oRow.Value(2) >= QdateF And oRow.Value(2) <= QdateT) _
      Or (oRow.Value(3) >= QdateF And oRow.Value(3) <= QdateT)
Then
      position = position + 1
      pQueryFilter.WhereClause = "venue_id = " &
oRow.Value(4)

      Set vCurs = venueT.Search(pQueryFilter, False)
      Set vRow = vCurs.NextRow
      intervalTRow.Value(1) = oRow.Value(4)
      intervalTRow.Store
      intervalTRow.Value(2) = oRow.Value(2)
      intervalTRow.Store
      intervalTRow.Value(3) = oRow.Value(3)
      intervalTRow.Store
      intervalTRow.Value(4) = "operation"
      intervalTRow.Store
      intervalTRow.Value(5) = oRow.Value(1)
      intervalTRow.Store
      intervalTRow.Value(6) = ""
      intervalTRow.Store
      If oRow.Value(2) >= QdateF And oRow.Value(2) <= QdateT
Then
          intervalTRow.Value(7) = "open"
          intervalTRow.Store
      ElseIf oRow.Value(3) >= QdateF And oRow.Value(3) <=
QdateT Then
          intervalTRow.Value(7) = "closed"
          intervalTRow.Store
      End If
      intervalTRow.Value(8) = -9999
      intervalTRow.Store
      intervalTRow.Value(9) = vRow.Value(2)
      intervalTRow.Store
      intervalTRow.Value(10) = vRow.Value(3)
      intervalTRow.Store
      intervalTRow.Value(11) = vRow.Value(4)
      intervalTRow.Store
      intervalTRow.Value(12) = vRow.Value(5)
      intervalTRow.Store
      intervalTRow.Value(13) = vRow.Value(6)
      intervalTRow.Store
      Set intervalTRow = intervalT.CreateRow
    End If
    Set oRow = oCurs.NextRow
  Loop
End If

'name
If nameBool = True Then
  Do Until nRow Is Nothing
    If nRow.Value(2) >= QdateF And nRow.Value(2) < QdateT Then
      position = position + 1
```

```
pQueryFilter.WhereClause = "venue_id = " &
nRow.Value(5)
Set vCurs = venueT.Search(pQueryFilter, False)
Set vRow = vCurs.NextRow
intervalTRow.Value(1) = nRow.Value(5)
intervalTRow.Store
intervalTRow.Value(2) = nRow.Value(2)
intervalTRow.Store
intervalTRow.Value(3) = -9999
intervalTRow.Store
intervalTRow.Value(4) = "name"
intervalTRow.Store
intervalTRow.Value(5) = nRow.Value(1)
intervalTRow.Store
intervalTRow.Value(6) = nRow.Value(3)
intervalTRow.Store
intervalTRow.Value(7) = nRow.Value(4)
intervalTRow.Store
intervalTRow.Value(8) = -9999
intervalTRow.Store
intervalTRow.Value(9) = vRow.Value(2)
intervalTRow.Store
intervalTRow.Value(10) = vRow.Value(3)
intervalTRow.Store
intervalTRow.Value(11) = vRow.Value(4)
intervalTRow.Store
intervalTRow.Value(12) = vRow.Value(5)
intervalTRow.Store
intervalTRow.Value(13) = vRow.Value(6)
intervalTRow.Store
Set intervalTRow = intervalT.CreateRow
End If
Set nRow = nCurs.NextRow
Loop
End If

'purpose
If purposeBool = True Then
Do Until pRow Is Nothing
If pRow.Value(2) >= QdateF And pRow.Value(2) < QdateT Then
position = position + 1
pQueryFilter.WhereClause = "venue_id = " &
pRow.Value(5)
Set vCurs = venueT.Search(pQueryFilter, False)
Set vRow = vCurs.NextRow
intervalTRow.Value(1) = pRow.Value(5)
intervalTRow.Store
intervalTRow.Value(2) = pRow.Value(2)
intervalTRow.Store
intervalTRow.Value(3) = -9999
intervalTRow.Store
intervalTRow.Value(4) = "purpose"
intervalTRow.Store
intervalTRow.Value(5) = pRow.Value(1)
intervalTRow.Store
intervalTRow.Value(6) = pRow.Value(3)
intervalTRow.Store
intervalTRow.Value(7) = pRow.Value(4)
intervalTRow.Store
intervalTRow.Value(8) = -9999
intervalTRow.Store
```

```
        intervalTRow.Value(9) = vRow.Value(2)
        intervalTRow.Store
        intervalTRow.Value(10) = vRow.Value(3)
        intervalTRow.Store
        intervalTRow.Value(11) = vRow.Value(4)
        intervalTRow.Store
        intervalTRow.Value(12) = vRow.Value(5)
        intervalTRow.Store
        intervalTRow.Value(13) = vRow.Value(6)
        intervalTRow.Store
        Set intervalTRow = intervalT.CreateRow
    End If
    Set pRow = pCurs.NextRow
Loop
End If

'Screens
If screensBool = True Then
    Do Until sRow Is Nothing
        If sRow.Value(2) >= QdateF And sRow.Value(2) < QdateT Then
            position = position + 1
            pQueryFilter.WhereClause = "venue_id = " &
sRow.Value(5)

            Set vCurs = venueT.Search(pQueryFilter, False)
            Set vRow = vCurs.NextRow
            intervalTRow.Value(1) = sRow.Value(5)
            intervalTRow.Store
            intervalTRow.Value(2) = sRow.Value(2)
            intervalTRow.Store
            intervalTRow.Value(3) = -9999
            intervalTRow.Store
            intervalTRow.Value(4) = "screens"
            intervalTRow.Store
            intervalTRow.Value(5) = sRow.Value(1)
            intervalTRow.Store
            intervalTRow.Value(6) = sRow.Value(3)
            intervalTRow.Store
            intervalTRow.Value(7) = sRow.Value(4)
            intervalTRow.Store
            intervalTRow.Value(8) = -9999
            intervalTRow.Store
            intervalTRow.Value(9) = vRow.Value(2)
            intervalTRow.Store
            intervalTRow.Value(10) = vRow.Value(3)
            intervalTRow.Store
            intervalTRow.Value(11) = vRow.Value(4)
            intervalTRow.Store
            intervalTRow.Value(12) = vRow.Value(5)
            intervalTRow.Store
            intervalTRow.Value(13) = vRow.Value(6)
            intervalTRow.Store
            Set intervalTRow = intervalT.CreateRow
        End If
        Set sRow = sCurs.NextRow
    Loop
End If

'capacity
If capacityBool = True Then
    Do Until cRow Is Nothing
        If cRow.Value(2) >= QdateF And cRow.Value(2) < QdateT Then
```

```

        position = position + 1
        pQueryFilter.WhereClause = "venue_id = " &
cRow.Value(5)
        Set vCurs = venueT.Search(pQueryFilter, False)
        Set vRow = vCurs.NextRow
        intervalTRow.Value(1) = cRow.Value(5)
        intervalTRow.Store
        intervalTRow.Value(2) = cRow.Value(2)
        intervalTRow.Store
        intervalTRow.Value(3) = -9999
        intervalTRow.Store
        intervalTRow.Value(4) = "capacity"
        intervalTRow.Store
        intervalTRow.Value(5) = cRow.Value(1)
        intervalTRow.Store
        intervalTRow.Value(6) = cRow.Value(3)
        intervalTRow.Store
        intervalTRow.Value(7) = cRow.Value(4)
        intervalTRow.Store
        intervalTRow.Value(8) = -9999
        intervalTRow.Store
        intervalTRow.Value(9) = vRow.Value(2)
        intervalTRow.Store
        intervalTRow.Value(10) = vRow.Value(3)
        intervalTRow.Store
        intervalTRow.Value(11) = vRow.Value(4)
        intervalTRow.Store
        intervalTRow.Value(12) = vRow.Value(5)
        intervalTRow.Store
        intervalTRow.Value(13) = vRow.Value(6)
        intervalTRow.Store
        Set intervalTRow = intervalT.CreateRow
    End If
    Set cRow = cCurs.NextRow
Loop
End If

'role
If roleBool = True Then
    Do Until rRow Is Nothing
        If (rRow.Value(2) >= QdateF And rRow.Value(2) <= QdateT) _
Or (rRow.Value(3) >= QdateF And rRow.Value(3) <= QdateT)
Then
            position = position + 1
            pQueryFilter.WhereClause = "venue_id = " &
rRow.Value(6) 'venueList(ocount)
            Set vCurs = venueT.Search(pQueryFilter, False)
            Set vRow = vCurs.NextRow
            intervalTRow.Value(1) = rRow.Value(6)
            intervalTRow.Store
            intervalTRow.Value(2) = rRow.Value(2)
            intervalTRow.Store
            intervalTRow.Value(3) = rRow.Value(3)
            intervalTRow.Store
            intervalTRow.Value(4) = "role"
            intervalTRow.Store
            intervalTRow.Value(5) = rRow.Value(1)
            intervalTRow.Store
            intervalTRow.Value(6) = -9999
            intervalTRow.Store
            intervalTRow.Value(7) = rRow.Value(5)

```

```
        intervalTRow.Store
        intervalTRow.Value(8) = rRow.Value(4)
        intervalTRow.Store
        intervalTRow.Value(9) = vRow.Value(2)
        intervalTRow.Store
        intervalTRow.Value(10) = vRow.Value(3)
        intervalTRow.Store
        intervalTRow.Value(11) = vRow.Value(4)
        intervalTRow.Store
        intervalTRow.Value(12) = vRow.Value(5)
        intervalTRow.Store
        intervalTRow.Value(13) = vRow.Value(6)
        intervalTRow.Store
        Set intervalTRow = intervalT.CreateRow
    End If
    Set rRow = rCurs.NextRow
Loop
End If

intervalTRow.Delete

Dim piDoc As IMxDocument
Dim piMap As IMap
Set piDoc = ThisDocument
Set piMap = piDoc.FocusMap

Dim pTable As ITable
Set pTable = intervalT
Dim piDataSet As IDataset
Dim pTableName As IName
Set piDataSet = pTable
Set pTableName = piDataSet.FullName

    ' Specify the X and Y fields
Dim pXYEvent2FieldsProperties As IXEvent2FieldsProperties
Set pXYEvent2FieldsProperties = New XYEvent2FieldsProperties
With pXYEvent2FieldsProperties
    .XFieldName = "longitude"
    .YFieldName = "latitude"
    .ZFieldName = ""
End With

    ' Specify the projection
Dim pSpatialReferenceFactory As ISpatialReferenceFactory
Dim pProjectedCoordinateSystem As IProjectedCoordinateSystem
Set pSpatialReferenceFactory = New SpatialReferenceEnvironment
Set pProjectedCoordinateSystem =
pSpatialReferenceFactory.CreateProjectedCoordinateSystem(esriSRProjCS_GDA1
994MGA_55)

    ' Create the XY name object and set it's properties
Dim pXYEventSourceName As IXEventSourceName
Dim pXYName As IName
Dim pXYEventSource As IXEventSource
Set pXYEventSourceName = New XYEventSourceName
With pXYEventSourceName
    Set .EventProperties = pXYEvent2FieldsProperties
    Set .SpatialReference = pProjectedCoordinateSystem
    Set .EventTableName = pTableName
End With
```



```
Set pXYName = pXYEventSourceName
Set pXYEventSource = pXYName.Open

    ' Create a new Map Layer
Dim pFPlayer As IFeatureLayer
Set pFPlayer = New FeatureLayer
Set pFPlayer.FeatureClass = pXYEventSource
pFPlayer.name = xyST

    'Add the layer extension (this is done so that when you edit
    'the layer's Source properties and click the Set Data Source
    'button, the Add XY Events Dialog appears)
Dim pLayerExt As ILayerExtensions
Dim pRESPageExt As New XYDataSourcePageExtension
Set pLayerExt = pFPlayer
pLayerExt.AddExtension pRESPageExt

    piMap.AddLayer pFPlayer

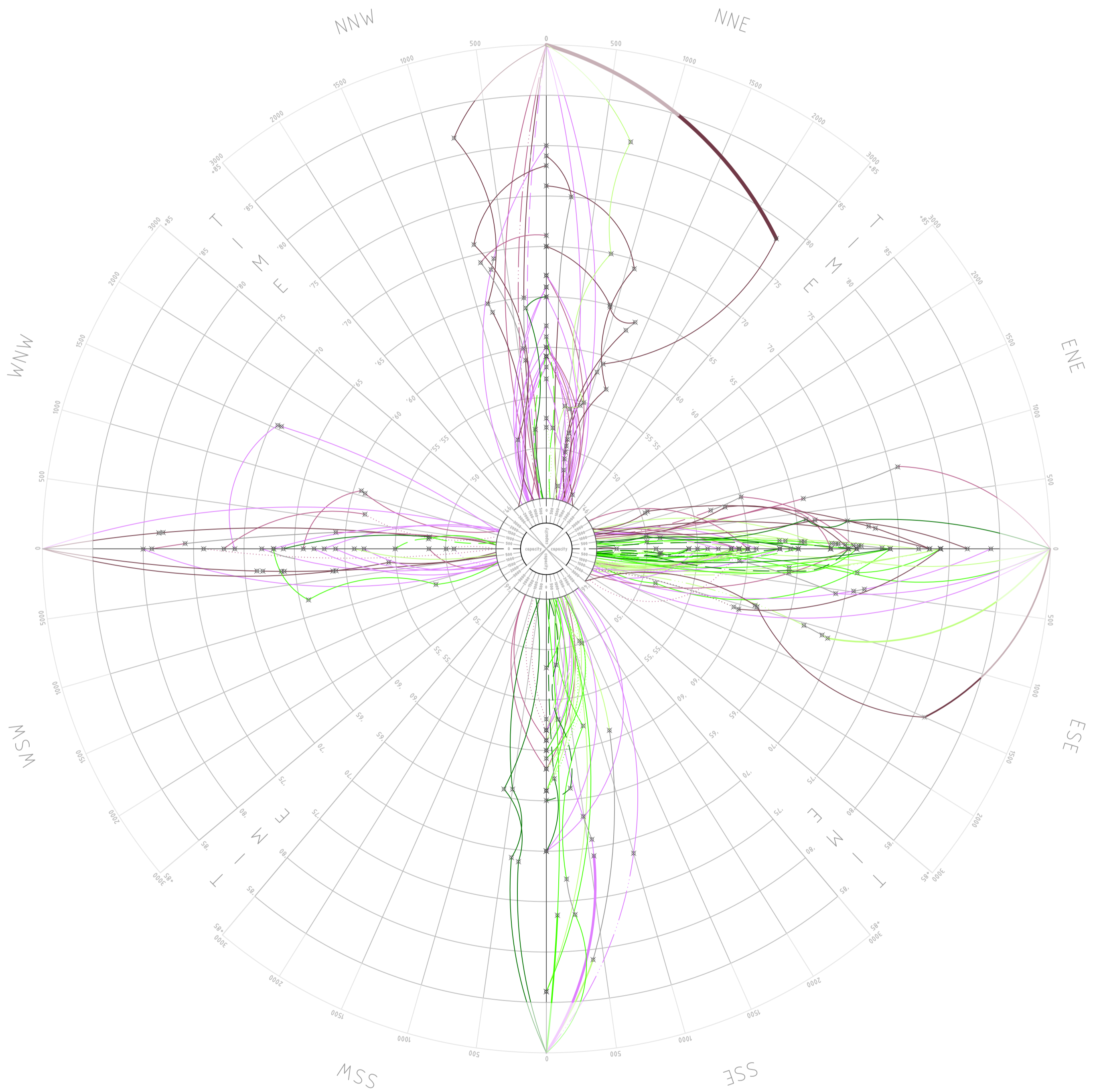
MsgBox "There are " & position & " events from " & QdateF & " to " &
QdateT

End
```

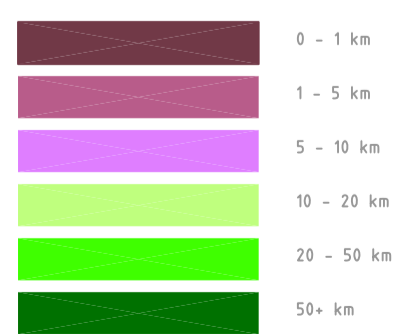
Sub

Appendix C – Visualisation 1

The Longevity of Melbourne Cinemas Operating in 1946



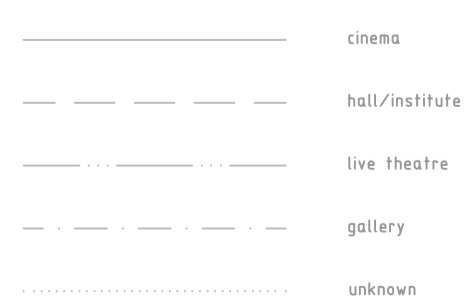
Distance from CBD



Number of Screens

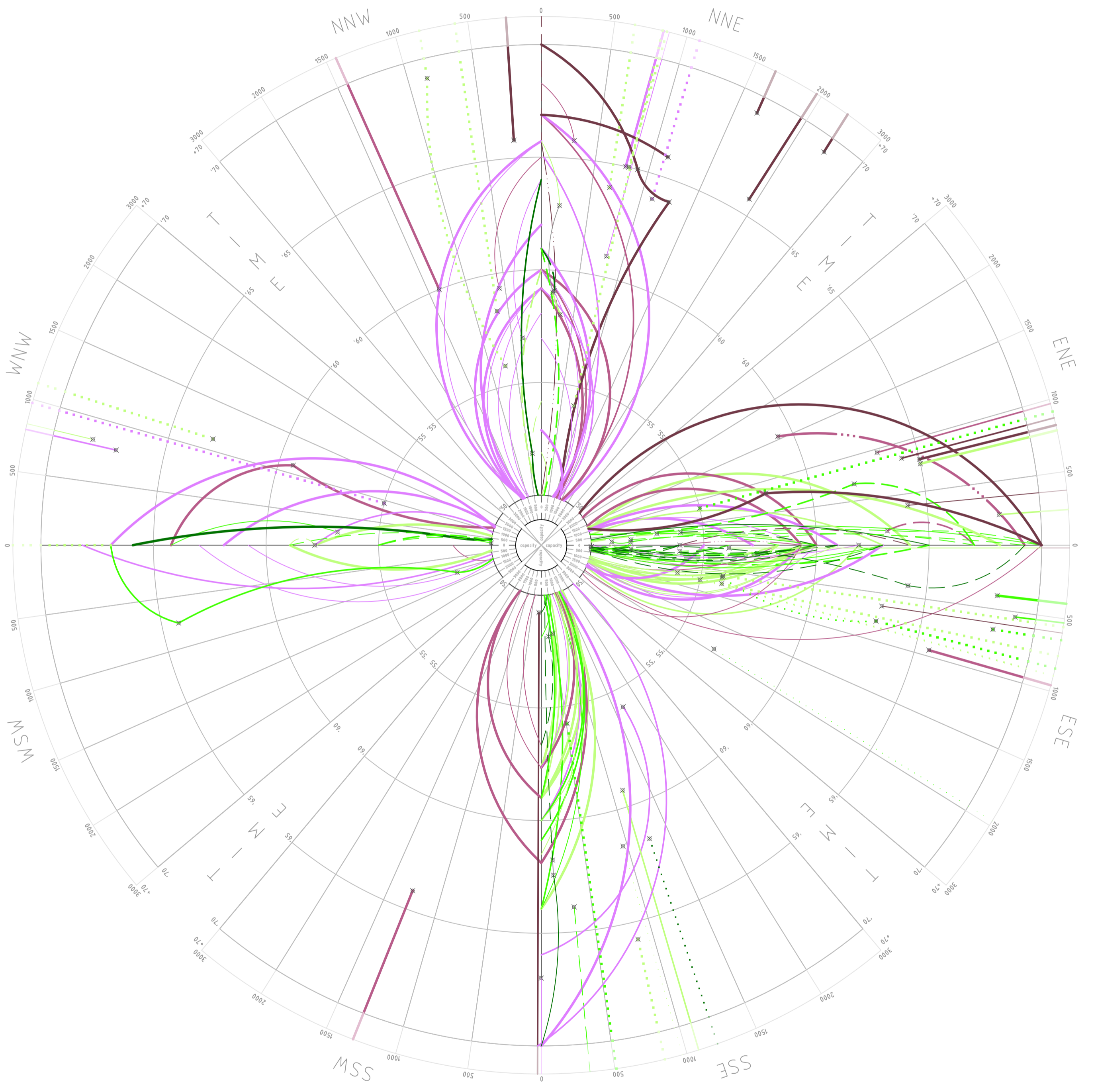


Primary Purpose

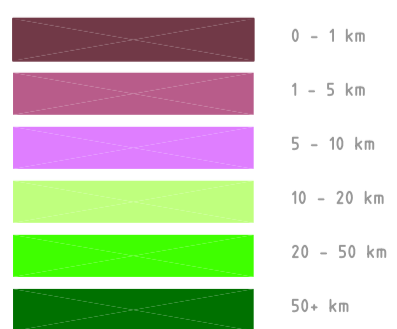


Appendix D – Visualisation 2

The Openings and Closures of Cinema Venues in Melbourne Between 1950 and 1970



Distance from CBD



Primary Purpose



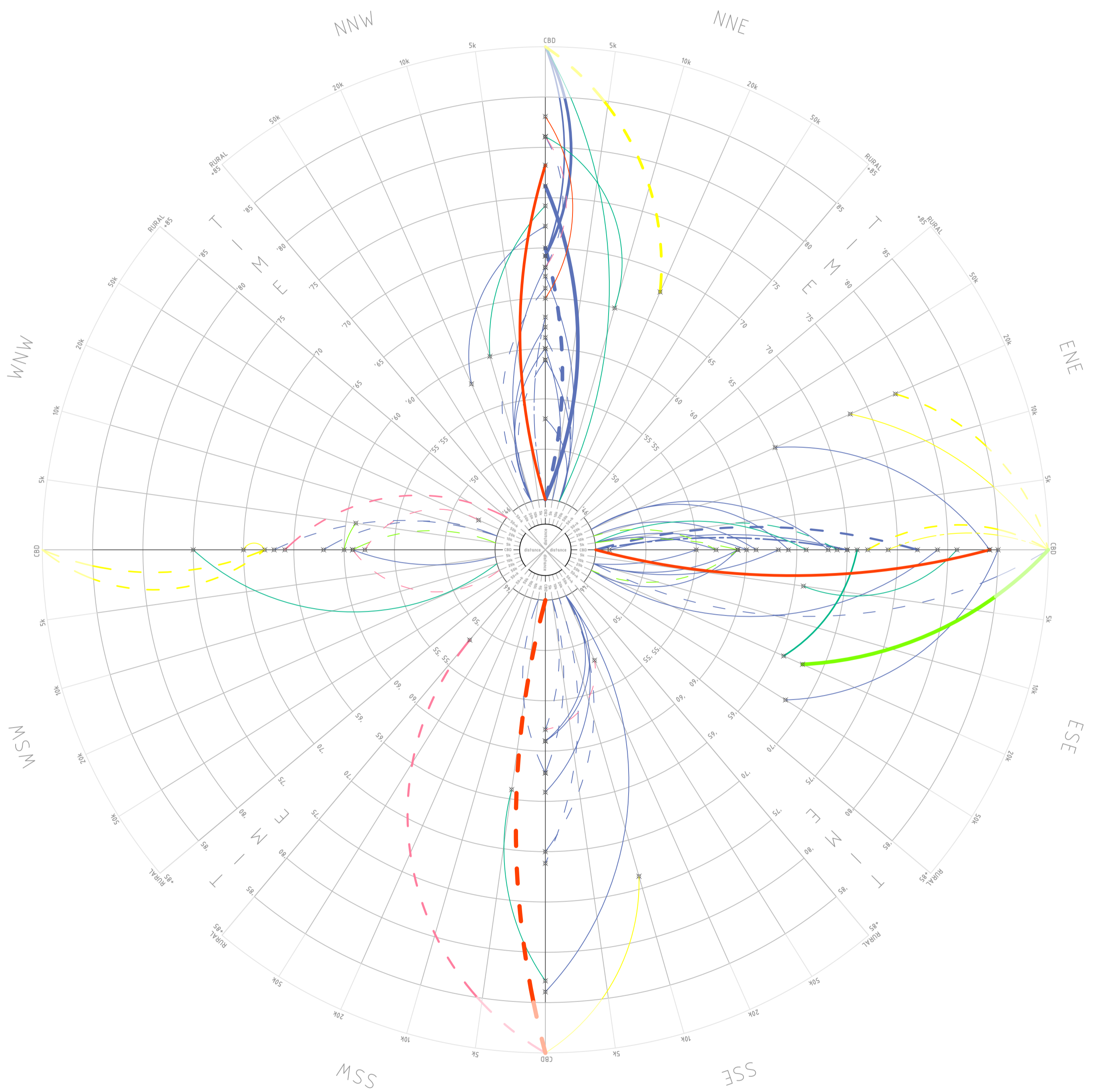
Size of Cinema Company



⊗ time of change

Appendix E – Visualisation 3

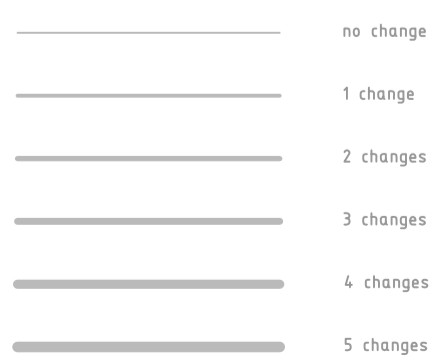
The Operation of Large Cinema Chains in Melbourne Between 1946 and 1986



Cinema Company



Number of Changes



Main Role

